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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 726

Joint Contribution from the Office of Farm Management, W. J. SPILLMAN, Chief, and Bureau of Plant Industry, W. A. TAYLOR, Chief.

Washington, D. C. ▼ December 14, 1918

CONTENTS.

INTRODUCTION.

The data presented in this bulletin are based upon 371 [1] farm estimates [2] obtained from representative sugar-beet growers in four counties in Colorado, viz, Otero, Morgan, Larimer, and Weld (fig. 1). These estimates are for the crop years 1914 and 1915. Agricultural conditions were approximately normal during this period.

While four counties were included in this survey, the records have been worked out in three distinct groups. The agricultural conditions in Weld and Larimer Counties were found to be very similar, hence it was thought that in this study these two areas could be combined to advantage (referred to in this bulletin as the Greeley district). Conditions prevailing in Morgan and Otero Counties were such, however, that it seemed desirable to work out the reports for these districts separately (referred to, respectively, as the Fort Morgan and Rocky Ford districts).[3]

[1] Some of the tables that are presented in this bulletin apply only to the crop year 1915. Four farm records, within the total number, contained complete notes and data on field practice, but they did not afford full information concerning all of the cost factors. Several of the summary tables are, therefore, based upon 367 records.

[2] This is the second of a series of bulletins giving the results of an investigation relative to the practice and cost of growing sugar beets in four of the most important sugar-beet areas in the United States. The practice and cost of growing beets in California and Michigan will be treated in later publications.

[3] The Office of Farm Management and the Office of Sugar Plant Investigations, Bureau of Plant Industry, cooperated in taking the farm records. The latter office was interested in securing a detailed account of the farmer's method of growing this crop. It was thought that these data would be of very great value in planning agronomic experiments for the purpose of solving some of the urgent problems that have arisen in areas where the sugar beet is cultivated. Acknowledgment is due to the farmers in these districts who gave willingly of their time in order to provide complete information concerning their field methods and also the details of their farm business, so that certain economic phases might be studied thoroughly. Acknowledgment is also due Dr. A. L. Thomson, expert, Joe G. Lill, assistant, and James W. Jones, agriculturist, who assisted in collecting field data.

During the years 1916–17, labor costs advanced appreciably in this region, and there was a corresponding increase in the cost of materials used in growing the sugar beet. This upward trend was also reflected in some of the other costs considered in this bulletin. In view of these changes, since the dollar is a fluctuating measure, special attention has been given in this study to values that are known to be much more stable than money values. The hours of man and horse labor do not vary greatly from year to year; the quantity of seed used remains about the same; the application of manure or fertilizer is not likely to increase or decrease perceptibly under a given type of

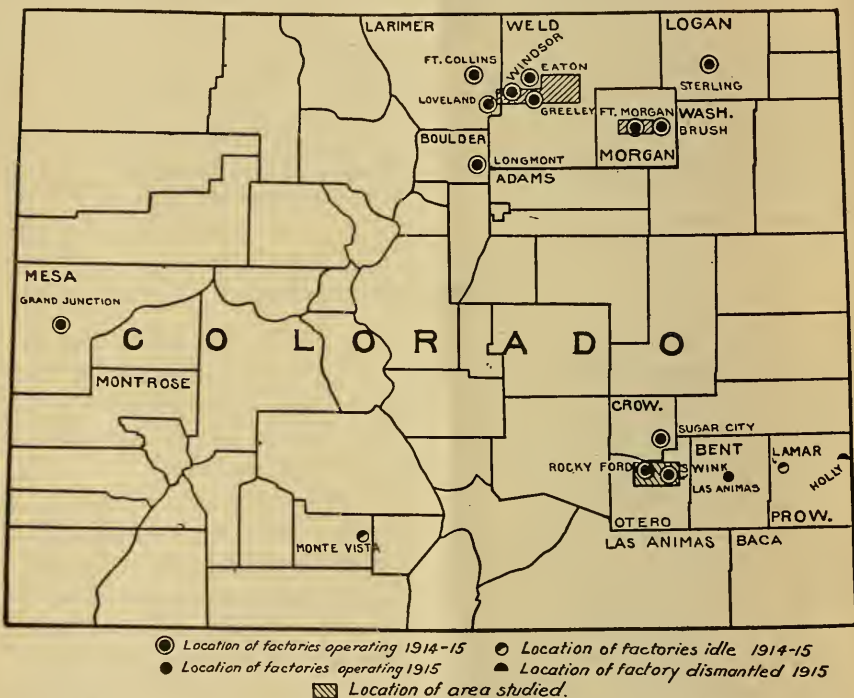

FIG. 1.—Map showing the three districts included in this survey, and location of the sugar factories of Colorado.

farming, and the quantity of other necessary supplies used will undoubtedly remain fairly constant, though the cost in money may not. Throughout this bulletin the emphasis has been placed upon these items, and money costs are referred to only incidentally.[1]

[1] Farm practice studies were begun in the sugar-beet sections of Colorado during the summer of 1910. Prior to this date reports had been received from several areas to the effect that difficulties were being met in securing satisfactory yields, and requests for assistance were brought to the attention of the Secretary of Agriculture. The problems under consideration involved not only the production of sugar beets but were also related to other important enterprises on these farms. It was felt, therefore, that a review of the practices on several of the successful as well as a similar number of the less remunerative farms in these areas would develop suggestions that might be helpful in this connection. This project was expanded in 1915 and arrangements were made to secure detailed records on the various items of cost that enter into the production of sugar beets. In order to get these data, it was necessary to make a careful analysis of the cultural treatment followed by individual growers in the three areas. While the primary object was to obtain cost figures, the development of the investigation has been such that it has been impossible to treat of costs without laying emphasis upon farm practice.

Field practice and related costs are controlled by several factors, some of the more important of which are: (1) season or climatic conditions; (2) soil type; (3) manurial practice; (4) methods of preparing the seed bed; (5) intertillage of the crop; (6) irrigation; (7) distance from market; (8) the efficiency of man and horse labor; and (9) crop yield.

By comparing the methods of field treatment in the Arkansas Valley with the methods that prevail in the Greeley area, it is found that in Otero County it is a common practice to irrigate land immediately after planting, while in Weld County the rainfall is usually sufficient to germinate the seed promptly, so that early spring irrigation is omitted. Season or climatic conditions in this particular case impose additional work upon the operator who is producing beets in the Arkansas Valley. Again, the soil type influences the amount of work required to bring the land into first-class condition for seeding. A heavy clay soil is much more difficult to handle than a type like the Colorado sandy loam, and additional field work means an increased cost. The same feature may be illustrated in methods of fertilizing the soil, or in the preparation of the seed bed, or in the cultivation of the crop. Investigations in other areas have emphasized the fact that the crop yields have a very important bearing upon cost.

Thus it will be seen that there is necessarily considerable variation in the practice of growing sugar beets, and this, in turn, enters into cost of production. A figure that may be applied to a given farm in a typical beet area may not be applicable to the adjoining farm. Likewise, a district average may be higher or lower than the cost of growing this crop in an adjacent district or in a bordering State. It is certain that a cost figure can not be used which will answer for the country as a whole. The best that can be accomplished in making these calculations will be found in a discussion of figures that can be used in a relative way. Having full information concerning the practice under which these costs were ascertained, the grower will be able to see wherein his methods coincide and wherein they differ from the record which has been compiled. By weighing each operation carefully, it will be possible for him to reach an estimate which should cover the requirements of his farm.

SUMMARY.

1. A review of the farm practice outlined in this study shows that the acre costs for all tillage operations for sugar beets performed by the operators, with the exception of plowing, rolling beets, irrigating, hoeing, and topping, were lower for the farms studied in the Greeley and Fort Morgan areas than for those at Rocky Ford. This was

due mainly to the heavier soil types at Rocky Ford, which necessitated a greater amount of tillage.

2. Labor, including man, horse, and contract labor, was the most important charge. It varied from 54.3 per cent to 59.1 per cent of the total cost.

3. Charges for materials, such as seed, manure, and water, varied from 8.6 per cent to 10.7 per cent of the total cost of production.

4. Other costs, such as interest on land for owners and land rental for tenants, insurance, taxes, and machinery, made up 32.3 per cent to 35 per cent of the total cost of raising this crop.

5. The total cost of production per acre in 1914 and 1915 was $72.53 in Greeley, $65 at Fort Morgan, and $64.87 at Rocky Ford. The total receipts per acre, including tops, amounted to $92.44 at Greeley, $81.66 at Fort Morgan, and $67.36 at Rocky Ford. The average yield for the Greeley area was 15.57 tons per acre, for Fort Morgan 13.65 tons, and for Rocky Ford 12.99 tons.

6. Farm owners produced beets at a lower cost per acre and per ton than tenant operators, with the exception of the Rocky Ford area, where the owners had the higher acre cost and a higher cost per ton. That it was possible for owners in the Greeley area to produce beets at a lower cost than the tenants was due chiefly to the fact that the interest charge on beet land in the owner group in 1914 and 1915 was much less than the corresponding rental charge on tenant farms.

7. Seventy-four per cent of the farmers fed beet tops directly to their own stock, 12 per cent fed a portion and sold the remainder, and 14 per cent sold all tops. The estimated farm value, $3.35 per acre, for beet tops was 28 cents per acre greater than the actual selling value in the districts under observation.

8. Since the cost of production per ton of sugar beets decreased as the yield increased, any change in the methods of sugar-beet growing which does not violate the principles of good farm management, and which will increase the tonnage per acre without materially increasing the cost of production, should receive the attention of sugar-beet operators in these areas.

METHOD.

The tables that are presented in this bulletin were not taken from systematic records kept on farms, but are based upon a large number of detailed reports given by beet growers on the 1914 and 1915 crops. The results represent the best judgment and experience of men who have been producing this crop for several years. During the year 1914 the field records were confined entirely to cost studies. In other words, the schedules, which were filled out by well-trained enumerators, contained only the items necessary to the compilation of cost data. In 1915 a combination survey and enterprise blank was used. This record form not only provided complete information pertaining to farm practice and farm costs in the production of sugar beets, but it also furnished data showing the outcome of the entire farm business for the crop year. The latter additions made it possible to compare the sugar-beet enterprise with other important farm enterprises.[1]

DEVELOPMENT OF INDUSTRY.

The building of a factory at Grand Junction in 1899 marked the beginning of the beet industry in Colorado. The Twelfth Census, taken that year, shows that 169 farms in Colorado reported on sugar-beet acreage. The total acreage grown was 1,094, producing a total of 6,656 tons, with a yield of 6.1 tons per acre. These estimates indicate an average of approximately 6.5 acres per farm. This acreage was produced largely in Mesa County, on the western slope.

Ten years later (Thirteenth Census) the acreage devoted to beets had increased to 108,082, with a total production of 1,231,712 tons, an average yield of 11.4 tons of beets per acre. Weld County occupied the first place in beet acreage in 1909, Larimer County second, Otero County third, and Morgan County fourth. Government estimates for 1915 indicated that this acreage had been increased to 160,800 for the State, with a prospective return of 1,706,300 tons, or an average of 10.6 tons per acre.

The beet-sugar factory at Rocky Ford was erected in 1900. This was the first plant to be installed in the Arkansas Valley. Five other factories have been added since 1900. In the northern part of the State the first sugar factory was erected at Loveland in 1901. By the year 1906, eight other factories had been built in northeastern Colorado (fig. 2).

The acreage and yield per acre for the sugar-beet crop in the areas surveyed will be found in Table I. While these figures cover only five seasons, they indicate that some increases in acreage have been made within the last few years.

[1] Studies which have been made by the Office of Farm Management indicate that the survey method of securing information used in this study furnishes very reliable results when enough records have been tabulated. This point is illustrated in the following table.

A comparison of farmers' estimates with factory records, crop year 1915, average per farm.

District.	Number of farms.	Acres in beets.		Tons per acre.		Total receipts.	
		Estimate.	Factory.	Estimate.	Factory.	Estimate.	Factory.
Greeley	90	26.1	25.5	15.5	14.6	$2,355	$2,236
Fort Morgan	66	37.1	36.0	13.5	13.2	2,897	2,754
Rocky Ford	37	22.3	21.8	11.7	11.2	1,429	1,335

This report is based on the records that were taken for the crop year 1915. The previous year's work was checked in a similar manner, though in one of the districts studied several growers sold to more than one company, so that complete reports were not secured for all farms. Taking the above groups as a whole, there was a tendency to report the acreage and yield a little above the actual acreage and returns.

TABLE I.—*Acreage and yield of sugar beets as reported by factories for five Colorado districts.*

[Data provided by Colorado beet sugar companies.]

Year.	Rocky Ford.		Fort Collins.		Greeley.		Eaton.		Fort Morgan.	
	Acreage.	Tons per acre.	Acreage.	Tons per acre.	Acreage.	Tons per acre.	Acreage.	Tons per acre.	Acreage.	Tons per acre.
1911	7,213	10.74	8,087	10.90	6,340	13.33	4,501	13.76	3,283	12.25
1912	10,925	11.89	12,348	10.09	10,089	12.07	10,451	15.40	5,155	12.24
1913	13,879	10.63	14,289	11.07	11,411	12.05	16,597	13.13	6,969	10.21
1914	11,208	12.39	11,900	13.02	8,892	12.74	11,547	13.22	6,575	13.01
1915	13,560	11.59	13,529	12.15	15,232	12.35	12,081	12.55	9,450	10.68
Average	11,356	11.45	12,031	11.89	10,393	12.42	11,035	13.50	6,286	11.48

FIG. 2.—One of the beet-sugar factories in northeastern Colorado. This plant, constructed in 1905, has a rated capacity of practically 1,000 tons daily.

The lowest average yield for the five-year period was recorded in the Rocky Ford district, although there is little variation in the average yields for the Fort Collins, Fort Morgan, and Rocky Ford areas. The average yield for the Rocky Ford area during the years 1914 and 1915, when the enterprise records were obtained, exceeded the normal yield. The maximum average yield was obtained in the Eaton district. A large number of the enterprise records for Weld County came from the Eaton area. Fort Collins and Fort Morgan were considerably above the normal for the year 1914. The latter was slightly below normal in 1915. On the whole, there were no wide differences in yield within the groups. The slight fluctuations that may be observed were undoubtedly due to climatic conditions.

CLIMATIC CONDITIONS.

The climate of Colorado is semiarid. To obtain maximum yields under semiarid conditions irrigation must be practiced. While it is possible to grow certain crops under dry-farming methods, some important staples, such as the sugar beet, are confined entirely to the irrigated valleys (fig. 3).

The three distinct areas in Colorado where farmers give considerable attention to beet culture are in three more or less extensive drainage basins, namely, the South Platte River and its tributaries, the Arkansas Valley, and the western slope. This bulletin is concerned with the first two areas. Rocky Ford was selected as a typical area in the Arkansas Valley. Fort Collins, Greeley, and Fort Morgan are important beet-growing centers adjacent to and in the valley of the South Platte.

TABLE II.—*Average annual rainfall for three districts in northeastern Colorado and one district in the Arkansas (Valley in inches).*

	Rocky Ford, 1889–1908.	Fort Collins, 1873–1908.	Greeley, 1888–1908.	Fort Morgan, 1889–1908.
	Mean.	*Mean.*	*Mean.*	*Mean.*
January	0.32	0.49	0.34	0.26
February	.34	.52	.37	.31
March	.68	.98	.81	.69
April	1.66	2.23	1.82	1.77
May	1.92	3.06	2.61	2.42
June	1.35	1.59	1.33	1.75
July	2.76	1.90	1.80	2.41
August	1.37	1.21	.97	1.56
September	.78	1 16	.82	.70
October	.90	1.02	.82	.80
November	.46	.33	.33	.30
December	.44	.32	.25	.29
Total annual precipitation	12.98	14.81	12.27	13.26
Elevation feet	4,177	4,985	4,639	4,338

Precipitation and seasonal distribution of rainfall are much the same for the four counties. The major portion of the annual rainfall occurs during the growing season. Generally speaking, the rainfall for April, May, and June is somewhat lower at Rocky Ford than at the other points, which accounts partially for the fact that it is customary there to irrigate immediately after planting, whereas in northern Colorado the grower invariably counts upon starting the crop with the spring precipitation.

The light rains which fall during July, August, and September do not benefit the crops greatly. In fact, they may do serious damage either by crust formation or by simply sprouting the seed without furnishing moisture enough for a satisfactory subsequent growth. The late fall and winter months are marked by few light rain or snow storms. The water which falls from November to March is probably sufficient one season in four to provide some moisture for crop production. When the winter rains are light, the fields remain hard and dry and are in poor condition in the spring unless irrigated thoroughly during the late fall or early winter.

The Greeley district lies close to the mountain range and the mean annual temperature there is 47° as compared with 51° at Fort Morgan. The range between extremes is wide, 100° being frequently reached in the summer season. The nights, however, are cool. The summer temperatures for the Rocky Ford district are somewhat higher than those recorded for the other districts included in this survey. Throughout the entire territory cloudy days are the exception.

FIG. 3.—Irrigation canal No. 2 in the Greeley district.

High winds are a characteristic feature of the region, and they usually blow with greatest persistence in the spring, when the fields are without vegetation. Thus it is a common occurrence for loose soil to be picked up and carried along with each strong current of air. If the young beet plants are still small and tender when the winds are high, considerable damage may be done to the crop by the moving soil. It is sometimes necessary to reseed large areas, owing to the fact that the plants from the first seeding have been destroyed by a wind storm. Only in some of the older districts has this difficulty been reduced by the growing of windbreaks.

SIZE OF FARMS.

The latest information available on size of farms in these districts is found in the report of the census for 1909. These figures have been incorporated in Table III, together with a distribution of the farms covered by this survey.

TABLE III.—*Number and size of farms in Larimer, Weld, Morgan, and Otero Counties; also number and classification of farms giving records.*[a]

Size of farm.	Larimer County.		Weld County.		Morgan County.		Otero County.	
	Thirteenth Census.	Survey records.	Thirteenth Census.	Survey records.	Thirteenth Census.	Survey records.	Thirteenth Census.	Survey records.
Under 3 acres	11	None.	6	None.	0	None.	16	None.
3 to 9 acres	121	None.	72	None.	28	None.	85	None.
10 to 19 acres	111	1	64	None.	23	None.	102	2
20 to 49 acres	204	12	181	9	42	4	326	33
50 to 99 acres	294	12	715	44	140	20	311	40
100 to 174 acres	559	26	1,846	49	450	29	438	27
175 to 259 acres	159	13	344	16	83	9	77	5
260 to 499 acres	204	9	626	4	255	3	105	3
500 to 999 acres	73	None.	81	None.	36	1	20	None.
1,000 acres and over	94	None.	46	None.	18	None.	18	None.

[a] The figures reported under Thirteenth Census were obtained by the Census Bureau and are applicable to the year 1909. The numbers that are included under "Survey records" apply to the farms used in this survey.

In all districts studied, according to census figures, the largest number of farms in any of the size groups falls between 100 and 174 acres, including 160-acre, or "quarter-section" farms. While it is customary to think of irrigation farming as more or less intensive, nevertheless it is a fact that there are comparatively few small farms in these districts.[1] In Morgan, Otero, and Weld Counties there is found a fair proportion of farms containing 80 acres.

When irrigated farms of this type are placed in contrast with farms of similar size in the humid belt, assuming that the groups are similar in every other respect, it will be found that much more labor is required to carry on the operations under irrigation than without.

Each of these counties has an extensive area devoted to dry farming, as may be inferred from the number of very large farms. Under this system these larger farms can be utilized to advantage. Small grain growing is the most important industry on this particular type of farm. Some corn is grown. A portion of this land is known as open range, and is devoted to pasture.

[1] It will be seen that each of the counties included in this study has a certain number of farms containing 9 acres or less. Sugar beets are grown on these tracts, but in making this investigation it was thought that the very small farms ought not be considered in making up the estimates. Usually, the acreage devoted to beets in these small units is much less than 5 acres. The man who produces less than 5 acres of sugar beets does not have enough work on such major operations as harrowing, disking, floating, planting, or cultivating to keep the horses employed for any considerable length of time, and it is therefore a difficult matter for him to estimate a day's work for such operations.

RELATION OF BEET ACREAGE TO IRRIGATED AREA.

It is a question whether the ideal rotation area for sugar beets can be given. There is no doubt a theoretically correct relationship between the areas devoted to the important staples in a given district, and this balance may be approximated on some farms each year. In a district where the various enterprises are well established the ideal cropping system may be more nearly approached than in sections where there is considerable change in the selected list from year to year. This study does not attempt to answer the point at issue, but it does show the average conditions that existed on these farms at the time of the survey.

Under the system of general farming that prevails in the Fort Morgan and Rocky Ford districts it appears that the list of leading crops is smaller than in the Greeley area. The Fort Morgan records indicated three staples, namely, alfalfa, beets, and barley, whereas in the Greeley section the list included alfalfa, potatoes, sugar beets, and spring wheat or barley. This brief discussion may therefore explain, in part, the difference of 10.6 per cent between the percentage of irrigated land in beets at Greeley and the percentage at Fort Morgan (Table IV).

TABLE IV.—*Average farm area, tillable area, irrigated area, acres in beets, and per cent of irrigated land in sugar beets.*

District.	Number of farms.	Acres per farm.	Acres tillable.	Acres irrigated.	Acres in beets.	Per cent of irrigated land in beets.
Greeley	195	136.40	112.39	107.40	25.72	24.0
Fort Morgan	66	143.40	113.59	107.55	37.20	34.6
Rocky Ford	106	92.33	70.72	65.77	22.91	34.9

SOIL TYPES.

The counties included in the beet-growing districts afford a large number of soil types for comparison. Two surveys have been made in these districts by the Bureau of Soils of the United States Department of Agriculture.[1] In the Rocky Ford area there are two important soil types, namely, Maricopa sandy loam and Fresno fine sandy loam. These two constitute approximately 70 per cent of the area mapped in the Arkansas Valley. The Fresno fine sandy loam has a fine sandy or silty texture, is yellowish in color, and extends to a depth of 6 feet. It is comparatively rich in plant food, but is sometimes deficient in organic matter. It is well adapted to such staples as alfalfa, sugar beets, melons, and grain, is easily tilled and can be maintained in first-class condition without an undue amount of work. The Maricopa sandy loam has a much more open texture

[1] Soil Survey of the Lower Arkansas Valley, Colorado, by H. Lapham and party, 1902. Soil Survey of the Greeley area, Colorado, by J. Garnett Holmes and N. P. Neill.

than the former type, and it absorbs moisture readily. The compact structure of the subsoil has a tendency to retard the movement of seepage water from canals and ditches. This soil is well suited to the production of the staple crops that are grown in the valley.

The prevailing soil type in the Greeley area is the Colorado fine sandy loam. It consists of a fine sandy loam, with a depth of 3 feet and is underlain by a heavier fine sandy loam. As the depth increases the proportion of silt and clay becomes greater. This formation has good drainage and the type is therefore quite free from seepage water. It is a good potato soil and is well suited to such crops as alfalfa, sugar beets, peas, beans, and grain. A review of the soils in this region will show that they grade from the more open type, known as the Colorado sand, to the exceedingly heavy type designated as Colorado adobe. While the agricultural methods which are followed on the different types may correspond in some respects, it will be entirely correct to say that considerable work is usually required to bring these types into the proper condition for planting seed, and greater care must be exercised in connection with intertillage and irrigation. These precautions with the extra work necessarily involve additional expense in the production of sugar beets.

CROP ROTATIONS.

Crop rotations in the irrigated districts of Colorado have been improved and strengthened very materially within the past 20 years. The evolution of these systems has taken place during the past 50 years or more. The race for gold brought a large number of settlers into Colorado in the early sixties. A few of these men were successful, others were less fortunate, and still others failed. There was practically no farming population at that time, and provisions had to be brought in from the outside. High prices prevailed. Men who had come from the farms of the East or Central West and who were disappointed in the results of their mining operations turned to farming for a living. The valleys to the east and north of the gold fields attracted them. They discovered that vegetables of good quality could be grown on these lands. The wild hay along the streams furnished roughage for farm stock. The salable products brought remunerative prices. Flour was in demand. Wheat growing became therefore one of the important enterprises of the farm during that early period.

It will be seen that a complete cropping system could not have been developed immediately, nor was it possible to determine at once the type of farming that would give the best returns. The grower did not have information concerning the adaptability of various crops, and special types of farming to meet the new conditions had not yet been evolved. Field experience had to be accumulated before any advanced steps could be taken.

Prior to the year 1885 comparatively few men had set aside part of their land for alfalfa, though the continued culture of wheat had reduced the supply of organic matter in the surface soil and a change in the method of cropping appeared to be essential. During this early period it was not thought that alfalfa could be used in a regular rotation. This plant possessed a long tap root and farmers had the opinion that the crop could not be subdued readily. However, the pioneer in this field soon demonstrated that alfalfa had many advantages, and before many years had passed it was recognized as a basic crop in the rotation. In all of the counties which were included in this study a considerable acreage is devoted to this legume. Alfalfa is the initial crop in the typical rotations that have been adopted in these regions, as will be seen from the following outline of cropping systems for four sugar-beet districts:

No. 1.—Rocky Ford.	No. 2.—Greeley.	No. 3.—Fort Collins.	No. 4.—Fort Morgan.
Alfalfa, 3 to 5 years. Cantaloupes, 1 year. Beets, 2 years. Cucumbers, 1 year. Grain, 1 year.	Alfalfa, 3 to 4 years. Potatoes, 1 year. Beets, 2 years. Beans or peas, 1 year. Grain, 1 year.	Alfalfa, 4 years. Grain, 1 year. Beets, 3 years. Grain, 1 year.	Alfalfa, 4 years. Beets, 3 years. Grain, 1 year.

The rotation given for the Rocky Ford district (No. 1) serves merely as a type. Many of the estimates obtained in this district did not provide any information on rotations. The form given has been adopted on several farms and has proved to be a very satisfactory system. The alfalfa is broken out early in the spring, after which either cantaloupes or cucumbers are planted. A crop of grain sometimes follows the alfalfa. In some cases beets are planted on the newly broken alfalfa field. A few men stated that the alfalfa was allowed to remain down for an indefinite period, the remaining crops being rotated on the land under cultivation.

In the Greeley area (rotation No. 2) 75 per cent of the reports show that potatoes were planted as the first crop immediately after breaking alfalfa. A few men put in potatoes two years on the same land. In a few cases peas or beans followed potatoes, then beets were grown for one to two years, grain being sown the fourth year after breaking, and the field reseeded to alfalfa. Farm practice studies show that potatoes serve as a better crop to follow alfalfa than sugar beets. The alfalfa roots interfere too much with the early cultivation of the latter crop. Approximately 15 per cent of the farms used the sugar beet as the first crop after breaking. On some farms grain, cabbage, beans, peas, or corn is used to fill this place in the cropping series.

In the Fort Collins district the alfalfa is followed by a crop of grain, which assists in getting rid of the alfalfa roots and stems, so that beets can be grown to advantage the second year. This system (No. 3) is very popular outside of the potato district proper.

Rotation No. 4, the standard for the Fort Morgan district, differs slightly from No. 3 in that sugar beets follow alfalfa immediately after breaking. It should be stated, however, that approximately 15 per cent of these farms used a grain crop after breaking.

There are farms in all these areas where the sugar beet has been grown for a period of 1 to 10 years upon the same piece of land. It is, however, quite a general practice to employ a systematic rotation.

MAN AND HORSE LABOR.

Complete data were secured in each district with reference to the cost of man and horse labor. The man-labor rate was based on the average man-labor cost throughout the working season. Farm labor here can be divided into three classes, namely, regular labor, extra labor, and contract labor. The regular labor includes those who are given continuous employment; extra labor, those who are hired at certain busy periods during the spring and summer. On farms where a large percentage of the land is devoted to hoed crops, extra labor may be required to care for these fields. Then, too, the harvest season frequently demands additional help. Contract labor includes the men who are paid a stipulated amount to do certain tasks, such as the hand work on beets. As a rule, the rates for special labor are somewhat higher than the rates paid the regular labor.

The man and horse rates which are given in Table V are based upon records obtained during the years 1914 and 1915:

TABLE V.—*Average cost per hour of man and horse labor (1914–15).*

	Rocky Ford area (110 farms).	Greeley area (195 farms).	Fort Morgan area (66 farms).
	Cents.	*Cents.*	*Cents.*
Man	18	19	20
Horse	10	11	10

In working out costs, the operators in the respective districts have been given an arbitrary allowance of 18, 19, and 20 cents per hour for their work (see Table V), no charge being made to cover the general management of the farm.

The variation in labor rates was so slight that a uniform rate of 20 cents per hour for man labor and 10 cents per hour for horse labor might have been used to advantage in all of these sections. Labor rates may fluctuate greatly, but if the sugar-beet grower wishes to determine the cost of producing sugar-beets under new conditions it will only be necessary to calculate on the basis of actual time required to do the work.

The rates for horse labor were established in precisely the same manner as for the regular labor. It often happens that the operator is obliged to hire an extra team for rush work. The price which is paid is based usually upon the prevailing rate in the district. This furnished a very reliable guide for our calculations.

Contract labor takes care of such items as blocking and thinning, first and second hoeing, pulling weeds, and topping. On a few of these farms this work was done by the operator and his family. For the remaining farms, hands (often entire families) were engaged for the season. Fairly uniform acre rates have been established, though some variation may be found in comparing one district with another. In sections where a flat rate prevailed, the blocking and thinning rate was usually $6 per acre. The first hoeing cost $2 per acre, second hoeing $1 per acre, and the pulling and topping, together, amounted to $9 per acre, making a total charge of $18 per acre for the contract work or hand labor.

FARM PRACTICE.

REMOVING TRASH.

Some preliminary work is occasionally necessary, particularly on fields where vine crops have been grown or where potatoes with luxuriant tops have been produced. It may not be possible to incorporate the residue with the soil; consequently this material may either be placed in a composite heap to decay, or burned. There were only two records reporting work of this character. On one farm, at Greeley, removing a very small amount of residue cost but 12 cents per acre. On another, at Rocky Ford, where there was a heavy growth of vines to be removed, the cost was considerably greater than this. The true average labor requirement for this operation could not be determined with the limited number of records available.

SCRAPING THE LAND.

When new fields are brought under cultivation, some work is usually done with a scraper for the purpose of creating a level surface, thereby facilitating irrigation. Indeed, some scraping may be done occasionally on old fields in order to reduce knolls and perhaps to fill in low places. In this study scraping is considered as improvement work. Two records on scraping were obtained, in Weld County. The operation was performed on one of these farms by one man and two horses, at a cost of $1.03 per acre, and on the other by one man and four horses, at $1.26 per acre.

FARM MANURE.

The value of farm manure should not be based entirely upon the percentage of fertilizing constituents found therein. Especially is this true in the West, where with many soils the addition of humus is highly desirable. Indeed humus may be more beneficial to some of these soils than commercial plant food. Occasionally a Colorado beet grower is found who hauls manure to some out-of-the-way place instead of scattering it over his fields, but, as a rule, the value of this by-product is appreciated and a systematic effort is made to treat various portions of the farm in regular order. Invariably better yields are harvested after farm manure is applied, though it may not always be possible to determine the exact benefit that should be credited to the manure. Instances are on record where the yield of sugar beets has been raised from 9 or 10 tons per acre up to 16 or 18 tons per acre, apparently entirely through the application of manure. The nature of the subsoil is important in this connection.

Some of the farms, however, do not have a large supply of manure, and on such farms it is impossible to give each field a liberal application. Under such circumstances it may be advisable to supplement farm manure with green manure. The plan of turning under a substantial growth of alfalfa at least once in the rotation is a feature of farm management which deserves more than passing attention. The farmer who has followed this practice knows that better yields result, and he therefore has sufficient reason for maintaining the practice. To raise the standard of agricultural methods on the average farm in these districts the adoption of this plan is needed. There are several other crops which may be used for green manure. Sweet clover may be mentioned in this connection.

Ninety-two per cent of the men interviewed applied manure. They reported, not only on the time consumed in doing the work, but also on the fertilizing value of this by-product. In the majority of cases the manure was scattered on beet land. There were 310 growers who followed this practice. On 22 farms the manure was applied to potato land, on 5 to grain, and on 1 each to tomatoes, cabbage, and cantaloupes (Table VI).

In working out the labor cost for manure, a 50 per cent charge was made where the crop received direct benefit. If sugar beets were removed one crop year after the application of manure, 30 per cent of the labor was charged against the crop. When two seasons intervened between the manuring of the soil and the production of sugar beets 20 per cent of the labor cost was charged to beets.

Some hauled manure in the autumn, others throughout the winter, and still others in early spring, the work being done partly with spreaders and partly with wagons. The implements used in the Rocky Ford district were not indicated on every record; hence it was not possible to determine the number of men using manure spreaders there. Fifty-eight per cent of the Fort Morgan growers and 77 per cent of the Greeley farmers used spreaders.

TABLE VI.—*Data on use of manure for three Colorado districts.*

District.	Year.	Number of farms.	Acres manured.	Tons per acre.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	99	9.12	11.82	1.5	2.56	17.67	34.60	$6.64
Fort Morgan	1915	64	17.90	14.34	1.6	3.20	15.10	30.80	6.26
Greeley	1914–15	180	12.80	18.60	1.6	3.30	13.50	27.70	5.61

There was a decided lack of uniformity in all districts with reference to size of crew used in handling manure. One hundred and thirty-five growers, or approximately 40 per cent of the farms reporting, used one man and two horses. Rocky Ford had the largest proportion of this group. Taking all districts into consideration, there were 51 men who used a crew of one man and three horses to haul the manure, and 25 who hauled with a crew of one man and four horses.

On 105 farms an extra man was used to assist with the loading. The horse power was about equally divided between two, three, and four horse crews on these farms.

About 41 per cent of the land devoted to beets was manured in the Rocky Ford district, 47 per cent in the Fort Morgan district, and 49 per cent in the Greeley district. Rocky Ford had the lowest average application per acre, while Greeley had the highest. There was a difference of $1.03 per acre in the cost of putting on manure between these two districts. The advantage for Greeley was undoubtedly due to the use of larger crews.

CROWNING ALFALFA.

It has been pointed out that the sugar beet is not grown very generally after alfalfa. When this plan is followed two plowings are frequently necessary. The first operation is commonly known as "crowning alfalfa." This study contains 53 records which deal with crowning. On these farms only part of the beet crop followed alfalfa. "Crowning" is shallow plowing. In two districts this operation is known as "scalping the land." The average depth which was reported on these farms was about 3 inches. It will be seen that the plow was run deep enough to cut the alfalfa crowns from the long tap root. The beet growers in the Fort Morgan and Greeley districts, where the largest amount of this work was done, used a two-way plow almost exclusively. The two-way plow consists of two plows, only one plow being available for use at a time. It is possible with this type to eliminate back furrows and dead furrows, and the land is left with a smooth, even surface for subsequent tillage. The labor requirements and the cost of this operation in 1915 are shown in Table VII.

TABLE VII.—*Data on crowning alfalfa in three Colorado districts.*

District.	Year.	Number of farms.	Acres crowned per farm.	Crew.		Hours per acre.		Total cost per acre.
				Man.	Horse.	Man.	Horse.	
Rocky Ford	1915	7	7.2	1	3.57	7.3	26.2	$3.94
Fort Morgan	1915	28	14.6	1	3.50	4.6	16.2	2.65
Greeley	1915	18	12.8	1	3.30	4.87	15.8	2.67

The crowning was done partly in the fall of 1914 and partly in the spring of 1915. The major portion of this work occurred during the early spring months. There were 32 operators who used a crew of one man and three horses to do the crowning. On 16 farms a crew of one man and four horses was used. It cost $1.29 per acre more to do the work of crowning in the Rocky Ford district than in northern Colorado. The Greeley and Fort Morgan records did not differ materially in total cost for crowning.

PLOWING.

A limited area in these three districts was plowed during the autumn and early winter months. The heavier types of soil are benefited by exposure to the frosts of winter, and much less work is required to bring them into a mellow condition when fall and winter plowing can be done. Furthermore, the water-holding capacity of the soil is thus increased and more moisture is stored for the crop the following season. The rough broken surface also has a chance to become partially pulverized by the repeated freezing and thawing which occurs throughout the winter and early spring. If the work is postponed until late in the season the other farm operations will be delayed.

No implement has been devised that will take the place of the plow in the preparation of the seed bed for sugar beets. This tillage implement not only loosens the upper layer of soil and in turning the furrow slice pulverizes the particles of which it is composed, but it also covers and incorporates with this layer any manure that may have been scattered upon the field or any residue that may have been present at the time of plowing.

In the three districts studied the greater part of the plowing was done in the early spring. Five growers in northern Colorado stated that this work was performed in the autumn, seven men did part of the plowing in the fall and completed this operation in the spring, while the remaining records indicated spring plowing. Usually the marketing of beets continues late into the autumn months, and this interferes with fall plowing. More attention would undoubtedly be given to the latter if there were no interference with other work, such as digging potatoes or taking out and hauling beets from the farm.

There are some soil types which can be penetrated very readily by plant roots, and such soils may not require deep plowing. However, there are other types which are exceedingly close in texture and do not afford a suitable feeding area for crops like sugar beets unless plowed deep. Frequently the soil carries a fair proportion of cementing material which has a tendency to hold the particles together. Consequently the roots do not develop rapidly and a short, stunted beet is the result. The ideal crop can not be produced on soil that

FIG. 4.—Fall plowing with a two way plow in the Arkansas Valley.

has an impervious subsurface. Deep tillage will open this layer and permit the plant roots to enter. An average depth of 5.8 inches was reached on the 104 farms reporting from the Rocky Ford district, 183 Greeley growers averaged 8.7 inches, while the 66 Fort Morgan operators plowed an average depth of 8.9 inches.

The two-way plow was used almost exclusively in northern Colorado, and it was mentioned in 41 per cent of the records from the Rocky Ford district (fig. 4). Sixty out of sixty-six farmers at Fort Morgan plowed with this type. For the Greeley area data on type of plow are incomplete. However, 53 per cent of all farms used the two-way type. The sulky plow with 14-inch or 16-inch bottom came second (fig. 5). Thirty-seven per cent of the Rocky Ford growers did the plowing with a sulky. Other types, such as the 14-inch walking plow and the two-furrow gang, appeared in scattered records.

TABLE VIII.—*Plowing data for three Colorado districts.*

District.	Year.	Number of farms.	Acres plowed per farm	Crew.		Hours per acre.		Total cost per acre.
				Man.	Horse.	Man.	Horse.	
Rocky Ford	1914-15	104	22.33	1	3.41	5.70	18.3	$2.86
Fort Morgan	1915	66	36.06	1	3.84	4.87	18.67	2.98
Greeley	1914-15	183	26.30	1	3.80	5.30	19.80	3.19

The crews for the respective districts varied somewhat in size. Sixty-three per cent of the Rocky Ford growers did this work with a crew consisting of one man and three horses, whereas 27 per cent

FIG. 5.—Breaking alfalfa with an ordinary sulky plow. This type in point of numbers stood second. On the above farm a considerable growth of alfalfa is being incorporated with the soil.

plowed with one man and four horses. Fort Morgan reported 22 crews with one man and three horses, 32 crews with one man and four horses, and 12 crews with one man and five horses. In the Greeley district the crews were distributed as follows: Sixty-six crews of one man and three horses; 80 crews of one man and four horses; 32 crews of one man and five horses. There were a few crews of odd sizes. By taking the crews according to size and combining these for the three districts it was found that in 1914 and 1915 154 farmers with 1–3 crews plowed at an average cost of $2.60 per acre; 141 with 1–4 crews at an average cost of $3.30, and 45 with 1–5 crews at an average cost of $3.63.

This does not necessarily mean that the large crews were less efficient than the crew consisting of one man and three horses. When the operator of a farm plans to increase the depth of his plowing, it is usually necessary to make provision for more horsepower. With the four- and five-horse crews it is altogether probable that the plowing was done somewhat deeper than on the group of farms using three horses per crew. An average day's work plowing varied from 1.7 acres to 2 acres for the different crews.

DISKING.

Occasionally some disking is done preparatory to plowing. Again, it is sometimes necessary to do the plowing when the soil is very dry. Consequently the surface may be left in a lumpy condition. The disk harrow can be run to advantage over such fields. This plan not only reduces the rough surface, but it also has a tendency to bring the

FIG. 6.—Disking land after plowing.

soil back to the proper tilth. The disk stands second to the plow in effectiveness.

The field records show that much more disking was done in the Rocky Ford district than in either of the other sections under study. This may have been due to a heavier soil and climatic differences. (This feature will be discussed more fully under irrigation practice.) Disking was done at the same time as plowing, or later. The average width of disk used varied from 6.5 to 8.6 feet (fig. 6).

The prevailing crew for disking consisted of one man and four horses. Forty-three growers in Rocky Ford, 15 at Fort Morgan, and 15 at Greeley did the disking with a 1–4 crew. There were 15 farms at Rocky Ford that utilized a crew of one man and three horses. It cost 54 cents more per acre to do the disking at Rocky Ford than at

Fort Morgan (Table IX). The higher acre cost for the former area has undoubtedly been due to the fact that the disk was used more often there than at Fort Morgan.

TABLE IX.—*Disking data for three Colorado districts.*

District.	Year.	Number of farms.	Acres disked per farm.	Number times disked.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	61	20.24	2.3	1	3.65	2.52	9.20	$1.37
Fort Morgan	1915	19	31.3	1.6	1	3.80	1.40	5.18	.83
Greeley	1914–15	19	22.8	1.16	1	3.85	1.58	6.15	.93

Occasionally extra work is done on plowed land in order to accomplish some of the objects which have been referred to under disking. On all fall-plowed land weeds may appear early in the spring and some cultivation must be given in order to keep the field clean. In this study three farms were found that reported tillage operations not common to other farms. Two growers in the Rocky Ford district used the cultivator, followed by a clod masher. The operation was done in 1914 and 1915 with a crew of one man and three horses at a cost of 95 cents per acre. One farm in Weld County reported some special cultivation with a crew of one man and two horses, at a cost of 28 cents per acre.

LEVELING.

To insure a uniform distribution of water, the surface of the field must be smooth and free from depressions. The land leveler (fig. 7) accomplishes this result. It takes the soil from the tops of small knolls and deposits the material in any slight depressions that may exist. Some operators make a practice of leveling diagonally across the field, and if this process is repeated at right angles the surface is usually left without any serious inequalities. However, leveling also serves the purpose of a float, in that it crushes many of the small clods that are frequently present on the recently plowed field. Ninety-eight per cent of the growers who are referred to in this study reported on leveling, hence it will be seen that this practice was almost universal on these farms.

TABLE X.—*Leveling data for three Colorado districts*

District.	Year.	Number of farms.	Acres leveled per farm.	Number times leveled	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	109	22.60	2.12	1	3.77	2.07	7.6	$1.13
Fort Morgan	1915	65	37.3	1.76	1	4.08	1.33	5.4	.84
Greeley	1914–15	188	25.54	1.51	1	3.87	1.23	4.7	.75

The leveling was done exclusively in the spring, the operation preceding planting at least ten days or two weeks. The implement varied in width from 8 to 10 feet. To do efficient work, the leveler must be of suitable length and should be heavy. In the Rocky Ford district the leveling was done with a crew of one man and four horses on 84 farms; 21 farms used a crew of one man and three horses. One man and four horses constituted the most important crew size at Fort Morgan. This was also true for the Greeley area, where 146 growers used this combination. There were 34 operators in the Greeley region with crews of one man and three horses. A few men in each of these areas used odd crews. It will be seen that the 1–4 crew was employed on more farms than any other, indicating that

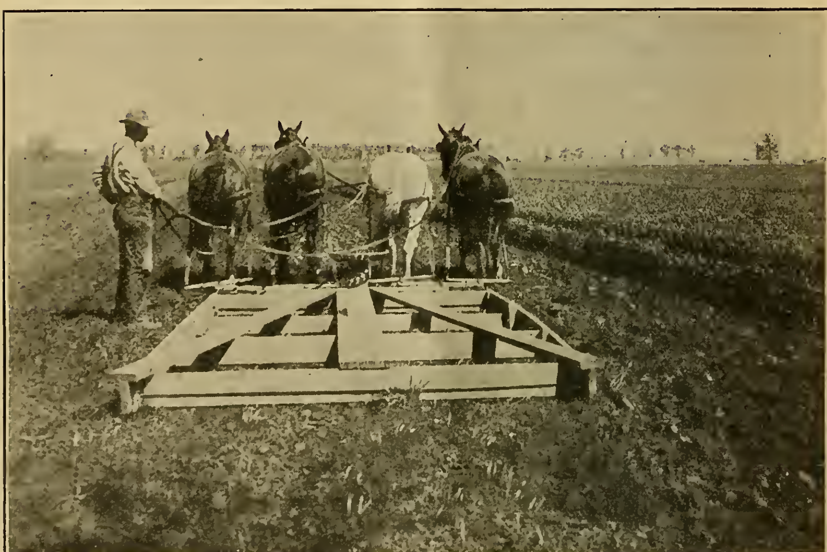

FIG. 7.—Leveling subsequent to plowing. This operation leaves the surface of the field in a smooth condition, and a uniform distribution of water is thereby made possible.

leveling is heavy work, demanding a strong team. Under average conditions an ordinary crew will level from 10 to 13 acres in a 10-hour day.

HARROWING.

Ninety-nine per cent of the growers included in this study used the spike-tooth harrow. The spike tooth not only has a pulverizing action on the soil, but it also has a slight leveling effect. On many farms it is customary to plow and harrow alternately from the beginning of the work until the entire field has been completed, harrowing "up to the plow" each night. Afterwards the beet land may be harrowed two, three, or more times at intervals of a week or 10 days. The harrowing season extended from March to May. The harrows used varied in width from 9 to 16 feet (fig. 8).

TABLE XI.—*Spike-tooth harrowing data for three Colorado districts.*

District.	Year.	Number of farms.	Acres harrowed per farm.	Number times harrowed.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	109	22.93	3.52	1	3.54	2.74	9.7	$1.46
Fort Morgan	1915	66	36.8	3.7	1	3.7	2.3	8.4	1.36
Greeley	1914–15	191	25.9	2.76	1	3.57	1.8	6.17	1.02

For all districts nearly all harrowing was done either by one man and four horses or one man and three horses. In the Rocky Ford district 58 per cent of the growers reporting on this operation used a

FIG. 8.—Harrowing with the spike tooth is one of the common operations in fitting the land for sugar beets.

1–4 crew. At Fort Morgan the percentage for this crew was 71, while in the Greeley district it was 56. The 1–3 crew was used by 37 per cent at Rocky Ford, 30 per cent at Fort Morgan, and 39 per cent at Greeley. There were a few crews smaller and a few larger than these two. The Fort Morgan group did more harrowing than the Rocky Ford group and the average cost per acre was 10 cents lower in the former in 1915 than in the latter in 1914 and 1915. Greeley farmers had the lowest cost per acre for spike-tooth harrowing, but went over the beet land fewer times than did the men of either of the other areas. A day's work with the spike-tooth harrow with an average crew varied from 12.8 to 15 acres.

SPRING-TOOTH HARROWING.

The spring-tooth harrow was operated on relatively few farms in the Rocky Ford and Fort Morgan districts, but enough growers at Greeley used this implement to afford reliable data. The spring-tooth is an excellent implement with which to loosen up fall-plowed land. Land plowed in early spring, which has been partially worked and has been packed with a few heavy rains, can also be brought into proper condition with a spring tooth. Inasmuch as only a small amount of plowing is done here in the autumn, it is highly probable that the spring-tooth was operated for the latter purpose. According to these records the season for spring-tooth harrowing extended from March to May. The average implement was 6 feet in width (Table XII).

Table XII.—*Spring-tooth harrowing data for three Colorado districts.*

District.	Year.	Number of farms.	Acres harrowed per farm.	Number times harrowed.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	5	13.7	2	1	3.4	3.42	11.4	$1.76
Fort Morgan	1915	10	17.0	1.8	1	4.2	2.3	9.8	1.52
Greeley	1914–15	62	21.05	1.56	1	4.0	1.77	7.0	1.11

On the Rocky Ford and Fort Morgan farms the beet land was spring-tooth harrowed approximately twice. Greeley farmers averaged one and one-half times. In the latter region 54 growers used a crew of one man and four horses. It will be observed that the cost per acre for spring-tooth harrowing was slightly more than the cost for similar work with the spike-tooth. Since the number of farms reporting from the Rocky Ford and Fort Morgan areas is small, it would be unfair to make a direct comparison with the Greeley group where the larger number obtains. Under average conditions 8 acres appears to be about the usual area covered per day with the spring-tooth.

ROLLING.

The roller not only serves a useful purpose in reducing clods or lumps in a dry soil, but also is valuable in packing the loose surface soil and in restoring connection with the supply of moisture in the subsoil. Only 17 per cent of the growers did rolling in the preparation of the seed bed. The majority of these were found in the Greeley district. At times the roller may be serviceable in producing a smooth surface for the drill.

The corrugated roller was used principally by Greeley growers. This implement varied in width from 8 to 9 feet and was operated on 29 Greeley farms by crews of one man and two horses, and on 16 farms by crews of one man and four horses. One man used a 1–3 crew. From 11 to 16 acres constituted a day's work with a roller (Table XIII).

TABLE XIII.—*Rolling data for three Colorado districts.*

District.	Year.	Number of farms.	Acres rolled per farm.	Number of times rolled.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	14	24.2	1.46	1	2.92	1.26	3.7	$0.60
Fort Morgan	1915	2	10.0	1.00	1	2.00	.60	1.3	.26
Greeley	1914–15	46	24.05	1.10	1	2.70	.77	2.15	.39

CLEANING DITCHES.

Cleaning the laterals that connect the fields on the farm with the main canal is usually considered a special task, otherwise this work might be included under irrigation. During the irrigation season silt is deposited in the main laterals as well as in the distributing ditches. Dust and dead weeds may accumulate in the distributing canals during the winter months. Frequently also, weeds make such vigorous growth in the ditches that cutting them with a scythe and clearing them away becomes necessary. In order, therefore, to insure rapid delivery of water when the crop requires it, some work must be devoted to cleaning ditches prior to the first run in the canal. On many farms the cleaning is done with man and horse labor, while in some cases man labor only is expended.

Fifty-four per cent of all farms reporting on the field operations did the cleaning by hand (Table XIV). For the majority of the farms in this group cleaning was done once during the season, although a few men cleaned twice. Consequently, the averages which are given for the respective districts indicate slightly more than once over. This operation began early in the spring and extended almost to the end of the irrigation season. The greater part of the cleaning was done during the month of May or early in June. There were special instances where it was expedient to do some cleaning throughout the summer months. Rocky Ford growers put much more time on the cleaning than was expended at Greeley or Fort Morgan. The highest acre cost was reported from the former area. Considerable variation was found in the number of acres cleaned per day. The average area covered per day for the Rocky Ford area was 5.1 acres, for Greeley 9 acres, and for Fort Morgan 12 acres (fig. 9).

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TABLE XIV.—*Cleaning data for three Colorado districts (work done by hand).*

District.	Year.	Number of farms.	Acres cleaned per farm.	Number times cleaned.	Number of men.	Hours per acre.	Cost per acre.
Rocky Ford	1914–15	52	22.75	1.21	1	2.37	$0.43
Fort Morgan	1915	42	37.97	1.09	1	.91	.17
Greeley	1914–15	107	25.6	1.06	1	1.12	.23

TABLE XV.—*Cleaning data for three Colorado districts (work done by man and horse labor).*

District.	Year.	Number of farms.	Acres cleaned per farm.	Number times cleaned.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	55	25.2	1.44	1.6	2.49	1.73	2.90	$0.60
Fort Morgan	1915	56	37.53	1.44	1.62	3.12	.94	2.07	.41
Greeley	1914–15	53	28.9	1.04	1.34	3.24	.3	.63	.13

FIG. 9.—Removing silt from an irrigation ditch. In order to insure rapid delivery of water when the crop requires it, some work must be devoted to cleaning ditches a few weeks prior to the first run in the canal.

On farms where the canal and distributing laterals are accessible to horses, silt and other débris that have been deposited can be loosened with a plow and the accumulated material can be removed with a home-made V ditcher (fig. 10). By using horses much more work usually can be done within a limited period than by hand, though it does not necessarily follow that the work can be accomplished at a lower cost. Where equal amounts of work are involved, the combined crew will undoubtedly have the advantage. The three districts were represented by approximately equal numbers of men who did cleaning with a combined crew. Cleaning was done practically 1½ times at Rocky Ford and Fort Morgan. Greeley growers averaged slightly more than once over. In this practice there was also a marked difference in the area ditched per day—from 8.3 acres in the Rocky Ford district to 34.6 in the Greeley area. Manifestly, the cost per acre for each district is directly related to the amount of work done per day. It should be noted that during certain seasons much more ditch-cleaning work is necessary in some districts than in others. Out of 164 growers reporting, 44 used crews made up of one man and two horses, 40 employed crews of two men and three horses, 22 indicated the use of one man and three horses, and 19 had crews of two men and two horses. The records do not indicate that the crew size increased or decreased the cost per acre

FIG. 10.—Removing silt and other débris with a homemade V ditcher. It will be seen that the deposit of silt was first loosened with a plow.

for cleaning. Where high costs are shown it simply means that more work was necessary there to place the ditches in good condition. In comparing hand labor with hand and horse labor in ditch cleaning, it must not be assumed that the lower cost for the former justifies a recommendation that the work always be done by hand. It is probably true that effective work with a plow and V ditcher one season will enable the grower to handle the situation by hand the succeeding season.

PLANTING.

Planting practice was uniform throughout the three districts. As a matter of fact this operation does not vary much, no matter what the conditions. The four-row beet drill is an implement common to all beet-growing areas of this country, and it is everywhere used in about the same way. To insure good work with the planter, the surface of the field should be smooth and free from any large clods, and the soil ought to be firm enough to enable the operator to manipulate the drill readily, otherwise the drill wheels will sink and the seed can not be planted at an even depth. If these essentials are obtained, straight rows can be made, which are not only pleasing to the eye and give the owner a sense of gratification as the season advances, but also make it easier for the driver to operate the cultivator, especially while the plants are small. Thus the stand is not impaired by having some of the beets cut out with the cultivator knives. The rows averaged 20 inches apart in the Fort Morgan district, approximately the same in the Greeley district, and at Rocky Ford 19 inches. Some of the Greeley farmers made a practice

Fig. 11.—Planting beet seed with a four-row beet drill. The marker to the right makes a line that serves as a guide for the driver. Furrowing-out shovels are also attached to this beet drill.

of planting wide and narrow rows in pairs. The usual distance apart for these pairs was 16 and 24 inches. Such an arrangement not only provided a set of wide rows in which to drive the horses when cultivating, but also furnished more space for irrigation ditches (fig. 11).

The dates of planting in the Rocky Ford district varied from April 1 to June 15, at Fort Morgan from May 10 to June 22, and at Greeley from April 1 to June 20. These dates included the very early and very late planting. There was a little replanting in each district, which undoubtedly had a tendency to carry the latest date of planting somewhat beyond the customary limits. Under normal conditions planting in all of these areas is quite general during the latter part of April and early in May (Table XVI).

Table XVI.—*Planting data for three Colorado districts.*

District.	Year.	Number of farms.	Acres planted per farm.	Crew.		Hours per acre.		Total cost per acre.
				Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	109	23.02	1	2	1.14	2.30	$0.44
Fort Morgan	1915	66	37.2	1	2	1.03	2.09	.43
Greeley	1914–15	195	25.66	1	2	1.06	2.13	.43

It has been customary in these areas to use approximately 20 pounds of seed per acre. Recently, owing to the scarcity of beet seed the amount used has been reduced considerably. It has been found that a seeding of 10 to 12 pounds per acre gives very satisfactory results, provided soil conditions are right. Planting was done universally by one man and two horses. Growers in these three districts averaged nine to ten acres per day. The cost for planting in 1914 and 1915 was practically identical for the three districts.

ROLLING BEETS.

The practice of rolling has been discussed in part in connection with the preparation of the seed bed. However, the practice of rolling beets was considered important enough to be considered separately. This operation is performed after the seed had been planted and many of the young plants have begun to appear. Light showers occur frequently at this season of the year and the soil has a tendency to become baked. When this condition is pronounced, the young plants may be prevented from coming through and a poor stand will be the result. Some growers make a practice of harrowing in order to restore the surface mulch, but if the field is rolled, the crust can be broken and the beet plants will not be checked in their growth. Rolling at this period may also put the soil in better condition for bunching and thinning. Furthermore, rolling promotes capillary action, which is very essential to rapid growth. In these three districts the rolling after planting was done almost exclusively with a corrugated roller (fig. 12).

On some farms this work was done before thinning, on others after thinning and blocking. Rolling packs the soil about the beet and facilitates recovery of the plant after being disturbed with the hoe or by hand. Moreover, bunching with a hoe creates a small ridge between the rows, and if this is made smooth with a roller, the cultivator can be guided more readily. The Fort Morgan and Greeley growers averaged a little more than once over; the Rocky Ford growers one and one-fifth times over. The rolling was done almost entirely with crews of one man and two horses. The cost for this operation in 1914 and 1915 was somewhat lower than that for rolling in seed bed preparation (Table XVII).

TABLE XVII.—*Rolling beet data for three Colorado areas.*

District.	Year.	Number of farms.	Acres rolled per farm.	Number times rolled.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	74	22.4	1.21	1	2.1	0.97	2.1	$0.38
Fort Morgan	1915	20	16.9	1.05	1	2.1	.75	1.56	.31
Greeley	1914–15	96	24.28	1.18	1	2.26	1.01	2.2	.43

CONTRACT LABOR.

The hand work on sugar beets includes blocking and thinning, two regular hoeings, occasionally a third hoeing with some weeding, and pulling and topping. These operations, taken collectively, are

FIG. 12.—Rolling sugar beets. Rolling not only breaks any crust that may exist, but it also firms the soil and thereby facilitates blocking and thinning.

known as contract labor. The blocking is done with a hoe. The beet seed is drilled in a continuous row and after germination takes place more plants are usually present than are necessary to insure a good stand. By blocking or chopping out the surplus plants with a hoe, small bunches containing three or more beets are left 10 to 12 inches apart in the row. The thinning of the bunches which follows is done by hand. In addition to blocking, the operator cuts off any weeds left by the cultivator. The manner of performing these operations is described in the following rules and regulations governing hand work, from sample contract, 1915:

Bunching and thinning.—This work must be commenced by the contractor just as soon as the beets show four leaves and the grower has them cultivated, and must be completed as rapidly as possible in the following manner, to wit: Beets to be thinned from 7 to 10 inches apart, leaving only one plant in each place; no double beets shall be left. This work must be done so that the land will be entirely free from weeds.

Second hoeing.—This work must be commenced by the contractor as soon as the thinning is completed and the grower has finished the second cultivation by hoeing a little deeper than the first hoeing, killing and removing all weeds, and removing any double plants that may have been overlooked in the thinning. The grower must keep the crop cultivated so that at least 10 inches of the center of the row remains clear of all weeds and foul growth up to the time of the third hoeing.

Third hoeing.—A third hoeing must be given the beets by the contractor, and in addition to such third hoeing any and all further hoeing necessary to keep the beets free from weeds until harvest of the beets is commenced must be done by the contractor, and in the event of the beets having grown so large that a third or further hoeing would injure them, then all weeds that grow up to the time of the commencement of harvest must be removed by hand, as the beets must be kept free from weeds at all times until harvested.

Blocking and thinning.—For the early plantings, the blocking and thinning may begin in the latter part of April. Under normal con-

FIG. 13.—Bunching and thinning.

ditions the contract labor should be well under way by the middle of May. For the late plantings, or fields that may require replanting, the time for blocking and thinning may extend to the middle of June. This work was done in the Rocky Ford district almost entirely on a contract basis. There were but two men in this region who did their own hand work. The blocking and thinning on these farms required 30.8 hours per acre and cost $5.54. There were 23 growers at Fort Morgan who handled either a part or all of their own blocking and thinning, while the Greeley list afforded only 28 records on this operation. The Fort Morgan growers spent 28.6 hours per acre in blocking and thinning, involving a cost of $5.44 per acre, in 1915, while the Greeley growers had an average labor requirement of 25.4 hours per acre, with a cost of $4.83 per acre, in

1914 and 1915. The usual contract price for the blocking and thinning in northern Colorado during 1914–15 was $6 per acre (fig. 13). It will be seen that the estimated cost for those farms where the operator did this work himself was somewhat lower than the contract price. This was also true of hoeing.

Hoeing.—There were 28 farms in the Rocky Ford section, 23 at Fort Morgan, and 32 at Greeley that reported on hoeing practice. Practically two hoeings were given in addition to the blocking. It required 10.2 man-hours per acre to do the hoeing on the Rocky Ford farms in 1914 and 1915, and the cost was $1.84 per acre. The Fort Morgan growers spent 12.2 hours per acre in 1915, involving a cost of $2.33, while at Greeley, in 1914 and 1915, 10.9 hours per acre were consumed in doing the hoeing, and the cost was $2.07.

FIG. 14.—Hoeing beets. This work must be commenced by the contractor as soon as the thinning is completed and the grower has finished the second cultivation.

The contract acre rate for the second and third hoeings at Greeley and Fort Morgan was $2 and $1, respectively. It will be observed that the estimated cost for hoeing was much less than the contract labor rate. The time for hoeing extended from May to August (fig. 14).

CULTIVATION.

As soon as the plants show four leaves, before blocking and thinning, the first cultivation is given (Table XVIII). The cultivator is equipped with L-shaped knives for cutting a small amount of earth away from the row (fig. 15). A small duck foot is used to stir the

TABLE XVIII.—*Cultivating data for three Colorado districts.*

District.	Year.	Number of farms.	Acres cultivated per farm.	Number times cultivated.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	110	22.90	5.54	1	1.96	6.54	12.8	$2.46
Fort Morgan	1915	66	36.9	5.09	1	2.00	4.94	9.89	2.03
Greeley	1914–15	195	26.09	4.31	1	2.00	4.85	9.35	1.95

soil between the rows. All of the small weeds outside of the row are cut off at the first cultivation. The object usually is to make a mulch of granular soil, which checks the upward movement of

FIG. 15.—Giving the first cultivation. This work is done as soon as the plants show four leaves.

moisture, but does not blow readily. On some farms the disk cultivator is used for the preliminary work. The dates of cultivation varied for the majority of operators from May to July. On some farms work on late beets ran into August. It is customary in these three areas to give from three to five cultivations per season. The Greeley growers averaged slightly more than four times in cultivating the beet crop in 1914–15 (fig. 16).

All of the farmers reported on this operation. The common-field crew required in handling the ordinary 4-row cultivator consisted of one man and two horses. There were a few operators who cultivated with a one-man-one-horse crew on small tracts. The cost per acre was approximately $2 for the Fort Morgan and Greeley areas, while in the Rocky Ford region it was about $2.50. A day's work with a cultivator varied on the average from 8.4 acres in the Rocky Ford district to 8.8 acres in the Greeley district.

TABLE XIX.—*Furrowing data for three Colorado districts.*

District.	Year.	Number of farms.	Acres furrowed per farm.	Number times furrowed.	Crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	66	20.73	2.75	1	1.93	2.93	5.80	$1.11
Fort Morgan	1915	66	36.9	1.08	1	2.00	.99	2.08	.42
Greeley	1914–15	195	25.76	1.42	1	1.98	1.51	2.94	.61

FIG. 16.—Cultivating sugar beets.

Eighty-eight per cent of the growers reported on furrowing, or preparation for irrigation. In the Rocky Ford district the operators furrowed approximately three times, one furrowing coming early, immediately after planting. There was an intermediate furrowing and a third after cultivation had ceased. Cultivating the land after an irrigation necessitates a repetition of the furrowing. In northern Colorado furrowing was done almost entirely after the last cultivation. This operation required, in general, a crew of one man and two horses. The variation in cost in 1914 and 1915 shown in Table XIX is mainly due to variation in the number of times the fields were furrowed. A day's work furrowing ranged from 9.4 acres to 10 acres as averages for these groups.

SLEDDING.

Sledding is an operation which was common in the Arkansas Valley only. The operation was performed with a homemade sled consisting of two small logs held together by crosspieces. These logs are just far enough apart to span a pair of furrows, each log, when the sled is running, crushing any clods or lumps that may be in its furrow and leaving the surface smooth (fig. 17). Thus, when the water is turned into the furrow it passes rapidly from one end to the other and a uniform distribution is secured. Sixty-eight growers reported on sledding in 1914 and 1915. The fields were gone over twice during the season, once for the first irrigation and once later.

FIG. 17.—Sledding out prior to irrigating the young sugar beets. This insures a more rapid movement of the water and assists in obtaining a more even distribution of water in the soil.

The crew on many of these farms consisted of one man and one horse. A few growers used one man and two horses. Sledding required 2.2 man-hours and 3.5 horse-hours per acre, and cost 75 cents per acre. These growers averaged 9.3 acres per day sledding. In the other districts small logs sometimes were attached to the shovels on the cultivator and the sledding was done simultaneously with the furrowing out.

IRRIGATION.

It has been pointed out that there is a slight difference in climatic conditions between the Arkansas Valley and the northern and eastern areas of the State. It is customary to irrigate early in the season in the Arkansas Valley (fig. 18). This means turning the water into the field immediately after planting. On some farms, however, it is the practice to irrigate the land in the autumn (fig. 19).

FIG. 18.—Showing irrigation water in rows that were made smooth and even with the aid of a sled.

FIG. 19.—Irrigating sugar-beet land in the autumn. The moistened soil responds more readily to the action of frost than dry soil.

The available supply of water in this region depends largely upon the water stored in reservoirs for irrigating sugar beets. Ordinarily the rivers do not carry much water that can be utilized for irrigation after July 1. From 12 to 20 inches of water is used upon the beet crop.

TABLE XX.—*Irrigation data for three Colorado districts.*

District.	Year.	Number of farms.	Acres irrigated per farm.	Number times irrigated.	Number of men.	Man hours per acre.	Cost per acre.
Rocky Ford	1914–15	110	22.9	3.58	1	8.7	$1.57
Fort Morgan	1915	66	36.7	2.49	1	7.79	1.48
Greeley	1914–15	192	25.79	2.96	1	8.5	1.62

Practice records on irrigation were obtained from 368 growers (Table XX). In the Arkansas Valley the time for irrigation varied from April 15 to September 10, while in northern Colorado the initial

FIG. 20.—Irrigating sugar beets in the Greeley area. The method of distributing water is shown in this illustration.

irrigation was given July 1 and the final work was completed September 30. Greeley growers averaged three irrigations for the season, Fort Morgan operators two and one-half, and the Rocky Ford area three and one-half. There was little variation in the labor requirements or the final costs for this operation in 1914 and 1915. A day's work of eight hours amounted to 3.5 acres in the Greeley area and 4.1 acres in the Rocky Ford district. This would mean irrigating from 10 to 12 acres in 24 hours. Water is usually run continuously day and night and is given more or less attention throughout the run (fig. 20).

LIFTING, OR PLOWING OUT.

Lifting, topping, and hauling are three operations which go hand in hand. Lifting involves loosening the beets in the soil so that they can be taken out readily by hand and thrown into piles. Two types of pullers or lifters were used in these districts. One, known as the "crotch" or "straddle puller," has two shafts, with special points which pass on either side of the row. The other type is known as the "side puller" and has only one shaft with a single point. In both cases only one row is pulled at a time (fig. 21). Lifting or pulling coincides with the harvesting dates (Table XXI). During the two years of this investigation (1914 and 1915) harvesting in the Rocky Ford district ran from September 1 to December 15, at Fort Morgan from September 20 to November 20, and at Greeley from August 25 to November 26. Occasionally unfavorable weather occurs during the harvest period and this has a tendency to delay or prevent harvesting.

FIG. 21.—Plowing out sugar beets in the Fort Morgan district. On 46 farms the crew for this operation consisted of one man and four horses.

TABLE XXI.—*Lifting data for three Colorado districts.*

District.	Year.	Number of farms.	Acres lifted per farm.	Crew.		Hours per acre.		Total cost per acre.
				Man.	Horse.	Man.	Horse.	
Rocky Ford	1914–15	106	22.95	1	3.42	5.54	18.43	$2.84
Fort Morgan	1915	66	36.7	1	3.00	4.09	12 10	2.11
Greeley	1914–15	195	25.76	1	3.05	5.12	15.54	2.68

There was considerable difference in each area in the number of horses used to do the lifting. In the Rocky Ford area on 52 farms a crew of one man and three horses did the plowing out; on 46 farms one man and four horses; and on 6 farms one man and two horses. In the Fort Morgan district the farms reporting were about equally divided among these three crew sizes. Greeley growers favored the 1–3 crew, 129 farmers reporting this size; 38, the 1–4 crew; and 28 the 1–2 crew. A few crews of odd sizes were used.

The number of horses used in plowing out beets is determined largely by the type of soil, and by the climatic conditions at the time of harvest. A day's work with the lifter varied from 1.8 to 2.2 acres.

TOPPING.

Fifteen per cent of the farmers reporting did a part of the topping themselves and gave estimates on this operation. The work was done from the latter part of August to the middle or latter part of December (fig. 22). The estimated labor costs for topping in 1914 and 1915 were much lower for all districts than the rates charged under the contract method. In the Rocky Ford district 25.8 man

FIG. 22.—Topping sugar beets. It is stipulated that the tops shall be cut off squarely just below the crown at the base of the bottom leaf.

hours were expended in topping an average yield of 11.2 tons per acre, in the Fort Morgan area 30.4 hours for a 13.4-ton yield, and at Greeley 25.1 hours for a yield of 14.2 tons per acre. The cost for these few farms varied from $4.64 to $5.78 per acre. The contract price for pulling and topping in the Greeley and Fort Morgan districts was $9 per acre. The prevailing price for man labor is much higher during the harvest season than at other seasons of the year.

Taking all items into consideration, the hand labor received $18 per acre plus an additional 25 cents per ton for each ton in excess of an average yield of 12 tons per acre.

Following are the rules and regulations governing pulling and topping in the areas covered in this study:

The work must be done just as soon as the grower receives orders from the company to dig his beets. The plowing out shall be done by the grower. The beets must be pulled by the contractor, and cleaned of adhering dirt by knocking the beets together or otherwise as pulled, and throwing them into piles. The ground on which the beets are to be piled must be cleaned off and leveled down by the contractor, so that the grower may fork the beets into the wagon free from dirt, rocks, leaves, or other trash.

The beets shall be topped by the contractor in the following manner, to wit, by cutting off the tops squarely just below the crown at the base of the bottom leaf. Knives shall not be used for lifting beets, but hooks may be used, provided they are properly driven into the top of the crown of the beet only.

All tools for hand work shall be furnished by the grower.

All cultivating, irrigating, plowing out, and loading shall be done by the grower, unless otherwise agreed upon.

All beets left in the field over night must be protected properly from frost by the contractor by covering the piles with beet tops, the tops to be removed by the grower before beets are loaded.

FIG. 23.—Sugar beets piled at a loading station. Surplus beets are sometimes thrown into large piles at the receiving stations, and these are then reloaded when the supply from the field is curtailed by bad weather or otherwise.

The grower reserves the right, in the event the hand work is not done properly or with sufficient rapidity by the contractor that the crop would thereby suffer, to engage additional help for doing the work as cheaply as practicable under existing conditions, and to deduct the expense of the same from this contract, it being agreed and understood, however, that in the event of any dispute arising between the grower and contractor as to the interpretation of the above rules, as to the manner in which the work is being done, or as to the necessity of additional help, the agricultural superintendent or field man of the company shall act as referee, and his decision shall be final and binding on both the contractor and grower.

PITTING SUGAR BEETS.

During the harvest season beets are sometimes taken out much more rapidly than they can be received by the sugar company. It is therefore the custom to put a portion of the crop in pits during this period. Pitting was found to be much more common in the

Arkansas Valley than in northern Colorado. In the latter district surplus beets were thrown in large piles at the receiving stations and loaded at times when the delivery from the growers was slack (fig. 23). In the Arkansas Valley when beets are held in the field they are placed in a cone-shaped pile and are covered with a small quantity of earth to prevent freezing. As soon as the beets have all been harvested and available supplies have been sliced, the growers are called upon to deliver their pitted beets. Inasmuch as this operation required extra labor, the sugar company paid an additional premium of 75 cents per ton over and above the regular market price.

Twenty-eight growers reported on pitting beets in the Rocky Ford district. These men cared for 6.6 acres per farm in this way. The average yield for this area was 13.2 tons per acre. Man labor only

FIG. 24.—Leveling a strip of land upon which topped beets are to be piled. The contract requires the man who is engaged to do the hand labor to clean off and level the ground so that the beets may be thrown into the wagon free from dirt or trash. In this case the operator did a large part of the hand labor.

was involved, the cost per acre approximating $1.30 in 1914 and 1915. On some farms it is necessary to use horses to haul beets to the pit. There were three records reported from the Greeley area and a like number from the Fort Morgan district. Both man and horse labor entered into this work. The cost varied from $1.83 per acre at Greeley to $2.80 per acre at Fort Morgan.

LEVELING FOR BEET PILES.

Within recent years a large number of farmers have adopted the practice of using a V leveler for the purpose of making a smooth strip of soil upon which to throw the beets. Where no leveling is done, small clods and beet tops will be taken up when the sugar beets are loaded on the wagon. Leveling removes a part of this trash. Only a few growers, however, reported on this operation. This work in a number of cases was included with the lifting of the crop, and on other farms the contract laborer was required to do this work with a garden rake as a part of his contract labor. The number of records obtained was not large enough to warrant any definite conclusions with reference to the time consumed or the cost per acre. A span of horses with a V-shaped leveler can prepare sufficient space for several rows of beets in a short time (fig. 24).

HAULING.

It has been pointed out that hauling is done at the same time as the lifting and topping. Ninety-six per cent of the growers included in this investigation gave information on hauling; the remainder of

FIG. 25.—Loading sugar beets with fork from small piles in field.

these growers hired hauling done by contract. Heavy wagons were used, equipped with strong, well-built beet boxes of special type (figs. 25 and 26). The loading was done with forks or by hand. Rain occasionally leaves the ground heavy and makes it necessary to use an extra team. In cases in which the crop was delivered directly to the cars at the loading station, no hand labor was required. The unloading at the beet dump was done mechanically (figs. 27 and 28).

In the Rocky Ford district 22 growers marketed the beets with a crew of one man and two horses, while 67 growers utilized a 1–4 crew. In the Fort Morgan area 43 operators used a crew consisting of one man and two horses, while 13 growers hauled with a crew of one man and four horses. The Greeley area, which furnished the largest number of records, had 126 growers who reported a crew of one man and two horses, 46 reporting one man and four horses, and 8 reporting one man and three horses. A few odd crews were

FIG. 26.—Hauling sugar beets from the field. When the soilis soft an extra team is used to assist in getting the load to a solid road.

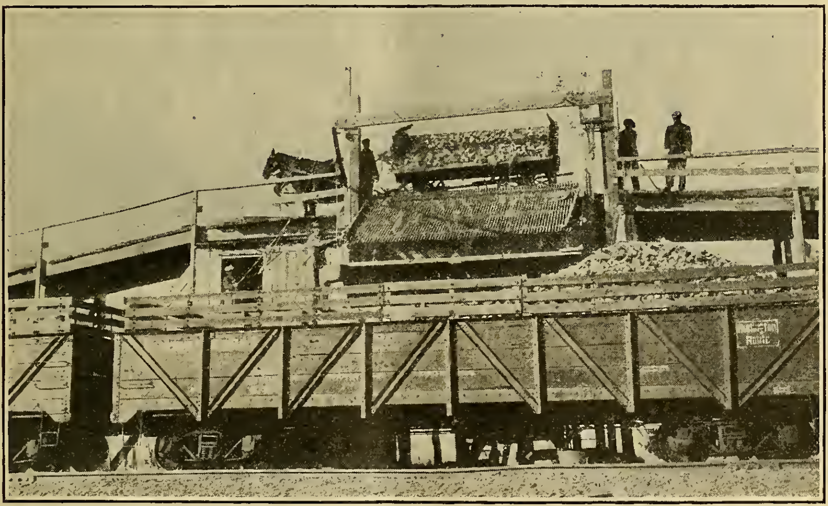

FIG. 27.—Unloading beets mechanically. This type of machine is known as the rocker dump.

reported. There was a variation in cost from $5.64 per acre, which was the average for the Fort Morgan list of growers in 1915, to $6.86 per acre for the Rocky Ford group in 1914 and 1915 (Table XXII).

TABLE XXII.—*Hauling data for three Colorado districts.*

District.	Year.	Number of farms.	Acres hauled per farm.	Tons hauled per acre.	Distance hauled.	Average crew.		Hours per acre.		Total cost per acre.
						Man.	Horse.	Man.	Horse.	
					Miles.					
Rocky Ford	1914–15	107	22.84	13.07	1.81	1.1	3.56	13.61	44.11	$6.86
Fort Morgan	1915	66	35.58	13.94	1.8	1.07	2.59	12.34	30.01	5.64
Greeley	1914–15	184	25.56	15.35	1.54	1.00	2.53	13.03	32.44	6.05

Distance of hauling and its relation to cost.—It is generally conceded that the distance from the loading station is an important factor in determining cost. The records for all districts were sorted upon the basis of distance, and the average cost per ton for the several groups was computed.

FIG. 28.—Showing device at loading station for removing the soil that sifts through the sieve as the beets pass from the wagon to the car.

TABLE XXIII.—*Relation of distance from loading station to cost of delivering the sugar beet (1914 and 1915).*

Distance (miles).	Average distance.	Number of records.	Average crew.		Average cost per ton.
			Man.	Horse.	
	Miles.				
1 or less	0.80	93	1	3.19	$0.40
1 to 2	1.63	151	1	2.81	.44
2 to 3	2.64	72	1	2.90	.55
3 to 4	3.70	14	1	2.90	.63
Over 4	4.87	2	1	4.00	.68

The significance of this study may be seen by comparing group 1 with group 3. Hauling an average distance of 2.6 miles in comparison with an average distance of 0.8 mile increased the cost 15 cents per ton. If the grower obtained an average return of 12 tons per acre, this difference would make a total increase of $1.80 per acre. As the distance increased, the cost per acre increased throughout all of the groups. Only two records were obtained in group No. 5, hence it would scarcely be fair to compare this group with No. 1, in which 93 men reported on hauling a distance of approximately 1 mile. It may be observed, however, that the average cost for group 5, with a 12-ton yield, would be $3.36 per acre more than the cost involved in hauling beets under the conditions stated for group No. 1.

COST OF PRODUCING SUGAR BEETS.

The total cost figures were classified and compiled under three distinct divisions, viz, (1) labor, (2) materials, and (3) other costs. In computing the various costs a weighted average was used. The cost per acre was found by dividing the total costs by the number of acres grown, and the cost per ton by dividing by the total number of tons produced.

LABOR COSTS.

The operators' labor, horse labor, and contract labor, when added together, gave the total labor costs for the respective districts in 1914 and 1915. This also includes man labor hired by the day or by the month. The rate per hour, or the contract rate used in obtaining the final results, has been explained fully in connection with the practice of growing beets.

Table XXIV.—*Labor costs for three Colorado districts.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.	Cost per ton.
Greeley	1914–15	195	5,028.40	$39.17	$2.53
Fort Morgan	1915	66	2,455.50	37.00	2.71
Rocky Ford	1914–15	106	2,428.95	38.34	2.95

The highest labor cost per acre ($39.17) was reported for the Greeley area (Table XXIV). Fort Morgan growers were $2.17 per acre below this average, but it will be seen that the average cost per ton was greater for Fort Morgan than for Greeley. Yield per acre was the factor that controlled the cost per ton in these districts.

In discussing these labor costs, it should be borne in mind that the hand work or the contract labor constituted a considerable proportion of the total labor costs. The standard contract rate for districts in northern Colorado was $18 per acre, plus a bonus of 25 cents per ton for each ton over an average yield of 12 tons per acre. For a 15-ton average this would necessitate the payment of $18.75 per acre. If all the growers represented in the Greeley district had paid for the hand labor on this basis, this item would have approximated 47 per cent of the total labor charge. It will be remembered that several growers did their own hand labor at a lower cost for this work than the contract price, hence the total charge for the latter in the district was reduced slightly for this reason.

MATERIALS.

The materials that were bought or used in the production of beets within these districts included seed, manure, poison for control of insects, and water. These items were therefore treated separately as a part of the expense incident to raising this crop (Table XXV).

TABLE XXV.—*Cost of materials for three Colorado districts.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.				Cost per ton.
				Seed.	Manure.	Water.	Total.	
Greeley	1914–15	195	5,028.40	$1.80	$5.50	$0.51	$7.83	$0.50
Fort Morgan	1915	66	2,455.50	2.11	3.46	.57	6.16	.45
Rocky Ford	1914–15	106	2,428.95	2.16	2.93	.50	5.60	.43

Beet seed.—The sugar company usually arranges to maintain a supply of seed sufficient for one or two seasons in advance. War conditions have interfered seriously with the importation of seed from abroad, consequently the ordinary stocks have been depleted and it has been necessary to urge the use of less seed per acre in starting the crop.

Seed was planted at the rate of 21 pounds per acre at Rocky Ford, 18.9 pounds per acre at Fort Morgan, and 18 pounds per acre at Greeley. A charge of 10 cents per pound was made for the beet seed. This would seem to indicate that the actual cost for seed in the Fort Morgan area should be $1.89 per acre in place of $2.11, as shown in the foregoing table. However, there was some replanting in each district and the cost of the seed used for this purpose, when charged to the entire acreage for each region, made the acre cost in 1914 and 1915 slightly more than the standard cost. There was a difference of 36 cents between the acre charge for seed as reported by the Greeley operators and that given for the Rocky Ford group.

Manure.—The value of the farm manure applied was estimated by each grower and served as a basis in computing the amount that should be charged against the 1914 and 1915 sugar beet crop. The Greeley and Fort Morgan growers manured essentially 50 per cent of the land in beets, whereas in the Rocky Ford section only 41 per cent of the beet land was treated. There was considerable variation in the rate of application. The Rocky Ford group had the lowest rate, 11.8 tons per acre, while the Greeley growers had the highest, 18.6. The Fort Morgan operators applied manure at the rate of 14.3 tons per acre.

Spray material.—Relatively few farms expended any money for the purchase of materials to use in destroying insects or to apply for the purpose of controlling plant diseases. Grasshopper poison was put out by 10 operators in Otero County, by 4 in Weld County, and by 5 in Morgan County. This item of cost, though exceedingly small, must not be ignored entirely, as each grower may at some time in his experience be called upon to do this kind of work. It frequently happens that a little money expended for poison insures a much better yield.

Irrigation water.—The annual charge for water did not differ greatly in the three districts under observation. The average for all districts was slightly more than 50 cents per acre. Several irrigation companies operate in each area, and some growers obtain water from two or more sources. This feature was given careful consideration, and an attempt was made to compute a fair charge for the annual use of water. Some of the original ditches have comparatively low water rates on account of early priorities. While there may be wide variation in the annual water assessment paid by individual growers who are receiving their supplies from different sources there is uniformity in the farms served by a given canal and the average charges for each district are also quite uniform.

OTHER COSTS.

There are certain expenses that must be carried by the farm as a whole, of which each enterprise must bear a just proportion. The solution of this problem in connection with a single enterprise involves a careful study of the entire business of the farm. Having obtained a true perspective of the relationships that exist between the various branches of the business, it was possible to distribute such costs as insurance and taxes, interest on land and land rental, machinery charges, and overhead expense on an equitable basis (Table XXVI).

TABLE XXVI.—*Other costs for three Colorado districts.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.					Cost per ton.
				Insurance and taxes.	Interest and rent.	Machinery.	Miscellaneous.	Total.	
Greeley	1914–15	195	5,028.40	$0.85	$21.21	$2.06	$1.41	$25.53	$1.63
Fort Morgan	1915	66	2,455.50	1.05	16.65	2.85	1.29	21.84	1.60
Rocky Ford	1914–15	106	2,428.95	.74	16.87	2.00	1.32	20.93	1.61

Insurance and taxes.—Each operator gave a report on the insurance and taxes paid during the year. These expenses were apportioned to the different enterprises of the farm and the amount to be assigned to sugar beets was determined. The insurance and taxes paid by tenant farmers in 1914 and 1915 were only personal taxes and were relatively small in comparison with the amount paid by owners or owners renting additional land, who had a land tax to pay in addition to personal property tax. A group of farms including a large number of tenants would show therefore a comparatively small charge under the heading "Insurance and taxes," but the proportion included with rent would balance up this apparent deficiency. The Greeley and Rocky Ford groups were almost equally divided between owner and tenant farms, while the Fort Morgan district gave only 42 per cent of straight tenant operators. This explains the slight difference in the amounts given for insurance and taxes in the three districts.

Interest and rent.—The investment of a given amount of capital in land should bring a definite return each year. When money is borrowed and farm land secures this loan, interest must be paid. If money is worth 7 per cent and land is valued at $200 per acre, then the crop which is grown upon that soil should be charged with $14 as interest.

In each of these districts estimates showing the value of farm land were secured and used in figuring the interest charge. Land rental was computed from the amounts received by the landlord in 1914 and 1915 as a direct cash payment or indirectly through the sale of sugar-beets. The Greeley group had the highest interest and rental cost per acre ($21.21). The Fort Morgan and Rocky Ford operators had an average interest and rental cost approximating $17 per acre.

Some cash is required to meet the operating expenses of the farm during the growing season. A part of the total cost of the contract labor must be paid when the bunching and hoeing are completed. Money for this purpose is frequently provided by the sugar company, but principal and interest must be met when the crop is harvested. The interest on this loan was included along with interest and rent.

Machinery.—These costs not only involve interest on the original investment in machinery, but also embrace depreciation and annual repairs. There are a few implements, such as the beet drill, topping knives, and the lifter, that are used exclusively on sugar beets. Other equipment, like the plow, harrow, disk, leveler, cultivator, wagons, etc., may be used for several crops, hence the costs that are involved must be apportioned according to the relative importance of the enterprises. This expense stands second in this group of costs. In the Greeley and Rocky Ford sections the machinery costs per acre were practically identical. The sugar beet is by far the most important crop at Fort Morgan, hence the machinery charge is somewhat greater than in the other two districts, where more enterprises shared this cost.

Miscellaneous expense.—Some of the expenses of the farm, such as telephone charges, office supplies, etc., are general in nature and are not applicable to any special enterprise. They must therefore be carried by the farm as a whole. To make provision for these items, a 3 per cent charge was made on the basis of labor and material costs combined. If the labor and materials amounted to $60 per acre, 3 per cent of this sum would be $1.80. This would be taken as a part of the total cost of producing the crop. It will be seen that the overhead expense for the three Colorado districts did not vary greatly.

SUMMARY OF COSTS.

In Table XXVII is shown a summary of costs in 1914 and 1915 for the three districts. The highest cost per acre was found in the Greeley district, but as this region was credited with the highest average yield, these growers had the lowest cost per ton. The cost per acre was $7.66 greater in the Greeley district than in the Rocky Ford section, but, the Greeley farmers produced sugar beets at a cost of $4.66 per ton, which was 33 cents per ton less than the cost at Rocky Ford.

TABLE XXVII.—*Summary and distribution of costs for three Colorado districts.*

District.	Year.	Yield per acre.	Cost per acre.	Cost per ton.	Distribution of costs.		
					Labor.	Materials.	Other costs.
					Per cent.	*Per cent.*	*Per cent.*
Greeley	1914–15	15.57	$72.53	$4.66	54.3	10.7	35.0
Fort Morgan	1915	13.65	65.00	4.76	56.9	9.5	33.6
Rocky Ford	1914–15	12.99	64.87	4.99	59.1	8.6	32.3

Labor costs constituted the most important part of the expense in producing sugar beets. In the Rocky Ford district this amounted to 59.1 per cent. Greeley growers had the lowest percentage under this heading. Materials constituted from 8.6 to 10.7 per cent of total cost, and other costs approximately one-third.

LABOR REQUIREMENT.

As already stated the labor requirement in the production of sugar beets includes man, horse and contract labor. Since it is the general practice to hire a part of the work done at a stipulated price per acre, this contract labor is usually treated as a direct cash outlay against the beet crop. This item was converted to man hours by dividing the cash outlay per acre by 25, the cost per hour in cents. Table

XXVIII contains the total labor requirement per acre for the three districts represented in this study.

TABLE XXVIII.—*Labor requirement in producing an acre of sugar beets.*

District.	Year.	Acres grown.	Yield per acre.	Hours per acre.	
				Man.	Horse.
			Tons.		
Greeley	1914–15	5,028.4	15.57	123.9	104.5
Fort Morgan	1915	2,455.5	13.65	118.1	103.0
Rocky Ford	1914–15	2,429.0	12.99	117.3	132.7

It will be seen that there is little variation in the number of man hours. There is a difference of about 6 hours of man labor between Greeley and Fort Morgan. A greater variation is apparent in the horse labor expended. At Rocky Ford about 30 hours more horse labor were necessary than at Greeley or Fort Morgan. A study of the farm practice tables shows that the tillage operations were performed a greater number of times at Rocky Ford than at Greeley or Fort Morgan. This was true, especially with such work as crowning, disking, leveling, cultivating, and furrowing out. Ordinarily the hours of man labor will exceed the hours of horse labor in the production of sugar beets. However, one of these regions furnishes an exception to this rule.

PROFIT.

In the last analysis the success of a given farm depends not so much upon the profit that may be derived from a single enterprise as it does upon the balance and stability of the entire organization. A certain enterprise on the farm may bring an exceedingly small profit at the end of the year, and in comparing the returns with the income from other crop or live-stock enterprises, the operator might conclude that the one showing a narrow margin would have to be discarded, but in reaching this decision he may overlook the fact that the industry in question enables him to utilize hands and teams to advantage when otherwise they might be idle and merely entailing expense. Large direct profits from a single crop should not be the determining factor in leading the operator to increase his acreage greatly, since the seemingly less profitable enterprises may be contributing much to his success; indeed, failure might follow if they were dropped. This is merely another way of saying that farming is a complex business, and that in order to attain the highest success each enterprise should be considered not only in its relationship to others but also in its bearing upon the farm policy as a whole. Cost figures should be discussed in the same manner. However, it may be pointed out that estimates can be obtained more readily with a single crop than with all enterprises combined (Table XXIX).

TABLE XXIX.—*Average returns and margin above cost in producing sugar beets, 1914–15.*

District.	Yield per acre.	Receipts, beets and tops per acre.	Cost per acre.	Margin per acre.		
				Beets.	Tops.	Total.
Greeley	15.57	$92.44	$72.53	$16.93	$2.98	$19.91
Fort Morgan	13.65	81.66	65.00	12.70	3.96	16.66
Rocky Ford	12.99	67.36	64.87	—.12	2.61	2.49

During the years 1914–15 the 195 Greeley farmers represented in this study received an average price of $5.74 per ton for sugar beets. The 66 Fort Morgan growers were paid $5.69 per ton as an average for the year 1915. The 106 Rocky Ford growers realized $4.87 per ton as an average for the crop years 1914–15. In the latter district the beet crop was grown at a loss, provided no credit is given for beet tops. This by-product had an estimated value of $2.61 per acre, and when this was considered there was a margin of $2.49 per acre. Greeley growers secured a margin of almost $17 per acre on sugar beets alone. The sugar beets were sold largely on the basis of sugar content. Selling beets on a percentage basis involved the use of a sliding scale.[1]

SUMMARY OF COSTS BY TENURE.

The records for the three Colorado districts were classified by tenure, and cost figures were compiled for three groups, namely, owners, renters, and owners renting additional land. In the three districts there were 155 owners, 182 renters and 30 owners renting additional land, the latter mostly in the Greeley district. The distribution of these farms with the costs for each group is given in Table XXX.

[1] This method is illustrated in the following scale, adopted by one of the sugar companies for the 1915 crop (northern Colorado):

Scale of prices adopted by a Colorado sugar company in 1915.

Price paid for beets per ton.	Sugar content.		Price paid for beets per ton.	Sugar content.	
	Minimum.	Maximum.		Minimum.	Maximum.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
$5	12	14	$5.875	16.5	17
$5.125	14	14.5	$6	17	17.5
$5.25	14.5	15	$6.125	17.5	18
$5.50	15	15.5	$6.25	18	18.5
$5.625	15.5	16	$6.375	18.5	19
$5.75	16	16.5	$6.50	19	19.5

12½ cents per ton additional is paid for each one-half per cent above 19½ per cent.

TABLE XXX.—*Summary of costs by tenure (1914-1915).*

District.	Owners.			Renters.			Owners additional.		
	Number.	Total of all costs.		Number.	Total of all costs.		Number.	Total of all costs.	
		Per acre.	Per ton.		Per acre.	Per ton.		Per acre.	Per ton.
Greeley	78	$70.23	$4.36	96	$74.40	$4.95	21	$71.15	$4.37
Fort Morgan	33	62.48	4.52	28	67.54	4.95	5	62.42	4.99
Rocky Ford	44	69.76	5.20	58	62.54	4.88	4	63.28	5.52

In the Greeley district the farm owners had a higher cost per acre for labor and manure, and they paid more for insurance and taxes than the tenant farmers. The interest charge in the owner group averaged $14.18 per acre, whereas rent on the tenant farms averaged $25.82. It has been pointed out that this latter item not only includes enough to cover interest on capital but also to meet taxes on land and provide for a certain amount of upkeep. Sugar-beet land is rented quite generally in the Greeley area on a share basis, the landlord receiving one-quarter of the crop. This system does not carry the same degree of risk for the tenant as a cash rental; however, when the crop produces a good yield a greater benefit accrues to the landlord.

The cost per acre and per ton in the Greeley and the Fort Morgan districts was much greater on the tenant farms than the costs reported for the owner farms, and the owners obtained a better average yield than the tenants. Owners renting additional land in the Greeley district had about the same costs as owners. It will be observed that in the Rocky Ford area the position of owners and tenants as to total costs was reversed, the owners having a higher acre cost and a higher cost per ton than the tenants. The owners, however, had a better average yield than the tenants.

COST IN RELATION TO ACREAGE AND YIELD.

The question is sometimes asked whether the grower who is producing a comparatively small acreage of sugar beets has a better chance to secure higher yields than the operator who plants a relatively large acreage to this crop. What effect does the production of a large acreage have upon yield and cost? Three hundred and sixty-seven farms in this survey were classified according to the acreage grown, and also with reference to yield per acre; and the average cost per acre and cost per ton were determined. The results are shown in Table XXXI.

TABLE XXXI.—*Relation of acreage and yield per acre to cost per acre and per ton (1914–15).*

	10 tons or less.			11 to 15 tons.			16 tons and over.		
	Number of farms.	Cost.		Number of farms.	Cost.		Number of farms.	Cost.	
		Per acre.	Per ton.		Per acre.	Per ton.		Per acre.	Per ton.
10 acres or less	12	$72.31	$7.72	23	$71.90	$5.64	24	$83.22	$4.87
11 to 20 acres	10	62.38	7.92	46	66.77	4.99	40	78.25	4.42
21 to 40 acres	21	57.35	6.30	80	65.78	4.99	56	75.09	4.21
41 acres and over	1	49.85	4.92	33	63.86	4.68	21	75.82	4.43

There were 59 farmers who planted 10 acres or less to sugar beets. Twenty-one per cent of these operators had an average yield of 10 tons or under per acre, and these beets were grown at a cost of $7.72 per ton. Approximately 38 per cent of these farms made average yields that varied from 11 to 15 tons per acre. The cost per acre was essentially the same as in the first group but the higher yield enabled them to reduce the cost per ton. Even with this advantage the margin of profit was comparatively small. Forty-one per cent of the farms raising 10 acres or less secured average yields of 16 tons and over. The cost advanced about $11 per acre over the preceding groups, but the higher yields brought the cost per ton down to $4.87.

There were 96 farmers who planted from 11 to 20 acres to beets. Ten per cent of these men produced the crop at a loss. Increasing the yield per acre within this group produced the same effect as in the preceding list of farms. Where the average yield was 16 tons or over, the maximum cost per acre for these farms was attained, but the cost per ton was only $4.42.

There were 157 farms with beet fields that varied from 21 to 40 acres. Thirteen per cent of these operators produced the crop at a loss. The lowest cost per ton was reached by 56 farms with an average yield of 16 tons and over.

The last group contained 55 farms with 41 acres and over of beets. There were no failures in this class. One man had a yield of 10 tons or under, but the cost per ton was only $4.92. It would seem that the man with the small acreage per farm can not afford to have a low yield, whereas the man who is cultivating 41 acres of beets or over has a chance to break even with a crop of only 10 tons per acre. Good yields aid in securing a low cost per ton. This is essential if the grower expects a substantial profit. This point is illustrated even more effectively in figure 29. This diagram shows that the lowest cost—$3 per ton—was reached by six operators who produced an average yield of 18.66 tons per acre. The highest cost per ton shown in this investigation was $12.50, which was on a farm with a yield of only 5 tons per acre.

There were 297 farmers who produced beets at a cost of $5.50 per ton or less. The average price received was slightly greater than this amount. It will be seen, therefore, that 70 growers in these

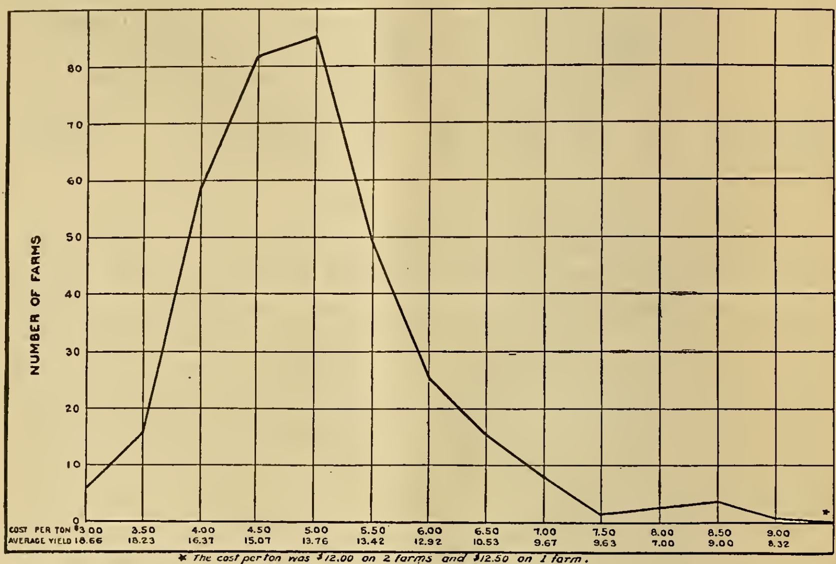

FIG. 29.—Frequency curve showing the distribution of farms in relation to the cost per ton and yield per acre, 1914–15.

three districts produced sugar beets at a loss. An average price of $6.50 per ton would have added 42 farmers to the profit group.

FIG. 30.—A portion of the crop has been lost on account of improper use of irrigation water.

There will always be a small group of inefficient operators or growers who for one reason or another will fail to make a profit on this crop (fig. 30).

Good yields are invariably associated with thorough tillage methods and a well-regulated cropping system. If the returns on a given farm are below the average for the district, it is highly probable that some improvement can be made by giving attention to the following points: (1) Better utilization of the manure which accumulates on the farm; (2) increasing the supply of organic matter in the soil through green-manuring crops; (3) more thorough tillage, not only in plowing, but also in the subsequent preparation of the seed bed; (4) exercising greater care in doing the handwork, expecially the bunching and thinning; (5) better cultivation; (6) the proper use of water. A good rotation should be adopted and adhered to systematically.

VALUE OF BEET TOPS.

Beet tops may be considered as a by-product of the beet-sugar industry. After the beets are pulled the tops are cut off squarely just below the crown at the base of the bottom leaf. The crown part of the beet, together with the leaves, is left upon the field. Sometimes the topping is done in such a manner as to leave the tops in small piles. By following this plan they are not tramped into the soil when the beets are loaded and hauled from the field. Beet tops make excellent feed for all classes of stock and can be used to advantage by most growers in the fall of the year. In this investigation an attempt was made to get the growers' estimate with reference to the value of beet tops in 1914 and 1915. The figures obtained were based upon actual value when sold or upon the value of hay and roughage saved through the use of tops. Seventy-four per cent of the operators fed the tops to their own stock. A few men fed a part of the tops and sold the remainder, while a few other men sold all the tops (Table XXXII).

TABLE XXXII.—*Disposition and estimated acre value of sugar-beet tops.*

District.	Number of farms.	Year.	Per cent fed.	Value when fed.	Per cent fed and sold.	Value [a] when fed and sold.	Per cent sold.	Value when sold.
Greeley	195	1914–15	73	$3.07	12	$2.70	15	$2.97
Fort Morgan	66	1915	65	4.31	21	4.25	14	3.77
Rocky Ford	106	1914–15	79	2.82	8	2.65	13	2.54
Total	367	....	74	3.35	12	3.30	14	3.07

[a] Part of crop was fed on farm and remainder was sold. In the latter instance the tops were invariably fed in the field where the beets were grown.

The average values for the Fort Morgan area were uniformly higher than the values for the Greeley and Rocky Ford districts. Sugar beets are relatively more important in the management of the farm at Fort Morgan than in the other two districts, and for this reason greater value is placed upon the tops. Furthermore, the district in question has a winter with less snow than the others, and the relative loss is undoubtedly smaller on this account. Moreover, many cattle are brought in from the ranges for feeding or wintering. These facts taken together may explain the higher average value reported for this district.

The estimated farm value of beet tops was greater than the selling value in each of the districts. The man who feeds tops to his own stock evidently believes that they are worth more to the farm than the customary selling price.

RELATIVE IMPORTANCE OF BEET RECEIPTS.

A comparison of the crop, live stock, and miscellaneous receipts of the farms studied, for the crop year 1915, will convey to the reader some idea of the relative importance of the sugar beet (Table XXXIII). In the Greeley area, sugar beets contributed 32 per cent of the total farm receipts and almost one-half of the crop receipts. The importance of the sugar beet in the Fort Morgan district is shown by the fact that this crop afforded 61.7 per cent, or almost two-thirds, of the total farm receipts. On the Rocky Ford farms the sugar beet was also the most important cash crop.

TABLE XXXIII.—*Average beet receipts per farm in comparison with other farm receipts in 1915.*

District.	Number of estimates.	Average total receipts per farm.	Per cent of total receipts from—				Per cent of crop receipts from beets.
			Crops.	Live stock.	Miscellaneous.	Beets.	
Greeley	90	$7,436.62	71.4	27.4	1.2	32.1	45.0
Fort Morgan	66	4,763.49	69.4	29.6	1.0	61.7	88.9
Rocky Ford	37	2,754.95	74.4	22.2	3.4	52.8	70.8

VARIATION IN FARM PRACTICE.

Although certain field methods in preparing the seed bed for sugar beets and in tending and harvesting the crop are common to all growers, the desired results are often accomplished in a number of different ways. The condition of the soil at the time the land is worked sometimes determines the character of the operations necessary to put the ground in shape for planting. Some land may have to be disked and harrowed with a spring-tooth and a spike-tooth harrow, while other land may require only spike-tooth harrowing. The same is true for rolling the land. The climatic conditions usually govern the method of handling the growing crop, while certain economic factors, together with climate, have much to do in shaping the field operation and practice in harvesting and hauling the crop.

The blocking and thinning are usually contracted, but some farmers do their own work in hoeing the crop. Occasionally all of the handwork will be done by the farmer, his family, and hired hands.

The number of times the crop is cultivated varies considerably, as well as the number of irrigations. Then, too, the practice of harvesting depends on the available supply of labor. A portion or all of this work may be done by the day or may be contracted by the ton.

Some of these features are illustrated in Tables XXXIV, XXXV, and XXXVI, which show variations in farm practice for 10 representative farms in each district.

TABLE XXXIV.—*Variations in farm practice on 10 farms at Rocky Ford.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Time over.*
Plowing	1	1	1	1	1	1	.6	1	1	......
Disking	2	......	1.5	......	......	......	......	1	......	2
Leveling	4	2	3	4	2	2	2	3	4	1
Harrow:										
Spike	3	7	3	3	4	2	4	2.5	2	2
Spring	......	......	......	......	......	......	......	......	......	......
Rolling	......	......	......	1	......	......	......	1	......	......
Ditching:										
Plow	......	2	......	......	......	......	1	2	......	......
Shovel	......	......	1	1	1	1	1	1	......	1
Planting	1	1	1	1	1	1	1	1.5	1	1
Harrowing beets	......	1	2	......	1	......	......	......	......	......
Rolling beets	.2	......	1	.2	1	......	1	.3	1	......
Spraying G. H. poison	......	1.4	......	......	......	......	......	2	......	2
Cultivating	5	2.1	6	4	5	4	6	4	4	4
Furrowing	1	2.1	2	4	1	1	3	3	4	1
Sledding	......	1	1	......	2	.4	......	......	1	......
Irrigating	2	4	2.5	3	2	1.4	3	3	5	3
Block and thin	[a] C	C	C	C	C	C	C	C	C	C
Hoeing:										
First	C	1	1	1	1	C	C	1	1	1
Second	C	1	......	1	......	C	1	1	1	1
Third	......	......	......	......	......	......	......	......	1	......
Topping and loading	C	C	C	C	C	C	C	C	C	1
Lifting	1	1	1	1	1	1	1	1	1	1
Pitting	C	......	.2	.2	.1	......	......	......	......	......
Hauling	1	C	1	1	1	1	1	1	1	1
Manuring	[b] .3	.2	.4	.5	.3	.2	.2	.4	.4	.1
Hauling manure from town	......	......	.4	......	......	.2	......	......	......	......
Crowning alfalfa	.1	1	......	......	......	......	......	......	......	......
Man-hours per acre	42	57	51	57	64	36	55	57	49	97
Horse-hours per acre	124	99	125	129	143	102	123	150	110	89
Yield per acre (tons)	15	7.8	11.5	12.5	14	10.6	12	11.9	12	14
Total cost per acre	$65.78	$58.62	$62.00	$68.84	$62.20	$58.02	$62.48	$63.27	$61.52	$58.71

[a] The letter C indicates that this operation was performed on a contract basis.

[b] Under the operation manuring, the fractional numbers indicate the portion of the beet acreage which received an application of barnyard manure. For instance, Farm No. 1 in the Rocky Ford district, put farm manure on three-tenths of the beet land. On the same farm one-tenth of the beet acreage was located on a field that was previously in alfalfa. The initial operation on this tract was crowning. After the beets had been planted the operator used the roller on two-tenths of the acreage.

TABLE XXXV.—*Variations in farm practice on 10 farms at Fort Morgan.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Plowing	1	1	1	1	1	1	0.6	1	1	1
Disking				1		.7		2		
Leveling	1	3	2	2	1	3	5	2	2	1
Harrow:										
Spike	3	2	4	2	4	3.5	5	4	4	6
Spring										
Rolling		2								
Ditching:										
Plow	2				1	1	2		2	1
Shovel		1	2	2	1				1	1
Planting	1.1	1	1	1.8	1	1	1	1.9	1	1
Rolling beets			.2							.2
Cultivating	4	3	6	4	6	4	5	7	5	5
Furrowing	1	1	1	1	2	1	2	1	1	1
Irrigating	2.5	3	3	4	2	2.5	4	3	2	2
Block and thin	a C	C	1	1	C	C	1	1	C	C
Hoeing:										
First	C	C	1	1	C	C	1	1	C	C
Second	C	C	1	1	C	C	1	1	C	C
Topping and loading	C	C	1	1	C	C	1	1	C	C
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Manuring	b .7	.3	.4	.7	.5	.4	.4	.2	.3	.5
Hauling manure from town										
Crowning alfalfa						.2	.4		.4	
Man-hours per acre	46	48	113	140	36	42	111	132	46	50
Horse-hours per acre	106	115	82	99	110	106	131	112	119	79
Yield per acre (tons)	12.5	13.0	12.2	16.5	12.0	14.0	14.0	17.5	12.5	13.0
Total cost per acre	$64.47	$67.48	$54.80	$67.59	$59.49	$61.08	$66.14	$67.00	$63.57	$70.82

a See footnote, p. 57. b See footnote, p. 57.

TABLE XXXVI.—*Variations in farm practice on 10 farms at Greeley.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Plowing	1	1	0.2	1	1	0.5		0.6	0.6	1
Disking						1				
Leveling	1	1	1	2	1	1.5	2	2	1	1
Harrow:										
Cyclone										
Spike	5	2	1.7	2	4	3.5		5	2	2
Spring			1.5	2		2	2	2		
Alfalfa renovator									.7	
Rolling		1	.5		1			1	1	1
Ditching		1	1	1	1	1		1	1	
Shoveling	1		1		1	1	1			1
Planting	1	1.1	1.4	1	1	1	1	1.6	1	1
Harrow beets										
Rolling beets			.2		1			.6		
Spraying									3	
Applying G. H. mixture							1	3		
Cultivating	3	3	3	4	6	4	3	5	3	5
Furrowing	2	2	2	2	1	1	1	1	2	1
Sledding										
Irrigating	4	4	4	3	5	3	3	3	4	2
Block and thin	a C	C	C	C	1	C	C	C	C	C
Hoeing:										
First	C	C	C	C	1	C	C	C	C	C
Second	C	C	C	C	1	C	C	C	C	C
Topping and loading	C	C	C	C	1	C	C	C	C	C
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	C	1	1	1	1	1	1	1	1
Manuring	b .5	.2	.2	.7	.6		.1	.1	.5	.3
Hauling manure from town			.2							
Crowning alfalfa	1	.3			.4					
Man-hours per acre	41	36	51	48	155	44	57	44	50	51
Horse-hours per acre	74	76	98	109	124	124	102	111	88	144
Yield per acre (tons)	19.0	16.0	16.7	19.0	14.0	14.0	13.5	15.0	17.0	19.5
Cost per acre	$72.25	$76.99	$76.27	$74.39	$73.40	$65.90	$68.78	$77.61	$80.83	$66.14

a See footnote, p. 57. b See footnote, p. 57.

A review of these tables will show that some of the operations were not common to all farms. This was particularly true of such work as disking, harrowing with a spring tooth, rolling the land prior to planting, sledding out, and pitting sugar beets. Such major field operations as plowing, harrowing with a spike tooth, leveling, planting, cultivating, furrowing out, the handwork, lifting and hauling, are common to practically all farms. There may be a slight variation in the number of times each operation is performed.

Referring to the Rocky Ford summary table, it will be seen that a few farmers harrowed twice with the spike tooth, that others went over their fields three or four times with this implement, and that in one case the ground was harrowed seven times. When extra work is done, and this applies to several operations on the same farm, it will have a tendency to give a man and horse labor requirement somewhat above the average.

On a few farms it was necessary to do some replanting. If two-tenths of the field had to be reseeded, then the number of times over is indicated by 1.2. It will be noted that a small amount of work in addition to the hand labor, such as lifting and hauling, was done on a contract basis.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 727

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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ANTHRACNOSE OF CUCURBITS.[1]

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CONTENTS.

SCOPE OF THE INVESTIGATION.

Anthracnose of cucurbits is a common and widely distributed disease of the cucumber, muskmelon, watermelon, certain gourds, and a few other cucurbits. It is apparently limited to this family of host plants.

The disease is caused by the fungus *Colletotrichum lagenarium* (Pass.) Ell. and Hals., and is characterized by sunken or discolored lesions on the leaves, stems, and fruits of its host plants. These lesions are not limited in size, and under certain conditions the

[1] The data here presented were obtained as the result of a cooperative arrangement between the Bureau of Plant Industry, the University of Wisconsin, and certain cucumber growers during the seasons of 1915, 1916, and 1917. The writer, as a graduate student, was designated by the University of Wisconsin to carry out its part in the cooperation, which also extended to Indiana and Michigan under the leadership of W. W. Gilbert, of the Bureau of Plant Industry. Most of the laboratory studies herein reported were conducted in the laboratory of plant pathology of the University of Wisconsin, and the article itself was presented to the faculty of that university in partial fulfillment of the requirements for the degree of doctor of philosophy.

The writer wishes to acknowledge his indebtedness to Prof. L. R. Jones, of the University of Wisconsin, for supervision and helpful suggestions throughout the progress of this work, and to Dr. W. A. Orton, Mr W. W. Gilbert, and Dr. E. Carsner for their assistance and cooperation.

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production of new lesions is very rapid. Therefore, upon its hosts under cultivation this disease often becomes epiphytotic and may cause serious loss. While primarily a field-crop disease it also occurs as a greenhouse trouble in cucumber culture.

Anthracnose was noted as early as 1867, and it now occurs quite commonly throughout Europe and the eastern United States. The disease has received considerable attention from mycologists and plant pathologists, and while diverse names were given to the causal organism agreement seems to have been reached that the several descriptions apply to the same fungus.

Among the outstanding disputed questions are that of the correct generic name of the fungus and that of the relation of this fungus to the causal organism of bean anthracnose. The latter question is about settled.

As in the case of other anthracnoses, the increased prevalence of this disease following wet weather has been recognized. It seems to be rather generally held that this anthracnose may be controlled by spraying.

In the present bulletin it has been the purpose to bring together and summarize the work of others upon this disease and to add something from observation and experiment. While a little is added to the record in the way of a description of the disease, the main purpose has been to learn more details regarding the life history of the causal fungus with relation to the disease and to devise a method of control with special reference to the disease as it occurs in the cucumber-pickle crop. The phases studied in particular are the overwintering of the parasite, manner of introduction into fields, mode of dissemination, method of host infection, and means of control.

THE DISEASE.

HOSTS.

The economically important hosts of anthracnose are the cucumber (*Cucumis sativus*), the muskmelon (*Cucumis melo*), and the watermelon (*Citrullus vulgaris*). Among the noneconomic hosts are gourds of the genus Lagenaria, two species of Cucumis, *Benincasa cerifera*, and *Trichosanthes colubrina*. Saccardo (42, v. 3, p. 719–720)[1] lists *Cucumis colocynthis* as a host.

While Farlow (17, p. 202) in his host index includes squash and pumpkin as hosts, subsequent observations indicate that anthracnose does not occur as a vine disease in the genus Cucurbita, although it is reported on squash fruits (45, p. 15). More details regarding the host range of the fungus are presented later, in the consideration of pathogenicity.

[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

HISTORY.

The first authentic report of anthracnose is that of Passerini (16), who in 1867 found the disease on Lagenaria fruits at Padua, Italy. Eight years later, he (16) reported its extensive occurrence on watermelons and cantaloupes in the Province of Parma, Italy.

In 1871 and in 1876 Berkeley (3, 4) reported in the Gardener's Chronicle a Gloeosporium on cucumber fruits in England, the identity of which is doubtful. He (4) noted that Gloeosporia occurred on many hosts and thought them all cross inoculable. During the latter year D. T. Fish (18), a cucumber grower, reported in the same journal a new disease in his greenhouses which he recognized as distinct from the well-known downy mildew. From his rather careful description of the symptoms and behavior of this disease on cucumbers and muskmelons it seems quite likely that it was anthracnose.

Roumeguère (41), in France, published in 1880 a rather detailed account of this disease, occasioned by its occurrence in epidemic form on melons at Chalons the year previous. In a letter to Roumeguère in 1880 Saccardo reports the disease as causing serious damage in Italy since 1877.

In Germany Frank (19, p. 518) reported in 1883 that a Gloeosporium had been destructive on cucumbers and melons. Acting upon Berkeley's suggestion he tried cross inoculations of cucumber fruits with bean anthracnose. Negative results led him to conclude that the two species of fungi were distinct.

In America the chief interest seems to have centered about the relation of the bean and the cucumber anthracnoses. The disease was noted as early as 1885 on gourds in Philadelphia by Dr. Eckfeldt and on watermelons in Wisconsin by Prof. A. B. Seymour, according to specimens listed by Ellis and Everhart (15, p. 112; 23).

Cavara (8, p. 179), at Pavia, Italy, in 1889 found the fungus parasitic upon the stems and first leaves of *Lagenaria vulgaris* in the botanical garden. He noted that the plants were killed by the disease and that its spread was very rapid. Later, in 1892, he (39) reported the disease on the cotyledons, foliage, stems, and fruits of different cucurbits in the gardens of Pavia.

Galloway (20) in 1889 reported anthracnose on melons in New Jersey, Virginia, and North Carolina. Halsted (23), in New Jersey, reported a serious blight of cucumbers in 1890 and of muskmelons in 1892 due to this disease. Basing his belief upon successful cross inoculation from a watermelon fruit to bean pods and from both of these to a citron fruit, he concluded that the fungus was identical with that of bean anthracnose.

Although not recognized as the same disease previously studied by Roumeguère, anthracnose of melons was described by Prillieux and Delacroix (39) in France in 1894. They noted that young plants were killed and that fruits of older plants did not mature. Studies were made upon the pathological anatomy. Attempts at control with flowers of sulphur and Bordeaux mixture were unsuccessful.

Between 1894 and 1902 spraying experiments were conducted in New Jersey by Halsted. Success was obtained with Bordeaux and soda Bordeaux mixtures (37, p. 11). Stewart (47, p. 159) in 1897 records much damage to cucumbers in New Jersey by anthracnose. During the years 1896, 1897, and 1898 Selby (43, 44) studied the disease in Ohio, where great damage was done to muskmelons and to cucumbers grown for pickles. He noted that showers and heavy dews favored the disease and found that a Bordeaux spray checked its spread among muskmelons. In 1894 Garman, of Kentucky (22, p. 51), noted anthracnose on melons shipped from the Gulf States and in 1901 gave a brief description of the disease, in the course of which he warns against seed infection.

Tubeuf in his textbook (53, p. 486–487) states that this fungus is very injurious to seedlings of watermelon, muskmelon, and gourd. He lays emphasis upon the injury to cotyledons and stems. In 1904 Eckardt (11) in Germany recommended soaking cucumber seed for one hour in ammoniacal copper carbonate in order to prevent the spread of anthracnose.

During the years 1901 and 1903 cucumber diseases seem to have become increasingly prevalent in this country. Although downy mildew was probably the main source of loss, anthracnose received added attention, and the more or less purely mycological work of the past began to be supplemented by work of a pathological nature.

Stone and Smith (49, p. 64) in 1902 reported that anthracnose had been prevalent on muskmelons and watermelons in Massachusetts in 1899 and that it was also common among greenhouse cucumbers in 1901. In 1903 Stone (48, p. 35) again briefly described the disease and noted that it occurred early in the season in greenhouses. Clinton, in Connecticut (10, p. 246), reported in 1904 that anthracnose was a common and widespread trouble among cucumbers and muskmelons, which recurred annually. The same year, Chester and Smith (9, p. 28) published the results of unsuccessful cross inoculations from bean to cucurbits made at Cornell University. These led them to conclude that bean anthracnose is due to a separate and distinct fungus.

In the same year Sheldon (46, p. 127–137), of West Virginia, published the results of the most complete study of this disease that had been made up to that time. Anthracnose was the cause of serious damage to watermelons and muskmelons in that State. He described the symptoms of the disease, and the morphology of the fungus and made numerous cross inoculations. Among his interesting observations was the fact that anthracnose was more severe on land previously cropped to melons. He recognized the danger of dissemination by the transportation of diseased fruit and by means of contaminated seed. As a result of spray tests with watermelons he found soda Bordeaux to be a successful control, while normal Bordeaux mixture and ammoniacal copper carbonate were ineffective.

Between 1903 and 1908 this disease received considerable attention from Orton, of the United States Department of Agriculture. He (31, p. 553) noted that in 1903 anthracnose was more prevalent in cucumbers from New Jersey to Connecticut than in 1902, and his annual observations during subsequent years reveal its prevalence, as follows:

In 1904 (32, p. 584) anthracnose was relatively unimportant except upon watermelons in South Carolina, West Virginia, and elsewhere. In 1905 (33, p. 607) it was common on cantaloupes and caused losses of 50 to 100 per cent of the crop in Nebraska. On cucumbers it was more prevalent than in the previous year. It caused losses in North Carolina, West Virginia, Ohio, and Massachusetts, and together with wilt caused a loss of $100,000 in Nebraska. A severe epidemic occurred on watermelons in West Virginia.

In 1906 (34, p. 503) the disease was prevalent on cantaloupes in Indiana, Nebraska, New Jersey, and West Virginia and on cucumbers in New Jersey, North Carolina, West Virginia, Nebraska, Wisconsin, and Ohio. In Ohio a loss of 25 to 60 per cent of the crop was estimated. Anthracnose of watermelon was reported from Nebraska, Ohio, Indiana, Rhode Island, and South Carolina, and an epidemic occurred in the Ohio Valley, especially in West Virginia.

In 1907 (35, p. 582) anthracnose of cantaloupes caused injury in Massachusetts and Vermont and was reported from New Jersey on cucumbers. Anthracnose was prevalent in the region around Norfolk, Va., and was also reported from Massachusetts, New Hampshire, Nebraska, New Jersey, North Carolina, and Vermont. Anthracnose of watermelons was recorded from New Jersey, South Carolina, and Ohio, and another epidemic occurred in the Ohio Valley.

In the 1908 report (36, p. 534), anthracnose is recorded as the cause of foliage injury to watermelons in the South and the statement is made that the disease had been gaining headway during the few years previous.

This increasing importance of anthracnose as well as the recurrent downy mildew led to rather extensive attempts at control by spraying. Besides the trials made by Selby and by Sheldon, Orton and Garrison published in 1905 (37) the results of spraying tests with cucumbers and melons in South Carolina. The results of these tests seem rather inconclusive.

Potebnia (38, p. 82), of Russia, published in 1910 the result of rather extensive studies upon the causal fungus of this disease, including inoculation experiments. Krüger, in a general consideration of Gloeosporia in 1913, reported an unsuccessful attempt to infect cucumber fruits with the fungus of bean anthracnose (28, p. 294) and concluded that there is no reason for considering the fungi identical (28, p. 311). Matouschek (29) in 1914 recorded a heavy attack on cucumbers at Vienna, and since no bean anthracnose occurred near by as a source of infection he held that the two fungi were not identical. Traverso (52) reported a severe attack of anthracnose near Chioggia, Italy, in 1913, which lowered the value of a large part of the crop.

Working at the University of Wisconsin in 1913 and 1914, Carsner[1] found that anthracnose caused damping-off of cucumber and muskmelon seedlings when the seed was immersed in a spore suspension before planting. He secured damping-off due to anthracnose in cases where seed was planted in soil collected from diseased fields four months previously, and likewise in sterilized soil with which were incorporated dry, chopped, diseased vines collected five months before. In the case of seeds dipped in a spore suspension, he found that formaldehyde treatment prevented subsequent seedling infection.

In 1915 Eriksson (16, p. 121–125) reported at length on certain difficulties with anthracnose on cucumbers and melons in Sweden. The occurrence of the disease from 1910 to 1913 among garden and greenhouse cucumbers is recorded. In one locality it seems to have caused a total loss of the greenhouse crops in 1912 and 1913 and to have discouraged cucumber and melon culture. Very convincing evidence is presented to show that the disease was introduced with seed of a much-prized Rockford variety from England, and Eriksson makes the very important suggestion that clean seed be used.

Taubenhaus (51) in 1916 reported the serious prevalence of the disease in Delaware on watermelons, cucumbers, cantaloupes, citrons, and cultivated gourds, and he reports cross inoculations proving the identity of the fungus on all of these hosts.

From this review of the history of the disease it is seen that much of the earlier work is naturally of a purely mycological nature, although some of the early writers appreciated fully the serious nature of anthracnose. Later, with the adoption of the phytopathological point of view, interest centered about the pathogenic characteristics of the fungus and the control of the disease.

GEOGRAPHIC DISTRIBUTION.

Anthracnose of cucurbits apparently occurs wherever the hosts are grown in a humid climate. This includes Europe and the United States east of the Rocky Mountains. Except for a report from Arizona in 1912 and another from Colorado in 1917 anthracnose has not been reported from the arid regions of the West.

The following data relative to the occurrence and distribution of the disease in this country since 1908 were obtained from the records of the Office of the Plant Disease Survey of the United States Department of Agriculture. The blanks in the earlier records are no doubt due in part to incomplete reports. (Table I.)

[1] Carsner, E. Studies upon cucumber diseases. MS. thesis, University of Wisconsin, 1914. (Not published.)

TABLE I.—*The distribution of anthracnose of cucurbits in the United States during the years 1908 to 1915, inclusive.*

[Abbreviations: C = on cucumbers, M = on muskmelons, W = on watermelons.]

State.	1908	1909	1910	1911	1912	1913	1914	1915	1916
Alabama			W		W	W			
Arizona					W				
Arkansas								M	
Connecticut		M		M C					
Delaware								M C W	M C W
Georgia							W		W
Illinois				C					
Indiana	M	M W	M W	M W	M W	M W	M W	M C W	C
Iowa					W		M W	W	W
Kansas								W	
Louisiana						W			
Massachusetts	C	C W	C W	C	C			C	C
Maryland							M	C	
Michigan					C	C		C	C
Minnesota					M			C	
Missouri									W
New Jersey	M C W	M C W					W	W	M
North Carolina			W		M C W	W?		W	W
New York							M	M C	
Ohio	M C	C	C	M C	M	M C W	M C	M C W	M C W
Pennsylvania							W	W	
South Carolina			M W			W		W	W
Texas								W	
Virginia			C W	M W		W		M C W	
West Virginia	W	C W				W	M	C W	
Wisconsin							C W	C	M C

Certain observations relative to the incidence of this disease are of interest here. In survey trips made by the writer in 1915 anthracnose was found in only 1 among 23 cucumber fields visited near Wautoma, Wild Rose, and Almond, Wis., in none of the 10 fields visited near Portage, and in only 1 of the 13 fields visited at Baraboo. On the other hand the disease was found in 3 among the 10 fields visited at Neshkoro, 2 out of 6 at Princeton, and 17 out of 21 near Sparta. Thus the disease seemed to prevail in certain localities and not in others.

In rather extensive surveys made in the region around Ripon, Wis., in 1914 and again in 1916, Mr. Carsner was unable to find this disease although it was abundant around Princeton, 16 miles distant.

In 1916 the writer was unable to find this disease in 12 cucumber fields visited near Baraboo, but found it in 9 out of 11 fields near Princeton. With regard to these two localities, the situation remained much as in 1915.

In the neighborhood of Madison, anthracnose was found in 1916 in only 1 out of 39 garden patches of cucumbers and in none of the 8 private fields of muskmelons. In 7 gardens visited at Burnett, Wis., no anthracnose was found on cucumbers.

In the southern melon region in 1917 the disease was found quite prevalent among watermelons, but in 16 fields of muskmelons visited near Blackville, S. C., anthracnose was found in only one field, and in that case it had very evidently come from a row of badly diseased cucumber plants adjacent to the melons. No anthracnose was found in about 80 acres of pickling cucumbers inspected in Alabama.

Therefore, much remains to be explained concerning the distribution of this disease. Whether or not soil differences have anything to do with the occurrence of anthracnose is at present unknown. However, it is worth while to point out that the Princeton-Neshkoro and the Sparta regions of Wisconsin are characterized by very light sand, while the Portage and Baraboo regions have heavier soils. Evidence which proves that the fungus overwinters in the field will be presented later.

ECONOMIC IMPORTANCE.

As has been previously recorded, anthracnose has caused very serious losses from time to time among its host crops in almost every part of its range. In Europe the epidemics in Italy, France, and Sweden and in this country the repeated outbreaks of the disease throughout the Atlantic Coast States, the Ohio Valley, and Nebraska have been mentioned.

Orton (33, p. 607) reports that in 1905 from 50 to 100 per cent of the cantaloupe crop was lost in Nebraska, while in 1906 (34, p. 503) a loss of between 25 and 60 per cent of the cucumber crop in Ohio occurred. It will be recalled that Eriksson (16, p. 121) reports the disease so serious on cucumbers under glass as to discourage that industry in one locality in Sweden.

Among the estimates of loss recorded in the Office of the Plant-Disease Survey are the following:

> Anthracnose of muskmelon caused a 35 per cent loss in Indiana in 1908; considerable fruit rot in Connecticut in 1909; 5 per cent crop injury in two counties in Minnesota in 1912; and a large percentage of the crop injured in Arkansas and a 25 per cent crop injury in southeastern Virginia in 1915. Anthracnose of cucumbers caused a 50 per cent crop injury, with a loss of $1,000,000, in southern Michigan in 1912 and a 25 per cent crop injury in Norfolk County, Va., in 1915. Anthracnose of watermelon caused a 50 per cent crop injury in two counties in Virginia in 1910; 75 per cent loss in places in West Virginia in 1913; 15 per cent injury in Delaware, 5 per cent in North Carolina, and 25 per cent in Norfolk County, Va., in 1915; 10 per cent injury in Georgia and 30 per cent injury in South Carolina in 1916.

High temperature and humidity are favorable to the disease; hence its ravages are worse where these conditions prevail. This may explain its destructiveness on cucumbers grown under glass. In this respect the disease has been very important in Massachusetts. Among field cucumbers grown for slicing purposes the disease may cause loss either by vine injury or by fruit disfiguration. Among coldframe cucumbers, where the individual plants represent a greater value, anthracnose may cause great loss by its attack on the foliage, especially where overhead watering is practiced. One grower near Norfolk claimed a loss of at least $1,000 in 1917 on 1½ acres, due to vine injury by anthracnose alone.

In the cucumber crop grown for pickling purposes, anthracnose may become epiphytotic, especially in warm wet seasons, and may result in serious loss due to foliage injury and consequent reduction in yield, as well as to occasional direct loss from fruit infection. The latter development is rather uncommon and is noted as a rule only on the larger dill stock and on pickles that have remained too long in transit.

To illustrate the severity and importance of the anthracnose of cucumbers, the results of disease surveys made in Wisconsin. Michigan, and Indiana in 1915 and 1916 are herewith presented.

In Wisconsin, the disease usually assumes the proportions of an epiphytotic only late in the season and is not therefore as serious as some of the other diseases. In 1915 out of 84 fields anthracnose was found in 24 and was causing serious loss in 5. In 1916, anthracnose was found in 1 field out of 12 visited near Baraboo and in 10 out of 11 examined near Princeton. As previously noted, the disease seems to be much worse in certain localities than in others.

In Michigan in 1915, anthracnose was reported from 6 fields out of over 35 inspected and was very serious in 2 fields. In 1916 the disease was not at all prevalent and was noted in only 4 fields out of about 30 visited.

In Indiana in 1915, anthracnose was considered second only to mosaic in importance and was reported from 18 fields in 9 localities. It was the cause of serious injury in 9 fields. In 1916 the disease was found in 64 fields in 18 localities and was causing serious damage in 20 fields. Anthracnose was considered the most serious foliage disease of cucumbers in northern Indiana during 1915 and 1916.

Among muskmelons, the attack of this disease on the vines seems to be more severe than in the case of cucumbers, and the factor of fruit injury may assume great importance. Outbreaks of the disease on this crop in 1906 and 1907 have been noted. In 1917 the disease did not seem to be at all prevalent in the commercial muskmelon fields of the South.

Probably the attack on the watermelon crop is more severe and more universal than is the case with the other economic hosts. The annually recurrent epiphytotics in the Ohio Valley have been noted. The spotting of the fruits is a familiar sight in our northern markets. The potential importance of the disease is, of course, very great in a crop in which the individual fruits represent so much value and are so long exposed to infection in the field. Besides the disfiguration of mature fruits, which may be followed by rotting, there is a large loss in the field, due to reduction in yield by vine injury and by attack on the immature fruit. Since a vine does not usually mature more than two melons, any injury to young fruits is a very important factor.

In the southern melon districts in 1917 anthracnose was in general so retarded by drought that in most fields the attack came too late to cause serious loss. Exceptional fields were found, such as one 120-acre field near Quitman, Ga., in which it was evident that the yield would be reduced by several carloads, a loss of, perhaps,

$500. At Live Oak, Fla., there was a report of a total loss of the crop on one 15-acre field in 1916 due to this disease.

To summarize, it is evident that this disease under certain conditions becomes epiphytotic and causes serious losses, especially among watermelons and coldframe cucumbers. On the pickle crop it is of less importance. Anthracnose seems to be primarily a disease of large fields rather than small gardens, a disease which, as a rule, becomes a serious factor only where its hosts are grown in extensive "pure culture."

DESCRIPTION.

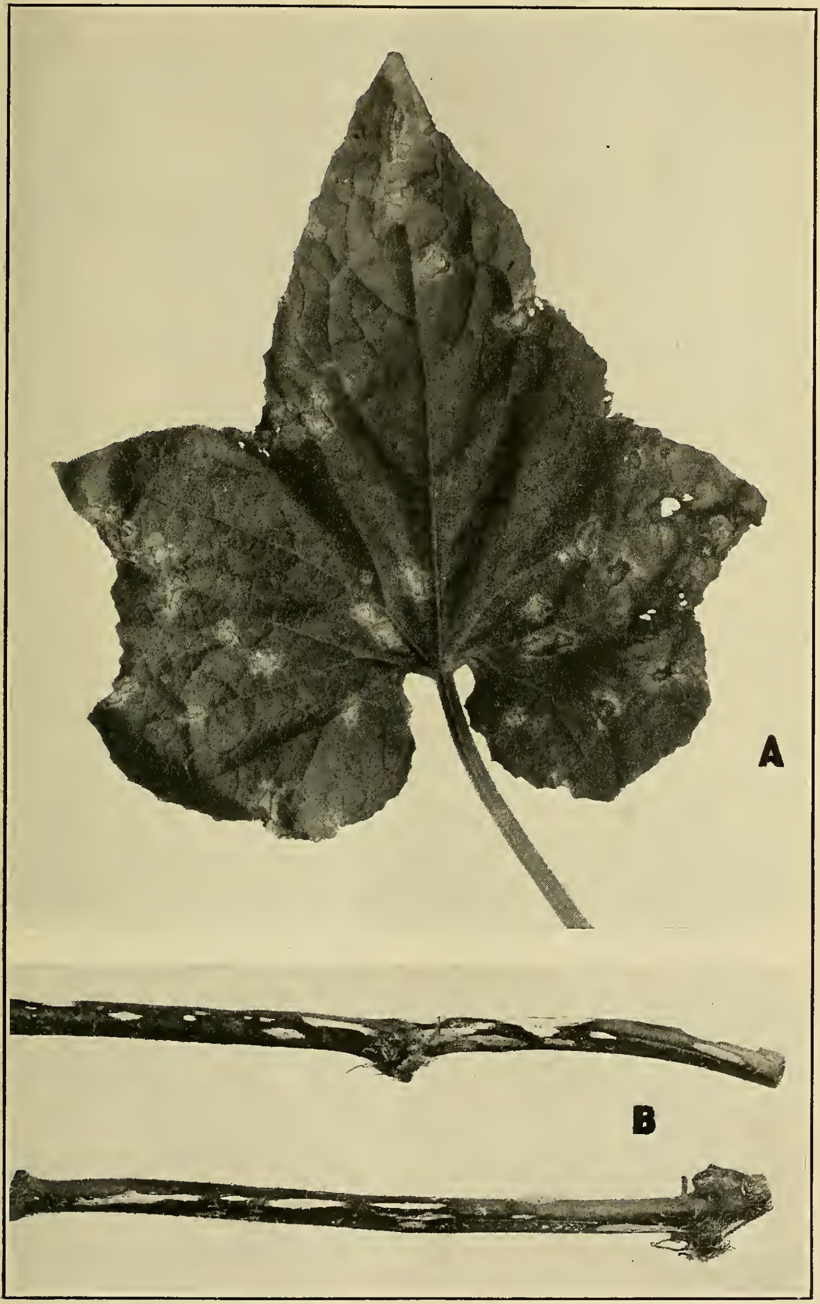
The symptoms of this disease vary somewhat with the different hosts. All parts of the host plant are subject to attack. Lesions tend to increase continuously in size. Acervuli are formed in abundance.

On cucumber leaves the lesions usually first appear on a vein and become angular or amœboid in shape, owing to the more rapid development and consequent rhizoid extension along the veins. The lesion consists of reddish brown, dry, dead tissue, often surrounded in its earlier stages by a narrow, yellowish, translucent or water-soaked border (Pl. I, *A*). Inconspicuous acervuli are produced along the veins on the upper epidermis of the brown center. Larger lesions become more circular and blotchlike (Pl. II, *B*). The dead centers crack transversely and may be beaten out by rain. Leaves being killed by the coalescence of a few large lesions become ragged in appearance (Pl. II, *B*). Very numerous incipient lesions may cause the sudden blighting of leaves. On young rapidly growing leaves small lesions may cause crinkling and extreme distortion.

Cucumber petiole and stem lesions are linear to narrowly oval, first slightly sunken and water-soaked or yellowish. Numerous acervuli are formed. The surface of such lesions later becomes quite dry and chalky in appearance (Pl. I, *B*). Cucumber stem lesions tend to remain shallow and superficial, and the collapse of mature stems at diseased points is uncommon.

Cucumber fruit lesions appear first as more or less circular, sunken, water-soaked areas. Sporulation is abundant. The surface of such lesions becomes buff or pinkish in color, later turning to black. On mature fruits the black lesions may show white central areas bearing the old acervuli as conspicuous black dots. A dry rot is usually produced in the underlying tissue and the sunken epidermis may crack, exposing a cavity underneath.

In the field, anthracnose of cucumbers is characterized by the parched or scorched appearance and spotting of the leaves. The chief damage is due to the destruction of the leaf laminæ. Stem and petiole attack is not very evident and fruit injury is conspicuous only in the seed crop.

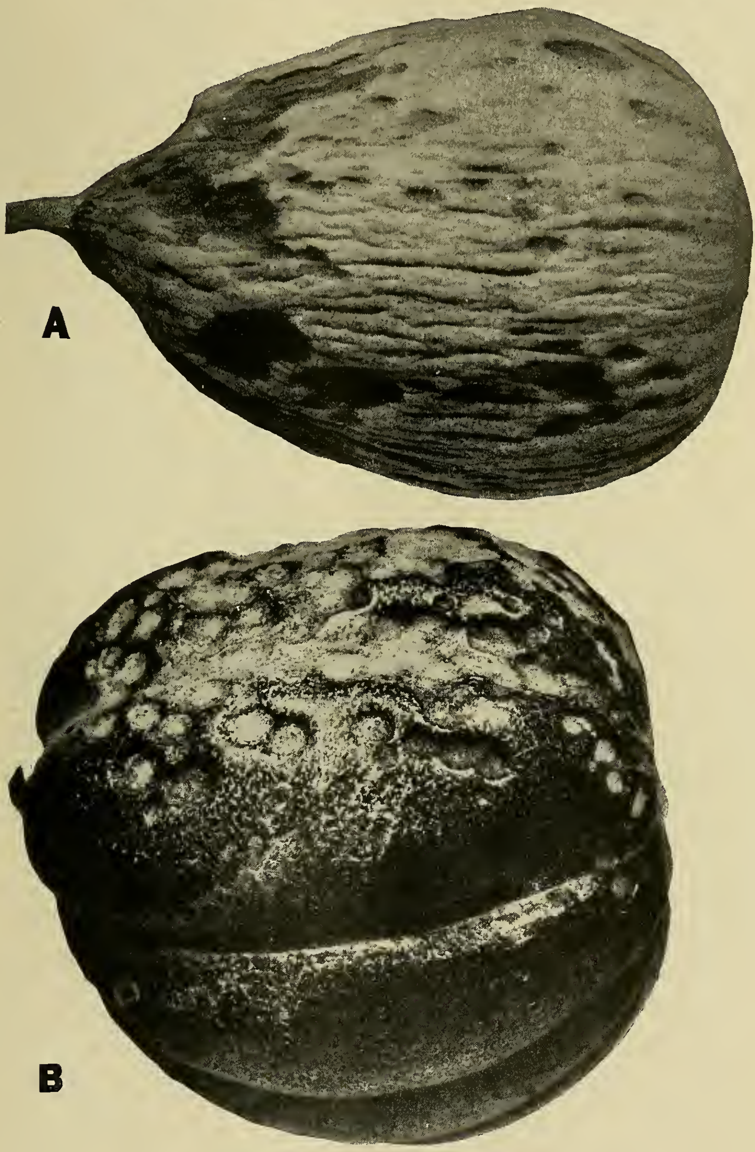


ANTHRACNOSE LESIONS ON A LEAF AND STEMS OF CUCUMBER.

A, Young lesions on a leaf, Madison, Wis., August 19, 1916; *B*, conspicuous whitened stem lesions, Madison, Wis., August 19, 1916.

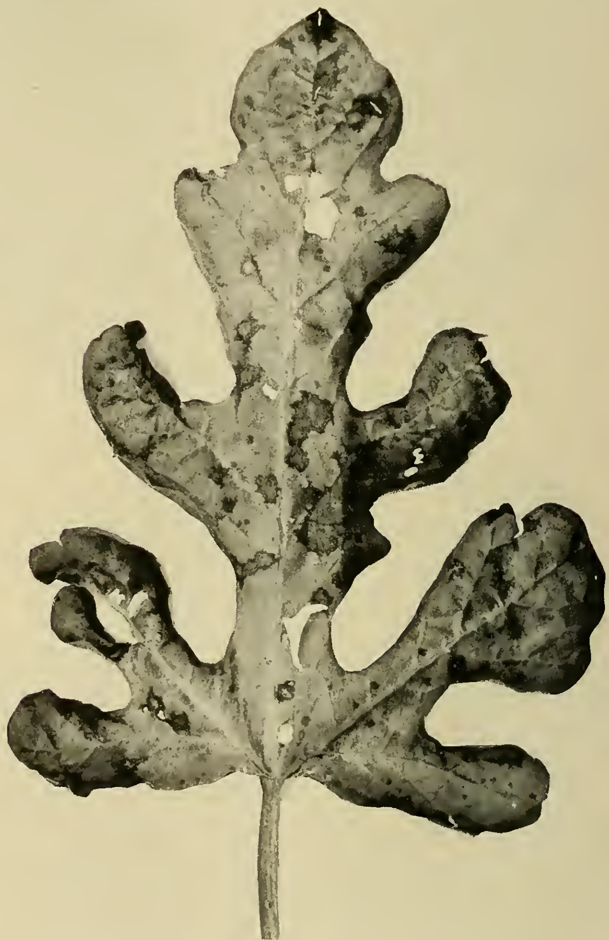
ANTHRACNOSE LESIONS ON A FRUIT AND LEAF OF CUCUMBER.

A, Small, sunken, water-soaked lesions on a green fruit, early stages of infection, Madison, Wis., September 19, 1916; *B*, advanced stage of leaf attack, Madison, Wis., August 19, 1916.



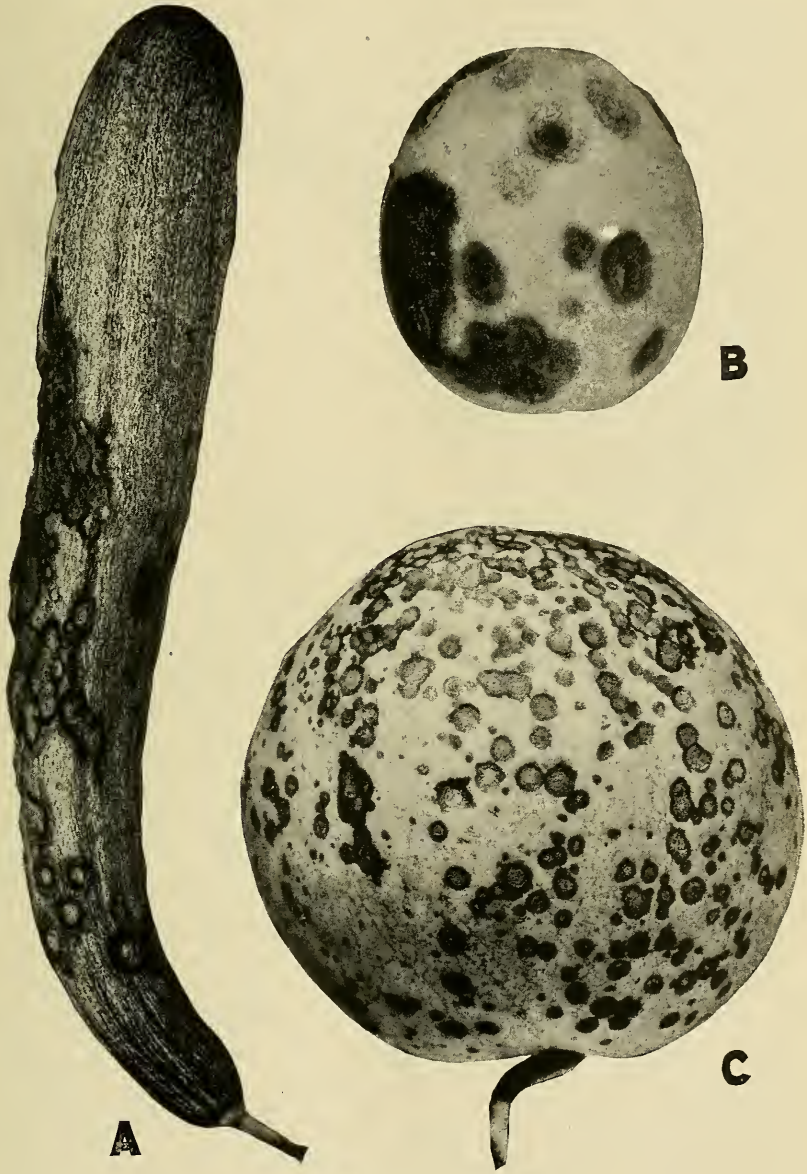
ANTHRACNOSE ON MUSKMELONS.

A, Lesions on winter pineapple muskmelon, Madison, Wis., September 12, 1916; *B*, lesions on Orange Christiana muskmelon, Madison, Wis., September 17, 1916.



ANTHRACNOSE LESIONS ON A WATERMELON LEAF.

Madison, Wis., September 12, 1916.



ANTHRACNOSE ON CUCURBIT FRUITS.

A, *Trichosanthes colubrina*, Madison, Wis., September 6, 1916; *B*, mango melon, Madison, Wis., September 12, 1916; *C*, *Citrullus vulgaris*, Princeton, Wis., September 15, 1916.

ANTHRACNOSE LESIONS ON A FRUIT AND LEAF OF GOURD (LAGENARIA VULGARIS).

On muskmelon the leaf lesions are quite similar to those on cucumber. The attack on petiole, stem, and fruit is more severe. Petiole and stem lesions are sunken and dark colored, penetrating deeply and finally girdling. A red gummy exudate is often present. Fruit lesions vary with the host variety (Pl. III, *A* and *B*) and are less conspicuous on the netted varieties. In general, fruit lesions are oval or circular and sharply depressed (Pl. III, *B*). On some varieties the depressed epidermis may form a white background for the pink spore cushions. The latter are represented by black dots after sporulation ceases and may be arranged in concentric lines if the lesion is on the upper exposed surface of the fruit. Rotting of the fruit in the field may result from anthracnose lesions on its lower surface.

In the field, anthracnose of muskmelons is characterized by rather complete defoliation, due to the severity of petiole attack, and by the death of whole runners. Fruit lesions are also very conspicuous.

The symptoms on watermelon have been well described by Sheldon (46). On watermelon leaves the lesions are black rather than brown (Pl. IV). Petiole and stem lesions resemble those on muskmelon in appearance and severity, and as a rule such lesions cause the death of the distal portions. Infection of young fruits results in their abortion or malformation. Small lesions on such fruits are black depressed spots, soon bearing pink acervuli (Pl. V, *C*). On older fruits the lesions first appear as elevated pimples with a yellow translucent center. More common on mature fruits is the nailhead type, consisting of a rather flat-topped, circular, water-soaked elevation. Such lesions soon become sunken and bear the familiar pink spore masses on a black or cream-colored background. Lesions on the under side of the melon where it is in contact with the soil may become black and corky. It is from lesions thus situated that rotting in the field may result.

In the field, watermelon anthracnose is characterized by the scorched appearance of the foliage and by the bare, leafless areas at the centers of the hills, the stem lesions, and the disfiguration of the fruit.

On *Lagenaria vulgaris*, or gourd, the leaf lesions are also black and the petiole and stem lesions resemble those on muskmelon and watermelon. Lesions on young fruits are black, while on older white fruits the lesions are brown at first, with conspicuous yellow and water-soaked borders, and crack transversely while rather small (Pl. VI).

The symptoms on *Cucumis melo* var. *dudaim*, *C. melo* var. *flexuosus*, and the mango melon are much like those on muskmelon. On the leaves of *Cucumis dipsaceus* the spots are very light tan colored. Fruit lesions on *Trichosanthes colubrina* are illustrated in Plate V, *A*, and on the mango melon in Plate V, *B*.

THE CAUSAL ORGANISM.

TAXONOMY.

The fungus causing anthracnose as it occurred on Lagenaria fruits at Padua, Italy, was described by Passerini (16) in 1868 under the name of *Fusarium lagenarium* Pass.

Berkeley (3) in 1871 reported *Gloeosporium laeticolor* on a ripe cucumber and in 1876 (4) reported Gloeosporia on various hosts, including cucumbers and melons. He suggested that all were transferable from one host to another and that all these fungi might be identical with a fungus on gourd fruits "known to mycologists as *Gloeosporium orbiculare* Berk." Owing to imperfect description the identity of this fungus is a matter of question. In his 1910 index, Saccardo (42, v. 19) still retains this species.

In 1880 Roumeguère (41) described this disease as it occurred on muskmelons at Chalons, France. He recognized the fungus as a Gloeosporium, but at first believed it identical with a *Fusarium reticulatum* Mont. observed on watermelons in 1843, and hence named it *Gloeosporium* (*Fusarium*) *reticulatum* (Mont.) Roum. Later in the year 1880, upon the advice of Saccardo, Roumeguère (40) recognized that Passerini was the first to describe the fungus under consideration and changed the name to *Gloeosporium lagenarium* (Pass.) Sacc. and Roum. He takes no notice of Berkeley's work.

In 1882 Berkeley and Broome (5) reported a *Gloeosporium cucurbitarum* B. and Br. on Cucurbita fruits in Australia. This, Saccardo suggests, may be identical with *Gloeosporium lagenarium*, and he does not list it in his 1910 index.

In America in 1885 Ellis and Everhart (15, p. 118) list as *Gloeosporium lagenarium* Pass. a fungus found on gourds, and later *Gloeosporium lindemuthianum* S. and M. on watermelon rinds. Still later, specimens of *Gloeosporium lagenarium* (Pass.) var. *foliicolum* E. and E. upon cucumber, watermelon, and muskmelon leaves were distributed (23).

Cavara (8, p. 179) at Pavia, Italy, where Passerini first found this fungus, described in 1889 a *Colletotrichum oligochaetum* Cav., parasitic upon Lagenaria plants. He noted that this fungus differed from the earlier descriptions in that setæ were present in the acervuli and the spores were slightly smaller. Saccardo (42, v. 10, p. 469) in 1892 gave this form specific rank, but as a result of Halsted's critical examination of exsiccati it now seems certain, however, that Cavara had the same fungus previously described by Passerini and Roumeguère.

Basing his assumption upon morphological similarity and very meager cross inoculations, Halsted (23) in 1893 concluded that the fungi of bean and watermelon anthracnoses were identical. He noted that the watermelon fungus possessed setæ and decided that it was a Colletotrichum rather than a Gloeosporium. Since, however, the specific name of the watermelon anthracnose antedated that of the bean anthracnose by seven years or more, he followed a suggestion made by Ellis in 1890 and applied the name *Colletotrichum lagenarium* (Pass.) Ell. and Hals. to the causal organisms of both melon and bean anthracnoses. While all later work indicates that Halsted was in error in assuming the identity of the anthracnose fungi of bean and melon, it appears that his change of generic name was well warranted. Saccardo, however, does not recognize this name.

Following Saccardo's opinion regarding *Colletotrichum oligochaetum*, Prillieux and Delacroix (39), publishing in 1894 on the disease as it occurred on melons, considered the above and *Gloeosporium lagenarium* as separate and distinct species and used the former name because their specimens possessed setose acervuli. Their description of the disease leaves no doubt as to its being identical with the one under consideration.

In his index of 1910, Saccardo (42, v. 19) lists both of the above species and thus recognizes two distinct fungi causing anthracnose of cucurbitaceous hosts in addition to Berkeley's *Gloeosporium orbiculare*.

In a comparative study of anthracnose fungi in 1898, Miss Stoneman (50, p. 88) cultured forms from watermelon and cucumber and concluded them to be identical. By similar tests, she found bean anthracnose to be quite distinct. She went further, however, and described (50, p. 94) as a new species *Volutella citrulli* Stoneman, a form found on a citron fruit in the Ithaca market. According to her description, this fungus differed from *Colletotrichum lagenarium* in that dense raised stromata were formed on lesions and in certain cultural features. This is recognized as a species by Saccardo (42, v. 19) in his 1910 index. Since *Colletotrichum lagenarium* is known to occur on citrons, it seems quite possible that the above may be identical with it. On the other hand, no inoculations were reported and this Volutella may have been a saprophyte.

Evidence that Halsted was mistaken in assuming the identity of bean and cucurbit anthracnoses was secured by C. O. Smith (9, p. 28) and Sheldon (46) in 1904, by Edgerton (13) in 1909, and by Krüger (28, pp. 246, 294) and Shear and Wood (45) in 1913 as a result of unsuccessful cross inoculations.

In 1910 Potěbnia (38, p. 82), in Russia, published his opinion that *Colletotrichum oligochaetum* Cav. and *Gloeosporium lagenarium* (Pass.) Sacc. and Roum. were the same species, the latter being the nonsetose form.

The presence or absence of setæ in the acervuli has played a major rôle in the generic nomenclature of this fungus, since the presence of setæ forms the basis for the distinction between Colletotrichum and Gloeosporium. Krüger, in the publication above quoted (28, p. 299), faces this question as a general theme for the two genera of fungi. Miss Stoneman (50) had previously noted the sudden appearance of setæ in cultures of *Gloeosporium fructigenum*, and Krüger had also observed this phenomenon in his cultures of the above and other Gloeosporia.

Frank (19) had noted occasional lack of setæ in *Colletotrichum lindemuthianum* and Miss Stoneman had noted the same in cultures of three species, including *Colletotrichum lagenarium*. Potebnia (38) later noted the occasional lack of setæ in some acervuli of the latter fungus. Krüger (28, p. 299), working with the fungus of bean anthracnose, confirmed Frank's observation and claimed to have developed at will setose and nonsetose strains. He found that the age of the culture and the nature and moisture content of the substratum acted as controlling factors and concluded that the presence or absence of setæ can not be depended upon as a decisive generic distinction in this group of fungi. Krüger urges the necessity of some other basis of differentiation, such as cultural characters.

Shear and Wood (45) in 1913 divided the anthracnoses of 45 hosts into five species, of which three are Glomerellae and two are Gloeosporia. Of the latter, one is *G. lagenarium* (Pass.) Sacc. and Roum. on watermelon, cucumber, and squash. In the whole group of fungi studied they noticed (45, p. 64) that there was great variation as to the presence, absence, and abundance of setæ in cultures from the same host and even from the same spore. They also noticed that there was variation in size, length, and septation of setæ. In the form from cucumber they noted setæ sometimes present in culture, and in the form from watermelon setæ were abundant in lesions and in culture. Setæ were sometimes present in squash lesions.

Carsner[1] in 1914, using a strain isolated from a muskmelon fruit, found no setæ present and was inclined to retain the name Gloeosporium.

Eriksson (16, p. 125) studied the fungus causing the disease on greenhouse cucumbers in Sweden, found setæ present, and as a result of a rather careful review of the literature retained Halsted's name, Colletotrichum.

To sum up the situation relative to the nomenclature of this fungus, we have difficulties arising from several sources: (1) Synonyms, of which *Colletotrichum oligochaetum* Cav. is an example. (2) Fungi of uncertain identity, such as *Gloeosporium orbiculare* Berk. and *Volutella citrulli* Stoneman. (3) Halsted's theory that the bean and cucur-

[1] Carsner, E. Op. cit.

bit anthracnoses are caused by the same fungus. (4) The difficulty in distinguishing the genera Colletotrichum and Gloeosporium on the basis of the presence or absence of setæ. (5) The morphological similarity of conidial stages of all anthracnose fungi and the necessity of knowing the perfect stages in order to make specific distinctions. (6) The question as to the validity of species erected upon the basis of host relationships.

The evidence that the bean and cucumber anthracnoses are not identical has been augmented by numerous observations and cross inoculations made in the course of the present work, and there seems to be no further question as to the specific distinctness of the two. Several unsuccessful attempts have been made to cross inoculate with the causal organisms, and exposure of beans to natural infection has yielded only negative results.

The fungus of cucurbit anthracnose shows quite constant and distinctive cultural characters. The host relationships seem quite definite and check up with cultural and morphological characters. Upon the basis of host relationships as laid down by Edgerton (13), there seems to be no reason to doubt that there is one well-defined species of fungus causing the disease on the hosts listed. Since setæ are present in all of the strains studied during the course of this work, it seems quite logical to retain until a perfect stage is discovered Halsted's name *Colletotrichum lagenarium*, with the understanding that it holds for only one of the two fungi to which Halsted applied it. If, however, not much importance is attached to the presence or absence of setæ, the earlier name *Gloeosporium lagenarium* (Pass.) Sacc. and Roum. may be retained. It appears to be purely a matter of arbitrary choice between the two names.

SYNONOMY.

Colletotrichum lagenarium (Pass.) Ell. and Hals., 1893, in Bul. Torrey Bot. Club, v. 20, p. 246–250; or

Gloeosporium lagenarium (Pass.) Sacc. and Roum., 1880, in Rev. Mycol., année 2, p. 200–202.

Fusarium lagenarium Passerini, 1868, in Erbario Crittigamico Italiano, s. 2, no. 148.

Gloeosporium reticulatum Roumeguère, 1880, in Rev. Mycol., année 2, p.169–172.

Colletotrichum oligochaetum Cavara, 1889, in Rev. Mycol., année 11, p. 191.

RELATIONSHIP UNCERTAIN.

Gloeosporium orbiculare Berkeley, 1876.

Gloeosporium cucurbitarum Berkeley and Broome, 1882.

Volutella citrulli Stoneman, 1898.

MORPHOLOGY AND CULTURAL CHARACTERS.

MORPHOLOGY.

The morphology of this fungus has been described rather completely by various workers, such as Roumeguère (41), Cavara (8), Halsted (23), Prillieux and Delacroix (39), Stoneman (50), Sheldon (46), Potebnia (38), Shear and Wood (45), and Eriksson (16). Potebnia gives an especially good description.

Mycelium.—The mycelial characters vary greatly with age and substratum. At first the mycelium is colorless, thin walled, septate, and quite uniformly cylindrical. Many of the cells later increase in diameter about threefold and tend to become thick walled and dark brown in color, resembling intercalary chlamydospores. Oil drops are commonly present in old mycelium. In culture, the mycelium is first colorless, then pink, and finally black. In host tissue the pink coloration is sometimes seen, and the blackening is quite commonly produced in fruit lesions. The brown, thick-walled, large-celled mycelium occurs commonly in host tissue.

Acervuli.—The mycelial filaments tend to aggregate at certain points, branch, intertwine, and send out a palisade layer of short colorless conidiophores. The extent of stromatal development previous to sporulation varies greatly and is apparently greater in culture than in host tissue. The color of this stromatic tissue is brown or black.

Setæ.—Scattered about among the conidiophores are the long 2–3 septate, brown, thick-walled bristles, or setæ, varying in length from 90 to 120 μ and tapering toward a blunt point. The setæ may be much longer under certain conditions. The number in each acervulus varies greatly and is given as high as 24 to 36 by Potebnia.

Spores.—From the tips of the conidiophores the spores are budded off apically, one at a time, and pile up in a pink slimy heap on top of the acervulus. The spores are embedded in a sticky water-soluble matrix, and the heaps are often as high as the setæ, the latter apparently serving as supports to hold the spore mass in place. The spores are one celled, hyaline, oblong or ovate-oblong, and slightly pointed at one end. Spores vary considerably in shape. Their size is about 13 to 19 μ by 4 to 6 μ. Usually two or three vacuoles are present. The spores are pink in mass.

Sclerotial bodies.—These are usually the result of the further development of the stromata or bases of the acervuli, in which the whole mass becomes considerably enlarged and black in color. The size of these sclerotial masses varies greatly, as does also the degree of their development. Sclerotial masses are formed abundantly in culture and in fruit lesions. Sheldon (46) describes these in detail. In culture the spore mass may dry down and remain as part of the protruding sclerotium. In fruit lesions the spores are washed away and only the black stroma remains, forming the black spots in the fruit lesions previously described.

Appressoria.—Normally, a germinating spore on a firm or hard substratum forms an appressorium at the tip of each germ tube or branch thereof. The appressoria are brown, thick-walled, ovoid to spherical cells, in general appearance not unlike the intercalary chlamydospores of the mycelium. The analogy between these appressoria and chlamydospores is strikingly shown in cases where appressoria are formed in series, one apparently budding out to form another. The appressorium may taper slightly toward the point of attachment of the germ tube and may be flattened on the side in contact with the substratum.

A definite round germ pore is found in the center of the lower side of an appressorium from which leaf penetration has occurred. For all of the strains studied, the size and shape of the appressoria seem to be quite uniform. In a few cases appressoria have been observed to increase considerably in size and become two celled.

CULTURAL CHARACTERS.

Carsner [1] has described the cultural characters somewhat at length. No effort has been made in this work to compare the growth on different media. For general purposes a 2½ per cent water agar containing 2 per cent of dextrose has proved very useful. Besides this, potato, bean, and apple-twig agar have been used. The fungus grows rapidly and is easily cultured.

Isolation from diseased specimens was usually accomplished by first transferring spores from the acervuli to a drop of sterile water on a flamed slide. From this drop loop inoculations were made into tubes of melted agar. Plates were poured and transfers made from single colonies developing therein. Many of the strains were grown from a single spore.

There is great variation among different strains in the amount of aerial growth, the extent of the blackening, and the abundance of sporulation. Cultural characteristics tend to change during prolonged propagation, as has been noted in other anthracnose fungi by Edgerton (12, p. 393). The strains longest in culture seem to sporulate most abundantly. Sporulation can be readily secured by the use of sterilized segments of cucumber stems.

In test-tube culture the mycelium is first white or colorless, later pink, and finally black. The aerial growth usually becomes prostrate quite promptly. Acervuli appear first as black points and sporulation occurs within a week. The pink spore masses may be formed for several weeks. In old cultures the black sclerotial bodies are prominent on the surface and also scattered through the medium to some depth. General blackening of the mycelium may extend to some depth also.

[1] Carsner, E. Op. cit.

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PHYSIOLOGY.

Only preliminary work was done on the physiological phases of the problem, and since, as a rule, the tests were not made in duplicate, only a brief summary of the results will be presented.

NUTRITION.[1]

In studying the nutrition of the fungus, use was made of a standard nutrient solution containing molecular ÷ 8 ammonium nitrate, molecular ÷ 20 potassium acid phosphate, molecular ÷ 50 magnesium sulphate, molecular ÷ 1,000,000 iron chlorid, and about 5 per cent sucrose. By substitutions within this formula, the effect of the omission of an element was determined. The fungus was grown in parallel series with *Aspergillus niger* in flasks containing about 50 c. c. of the medium. Dry-weight yields were used as criteria.

Using the full nutrient solution, it was found that in 24 days Colletotrichum produced only about one-twentieth as much dry-weight yield as did Aspergillus in 15 days, but after a much longer interval the yield of Colletotrichum was almost as great. No sporulation of the latter was secured and it was evident that a liquid medium was not well adapted to the development of Colletotrichum.

As a result of substitutions in the formula it was found that carbon, nitrogen, potassium, and phosphorus were essential to the growth of Colletotrichum, while magnesium was needed in only very minute quantities. Sulphur and iron were not needed in excess of the amounts present as possible impurities. Colletotrichum seems to be less sensitive to a lack of magnesium and sulphur than Aspergillus and more sensitive to a deficiency of potassium and phosphorus.

Substituting other carbohydrates for sucrose, so that an equal amount of carbon was present, it was found that Colletotrichum, unlike Aspergillus, uses cornstarch to exceptional advantage. The other carbon sources, listed in descending order of suitability, are inulin, maltose, dextrose and galactose, salicin, glycerol, and lactose. Sucrose should probably be ranked with the dextrose and galactose. For Aspergillus the order would be sucrose, inulin and maltose, dextrose, cornstarch, galactose, tannin, glycerol, lactose, and salicin. Colletotrichum was unable to utilize tannin.

Further proof of the preference of Colletotrichum for the more complex carbon compounds was afforded by its abundant development on xylan as a carbon source. Using xylan prepared from straw in place of sucrose in an amount such that only one-fourth as much carbon was available as in the full nutrient solution, a similar dry-weight yield of fungus mycelium was obtained. Xylan appears to be fully as suitable a carbon source as cornstarch.

[1] The tests relative to nutrition and the effect of copper sulphate were made under the direction of Prof. J. B. Overton and Dr. J. P. Bennett, of the University of Wisconsin.

Cellulose may also be utilized as a sole source of carbon. Pure cellulose jelly prepared from absorbent cotton and substituted for sucrose supported a growth of mycelium which yielded in several months a dry weight greater than that of the cellulose added. Further proof of the ability of Colletotrichum to dissolve cellulose was furnished by the clearing of the turbidity in an unslanted test tube of cellulose agar to a depth of 1 cm. beneath the colony. This suggests that a cellulose-dissolving enzym was secreted, which acted in advance of the mycelium. In a similar tube containing sucrose in addition to the cellulose, growth was more vigorous, but little or no visible disappearance of the cellulose was noted. This indicates that the presence of sucrose may have inhibited the utilization of cellulose.

EFFECT OF COPPER SULPHATE.

Using the full nutrient solution, the influence of very low concentrations of copper sulphate upon the growth of Colletotrichum and Aspergillus was studied. Colletotrichum proved to be much more sensitive to copper sulphate. Whereas Aspergillus showed marked increase of yield in a concentration of molecular ÷ 16,000, toxic effects in molecular ÷ 1,000 and ability to grow in the presence of molecular ÷ 250, Colletotrichum was only stimulated slightly, if at all, by concentrations of copper sulphate as low as molecular ÷ 128,000 and showed toxic effects in molecular ÷ 64,000 and total inhibition of growth in molecular ÷ 2,000.

SPORE GERMINATION.

In poured plates of agar at room temperature, spores germinate within five hours. In drops of distilled water on slides at room temperature, germination usually occurs within 24 hours, although this time varies greatly. In some cases abundant germination occurred within 10 hours and appressorium formation within 20 hours. In pipette-dropper inoculations of leaves in the greenhouse, it has been found that abundant appressorium formation occurred within 24 hours.

In general, germination is favored by the presence of some nutrient material and a 2 per cent dextrose solution or a prune decoction made by steaming 10 grams of prune flesh in 1,000 c. c. of distilled water has proved very useful. An abundant oxygen supply seems quite essential. Germination is more prompt about the edge of drops containing spores and is more vigorous in exposed drops than in Van Tieghem cells.

To determine the effect of such factors as temperature, food supply, and aeration upon germination, a series of tests was run. This consisted of a quadruplicate series of hanging drops in Van Tieghem cells and exposed drops on flamed slides in prune decoction and in distilled water inoculated with spores and incubated at thirteen different temperatures between 3° and 31° C. secured in an Altmann compartment incubator and in other constant-temperature incubators. The results are presented in Table II.

TABLE II.—*Relation of temperature, oxygen supply, and food supply to spore germination and appressorium formation of Colletotrichum lagenarium.*

[Abbreviations: ab = abundant, ap = appressoria, d = day or days, g = germination, gt = germ tubes, hr = hours, mar = marginal, num = numerous, pc = per cent, spo = sporulation, sw = swelling, tg = trace of germination.]

Temperature (C.).	Distilled water.		Prune decoction.	
	Hanging drop.	Exposed drop.	Hanging drop.	Exposed drop.
2° to 3°	19 d, no g	19 d, no g	19 d, no g	19 d, some swollen.
3° to 4°		10 d, no g	10 d, no g	7 d, sw; 19 d, a few short gt.
6° to 7°	10 d, no g; 19 d, sw.	5 d, no g; 7 d, sw; 10 d, a few budlike gt.	19 d, no g	1 d, no g; 2 d, tg; 5 d, num short gt; 7 d, 50 pc short budlike gt.
9° to 10°		3 d, no g; 19 d, budding gt.	19 d, no g	1 d, no g; 2 d, 3 pc g; 7 d, 90 pc g, short gt, ap ab.
11° to 12°	2 d, sw; 10 d, no g	2 d, 10 pc g; 3 d, ap ab; 5 d, 80 pc g.	2 d, sw; 10 d, sw, no gt.	10 hr, tg; 1 d, 1 pc g, short gt; 2 d, 90 pc g; 3 d, ap general.
12.5° to 14°		1 d, 1 pc short slender gt; 2 d, 10 pc g, ap present.	1 d, no g; 2 d, swollen (septate); 7 d, 95 pc same, 5 pc normal g.	10 hr, tg; 1 d, 5 pc g; 2 d, a few ap; 10 d, acervuli spo.
14°	1 d, no g; 2 d, 5 pc g; 5 d, ap formed.	1 d, tg; 2 d, 90 pc g, ap num (mar).	2 d, no g (cell found air tight); 5 d, no g.	1 d, 20 pc g, gt robust; 2 d, 90 pc g, a few ap; 5 d, ap num, acervuli forming.
15°		9 hr, 1 spore germinating; 1 d, 5 pc g, a few ap.	1 d, 1 pc g; 2 d, 5 pc g, long gt; 3 d, no ap; 7 d, acervuli; 10 d, spo.	9 hr, tg; 1 d, 5 pc g, ap present (mar); 2 d, ap. num; 7 d, spo.
15° to 17°	2 d, no g	1 d, 20 pc g, ap present; 2 d, ap num (mar).	11 hr, 2 spores germinating; 1 d, 1 pc g; 2 d, 3 pc g, ap present; 4 d, acervuli forming; 5 d, no spo.	9 hr, 1 pc g; 1 d, 40 pc g, ap present; 3 d, ap num; 7 d, spo.
18° to 20°	10 hr, 2 pc g; 1 d, 10 pc g; 3 d, no ap; 4 d, ap num.	10 hr, 1 spore germinating; 1 d, 5 to 10 pc g, ap num (mar); 2 d, 10 pc g.	1 d, 90 pc g; 2 d, no ap; 3 d, ap num.	9 hr, 3 pc g; 1 d, 10 pc g, ap present (mar); 3 d, acervuli forming; 4 d, spo.
22°	8½ hr, 5 pc g; 1 d, 20 pc g, gt slender, a few ap (mar); 2 d, ap num.	1 d, ab g, ap present; 2 d, ap num (mar).	1 d, 90 pc g; 4 d, spo, no ap.	8 hr, 10 pc g; 1 d, 20 pc g; 2 d, ap; 4 d, spo.
26½° to 27½°	10 hr, 20 pc g; 1 d, 30 pc g; 3 d, a few long-stalked ap.	8 hr, 10 pc g, 1 d, 25 pc g, ap (mar); 2 d, ap num.	10 hr, sw; 1 d, 95 pc g; 5 d, no ap; 7 d, spo.	8 hr, 10 to 20 pc g; 1 d, 75 pc g; 2 d, ap present; 4 d, spo.
30° to 31°	9½ hr, lateral budlike gt; 20 hr, 40 pc g; 3 d extremely swollen budded spores or "involution forms"; no ap.	8 hr, tg; 1 d, 5 pc g; 4 d, 50 pc g; 5 d, no ap.	9 hr, sw; 20 hr, 95 pc g; 2 d, extreme sw of spores and mycelium; 3 d, no ap.	8 hr, 10 to 20 pc g; 1 d, 95 pc g, colonies visible to unaided eye, no ap; 5 d, no ap, no darkening.
44°		No g		No g.

More vigorous germination was obtained in prune decoction than in water, and in either medium the exposed drops furnished better conditions for germination than the hanging drops. The latter is attributed to lack of aeration in the Van Tieghem cells, although, in preparing these, care was exercised not to have the vaseline seal continuous around the edge of the ring. At the rather high temperature of 30° C. swollen "involution forms" were produced in the Van Tieghem cells.

The minimum temperature permitting germination was 4° C. in exposed drops of prune decoction, 7° in exposed drops of water, and 14° in hanging drops in either medium. The optimum temperature for germination apparently lies between 22° and 27° C. Edgerton (14) found that the optimum temperature for mycelial growth was 24° C. It is of interest to note here that at temperatures of 20°, 22°, and 27° C. the fungus in the exposed drop of prune juice completed its life cycle in four days with the production of sporulating acervuli. In the hanging drop of the same medium at 27° and in exposed drops at 16° C., seven days were required to complete the cycle.

Germination is favored, therefore, by the presence of nutrient material, by a good oxygen supply or at least good aeration, and by temperatures of 22° to 27° C.

APPRESSORIUM FORMATION.

As to the factors influencing the formation of appressoria in general, De Bary (2) held that, in Sclerotinia, appressoria were the result of a contact stimulus, and his opinion was corroborated by Büsgen (7), who worked with several parasitic fungi. Halsted (24) found that appressoria were generally produced by Gloeosporium and Colletotrichum. American writers in general have called them secondary spores or chlamydospores (26). Hasselbring (26), working with the fungus of apple bitter-rot, found that appressoria were formed only as a result of a contact stimulus in a medium poor in food supply. Appressoria were never formed until the germ tube came into contact with the glass, and not even then when in a nutrient medium. He found also that the appressoria tended to adhere to the glass.

In the course of this work some effort was made to throw further light on the factors controlling appressorium formation. In the germination tests mentioned above it was noted that the appressoria were usually but not always formed in contact with the glass. They occurred in the hanging drops usually up against the glass and were not as abundant as in the exposed drops. Appressoria were formed just as commonly in the nutrient prune decoction as in the distilled water.

It was noted that the formation of appressoria in exposed drops, as well as in hanging drops, occurred most readily about the margin of the drop. Furthermore, their formation in hanging drops of water was more general than in the hanging drops of prune decoction. In exposed drops of prune juice appressoria were formed at temperatures from 9° to 27° C.; in hanging drops, only between 17° and 20°. In exposed drops of water appressoria were formed between 12° and

27° C. and in hanging drops between 14° and 27°. In no case were any formed at the high temperature of 31°. The point to be noted here is limited appressorium formation in the hanging drops of the nutrient medium.

To account for certain of these phenomena it seems quite reasonable to assume that a rather abundant oxygen supply is one of the essentials for appressorium formation. It is likely that the spores about the extreme edge of a drop would be better supplied with oxygen than those in the interior. Exposed drops have an abundant oxygen supply. In Van Tieghem cells, where the oxygen supply is limited, it is quite likely that the demand for oxygen would be greater and hence the supply more quickly used up in the nutrient medium than in pure water, since more rapid growth occurs in the former.

With this fungus, then, the presence of food material does not seem to inhibit appressorium formation. The contact stimulus is apparently necessary as a rule, and a liberal oxygen supply seems to be favorable to appressorium formation. The function of appressoria will be considered later in connection with the relation of the fungus to the host tissue.

PATHOGENICITY.

Whether or not we accept Edgerton's (13) basis of species distinction by host range, it is essential from the phytopathological standpoint to know the exact host range of this fungus.

Under general field conditions the disease has been observed commonly on cucumbers, watermelons, muskmelons, and Lagenaria gourds. Experimental evidence of the identity of the fungus in these cases is furnished by the cross inoculations made by Sheldon (46), who secured infection of cucumber, watermelon, muskmelon, and gourd plants with a strain isolated from watermelon, and by Carsner,[1] who secured infection of cucumber plants with a strain from muskmelon.

During the course of this work, successful cross inoculations have been made from watermelon to cucumber, from cucumber to watermelon and muskmelon, and from muskmelon to cucumber. Leaf infection of vigorous plants was secured in all cases. Using the fungus from cucumber, successful cross inoculations have been made in the field upon eight varieties of muskmelon, upon *Cucumis anguria*, *C. melo* var. *flexuosus*, *C. melo* var. *dudaim* and *C. dipsaceus*, and upon *Trichosanthes colubrina* and *Benincasa cerifera*. In these inoculations a spore suspension was applied with an atomizer. Out of three series made upon about 40 varieties on August 4, 10, and 13, 1916, success was obtained only in the inoculations of August 13.

Out of a large variety of cucurbits exposed to natural infection by drainage water under conditions which practically precluded the pos-

[1] Carsner, E. Op. cit.

sibility of confusion with infection from any source other than badly diseased cucumbers, the list of hosts is increased by the addition of several varieties of cucumber, two varieties of muskmelon, citron, seven Lagenaria gourds, and *Cucumis anguria* var. *grossulariae.* Exposure to natural infection in an experimental field at Plymouth, Ind., in 1916 adds to this list of hosts *Momordica balsamina* and *M. charantia.*

Repeated attempts to inoculate 6 varieties of squash, 2 varieties of pumpkin, and 12 varieties of Cucurbita gourds yielded only negative results, as did also attempts to inoculate *Echinocystis lobata, Bryonopsis laciniosa,* 3 Momordica species, and a species of Luffa.

To determine just how the fungus might react toward squash, drops of a spore suspension were placed on the leaves of a squash plant in the greenhouse. Except for a slightly yellowed area on one old leaf no lesions developed. Microscopic examination of material from this yellowed area, fixed according to methods to be described later, showed that the fungus had penetrated the epidermal cells but had gone no farther.

Exposure to the same epidemic of natural infection above noted gave negative results in the following: Early Russian cucumber, Giant Pera cucumber, pumpkins (2 varieties), squash (6 varieties), *Bryonopsis laciniosa, Luffa* sp., and 16 varieties of Cucurbita gourds.

Using cultures from watermelon, Sheldon (46) was unable to infect squash, pumpkin, and wax-bean plants. Edgerton (12) and Taubenhaus (51) were unable to infect apple fruits. The latter also secured no infection of sweet-pea plants. In the present investigation no success was obtained in an attempt to infect apple fruits. Inoculations on five varieties of beans in the field gave negative results, as did also exposure of these varieties to natural infection during an entire season.

Following is a list of susceptible host varieties as noted during the course of this investigation:

Cucumbers.—Heinz Chicago Pickling, Nichols' Medium Green, Thorburn's Klondike White Spine, Japanese Climbing, Lemon, Boston, Jersey, Arlington, Milwaukee, Livingston, Emerald, Davis Perfect, Improved Long Green, Early Fortune, Telegraph, Vaughan's Prolific, Carter Model.

Muskmelons.—Banquet, Long Yellow, Shumway Giant, Orange Christiana, Hybrid Casaba, Hackensack, Rocky Ford, Winter Pineapple, Banana, Mango.

Watermelons.—Watson, Pierson, Red-Seed Citron.

Lagenaria gourds.—Bottle, Dishcloth, Knob Kerrie, Dipper, Hercules Club, Sugar Trough, Calabash.

Other cucurbits.—*Cucumis anguria, C. anguria* var. *grossulariae* (fruit only), *C. dipsaceus, C. melo* var. *flexuosus, C. melo* var. *dudaim, Trichosanthes colubrina, Benincasa cerifera.* Reported on *Momordica balsamina* and *M. charantia.*

RELATION TO OTHER ANTHRACNOSE FUNGI.

Upon the basis of Edgerton's theory of species determination by host range, it is of interest to note the reaction of anthracnose fungi from other than cucurbitaceous hosts to the latter. Using the fungus from bean Frank (19) failed to infect a cucumber fruit and C. O. Smith (9) secured no infection of plants in the cases of cucumber, pumpkin, squash, muskmelon, and watermelon. Likewise, Edgerton (13) was unable to obtain infection with the bean fungus upon cucumber plants and fruit, and Krüger (28, p. 246, 294) was unable to infect cucumbers with the fungus from bean. Shear and Wood (45) were also unsuccessful in their inoculations of watermelon, squash, and pumpkin fruits with the bean fungus, but were successful in their inoculations of the fruits of watermelon, squash, and pumpkin with the anthracnose fungus from grapes and also in their inoculations of watermelon and pumpkin fruits with the fungus from guava. Halsted (23) secured infection of a citron fruit with the fungus from bean.

It will be noted that in no case did the anthracnose fungus from another host infect cucurbitaceous plants. In cases of fruit infection it must be borne in mind that the fruit to some extent resembles a nonliving substratum and that successful fruit infection is not proof of active parasitism.

In the course of the present work, atomizer inoculations of cucumber plants in the field with spore suspensions from cultures of bean, cotton, banana, and fig anthracnoses yielded only negative results.

There seems to be no positive evidence that fungi causing anthracnose of hosts other than cucurbits are physiologically identical with the form under consideration, and, as was noted in the consideration of the pathogenicity of *Colletotrichum lagenarium*, this fungus causes anthracnose of cucurbits only.

RELATION OF THE FUNGUS TO THE HOST TISSUE.

Concerning the relation of the fungus to the host tissue, attention has been chiefly focused upon the mode of penetration of the host epidermis and the effect of the advancing mycelium upon the host cells.

PENETRATION.

To determine the method of host penetration, drops of spore suspensions were placed in ink circles on leaves of cucumber plants in the greenhouse, and at intervals thereafter these inoculated leaf areas were cut out with scissors, fixed in 10 per cent HCl, and cleared by storing in a saturated solution of chloral hydrate. This was followed by clearing in 3 per cent KOH, and in some cases staining in Delafield's hæmatoxylin. Glycerin mounts were made and the surface of the epidermis was carefully examined under the microscope.

As a result of the examination of a considerable number of these preparations, it was found that within 24 hours after inoculation appressoria had been formed in abundance, usually one to each spore, sessile, or on short germ tubes. These were particularly numerous

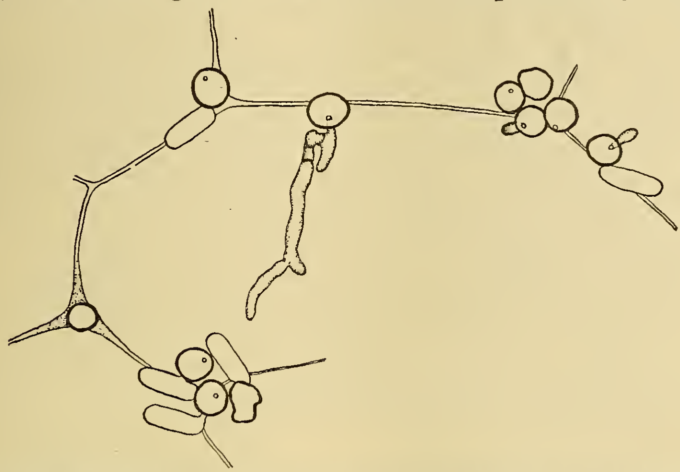


FIG. 1.—Surface view of a portion of a cucumber-leaf epidermal cell, showing appressoria and penetration tubes, six days after inoculation. In five instances the empty spore case is shown lying near the appressorium. The circular germ pores can be seen in the appressoria. Two appressoria (upper right) have formed short penetration tubes. Another has produced considerable mycelial growth within the host cell. (Camera-lucida drawing; magnified about 395 times.)

in the vein depressions and in the depressions bounding the epidermal cells. No signs of host penetration were found in this material or in material fixed 44 hours after inoculation.

In leaf areas fixed 65 hours after inoculation, penetration tubes were commonly visible within the epidermal cells underneath the appressoria and a small round pore was visible in the wall of the appressorium next to the host cuticle (fig. 1). Hasselbring noted similar pores in the appressoria of the apple bitter-rot fungus. In material fixed 121 hours after inoculation, when macroscopic symptoms were already apparent, the penetration tubes were found under a large percentage of the appressoria, and in many cases considerable mycelium was found in the epidermal cells underneath (fig. 2).

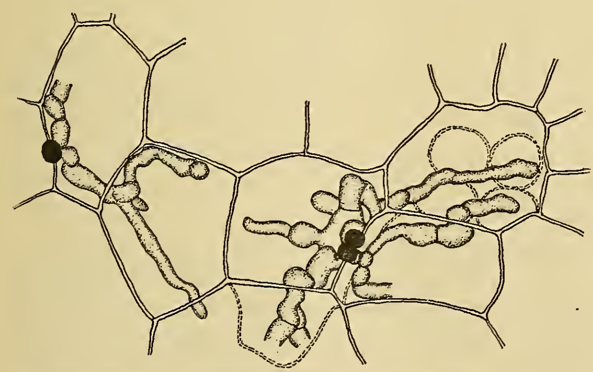


FIG. 2.—Surface view of epidermal cells of a cucumber leaf, showing intracellular mycelium from three appressoria, six days after inoculation. (Camera-lucida drawing.)

Incipient and advanced stages of penetration, as seen in surface view, are illustrated in figure 1. The appressoria are seen to be quite uniform in size, shape, and size and shape of germ pore. Although this material was subjected to several hours' washing in running water, the appressoria remained adherent to the cuticle. From a study of these preparations it appears that penetration never occurs except from an appressorium and that penetration occurs directly through the cuticle. From this, it seems safe to conclude that the appressoria have a definite function in connection with host penetration. No cases of stomatal entrance were found. A case was found in which a spore lying directly over a stomatal opening formed an appressorium at one side.

To better understand the mode of penetration, material similar to that above described was fixed in 10 per cent HCl, acetic alcohol, or Gilson's fixative, embedded, sectioned, and stained in the triple stain or Haidenhain's iron alum hæmatoxylin. Numerous penetrations were found in sections from fixations made 65 and 121 hours

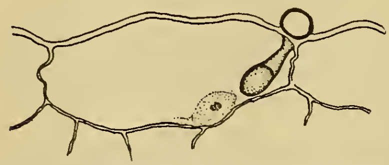


FIG. 3.—Cross section of leaf epidermis, showing penetration of epidermal cell from an appressorium, 65 hours after inoculation. The tip of the penetration tube is swollen. (Camera-lucida drawing; magnified about 575 times.)

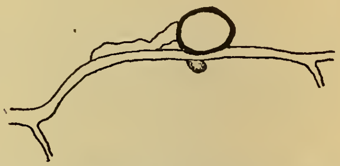


FIG. 4.—Cross section of the outer wall of a leaf epidermal cell, showing an incipient stage of penetration from an appressorium, 65 hours after inoculation. (Camera-lucida drawing; magnified about 1,300 times.)

after inoculation, and types are illustrated in figures 3 and 4. The latter represents an incipient stage. Here, again, it is seen that direct penetration of the cuticle and outer wall takes place. Stomatal entry does not occur. In one case (fig. 5) an appressorium has been formed in the stomatal pore and penetration of a guard cell has followed, rather than a direct invasion of the substomatal chamber. In figure 6, showing an apparent stomatal penetration, close examination reveals that the lower guard cell was pierced by the penetration tube, which then emerged into the substomatal chamber.

Appressoria may be distinctly flattened on the side next to the cuticle (fig. 6), and all are in very close contact with the latter. The penetration tube varies in shape, but is usually more or less club shaped, owing to the fact that it becomes swollen after gaining access to the lumen of the cell (fig. 3). In figure 7 it is quite evident that the contents of the appressorium have entered the penetration tube. In no case has it been possible to trace the course of the penetration tube through the cuticle and underlying wall layers.

In some cases of delayed or, perhaps, inhibited penetration, there is a swelling and change of staining reaction of the cell wall under the appressorium, characterized by retention of the safranin in the triple stain (fig. 8).

The mode of fruit penetration appears to be somewhat similar. Sections from fixations made two weeks after inoculation show numerous examples of direct penetration of the cuticle and thick outer wall, but no cases of subsequent mycelial development. In view of this fact, it seems likely that these are abortive or inhibited penetrations. Fruit penetration is illustrated in figure 9. Here the penetration tube is not as clearly distinguishable as in the leaf sections, and only the swollen tip is to be seen. There is indication of a splitting apart of the wall layers in some cases, and all cases are characterized by a marked retention of the safranin in the inner wall layer under the appressorium (fig. 9).

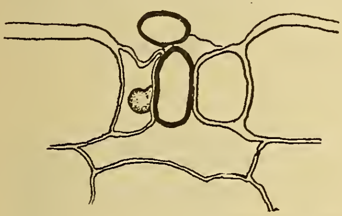


FIG. 5.—Cross section through a stoma, showing an appressorium formed directly within the stomatal pore. Penetration of a guard cell has occurred, 65 hours after inoculation. (Camera-lucida drawing; magnified about 1,300 times.)

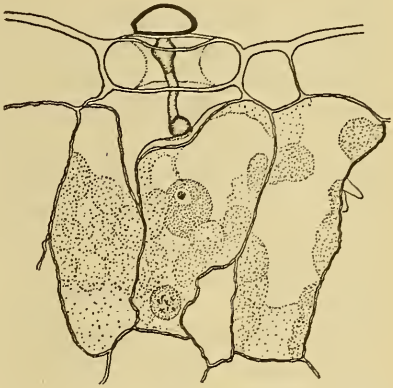


FIG. 6.—Cross section of leaf epidermis and palisade tissue, showing penetration of a stomatal guard cell from an appressorium, emergence of penetration tube into substomatal chamber, and indentation of palisade cell by the swollen tip of the tube. The wall of the palisade cell is swollen and retains safranin in the area in contact with the fungus; 65 hours after inoculation. (Camera-lucida drawing; magnified about 570 times.)

FIG. 7.—Cross section of leaf epidermis, showing penetration of an epidermal cell, 121 hours after inoculation. The contents of the appressorium have apparently passed into the penetration tube. Mycelial growth has begun from the swollen tip of the latter. Division of the host nucleus has occurred as a result of the fungous invasion. (Camera-lucida drawing; magnified about 615 times.)

The exact method of cuticle penetration is not yet understood. It is not known whether the penetration of the cuticle proper is due to mechanical pressure alone, as Blackman and Welsford (6) find in Botrytis, or whether there is some softening in advance of actual entry, or, at least, in conjunction with it, as De Bary (2), Büsgen (7), and Miyoshi (30) have concluded for certain parasitic fungi. There is no evidence of a cavity in the cell wall, indicating distinct solvent action, such as Hasselbring found in the barberry (26). Nor was any indentation and rupture of the cuticle discovered, such as Blackman and Welsford describe. However, the germ pore is very small, and swelling of the contents of the appressorium could exert considerable pressure on the cuticle at that point lying directly beneath the germ pore. This is suggested in figure 10, a case in which the appressorium has apparently forced itself loose. In figure 6 the palisade cell wall is clearly seen to be indented by the pressure of the hyphal tip. On the other hand, the swelling of the wall under an apparently unbroken cuticle has been noted (fig. 8), and swelling of an area of the palisade cell wall about the point in contact with the fungus is also evident in figure 6.

FIG. 8.—Cross section of the outer wall of a leaf epidermal cell, showing swelling under an appressorium accompanied by retention of safranin stain, 65 hours after inoculation. No penetration tube is visible. (Camera-lucida drawing; magnified about 1,300 times.)

FIG. 9.—Cross section of the upper end of a cucumber-fruit epidermal cell, showing penetration from an appressorium, two weeks after inoculation. Retention of the safranin stain is shown in the inner wall layer under the appressorium. (Camera-lucida drawing; magnified about 540 times.)

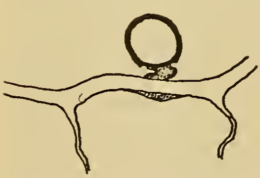


FIG. 10.—Cross section of the outer wall of a leaf epidermal cell, showing an appressorium apparently forced off by pressure exerted by the penetration tube, 121 hours after inoculation. (Camera-lucida drawing; magnified about 1,300 times.)

To summarize, penetration takes place directly through the cuticle from appressoria in close contact with the latter and provided with a small round germ pore. The exact method of cuticle penetration has not been determined.

EFFECT ON INVADED CELLS.

In the leaf sections from material fixed 121 hours after inoculation incipient lesions are found to be characterized by marked shrinkage and collapse of the epidermal and palisade cells. These cells stain deeply with the hæmatoxylin. The mycelium is almost entirely intracellular (fig. 11). In some cases the appressorium from which infection occurred is still to be seen (fig. 11). In sections of a stem lesion collapse of the collenchyma cells is plainly visible. In razor sections of diseased stems and petioles the intracellular mycelium about the advancing edges of the lesion is easily seen without staining.

As to the effect on host cells besides the shrinkage and the staining reaction above noted, there appears to be an enlargement of the host nucleus, often followed by its division (figs. 6 and 7) and in some cases by cell division (fig. 11). In cucumber-stem lesions there seems to be a tendency toward callus formation.

To sum up, it may be said that the mycelium is intracellular and that shrinkage and collapse of the invaded host cells occur. There are indications of a stimulus to cell division.

LIFE HISTORY OF THE CAUSAL ORGANISM IN RELATION TO THE DISEASE.

SEASONAL DEVELOPMENT.

Previous observations indicate that anthracnose is a disease which becomes serious only rather late in the growing season of its host. Observations made during the course of this work lead to the same conclusion. This appears to be due to the mode of origin of the disease in rather isolated and restricted centers in each field, from which subsequent spread, dependent upon heavy rains, is rather slow until a considerable reservoir of infection has developed. The strict relation of epidemics of this disease to wet weather is well recognized in the literature (41, 43, 44), and the importance of climatic conditions can not be overestimated.

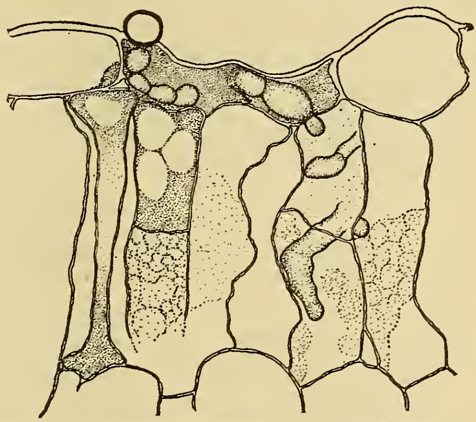


Fig. 11.—Cross section of a leaf lesion 121 hours after inoculation. Appressorium shown. Mycelium intracellular. The division of invaded palisade cells and collapse of epidermal and palisade cells are visible. (Camera-lucida drawing; magnified about 570 times.)

DEVELOPMENT IN 1915.

Observations upon the disease as it occurs among cucumbers were made during the summers of 1915, 1916, and 1917. The summer of 1915 was cool with frequent and abundant rainfall. At Princeton, Wis., the disease was first noted in a 2-acre experimental field on July 14. This infection was confined to lesions on the first and second leaves of two adjacent plants planted seven weeks previously. The next day the disease was found in a neighboring private field. By July 20 several centers of anthracnose were noted in the latter field. On July 21 anthracnose was found in another private field in town.

On July 26 a second center was found in the experimental field with secondary infection present. The rains of July 17, 19, and 21 probably account for this secondary infection, as well as that noted about the centers in the neighboring private field. An inspection of all of the 217 plats in the experimental field on July 28 resulted in the discovery of the disease in only two other plats. One week later scattered anthracnose lesions were noted in five more plats. It is of interest to note that up to this time all the anthracnose infection in this field was confined to one area consisting of 15 adjacent plats.

A careful inspection of all the plats on August 9 and 10 revealed anthracnose in five more plats in the area mentioned above and tertiary infection was noted about the old centers. Due probably to the rains of August 1 to 5, there followed a very rapid spread of the disease. An inspection of the field on August 17 and 18 revealed anthracnose in 45 plats outside of the diseased areas already alluded to. In two of these cases the infection was in apparent original centers. Thus, the most rapid spread in 1915 seems to have occurred prior to the middle of August, and it will be remembered that wet weather prevailed the first five days of that month. A frost killed the vines on August 28.

DEVELOPMENT IN 1916.

In the summer of 1916 the cucumber experimental work was located at Madison. With five rather scattered experimental fields, numerous small garden patches, and two private fields under constant observation during the early part of the summer, anthracnose was found only in the five experimental fields.

A diagram showing the weather conditions during this season is presented (fig. 12), to which reference may be made in connection with the discussion of the progress of the disease.

The disease was first noted on July 19, in field 1, planted five weeks previously. This center consisted of infection on two adjacent plants. As in 1915 the first infection was not found until after the rows had been thinned. All of the lesions were less than 1 cm. in diameter. On July 20 another center of two infected plants was found in field 1, and three centers of infection were found in field 2. On July 21 a third center was found in field 1 and a center was found in field 3. On July 22 anthracnose was found on one plant in field 4 and a center of two infected plants was found in field 5.

Rather thorough inspection of fields 1 and 2 made on July 26 and 27 revealed 12 additional centers in field 1 and two in field 2. On August 1 eight more centers were found in field 2 and the following day five more were found in field 1. The relation of this rather sudden increase in the number of new centers of infection to weather conditions is not clear, unless the rains of July 12, 16, and 19 served to render conspicuous the incipient centers already existent.

We have then, on August 1, 20 centers in field 1 and 13 in field 2, none of which were showing much secondary infection. The further observation of anthracnose occurrence in fields 3, 4, and 5 was inter-

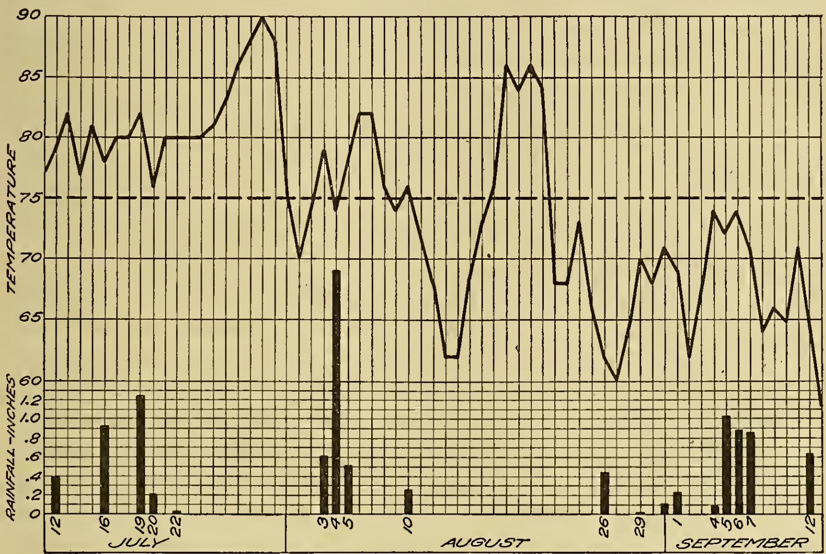


FIG. 12.—Diagram showing the weather conditions at Madison, Wis., during the summer of 1916. The curve represents the daily mean temperatures; the dotted line, the approximate optimum for the fungus; the black columns, the rainfall.

fered with by the removal of plants in connection with a mosaic control experiment. The data presented above, as well as results that were obtained later on these fields, are summarized in Table III.

TABLE III.—*Anthracnose in fields at Madison, Wis., in 1916.*

Field.	Date first noted.	Progress of disease.					
		Date.	Number of centers.	Date.	Number of centers.	Date.	Number of centers.
No. 1	July 19	July 27	15	Aug. 3	20	Aug. 15	46
No. 2	July 20	...do.....	5	Aug. 1	13	Aug. 14	30
No. 3	July 21	July 21	1	July 26	5	Aug. 11	12
No. 4	July 22	July 22	1	....	....	Aug. 18	6
No. 5	...do.....	...do.....	1	....	....	...do.....	10
No. 19	Aug. 24	Aug. 24	1	....	....	Aug. 30	2

The slowness of spread of the disease up to the first week in August may be in part explained by the extremely hot, dry weather of July, with no heavy rains after July 20. Reference to the weather chart will show that the daily mean temperatures during the latter part of July were well above the optimum (75° F.) for this fungus. Edgerton (14) finds the summer heat of Louisiana inhibiting bean anthracnose, and a similar situation may have existed in the case under consideration.

Very heavy rainfall on August 3, 4, and 5 was followed by a marked spread of the disease in fields 1 and 2. A rather careful inspection of field 1 on August 15 disclosed about 26 more or less distinct additional centers of infection, accompanied by rather widely scattered secondary infection in many cases. A similar situation obtained in field 2, and careful inspections on August 11 and 14 yielded a total of about 30 centers of infection, around most of which there was extensive secondary infection. This tended to extend farthest in the direction of the slope of the land and will be referred to later in connection with the consideration of water dissemination. On August 17 the disease was generally distributed in field 3 among the plants which had not been removed, especially at the lower corner of the field. A small private patch adjacent to this corner and hitherto undiseased, which received much of the drainage from field 3, also showed much infection of uniform age about this time. In field 4, occupying a very gentle slope, the disease did not become prevalent. By August 18 there were 10 centers in field 5 from which considerable spread had occurred, notably in the direction of the slope. Since an incubation period of a week or more is quite normal in the field, this first general spread of the disease seems to be closely associated with the period of abundant rainfall above mentioned.

During the week after August 18 the destructive effect of the disease became very apparent; the centers of infection were characterized by the death of the older diseased leaves and the rapid blighting of those near by. New centers of infection were found among the plantings of cucurbit varieties. Some new infection, due perhaps to the light rain of August 10, also appeared, but nowhere in such abundance as the infection which followed the heavy showers of the first of the month. Here it should be noted that, following this rain, the daily mean temperatures were quite low for five days. Occasional incipient lesions appearing within the infected areas previous to the rain of August 26 indicate that rain is not essential to infection. An hypothesis to account for the latter phenomenon is that, while rain is essential to the actual dissemination of the spores, germination and infection may occur later in the heavy dew which is formed during clear nights in August.

No anthracnose appeared in field 19, occupying level muck soil, until August 24, and it then remained confined to two small centers. In fields 9 and 10, belonging to private growers, no anthracnose appeared during this season.

Observations of August 21 to 31 made upon fields 1 and 2 showed that, as a rule, no marked extension of the areas of infection had occurred since that resulting from the heavy rains of the first week in the month. The light showers of August 26 seemed to result in very little new infection, due possibly to the low temperatures following this rain.

Infection was sufficiently distributed and abundant, however, to serve as ample source for a general spread of the disease in fields 1 and 2 following the heavy rains of September 4 to 7. A general epiphytotic became evident on September 12 and 13, the lesions being more or less of a uniform age. In field 1 the disease was not only prevalent in practically all of the plats, but the cucurbit varieties and a series of interplanted cucumber seedlings, all at the foot of the general slope of the field, became generally diseased, quite evidently as a result of surface-drainage infection. While the frost of September 15 killed the vines, anthracnose was prevalent on the remaining cucumber fruits of all sizes, as well as upon the fruits of the susceptible cucurbit varieties, and on these fruits the disease persisted and even spread consistently during the remainder of the month.

It is to be noted that the disease first appeared, as in 1915, near the middle of July and that there were two periods of extensive spread following the two periods of heavy rainfall. There also seems to be a rather noticeable temperature correlation, since marked spread of the disease did not result from the rains followed by excessively high or rather low temperatures. Owing to the lateness of a killing frost, the latter of the two periods of spread above mentioned developed into a genuine epiphytotic, thus demonstrating the potential destructiveness of this disease.

DEVELOPMENT IN 1917.

Observations made during June, 1917, in the watermelon regions of the South indicate that here again the weather plays an important rôle and that in general anthracnose becomes widespread only late in the growing season of the crop. Original centers were found in the fields where fruits were only one-third grown, and in some fields infection was still limited to original centers when the fruits were mature. In Georgia, where drought had prevailed, anthracnose was not yet prevalent in the fields, but later, in Florida, after the rainy season had begun, anthracnose was found quite prevalent in the commercial fields, from which shipping had almost ceased, and especially in the immature seed crop.

At Norfolk, Va., the first week in July, the disease was found in the "original-center" stage in field cucumbers, while it had become widespread and destructive in some of the coldframe beds.

In 1917 at Madison, Wis., six cucumber fields were under constant observation. This summer was characterized by frequent rains and, except for the last half of July, rather low temperatures. Light rains during the early part of July and a heavy rain on July 22, followed by temperatures favorable to this fungus, should have induced an early development of anthracnose. Although there were frequent rains during the remainder of the season, all daily mean temperatures remained well below 75° F., the optimum for the anthracnose fungus. The mean monthly temperature for August was 67° F., and for the first week of September, 63° F.

Anthracnose was first found on July 27 in field 1 and consisted at that time of eight infected plants scattered through four rows. On August 1 there was considerable anthracnose in 12 rows in the northwest corner of the field, in 3 rows in the southeast corner, and in a detached block at the southwest corner. This infection did not appear in typical original centers, but rather as scattered and comparatively recently infected plants. On August 13 anthracnose was found in a total of 28 rows scattered through the field, but was in no case serious. Inspections made August 25 and September 8 showed that no extensive spread had occurred. This can not be attributed to lack of rain and is probably due to the low daily mean temperatures prevailing after the end of July, as noted above.

In the other fields no anthracnose was found except in the Isom field, and there not until August 13, when old lesions were noted on the old leaves of two adjacent plants. On September 8 an additional original center from which very little spread had occurred was found. Why these were so late in developing is not understood.

LOCAL DISSEMINATION BY WATER AND OTHER AGENCIES.

Consideration of the subject of dissemination falls very naturally into two general categories: One, the mode of spread of the disease in the field during the growing season; the other, the manner in which the disease is first introduced into new fields (21). The former may conveniently be considered as local dissemination.

SPATTERING ACTION OF RAIN.

That water is essential to the separation and dispersal of the spores of this type of fungus is generally recognized. Since the spores tend to remain in masses adherent to the acervuli until their matrix is dissolved by water, the importance of the latter as a prerequisite for spore dispersal is quite evident. But the mechanical action of rain is more important.

The appearance of so-called centers in fields has been mentioned. The gradual enlargement of these foci of infection and the spread therefrom is the phase with which we are now concerned. Some of the experimental work on water dissemination has been previously reported (21).

Observations made in the Madison fields in 1916 showed that an enlargement of old centers of infection in all directions was to be noted within five to seven days after each rain. A new "crop" of young lesions of uniform age, many within the old infected area in the row, many out around its periphery, appeared after each period of rainy weather. As these centers thus increased in size they extended not only along the row on either side but also across into neighboring rows and up hill as well as down. On the other hand, after a period of dry weather very little new infection was to be found. While this type of gradual spread of the disease may occur during light rains, it is, of course, more marked after heavy rains.

Considerable observational evidence relative to this question has been accumulated. In Princeton in 1915 abundant incipient infection was noted about old centers on July 26, probably as a result of the rains of July 17, 19, and 21. By August 9 and 10 a second crop of incipient lesions appeared, quite evidently as a result of the rains of August 1 to 5.

In 1916 an examination of the anthracnose centers in field 2 after a period of 10 days of dry weather revealed little or no incipient infection on new growth and only a few incipient lesions on old leaves. The latter may well be attributed to delayed germination or the penetration of spores actually disseminated during the earlier rains. Observations made in this field on August 8, 11, and 14 revealed abundant new infection as a result of the rains of August 3, 4, and 5.

It is commonly held that this type of spatter infection takes place by the actual spattering of the spores from diseased to healthy leaves. The agency of the soil as an intervening depository has not been emphasized. It seems quite likely that much of this spatter infection is accomplished by spores first washed to the soil in great numbers and thence splashed on to neighboring leaves.

To determine the validity of this hypothesis, a test was made of the soil under diseased leaves in field 2 five days after a light rain of August 10, 1916. Two grams of the soil was shaken up in 99 c. c. of sterile water and 1 c. c. of this suspension was transferred to a second 99 c. c. of sterile water. From the latter dilution 1 c. c. and fractions thereof were taken as inoculum for poured plates in water agar plus 2 per cent dextrose. Two soil samples were thus tested with five plates each. No colonies of the anthracnose fungus appeared.

On August 26, while the soil was still wet from a rain of 0.31 inch, two more soil samples were collected under diseased foliage and in a small drainage channel in field 2. Dilution plates were poured as above, four from each sample. In each set of plates six colonies of this fungus were identified. This indicated, according to the dilutions used, a spore content of 15,937 per gram of wet soil in one sample and of 60,000 per gram in the other.

To further test the possibility of leaf infection from soil, a large sample of soil was collected from anthracnose centers in field 2 on August 14, 1916, four days after a rain. Under healthy runners in each of eight locations in four plats in field 1, 4 tablespoonfuls of this soil were sprinkled. In an examination of these runners on August 31 infection was found in one case consisting of lesions on six leaves, abundant on three. In this instance the soil inoculum had been sprinkled upon the leaves and then shaken off, while in all the other tests an effort was made not to sprinkle the soil on the leaves.

These tests prove that the spores of this fungus are abundant in the soil under diseased plants immediately after a rain and are viable even four days later. The common occurrence of anthracnose lesions on the lower side of a watermelon fruit in the field indicates infection from spores in the soil or in drainage water.

With regard to the spattering of spores upon healthy leaves, two tests were made. Within two hours after a heavy rain, September 5, 1916, an undiseased leaf was taken from field 2 near diseased leaves and the blade washed in 200 c. c. of sterile water. From the five dilution plates poured from this wash water, one colony of anthracnose was isolated. This indicated, according to the quantity of wash water represented, that there were 96 spores on the leaf lamina. A similar test made with an undiseased seedling within 1 foot of diseased leaves yielded negative results. The isolation of the fungus from an undiseased leaf proves that the spores were present on the leaf surface after a rain.

During both seasons of 1915 and 1916 anthracnose occurred on plants under cheesecloth cages which eliminated both insects and pickers as agents of dissemination. Since these plants were very evidently not original centers of infection, the entrance of the fungus can be attributed only to water splashing through the cloth or, more likely, washing under the cages.

Among watermelons in the field, cases have been noted in which the fruit lesions were arranged in vertical rows in such a way as to indicate beyond a doubt drip infection from overhanging diseased leaves.

ARTIFICIAL WATERING.

Another line of evidence relative to the local spread of the disease by the spattering of water is furnished by the severity of anthracnose as noted among certain of the fields of cucumbers in coldframes at Norfolk, Va., in 1917. Here, daily watering by an overhead system was practiced, and this may explain in part the advanced development of the disease in these fields as compared with its relative obscurity in other fields of the region.

SURFACE DRAINAGE WATER.

But the mere spattering of rain and blowing of the droplets by wind can not account for the extensive epiphytotics of this disease which suddenly appear in certain fields. A considerable mass of observational evidence has been accumulated relative to this point. It has been generally noted that extensive spread of this disease does not follow every rain, but only the very heavy rains during which considerable surface run-off takes place. The general trend of the evidence seems to indicate that epiphytotics tend to occur more commonly where the topography of the field is sloping or rolling.

As to the effect of heavy rains, it will be recalled that the first general spread of the disease in the Princeton fields in 1915 followed the rains of the first week in August. In the Madison fields in 1916, two periods of extensive spread of the disease were clearly recognized, one after the heavy rains of August 3 to 5 and the other, which resulted in a serious epiphytotic, after the heavy rains of September 4 to 7. Intervening lighter rains of 0.28 inch on August 10 and 0.31 inch on August 26 were not followed by an extensive spread of the disease. It is realized that here there is a difference in duration as well as in amount, and the longer rainy periods no doubt afforded conditions more conducive to infection. Furthermore, reference has been made to the significance of the lower temperatures of the periods following the light rains.

Additional observational evidence relative to the agency of surface drainage during heavy rains in spreading this disease is furnished by the direction of this spread from the old centers. This is revealed by the location of even-aged new infection following such rains.

Field 2 at Madison in 1916 afforded a good opportunity to observe this phenomenon. This field occupied a decided south slope and the rows extended across the slope. The new infection resulting from the rains of the first week in August was very evident by August 12 and a careful inspection of the field showed the manner of spread from the old centers of infection to be somewhat as illustrated in figure 13. There was a decided tendency for the greatest spread from the old centers to be across the rows and distinctly in the direction of the slope. At least nine of the areas of infection show elongations extending downhill; in fact, in four of these cases the new infection in the row below the old center was along small gullies or drainage channels leading directly from the old center in the row above.

Field 3 occupied a gentle southeast slope, and here again the rows crossed the slope. One original center occurred in a row along the upper edge, and from this center a drainage channel led down across the entire field to the southeast corner, where it formed a delta extending into a private cucumber patch. On August 17 the course of this drainage channel was found to be marked by new infection in at least three rows and by a second old center. There was also much scattered new infection in the region of the delta, both in field 3 and in the private patch as well.

In field 4 the rows were parallel to the very slight western slope. On August 18 a spread of even-aged secondary infection to the westward from four of the six centers was noted. Examination of the anthracnose centers in field 5 on August 18 showed a downhill spread of infection across the rows in three instances. In two cases

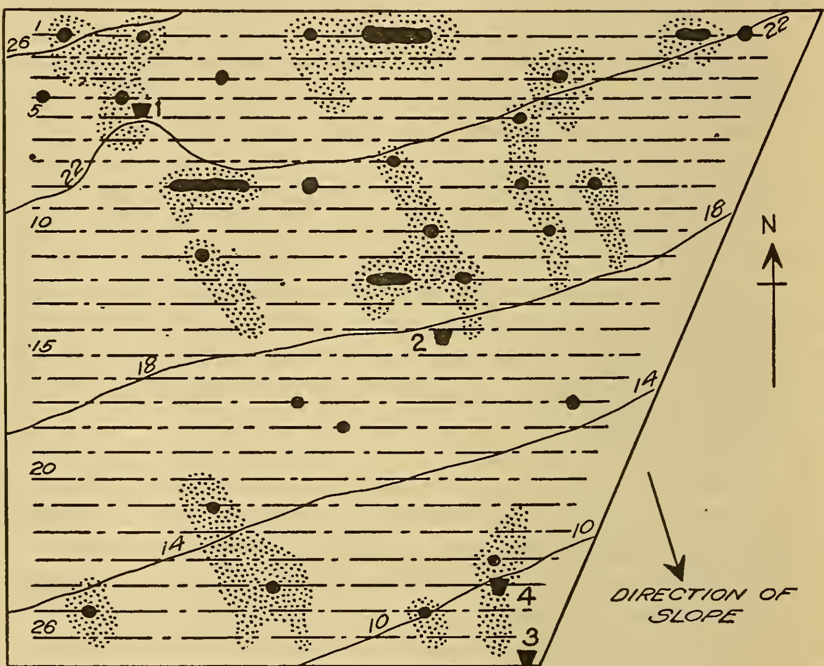


FIG. 13.—Diagram of field 2, Madison, Wis., August, 1916, showing the relation of surface drainage to the distribution of anthracnose. The cucumber rows are indicated by broken lines and the slope by the 4-foot contour intervals. The four trapezoids represent water traps 1 to 4; the black circles and ellipses, original centers of anthracnose; and the shaded areas, new infection noted on August 12.

this infection extended across two rows downhill (14 feet), and at the same time into the adjacent row above.

Among the Madison fields that season, anthracnose became prevalent only where there were slopes. In field 19 on level muck soil, there was very little spread from the old centers. In a large watermelon field near Quitman, Ga., infection was found to be widespread on certain slopes, but still restricted to small areas in the more level parts.

Late in the season of 1916 an excellent opportunity was afforded in field 1 to observe the results of the heavy rainfall of the first week in September. As may be noted in the accompanying diagram (fig. 14), this field occupied a decided westward slope, and the rows were parallel to the direction of the slope. Along the west side at the foot of the slope were grown the various cucurbits mentioned in the discussion of pathogenicity. While some anthracnose appeared among these earlier in the season, it was confined to a few well-defined centers. After the rains mentioned above, new even-aged infection of anthracnose was found on September 12 on all of the rows

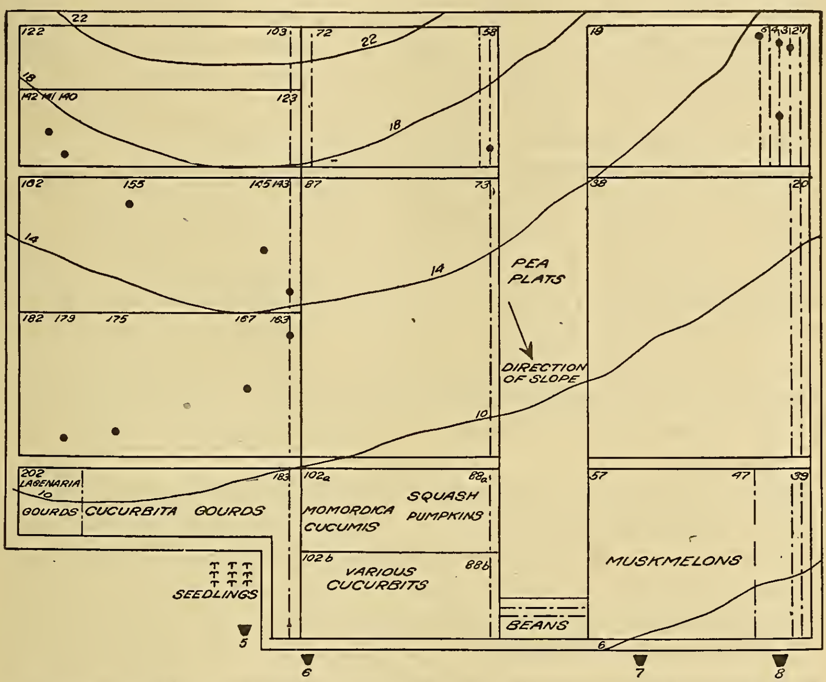


FIG. 14.—Diagram of field 1, Madison, Wis., 1916. The direction of the rows is indicated by broken lines, the slope by the 4-foot contour intervals. Where not otherwise indicated the crop was cucumbers. The original centers of anthracnose noted on July 27 are shown by the circles. The location of the seedlings planted late in the summer is shown in the lower left corner. Water traps 5 to 8 are shown by trapezoids.

of susceptible cucurbits, very evidently as a result of surface drainage from the diseased field above.

Still more convincing evidence was furnished by rows of cucumber seedlings planted late in the season between the rows in field 2 and on the west edge of field 1 (fig. 14). On September 11 these seedlings in field 1 appeared healthy, while the next day practically all of them were thickly spotted with incipient anthracnose lesions, so numerous as to cause many leaves to curl. By the next day many seedlings were dying. Drainage channels from the field above led directly through these rows of seedlings. Very evidently these seedlings were so abundantly infected during the preceding rains that they were practically blighted outright by the numerous lesions that developed simultaneously. An added point of interest is that this drainage water also passed through the rows of Cucurbita gourds, none of which became diseased (fig. 14).

In field 2 all of the rows of interplanted seedlings showed recent and even-aged infection on September 13. Besides leaf and cotyledon lesions numerous enough to cause these organs to curl up, some seedlings bore girdling stem lesions as well. This infection is likewise attributed to surface drainage during the rains of the week previous.

That the spores are washed from the leaves to the soil was proved by the tests previously cited. That the spores are carried considerable distances by the surface run-off during rains and spattered from this drainage water upon all plants along the drainage channel is to be inferred from the observations presented above.

To test experimentally the latter hypothesis, steps were taken to prove that the spores were present in surface drainage water. On August 14 four glass tumblers were sunk flush with the soil at the points indicated in figure 13, so as to intercept surface drainage water during the next rain. No tests were made until the rains of the first week in September. On the morning of September 5 the traps were emptied. A heavy shower occurred in the afternoon, after which the contents of the four traps were collected in sterile flasks. At the same time samples of the soil near two of the traps were collected.

Each sample of drainage water was tested by poured plates as follows: Of the drainage water 1 c. c. was transferred to a flask containing 99 c. c. of sterile water, and from this 1 c. c. was transferred to a second 99 c. c. flask. Using recorded amounts of inoculum from these dilutions, three plates were poured from the first flask and two from the second in water agar plus 2 per cent dextrose. No colonies of the anthracnose fungus appeared in any of these plates. The soil samples were also tested by the method outlined earlier, and only negative results were secured.

That spores of the anthracnose fungus were present in the samples of drainage water was proved in another way, however. The contents of each trap, after the removal of the sample for plating, were sprayed upon healthy potted cucumber plants.[1] The results of these tests are presented in Table IV.

Spores of the anthracnose fungus were present, therefore, in three of the four traps. Trap 1, in which no spores were found, was located near the upper edge of the field, and hence there was a smaller reservoir of disease contributory to it.

After the additional rains of September 6 and 7 a series of five plates each was poured from traps 1 and 2 in field 2, and, as in the

[1] These inoculations, as well as those described later, were made by Dr. E. Carsner in connection with his investigation of the angular leaf-spot of cucumber.

previous test, only negative results were obtained. Owing to the ravages of mosaic, field 2 was becoming unsuitable for work on anthracnose and field 1 offered better possibilities.

TABLE IV.—*Anthracnose dissemination test by spraying potted cucumber plants with drainage water from water traps.*

Trap.	Serial numbers of pots sprayed on Sept. 5.	Number of anthracnose lesions on Sept. 14.	Trap.	Serial numbers of pots sprayed on Sept. 5.	Number of anthracnose lesions on Sept. 14.
No. 1	139	None.	No. 3	136	5
	148	None.		137	None.
No. 2	145	2	No. 4	140	7
	146	1		138	6

On September 12 four water traps (5, 6, 7, and 8), similar to those in field 2, were placed in field 1 along the extreme western edge and at the foot of the slope. The location of these is shown in figure 14. The same day a rain of 0.66 inch occurred and the contents of these traps were collected immediately afterwards.[1] Using the method outlined above, dilutions were made from three of the samples and a series of seven plates poured in each case. No anthracnose colonies appeared in the plates from traps 5 and 7, but in the series from trap 6 two colonies of the anthracnose fungus appeared. According to the dilution used, this result indicates a spore content of 916 per c. c. in the water in trap 6.

The liquid collected from these traps was also sprinkled on healthy potted plants in the greenhouse.[1] Seven pots were thus inoculated, and on September 19 the plants in each pot were diseased. Each sample produced anthracnose infection, and it is quite evident that spores were present in the drainage water caught in each trap. It is also apparent that this method is superior to the poured-plate method for detecting the presence of the spores in such an inoculum.

These experimental tests prove conclusively that which the observational evidence indicated, namely, that the spores are carried through the fields by surface drainage water during rains. As to the distance carried, recovery of the fungus from these traps along the edge of the field indicates that the spores were transported at least as far as the extremities of the field in question, and there is no reason to suppose that they might not be carried much farther. However, the main importance attached to this agency is that it serves to disperse the fungus far and wide through the particular field already containing original centers of infection.

Water, then, is not only necessary for the germination of the spores, but is also essential to the separation of the spores from the lesion. In the shape of rain, it washes the spores to the soil and spatters them on to the host plants. In the shape of surface run-off, it dis-

[1] These traps were placed and the contents collected by Dr. E. Carsner.

perses the spores widely through the field and causes a marked downhill spread of infection.

MOISTURE CONDITIONS FAVORING INFECTION.

Judging from the evidence already presented under the consideration of water dissemination, it seems quite evident that the very agency of dissemination in that case furnishes the proper condition for spore germination and subsequent host infection. In view of the even-aged "crops" of new lesions following each rain, it appears that infection with anthracnose generally occurs while the plants are still wet from a rain.

However, it was pointed out that some incipient infections are often to be found after periods of prolonged drought, and this was attributed to delayed penetration by spores already present. Whether these spores were present as such or as appressoria is not known, although it seems quite probable that the latter may represent a resistant resting stage.

Now, as to the conditions favoring such cases of delayed infection, it is of importance to recognize that during August in Wisconsin heavy dews occur at night and cucumber foliage is heavily coated with moisture. Observation has shown that this water of condensation remains in drops on the lower epidermis of cucumber leaves, while it spreads over and thoroughly wets the upper epidermis. This daily wetting of the leaves no doubt affords favorable conditions for germination of the spores or penetration from the appressoria.

Furthermore, there is a possibility that infection may be facilitated by guttation water. Large drops of guttation water often collect about the margins of cucumber leaves when evaporation is retarded, as, for example, in the case of plants under cloth cages. This water is sometimes exuded in such quantities as to run down over the epidermis of the leaf. Marginal anthracnose lesions are common. Two samples of guttation water were collected from caged plants, September 6, 1916, and tested as a medium for spore germination. While only a very low percentage of germination was obtained, proof was afforded that the liquid was not toxic.

Examination of watermelon fruits in the South showed the frequent occurrence of dense masses of incipient anthracnose lesions, or "pimples," about the periphery of the bleached area where the melon was in contact with the soil in the field. Subsequent examination of fruits as they lay in the field revealed that this region of their surface was coated with a layer of minute droplets of condensation water, while the part in actual contact with the soil was thoroughly wetted. This condition obtained even during the heat of the day. It seems quite probable that the exposed band of condensation moisture on the under side of the fruit would afford conditions of moisture and oxygen supply very favorable to spore germination.

While rain water may be the usual requisite for infection, it is evident that other conditions may also permit its occurrence.

DISSEMINATION BY INSECTS.

While insects may possibly act as agents of dissemination, there is no indication that they are at all important in this capacity. It has been previously noted that the striped cucumber beetles often feed on the tissue about the margins of leaf lesions, and it is evident that infectious material might be subsequently transported by these beetles.

A few tests were made to determine what part insects might play as agents of disease transport. On August 11, 12 striped and 12 spotted beetles were collected from anthracnose centers in field 2 and about 10 of each species were introduced under two cheesecloth cages covering plants in field 1. Drainage-water infection of the plants under the cages in this field ruined this test. On September 6 three spotted beetles were collected in sterile test tubes from diseased plants and each beetle was placed in 50 c. c. of sterile water. Plates poured from this wash water yielded no colonies of the anthracnose fungus.

No proof was obtained, therefore, that insects spread the disease, and observational evidence has not tended to implicate them.

DISSEMINATION BY CULTURAL PRACTICES.

Since the spores may occur abundantly in the soil, it seems quite possible that the disease might be spread during the processes of cultivation. For this disease, unlike bean anthracnose, observation has not yielded indications of this type of dispersal.

The process of picking the cucumber crop grown for pickles would seem to afford a very fruitful means of disease dispersal. Since this process is repeated at least four times a week and involves considerable handling of the vines, it may contribute much to the spread of the anthracnose along the row from an old center. This is especially true if picking is done when the vines are wet with dew or rain. At one of the coldframe farms near Norfolk where the disease was very serious, it was found that picking was done early each morning, when, no doubt, dew was on the vines.

The occurrence of more or less isolated leaf lesions here and there among the leaves is taken as evidence of this type of dissemination. From these lesions as a source, new centers of infection may develop. Such infection differs from the type produced by drainage transport in that, in the latter, the infection is continuous along the row from the old center.

Among watermelons, quite conclusive observational evidence was secured relative to the agency of man in spreading anthracnose. In a large field near Quitman, Ga., considerable new infection in the shape of rather isolated infected leaves or groups of leaves was found out along the rows just outside of extensive heavily infected areas. These new infections were not downhill from the old centers nor was infection continuous along the row, so water dissemination was precluded. As a rule, these infections consisted of only a few older lesions, not scattered over the whole leaf blade, but commonly along one edge or along a vein. From these older lesions some secondary infection had occurred. The most striking feature of these incipient centers of infection was, however, that about two out of three were located on the leaves immediately surrounding or overhanging a fruit. About the edge of one area of old infection, 68 of these scattered new infections were found on foliage around fruits. This represented probably 5 to 10 per cent of all fruits lying within the area examined.

Upon inquiry of the plantation manager, it was learned that about two weeks previously the field had been gone over for the purpose of removing the malformed and rotting fruits. This period of time coincided well with the apparent age of the older leaf lesions above noted. This "culling" operation, it appears, is usually performed early in the morning when the vines are wet with dew. At any rate, in the case under consideration, all the evidence pointed to hand dissemination during the process of culling the vines. A likely hypothesis is that, in going up one row and down the next, the workman had repeatedly passed through the badly diseased area, had removed diseased fruits, and carrying spores on his hands had unconsciously inoculated the foliage farther along as he pushed the leaves aside to gain an unobstructed view of a fruit or to see if a fruit was concealed under the heavy foliage.

From these leaf lesions, spores are readily washed to the fruit underneath, and the insidiousness of these "hand" infections becomes obvious when it is realized that the new centers are so located that the worst possible damage is an immediate result.

The chief activity of man in local dissemination is, then, in inoculating leaves here and there along the row, which act as new centers of infection. Among watermelons, rather conclusive evidence of this type of disease dispersal has been obtained.

DISSEMINATION WITH THE SEED.

It is in the introduction of the disease into new fields that human agencies assume prime importance. Here will be considered some of the possible sources of infection. The overwintering of the fungus in the field is treated in a later chapter. The disease has not been found on wild cucurbits in the North. The occurrence of Lagenaria gourds and volunteer melon vines in the South is recognized as a possible source of infection. Country-wide transport of diseased watermelons unquestionably is another means of long-distance spread of the disease provided infectious material reaches the fields.

It seems fairly safe, however, to eliminate all of the above factors except overwintering as rather remote possibilities. As an explanation of the appearance of the disease in new localities, all evidence points toward introduction with the seed. Previous workers have suggested this possibility, notably Sheldon (46; p. 127–137), Garman 22, p. 51), Eckardt (11), and Eriksson (16, p. 126–127). Eriksson presents observational evidence which strongly indicates the introduction of anthracnose into greenhouses in Sweden with cucumber seed from England.

FIELD OBSERVATIONS.

The experimental field at Princeton in 1915 had previously been in sod for seven years. Anthracnose appeared in this field as soon as in any other fields of the region. So far as could be learned none of the five experimental fields at Madison in 1916 had previously grown host crops, yet the disease appeared simultaneously in all of these fields and in practically no other fields or gardens of the surrounding territory. In the watermelon industry of the South crop rotation is necessitated by the ravages of the wilt, yet anthracnose recurs annually.

Instances could be multiplied, but sufficient evidence has been adduced to show that the disease appears quite commonly in new fields. In a case such as that presented by the 1916 Madison fields there seems to be but one plausible explanation, namely, disease introduction with the seed.

The very manner in which the disease originated in these fields suggests this hypothesis. The disease first appeared in the Princeton field and in the Madison fields in what we have termed "original centers." These were scattered here and there through a field and were usually limited to a comparatively small number per acre (figs. 13 and 14). With a disease as infectious as this it is not always easy to differentiate between original and secondary centers, but in fields under constant observation those centers appearing first and about simultaneously may safely be termed "original."

The nature of these initial infections furnishes another argument in favor of their origin in situ. The first original center found in the Princeton field consisted of two adjacent plants not yet large enough to "run." These plants bore lesions on the first and second foliage leaves. Since the rows had already been thinned, several plants had been removed between and adjacent to the two above noted, and the hypothetical originally diseased plant might already have been removed.

In 1916 the first center of anthracnose found in field 1 consisted of two adjacent plants, one bearing one lesion on the fourth leaf, the other bearing one lesion near the tip of a cotyledon, one lesion on the first leaf, two on the second, and four on the third leaf. Unfortunately, thinning had again been completed. The next day in another part of the field an infected plant was found which had three lesions on the first leaf but none on the cotyledons. The same day two other centers of two infected plants each were found and the next day two more similar centers were found. In all of these cases the lesions were fairly large, indicating that infection had occurred perhaps two weeks previously.

In the other four fields, similar original centers of apparently the same age were found at about the same time. In field 2, the first one found consisted of two adjacent plants, one with numerous lesions on the first leaf. The first original center found in field 3 also consisted of two diseased plants, of which one bore lesions on the first leaf and on a cotyledon. In field 4 the first anthracnose center was one very badly spotted plant, and in field 5 the first center noted consisted of two diseased plants. Whether or not the originally diseased plant was present in any of these cases is rendered questionable because of the previous thinning operation. Just how the fungus had passed the five weeks elapsing since the time of planting the seed can not be answered at present.

Near Albany, Ga., in a large watermelon field not previously planted with this crop, careful search of about 1,000 hills revealed only two single-hill centers of anthracnose. In each of three melon fields near Monticello, Fla., one single plant center of anthracnose was found. Single plant centers of anthracnose were found in one field of cucumbers near Norfolk, Va.

Under the fairly well controlled conditions among the Madison fields in 1916, the simultaneous appearance of a few scattered centers in each of the five experimental fields on land not previously sown to this crop furnishes quite convincing evidence of disease introduction with seed. But still more striking is the fact that anthracnose appeared only in the five fields planted with seed from the same source and not in the two private fields and numerous gardens also under close observation (21). This correlates the occurrence of disease with seed from a particular source.

ANTHRACNOSE IN SEED FIELDS.

In view of the probability of seed carriage of the disease, as indicated above, the next step was to ascertain what opportunity there was for the seed to become contaminated. First, was the disease present in the seed fields?

A visit was made the first week in October, 1916, to a seed farm in Ohio. The vines were dead at this time, but anthracnose was found very prevalent on the fruits in certain fields. Since the seed fruits are allowed to lie in the field until thoroughly ripe, there is abundant chance for their infection. The disease was also found on cucumbers in several of the fields on a seed farm in Michigan, but it was not present in the melon fields. In August, 1917, the disease was found to be rather serious in several fields of cucumbers on another seed farm in Michigan, and in October, during the seed-harvesting season, anthracnose was found very prevalent on the seed fruits in one field. The badly diseased condition of the fruits in one hill is shown in Plate VII and the lesions on a seed fruit in Plate VIII.

On June 29, 1917, 12 seed fields were visited in Florida in the chief watermelon seed-producing region. Anthracnose was found in six of these fields; in one it was very serious and widespread and occurred on the young fruits as well as on the vines. The melon seed crop is later than the commercial crop of that region and runs along well into the rainy season of July, so that anthracnose development is favored. Melon seed is also secured in other districts from the unsalable fruits remaining in commercial fields after the better ones are shipped. This almost insures the use of diseased fruits. In any case, the melons are allowed to remain in the field until dead ripe, and on account of the higher temperatures of that region they are more subject to severe anthracnose infection than seed cucumbers.

Although the disease has been found in the State, no anthracnose has been reported in the cucurbit-seed fields in Colorado, and since practically all cantaloupe seed is produced in the West, this may explain the absence of anthracnose from the cantaloupe fields as observed at Blackville, S. C.

It is quite evident, then, that the disease is present in both cucumber and melon seed fields and that seed fruits become abundantly infected. It remains to be shown whether or not seed infection or contamination may occur. Theoretically, the fungus might be present within the seed, upon the surface of the seed, or in diseased fruit fragments mixed with the seed. First, what is the likelihood of the two latter contingencies?

PROCESSES OF SEED EXTRACTION.

In the North, cucumber and melon seed is extracted by passing the fruits through a machine known as a "grinder." The fruits are thrown into a hopper and pass down between revolving cylinders, the surface of which is spiked, ridged, or fluted. These rollers crush the fruits sufficiently to free the seed and pulp. The wet mass of seed, pulp, and rind fragments then passes through inclined revolving screens, which separate the seed and juice from the larger fragments of rind and pulp. The fluid mass of seed and juice is usually allowed to ferment two to four days in open barrels or pits, to remove from the seed the adhering pulp and the capsule or gelatinous epidermal layer of the seed. After this, the seed is thoroughly washed in a screen and dried in flats in the open or in a drying room. In the case of fermentation in pits, the seed may be dried without washing. By some growers, the fermentation process is now omitted.

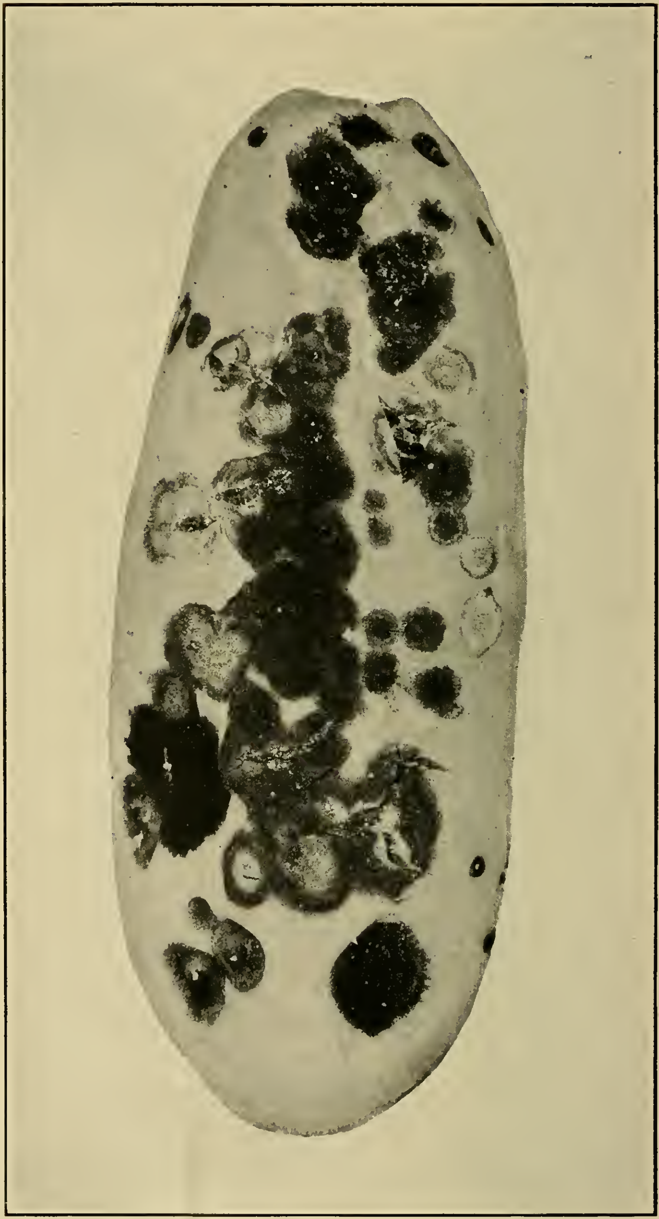
During the process of crushing and separating, the exterior of the rind becomes thoroughly drenched with the abundant juice from the crushed fruits, and it is inevitable that the spores should be washed from the fruit lesions into the juice which goes through with the seed. Conditions at the Ohio farm were very interesting in this respect. A considerable percentage of the fruits being ground bore anthracnose lesions, and, although the latter were not sporulating to any great extent, there appeared to be plenty of opportunity for wholesale contamination of the seed by the spores of the fungus. Similar conditions prevailed in the Michigan seed field visited in 1917, where a much larger percentage of the seed fruits was diseased.

In an attempt to prove that anthracnose spores were present in the seed and juice as it issued from the grinder and in the liquid in fermenting barrels filled the same morning, cultural tests were made at the Ohio farm. Test-tube water blanks were used in place of dilution flasks and sterile calibrated pipette droppers were used in place of pipettes. Two series of six plates each were poured, using water agar plus 2 per cent dextrose. No anthracnose colonies appeared. The heavy seeding of bacterial and fungous colonies in these plates showed, however, that the liquid tested contained an abundant and varied flora.

On October 6, 1917, a number of diseased seed cucumbers, one of which is shown in Plate VIII, were collected at a seed farm and brought to the laboratory, where the seeds were removed by hand the next day. To simulate as closely as possible the conditions in the commercial operation, the seeds, juice, and rinds were mixed together in a jar and then the larger rind fragments were removed. The material in the jar was allowed to ferment for two days in the laboratory. The gas produced yielded a froth which buoyed up numerous rind fragments. In such diseased fragments thus caught and held at the surface the fungus was found to be producing new acervuli and sporulating in abundance, thus greatly increasing the amount of infective material in the liquid.

The period of fermentation might allow the spores to germinate, but it is probable that the anaerobic conditions would prevent this. In case germination did occur on the wet seed, adherent appressoria would quite likely result. It is not considered at all likely that the biological action during this short period of fermentation would kill the spores. The washing process would remove by no means all of the spores from the seed, since the surface of the latter is not smooth but is covered with cellulose hairs. During the process of drying in

ANTHRACNOSE ON SEED CUCUMBERS IN THE FIELD, OCTOBER 6, 1917, JUST PREVIOUS TO SEED EXTRACTION.



ANTHRACNOSE LESIONS ON A SEED CUCUMBER, OCTOBER 6, 1917.

the open, exposure to sunlight might kill a negligible percentage of the spores. There remains only the factor of actual desiccation, which must be endured by every spore. The spores are, however, quite resistant to desiccation, and as to their longevity while in this state more will be said presently. The subsequent processes of re-washing, floating out the light seed, redrying, and fanning to remove skin fragments are not such as to eliminate contamination.

Furthermore, not all of the fragments of fruit epidermis and pulp are removed. A considerable percentage of the Ohio seed bore such adhering fragments, and it is quite possible that infectious matter may remain on the seed in the shape of mycelium within these fragments. In a small sample of unfanned seed from the seed field observed in October, 1917, numerous fragments of fruit epidermis dotted with blackened acervuli of this fungus were found both free and adherent to seed. In an attempt to prove the viability of the spores on these acervuli and of the mycelium within the tissue by plate tests on December 20 success was not obtained.

In the watermelon-seed regions some of the growers operate machines, but by the majority the work of seed extraction is done by hand. The fruits are cut in two and the seed and pulp scooped out by hand into tubs, where the mass is allowed to ferment. Then the seed is washed and dried. During this operation infectious material from surface lesions may readily gain access to the seed.

The process of seed extraction among cucumbers and melons therefore affords ample opportunity for seed contamination with infectious material, and no step in the whole process precludes the possibility of the latter remaining viable and going into storage with the seed.

FACTORS INFLUENCING EXTERNAL SEED CARRIAGE OF THE FUNGUS.

There still remains the long period of desiccation upon the seed surface to be reckoned with. Much of the melon seed used is 2 or more years old, and this fact offers a real difficulty. But much of the cucumber seed, for pickles at least, is used the next season and is in storage only seven to eight months. In this regard it should be recorded that spores on leaf lesions in dried specimens have commonly been found viable seven months after the collection of the material. Many spores should therefore remain viable on the seed until the next season, and were appressoria present the resistance to desiccation might be still greater.

It is also important in this connection to understand the nature of the seed surface. The familiar gelatinous capsule of freshly extracted cucumber seeds is the epidermis of the seed and consists of a single palisade layer of extremely elongated columnar cells prismatic in cross section and 160 to 260 μ or more in height (1, p. 283–

286). The lateral walls are thin except for a rodlike thickening extending from base to apex of each cell. The processes of fermentation and washing remove all of this cell layer except these rodlike thickenings, most of which remain as cellulose hairs (fig. 15). These hairs become closely appressed to the seed when the latter is dry and may protect adhering spores or appressoria from extreme desiccation. Furthermore, since the fungus may be present in the adhering fragments of fruit tissue it is evident that in this form desiccation could be more readily endured.

It is scarcely believed at present that the fungus will survive an additional year's storage, and hence it is only reasonable to maintain that the disease is introduced only with seed planted the year after it is harvested. This is an important consideration, since in practice much of the cucumber and melon seed is more than a year old when used. Cucumber seed is known to remain viable from two to six years, and many growers prefer old seed.

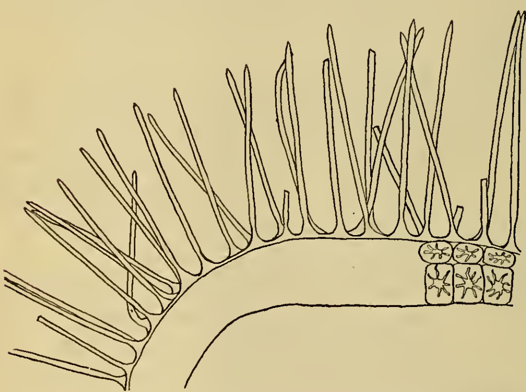


FIG. 15.—Cross section through the seed coat of a cucumber seed, showing cellulose rods, or "hairs."

POSSIBILITY OF INTERNAL CARRIAGE OF MYCELIUM.

There is also the possibility of internal carriage of dormant mycelium within the seed. Eriksson (16, p. 127), after failing to find mycelium in supposedly infected seed, advances his mycoplasm theory to account for anthracnose carriage in cucumber seed. The depth of fruit lesions as observed on seed cucumbers and watermelons suggests that seed infection may occur previous to seed extraction. From observations made upon seed cucumbers collected in October, 1917, it appears that there may be considerable opportunity for the internal infection of seed. Coalescent lesions were found penetrating the placentæ as far as the seed, and in some instances the gelatinous capsules were decomposed and the funiculi rotted off at the points of attachment to the seeds.

Samples of seed removed from beneath such lesions were tested in two ways for the presence of the anthracnose fungus. The seeds were sterilized in mercuric chlorid, 1 to 1,000, for five minutes, washed in sterile water, and some were planted intact in poured plates of 2 per cent dextrose agar. From others the embryos were aseptically removed and planted in similar plates. Tests were made on November 4 and December 14. In 87 seeds tested by the former method and 90 by the latter no trace of the anthracnose fungus was obtained.

ATTEMPTS TO PROVE THE PRESENCE OF THE FUNGUS ON THE SEED.

With all of the observational evidence pointing so strongly toward seed carriage of the fungus, repeated efforts were made during the spring of 1917 to isolate the organism from commercial seed or in other ways to prove its presence.

Besides numerous samples of seed collected at the Ohio farm at different stages in the cleaning process, a generous supply of 1916 seed was later secured from that farm. This seed, as well as some of that used in 1916, was tested in a variety of ways in an attempt to detect the presence of the anthracnose fungus. The following methods were employed:

(1) Seeds were placed in agar plates.

(2) Seeds were planted in Petri dishes on sterile filter paper moistened with water or a nutrient solution.

(3) Seeds were planted in large damp chambers on moistened filter paper.

(4) Seeds were planted in sterile sand in damp chambers.

(5) Seeds were planted in sterile soil in flats in the greenhouse.

In the first three methods the fungus might be detected by its saprophytic growth on the substratum or by its parasitic development on the seedling. In the last two methods the latter possibility was relied upon. The results of these tests are summarized in Table V.

TABLE V.—*Summary of laboratory tests of cucumber and muskmelon seeds to prove the presence of the anthracnose fungus.*

Date.	Seed used.		Method.	Time in days.
	Source.	Number.		
1916. Aug. 28	Iowa, 1915	[1]	11 dilution plates in 2 per cent dextrose agar from wash water.	8
1917 Feb. 5	Ohio	15	5 in each of 3 plates, 2 per cent dextrose agar.	8
5	Muskmelon seed, 1915	15	....do	8
5	Ohio (fruit tissue adhering)	24	6 in each of 3 plates, 2 per cent dextrose solution in filter paper.	17
5	Ohio	8	Same, in plate	17
5	Ohio (fruit tissue adhering)	30	6 seeds in each plate; filter paper plus water.	17
26	Ohio	200	Wash water on cucumber plants	14
26	Ohio (fruit tissue adhering)	33	In drops of water on cucumber foliage; 2 plants.	[2]
Mar. 3	Ohio	1,200	12 sterilized sand flats, in greenhouse	14
12	....do	150	Damp chamber, wet filter paper	18
12	Ohio, collected in October, 1916.	150	....do	18
13	....do	200	Sterile sand, in damp chamber	23
14	....do	48	2 per cent dextrose solution, in filter paper.	16
23	Ohio	6	Wet filter paper	16
23	....do	12	Prune decoction, in filter paper	16
23	Iowa, 1915	6	2 per cent dextrose solution, in filter paper	15
23	....do	6	Wet filter paper	15
23	....do	12	Prune decoction, in filter paper	15
23	Ohio	100	Wet filter paper, in damp chamber	17
24	Iowa, 1915	100	....do	16
27	....do	100	Sterile sand, in flat	16
27	Ohio, collected in October, 1916.	100	....do	16
27	Ohio	1,100	....do	16
27	....do	400	Sterile loam, in flat	16
May 1	Ohio (fruit fragments adhering).	60	Sterile sand, in damp chamber	14
	Total	4,069		

[1] Two pounds. [2] Failure.

In a total of more than 4,000 seeds tested no anthracnose was found. From the 3,100 seeds tested in sterile soil no diseased seedlings developed. Where culture media were used the profuse development of bacteria and fungi upon and around each seed proved that the latter bore an abundant and varied surface flora. On old seed the flora was less varied. The rapid development of these forms rendered anthracnose isolation by cultural methods a matter of great difficulty.

To determine whether or not the methods employed above were reliable, tests were made with seed previously dipped in a spore suspension. The results of these tests warrant a more detailed account. On March 13 about 500 seeds were immersed for 50 minutes in a heavy suspension of spores of the anthracnose fungus and then dried on filter paper. The next day 50 of these seeds were planted in sterile moist sand in a damp chamber. The seedlings were sprayed from time to time with sterile water. Sixteen days after planting, one seedling, which had carried its seed coat up with the cotyledons, showed an anthracnose lesion on the stem near the ground line and another on a cotyledon. Owing to the stem lesion the seedling had already fallen over, as in damping-off. On the stem lesion were numerous sporulating acervuli. In 22 days after planting, three more seedlings had damped-off with anthracnose and four others bore lesions at the ground line. In 29 days after planting, 16 out of the 45 seedlings had succumbed to anthracnose.

These results corroborate those secured by Carsner,[1] who obtained damping-off of cucumber and muskmelon seedlings when seeds previously dipped in a spore suspension were planted in sterile soil. Such results suggest that perhaps in the field the originally diseased plant may damp-off and disappear, so that the first lesions discovered are the result of spores splashed from this plant upon those adjacent to it.

To test the filter-paper culture method, 28 of these inoculated seeds were planted in four sterile Petri dishes on filter paper moistened with 2 per cent dextrose solution. Six days later, acervuli of anthracnose were found on two seed coats, and by nine days one more seed bore acervuli and its seedling was diseased. Two weeks after planting, two more seedlings were diseased. Mold and bacterial growth was as usual abundant on these seeds. The results of these and further tests with these seeds are presented in Table VI.

While it is evident that diseased seedlings may result from inoculated seed, it is noteworthy that not all inoculated seeds yield diseased seedlings in soil. Owing largely to the profusion of other organisms on the seeds, the methods of anthracnose detection used with the commercial seed, as summarized in Table V, show a low efficiency when applied to seed known to be heavily inoculated with the fungus.

[1] Carsner, E. Op. cit.

TABLE VI.—*Laboratory tests of seed inoculated with spores of the anthracnose fungus.*

Date of test, 1917.	Number of seed.	Medium used.	Days.	Result.
Mar. 14	50	Sterile sand, in damp chamber	29	16 out of 45 seedlings diseased.
14	28	2 per cent dextrose solution, in filter paper.	14	Anthracnose detected on five.
15	6	2 per cent dextrose agar	15	No anthracnose.
23	6	Wet filter paper	13	1 seedling diseased at heel.
23	6	2 per cent dextrose solution, in filter paper.	17	No anthracnose.
23	12	Prune decoction, in filter paper	17	Do.
23	100+	Wet filter paper, in damp chamber	18	Do.

As a result of the difficulties encountered and negative results secured in the endeavor to prove by laboratory methods the presence of the anthracnose fungus on commercial seed, the problem was approached in another way.

FIELD TESTS WITH DISINFECTED SEED.

Certain theoretical considerations form the basis of this method of attack. Since observation indicated that the number of original centers per acre was usually rather low, ranging perhaps from 1 to 10, and since about 2 pounds, or approximately 70,000 seeds, are used per acre, it was to be assumed on the basis of seed carriage of disease that not more than 1 to 10 seeds out of 70,000 were acting as successful bearers of the disease. In view of this possibility, the failure of the laboratory tests might be attributed in part to the relatively small numbers of seeds tested.

To obtain a test with larger numbers of seeds, recourse to field conditions was necessary. It was obvious that if the fungus could be eliminated by surface sterilization of the seed, the appearance of the disease in a new field planted with such seed should be prevented, while in a field planted with untreated seed the disease would normally be expected were the fungus present on the seed.

As to the character and effect of various seed treatments, more will be presented later. Suffice it to state here that the surfaces of seeds immersed in mercuric chlorid of a strength of 1 to 1,000 for 5 minutes were found by agar-plate tests to be sterile. With the other disinfectants employed, the effectiveness against the anthracnose fungus was assumed. Two classes of tests were made in the season of 1917, one limited to a few fields at Madison, the other being more extensive.

At Madison a mixture of 1916 Ohio seed previously tested with a new consignment from the same source was tested in four well-separated one-half acre fields on soil not previously in cucumbers or melons. In one field untreated seed was planted, while in the others seed treated as shown in Table VII was used. By planting double the usual number of rows, twice the ordinary quantity, or about 2 pounds of seed, was planted in each field. This allowed a test of about 70,000 seeds per field.

TABLE VII.—*Effect of seed disinfection upon the occurrence of anthracnose in cucumber fields at Madison, Wis., in 1917.*

Name of field.	Area.	Subdivision.	Seed treatment.	Results.	
				On Aug. 13.	On Sept. 8.
McKenna	One-quarter acre.	West half	2 per cent formaldehyde,[1] 10 minutes.	No anthracnose.	No anthracnose.
	do	East half	4 per cent formaldehyde,[1] 5 minutes.	do	Do.
Brittenbach	do	West half	0.5 per cent $CuSO_4$, 10 minutes.	do	Do.
	do	East half	1 per cent $CuSO_4$, 5 minutes.	do	Do.
Tobacco	do	North half	Hot water, 52° C., 10 minutes.	do	Do.
	do	South half	1915 seed, untreated	do	Do.
Isom	One-half acre		1916 seed, untreated	1 plant diseased	2 centers of anthracnose.

[1] 40 per cent solution.

Until August 1 careful inspection of all of these fields was made twice each week. A special effort was made to detect an original diseased plant in the Isom field before the thinning and the elimination of the interplanted rows, but no success was attained. Unfortunately, the first anthracnose did not appear until a month after its normal date of appearance, and a complication is afforded by the earlier appearance of anthracnose in field 1 as a result of overwintering in the soil. While the Isom field was a considerable distance from field 1, there is a possibility, even though very slight, of the introduction of the disease by insects, pickers, or cultural operations. Since, however, the other fields were equally exposed to this type of infection, it is significant that anthracnose appeared only in the field planted with 1916 untreated seed. This is taken as a rather convincing indication but not conclusive proof of disease introduction with the seed.

Assuming that anthracnose was present in the 1915 seed, its failure to appear in the south half of the tobacco field has some significance. It suggests that possibly the fungus does not survive the eighteen months' desiccation.

For the more extensive field tests arrangements were made with a pickling company whereby all of the seed distributed to its growers in one district was to be previously treated, while in a neighboring district similar seed, untreated, was to be used. This trial was made in triplicate, one trial in each of the three States of Indiana, Wisconsin, and Michigan. Both Ohio seed and Iowa seed were thus tested; the former in Indiana and Wisconsin, the latter in Michigan. For the disinfection of all of this seed the treatment of proved effectiveness and safety was used. This consisted of immersion in mercuric chlorid, 1 to 1,000, for 5 minutes, followed by 15 minutes' washing in running water. This bulk seed treatment, involving the handling of 400 pounds of seed, was done at Madison. By this cooperative method very large amounts of seed were tested in separate districts under a variety of conditions. As in the tests at Madison, these tests aimed not only at a proof of the theory of the seed carriage of disease but at the same time aimed at disease control, as will be noted later.

In Michigan anthracnose occurred in neither the 34 fields planted with untreated seed nor the 42 planted with treated seed, so it is obvious that there was no anthracnose in the Iowa seed. The results obtained in Indiana and Wisconsin are briefly summarized in Table VIII. It is to be noted that due allowance has been made for the complicating factor of possible overwintering in the soil.

TABLE VIII.—*Effect of seed treatment upon the occurrence of cucumber anthracnose, as shown by cooperative field tests in Indiana and Wisconsin, season of 1917.*

State.	Effect of seed treatment.							Overwintering.			
	Seed.	Number of fields.	Diseased plants.		Anthracnose not due to 1916 crop.[1]			1916 crop, same soil.		Anthracnose due to 1916 crop.[2]	
			Number.	Percentage.	Number.	Percentage.		Number.	Percentage of diseased fields.	Number.	Percentage of diseased fields.
Indiana	Untreated	30	15	50	4	13.3		9	60	11	73.3
	Treated	42	7	16.6	0	.0		4	57.1	7	100
Wisconsin	Untreated	43	2	4.7	1	2.3		0	0	1	50
	Treated	33	4	12.1	1	3.3		2	50	3	75
Total	Untreated	73	17	23.3	5	6.8		9	52.9	12	70.6
	Treated	75	11	14.6	1	1.3		6	54.5	10	90.9
Gain due to treatment.	....	....	....	8.7	....	5.5					

[1] 1916 crop not on same or neighboring field. [2] 1916 crop on same or neighboring field.

The results show that there was apparently very little anthracnose in the Ohio seed, since most of the cases of anthracnose occurrence may be attributed to overwintering. Among the very few cases in which anthracnose could not be due to the previous crop, the Wisconsin trials are inconclusive, while the Indiana tests indicate that anthracnose may have been introduced with the seed.

From the standpoint of the introduction of the disease with the seed, all of these seed-disinfection tests, while inconclusive, indicate that anthracnose may be carried with the seed, and they show the need of further tests of this nature.

OVERWINTERING.

Previous references have been made to the subject of overwintering, and it now remains to present the evidence relative to this phase of the problem. Sheldon (46, pp. 127–137) noted that anthracnose of watermelons was more severe where the crop was grown on the same ground or near the same ground used the previous year. Taubenhaus (51) made similar observations in Delaware and states that a 6-year rotation is thus necessitated.

In the course of the present work, much observational evidence has been accumulated during disease-survey trips, in which, however, only the statements of growers were available regarding the previous history of the fields. Concerning the 17 fields in which anthracnose was found near Sparta, Wis., in 1915, it was learned that in the case of 5 of these, cucumbers were grown on the same soil in 1914 and that in the case of 3 others the 1914 crop was adjacent to the 1915 field. The coldframe field near Norfolk, Va., previously mentioned, where anthracnose was epidemic in 1917, was in cucumbers in 1916 and the disease was present that year as well.

At Madison, Wis., anthracnose was prevalent in fields 1 and 2 in 1916. In field 1 a late epidemic left numerous diseased fruits as well as vines, which were plowed under late in the fall. In 1917, cucumbers were again planted in these fields, as well as the four mentioned in connection with the seed treatments. Field 2 was planted in part with seed treated with mercuric chlorid and in part with hand-thrashed seed from cucumbers free from anthracnose. Seed treated with mercuric chlorid was employed for all of field 1 except for one set of plats used to test out a variety of seed treatments. Among the latter were untreated control rows, but these were planted with Iowa seed which was proved to be free from anthracnose by the Michigan field trials previously described. The introduction of anthracnose into either of these fields with the seed is therefore unlikely.

In field 2 no anthracnose developed in 1917. In field 1, where much more diseased material was plowed under in 1916, anthracnose appeared, not in "original centers," but as rather scattered infected plants in at least three areas where diseased material was known to have been abundant the year before. No anthracnose developed in the three fields where treated seed was planted in soil not previously in cucumbers. The recurrence of anthracnose in field 1 under these conditions is taken as rather convincing evidence of overwintering in the soil.

In the course of inspection of the fields in the cooperative seed-treatment tests it became further apparent that the disease over-winters in the soil. It has been indicated in Table VIII that all of the outbreaks of anthracnose among the Indiana fields planted with treated seed and in three out of the four Wisconsin fields in which the disease occurred might be attributed to overwintering. By this it was meant that the previous crop was grown on the same or a neighboring field. Disease conditions in the 1916 crop were in most cases unknown, so it can only be assumed that anthracnose was or at least might have been present. Since treated seed was used, introduction by that means was not at all probable. Of the seven diseased fields in Indiana, four were in cucumbers in 1916 and the other three were adjacent or near the field used in 1916. Of the four diseased fields in Wisconsin, two were in cucumbers in 1916, and in one of these anthracnose had occurred that year. Of the remaining two fields, one was not far from the 1916 field in which anthracnose had been very prevalent. By chance, the owner planted in 1917 one row of treated seed across this field used the previous year. Anthracnose was abundant in this row, while in the 1917 field but one diseased plant was noted.

The evidence, as summed up in Table VIII for the 75 fields where treated seed was used, shows that 6, or 54.5 per cent, of the 11 diseased fields were on the same soil used in 1916 and 4 more were adjacent to the 1916 field, making a total of 10 out of 11, or 90.9 per cent, of the cases of anthracnose possibly attributable to a previous crop.

Where untreated seed was used the evidence is not quite so convincing, but it is rather striking that in Indiana cucumbers had been grown in 1916 in 9 of the 15 infested fields and that two others were adjacent to the field used in 1916. Thus 73.3 per cent of these cases may have been due to a previous crop.

Another type of evidence is also afforded by the above tests. Of the 42 fields in Indiana planted with treated seed, 4 were in cucumbers in 1916, and anthracnose occurred in all of these in 1917; 4 more were adjacent to the 1916 field, and anthracnose occurred in 3 of these. Similarly, of the 33 fields in Wisconsin planted with treated seed, 3 were in cucumbers in 1916, and in 2 of these anthracnose was found in 1917. Out of a total of 75 fields planted with treated seed, 7 were on the same soil used in 1916, and anthracnose occurred in 6 of these, or in 85 per cent of the cases where rotation was not practiced. In 10 fields adjacent to the 1916 sites 4 showed the disease. Likewise, out of 73 fields planted with untreated seed, 14 were on the same sites used in 1916, and in 9 of these, or 64 per cent, anthracnose was found in 1917. These results are briefly summarized in Table IX.

Such observational evidence, especially where the treated seed was used on fields in which the disease was present the year before, practically proves that anthracnose overwinters in the soil.

Two rather anomalous cases are worthy of note. One is the failure of anthracnose to recur in field 2 at Madison in 1917. The other is the fact that in one of the Wisconsin fields, where the disease occurred in 1914, 1915, and 1916, no anthracnose could be found in 1917 when treated seed was used.

TABLE IX.—*Relation between lack of crop rotation and the occurrence of cucumber anthracnose, season of 1917.*

Seed used.	Number of fields.	Fields used for cucumbers in 1916.		
		Number.	Anthracnose in 1917.	
			Number.	Percentage.
Untreated	73	14	9	64
Treated	75	7	6	85
Total	148	21	15	71

As to the mode of overwintering and the possibility of a perfect stage nothing definite is known. Using soil collected from a diseased field in October, Carsner [1] secured seedling infection in February. He also secured seedling infection in sterile soil with which were mixed chopped-up diseased vines previously kept in storage for five months. Potebnia (38, p. 82) left diseased host parts out of doors over winter but failed to find an ascus stage.

In the fall of 1916 diseased vines and fruits of various hosts were placed in wire cages and left on the ground in the garden over winter. On April 11, 1917, 14 samples of soil were taken in sterile pots from under these cages. Treated seed was planted in these pots, but no anthracnose appeared on the seedlings. Examination of some of the overwintered material in the cages on March 29 failed to show the presence of spores, and no development of the anthracnose fungus occurred under damp chamber conditions. More work should be done along this line.[2]

The present status of the problem is, then, that field observations and tests prove that the fungus overwinters in the field, although the exact mode of this overwintering is unknown.

CONTROL.

Consideration of the control of anthracnose may be conveniently divided, so far as this work is concerned, into two categories, spraying and seed treatment combined with crop rotation.

[1] Carsner, E. Op. cit.

[2] In the fall of 1917 diseased cucumber vines were buried in a small flower garden in Lansing, Mich., where anthracnose had never been present. In the summer of 1918 treated cucumber seed was planted in this spot. On August 4, 37 out of 58 plants were diseased with anthracnose, many damping-off with the disease. This proves that the fungus overwinters in the old diseased vines in the soil. Furthermore, treated 1916 seed was planted in 1918 in a 2-acre portion of the Michigan seed field which had borne a badly diseased crop in 1917. Anthracnose made its appearance at numerous and scattered points in this field in 1918, thus further proving that the fungus overwinters in the soil.

As to resistant varieties, it should be mentioned that among watermelons the citron is somewhat resistant, while practically all varieties of cucumber and muskmelon tested are susceptible.

SPRAYING.

As was pointed out in the historical account, many workers have held Bordeaux mixture to be an effective control for this disease, and the same opinion seems to be rather widely held at the present time.

At Princeton in 1915 plat tests were made of a variety of commercial sprays and of various Bordeaux formulæ. None of the applications seemed to control anthracnose, since it spread consistently through the sprayed rows.

In 1916 at Madison block tests were made with Bordeaux mixture (3–6–50 formula plus soap) and row tests with Pyrox and other strengths of Bordeaux mixture. Anthracnose spread through the sprayed rows as well as the controls, and neither observational nor yield-record evidence indicated that any of the spray applications controlled the disease. Its severity was, however, somewhat checked by the sprays, since it was very serious in only 5 out of 17 sprayed rows, as compared with 7 out of 11 unsprayed controls.

To gain some insight into the effect of the presence of the spray upon leaf infection, a series of atomizer inoculations were made on August 13 upon the upper surfaces of certain leaves and the lower surfaces of other leaves among the sprayed rows. Well-sprayed leaves were chosen. The results of these inoculations are presented in Table X.

TABLE X.—*Results of atomizer inoculation of sprayed cucumber leaves at Madison, Wis., in 1916.*

Spray treatment.	Number of leaves.	Surface inoculated.	Results, Aug. 24.
None	1	Both	?
Do	10	Upper	−(8 located. No infection).
Do	10	Lower	?
Bordeaux mixture, 3–6–50 formula	10	Upper	−(9 located).
Do	10	Lower	+(9 located; all infected).
Do	36	Upper	−
Do	25	Lower	+(7 typically infected).
Bordeaux mixture, 2–4–50 formula	25	Upper	−
Do	25	Lower	+(6 typically infected).
Bordeaux mixture, 4–6–50 formula	25	Upper	−
Do	25	Lower	+(4 typically infected).
Pyrox	25	Upper	−
Do	25	Lower	+(9 typically infected).

While natural infection interfered to some extent with these tests, no unquestionable atomizer infection occurred in any case where the upper epidermis of sprayed leaves was inoculated, while in all cases some typical atomizer infection was secured where the lower epidermis of sprayed leaves was inoculated. Of these leaves, only the upper epidermis was covered with the spray. These results indicate that an actual coating of spray material prevents infection through the upper epidermis, but that infection may readily occur through the unprotected lower epidermis.

In practice, it is impossible to coat the lower surfaces of the leaves, and a spray is therefore only one-half efficient as a protection. Furthermore, the rapid growth of runners constantly exposes unprotected tissue.

For the partial protection afforded, growers of melons, field cucumbers, and seed crops can probably spray with profit. The fruits in these cases are longer exposed to infection and the economic difficulties are negligible. But in the cucumber-pickle industry, where the crop is grown in widely scattered small patches, usually among the less prosperous farmers, the practical difficulties in any spraying program become insurmountable.

SEED DISINFECTION AND CROP ROTATION.

Since it has been shown that the disease overwinters in the soil, it goes without saying that a rotation of crops should be practiced and that clean soil should be considered a prime requisite. The site chosen should be well removed from any field in which the disease was present the preceding year.

Given a clean soil, the problem of disease prevention depends largely upon the validity of the seed-carriage hypothesis previously presented. If this hypothesis is correct, prevention depends upon the development of a harmless, effective, and practicable seed treatment or upon the availability of disease-free seed. Regarding the availability of disease-free seed, anthracnose seems to be prevalent in eastern seed farms, but not in Colorado. Although the disease was reported from that State in 1917, Colorado-grown seed should be comparatively free from anthracnose.

Concerning the effect of seed treatment upon germination, much remains to be done. Injury has resulted from hot water and formaldehyde. Carsner found that hot water, 52° C. for 10 minutes, was harmless. Field tests in 1917 indicate the safety of all of the treatments except that of formaldehyde in Table VII. The 4 per cent formaldehyde[1] for 5 minutes caused great damage and the 2 per cent solution for 10 minutes caused rolling of the cotyledons. Mercuric chlorid, 1 to 1,000, for 5 minutes appears to be harmless except that in some cases a very slight retardation after germination can be detected. Copper sulphate is somewhat objectionable because of the bluish stain left on the seed.

While the 1917 experimental field tests at Madison were inconclusive because of the late appearance of disease in the control field, it

[1] 40 per cent. solution.

is of interest to note that the 1915 seed was apparently as free from disease as treated seed. All of the treatments appear to have been effective in these field tests.

The effectiveness of formaldehyde, 1 per cent for 20 minutes, and of mercuric chlorid, 1 to 1,000, for 5 minutes, was tested in the laboratory by avoiding contamination after sterilization and planting the seed in culture media. One test was made on seed previously inoculated. In all cases, however, the effect upon the normal surface flora of the seed was used as a criterion. The results of these tests are presented in Table XI.

TABLE XI.—*Laboratory tests of the treatment of cucumber seeds with mercuric chlorid and formaldehyde for the control of anthracnose.*

Seed used.	Date, 1917.	Method.	Mercuric chlorid.		Formaldehyde.	
			Number tested.	Results.	Number tested.	Results.
Ohio	Apr. 9	2 per cent dextrose agar, in plate.			20	10 sterile; 1 with fungus; 9 with bacteria.
Inoculated on Mar. 13, 1917.	...do	...do	20	All sterile	20	4 sterile; 4 with fungi; 12 with bacteria; no anthracnose.
Do	May 13	...do	30	All sterile except one; anthracnose on cotyledon.	40	None sterile; 7 with fungi; no anthracnose.
Do		Bouillon tubes	10	9 sterile; 1 developed a fungus.		
Do		Nutrient agar	16	All sterile		

These results show that the mercuric-chlorid treatment is more reliable than the formaldehyde in absolute effectiveness. The very interesting case in which 1 out of the 136 inoculated seeds yielded a diseased seedling deserves some comment. The age and location of the lesion indicated that it had resulted from a recent spore infection rather than an earlier micropylar invasion. This would mean that the spore had not only escaped the germicide but had also survived two months of desiccation. It was probably lodged in the micropyle and protected from the germicide by an air bubble.

Owing in part, no doubt, to organic matter on the seed, there is a marked decrease in the strength of mercuric-chlorid solutions after seed is immersed therein. Six liters of seed decreased the concentration of mercuric chlorid in eight liters of the germicide by almost one-half. This means that the solution can be safely used only once or twice.

The effectiveness of a 5-minute immersion in weaker solutions has been tested by the agar-plate method. Using about 100 seeds for each series, the following percentages of sterile seeds were obtained:

Mercuric chlorid, 1 to 1,500 .... 99 per cent sterile.
Mercuric chlorid, 1 to 2,000 .... 94 per cent sterile.
Mercuric chlorid, 1 to 3,000 .... 97 per cent sterile.

These results indicate that lower concentrations are fairly effective. For practical use, however, the standard strength of 1 to 1,000 is preferable.

In the large-scale field tests summarized in Table VIII, the determination of the value of seed disinfection as a control measure is complicated by the relatively few cases of anthracnose occurrence in which there was no possibility of soil infestation. Disregarding this contingency, it is rather striking that the disease was present in only 14.6 per cent of the fields planted with treated seed as compared with 23.3 per cent of the controls. This indicates a prevention of disease in 8.7 per cent of the fields, or, on a comparative basis, prevention of 37 per cent of the cases that would normally have occurred. Eliminating all cases possibly attributable to overwintering, we find the disease present in 1.3 per cent of the fields planted with treated seed as compared with 6.8 per cent of the controls, indicating a net gain of disease prevention in 5.5 per cent of the fields, or, on the comparative basis, a prevention of 80 per cent of the outbreaks.

In conclusion, it may be said that a successful control of anthracnose may quite possibly be secured by the use of disease-free seed in clean soil.

SUMMARY.

Anthracnose of cucurbits is caused by the fungus *Colletotrichum lagenarium* (Pass.) Ell. and Hals.

The hosts are limited to the family Cucurbitaceæ. Those of economic importance are the cucumber, muskmelon, and watermelon. The disease is common among Lagenaria gourds. The following cucurbits are added to the list of hosts: *Benincasa cerifera*, *Trichosanthes colubrina*, *Cucumis dipsaceus*, *C. melo* var. *dudaim*, and *C. melo* var. *flexuosus*. Fruit infection occurred in *Cucumis anguria* and *C. anguria* var. *grossulariae*. Anthracnose was not found as a vine disease in the genus Cucurbita, which includes squash, pumpkin, and certain gourds. Beans are not susceptible.

This disease was first noticed in 1867 in Italy among Lagenaria gourds. Later, it appeared on melons in France, and it now occurs throughout Europe and the eastern United States wherever the hosts are grown.

Serious losses are caused in the watermelon-growing industry of this country and among cucumbers grown for slicing purposes. Since the disease is more serious on crops in which the fruits are long exposed to infection, the losses in the cucumber-pickle crop are not as great.

Leaves, stems, and fruits are attacked. Leaves and even whole runners and plants may be killed, and fruits may be blemished or become malformed. The lesions increase rather indefinitely in size.

Fruiting bodies, or acervuli, are conspicuous on fruit lesions, occur in abundance on stem and petiole lesions, and are less abundant on leaf lesions.

The fungus grows and sporulates readily in culture and is not exacting as to nutrients. Under optimum conditions the life cycle may be completed in four days.

As to essential elements, iron and sulphur are not needed in detectable concentrations, and only very minute amounts of magnesium are necessary. As sources of carbon the more complex carbohydrates seem to be more suitable. Corn starch and xylan were used to good advantage, and fair growth occurred on cellulose.

The fungus is quite sensitive to copper sulphate. Growth was prevented by a concentration of molecular ÷ 2,000 and was retarded in molecular ÷ 64,000.

Spore germination is favored by the presence of a nutrient and by a plentiful supply of oxygen. The optimum temperature for spore germination lies between 22° and 27° C.; the minimum is about 4° C. Guttation water from cucumber leaves is apparently not toxic to spores. There is evidence that spores may germinate in moisture condensed on the lower sides of watermelon fruits in the field.

Thick-walled egg-shaped appressoria are normally formed by germinating spores. These appressoria are usually in contact with a solid substratum. An abundant oxygen supply favors their formation. Appressoria were not formed at 7° C. and below.

Spores germinating upon a host normally form appressoria closely adherent to the cuticle. Host penetration occurs directly through the leaf cuticle, not through a stoma. The penetration tube issues from a small pore in the under side of the appressorium.

The mycelium is intracellular. Invaded host cells become collapsed and stain deeply. There seems to be a previous stimulation of nuclear and cell division.

In a field the disease usually appears first in isolated "original centers" of one or two infected plants each. Marked spread of the disease from these centers follows rainy periods, particularly, it would seem, when the temperatures are not too far above or below 75° F., the optimum for this fungus. The disease ordinarily becomes epiphytotic only late in the life of the host crop.

The principal agencies of dissemination in the field are rain and surface drainage water. The spore masses disperse readily in water. During rains the spores are washed to the soil and thence splashed upon the leaves. Centers of infection are thus enlarged. Extensive spread from such centers is usually in the direction of the slope and is accomplished by surface drainage during heavy rains. The fungus has been isolated from soil under diseased plants and from surface drainage water after rains.

The disease is especially destructive in certain fields where artificial overhead watering is practiced. Convincing evidence of hand dissemination by workmen during the process of culling watermelon fields has been secured.

The mode of origin of the disease in new fields in original centers and its appearance in only the fields planted with seed from certain sources suggest that the fungus is introduced with the seed.

Anthracnose has been found prevalent in seed fields on the fruits. The process of seed extraction affords ample opportunity for wholesale surface contamination of seed. The cellulose "hairs" on the seed coat would afford lodgment and protection to spores. Fragments of tissue from fruit lesions have been found among and adherent to seeds. No evidence of the presence of dormant mycelium within seeds removed from beneath deep fruit lesions has been secured.

Numerous laboratory and greenhouse tests have failed to prove the presence of infectious material on commercial seed. With inoculated seed, diseased seedlings result.

Extensive field tests with treated and untreated seed, while inconclusive, indicate that the fungus is carried with the seed.

Convincing evidence that the fungus overwinters in the field has been accumulated. The disease recurs annually in certain localities and not in others. In experimental fields planted with treated seed, the disease reappeared in those which bore a diseased crop the previous year. In extensive field tests with treated seed, 90 per cent of the cases of anthracnose may possibly be thus explained. It has been proved that the fungus overwinters in diseased-vine débris buried in soil.

Bordeaux sprays check but do not prevent the spread of the fungus. The lower epidermis of a sprayed leaf is unprotected. Spraying may be advisable in the melon, slicing-cucumber, and seed-cucumber crops, but is not practicable in the cucumber-pickle growing industry.

It is believed that surface disinfection of the seed will eliminate the infectious material. For this purpose, immersion in mercuric chlorid, 1 to 1,000, for 5 minutes has been found effective and practically noninjurious. Disease-free seed may also be secured from disease-free seed fields, and possibly by the use of old seed.

The use of disease-free seed and a proper crop rotation to insure clean soil are recommended as control measures.

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BULLETIN No. 728

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WM. A. TAYLOR, Chief

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CERTAIN DESERT PLANTS AS EMERGENCY STOCK FEED.

By E. O. WOOTON, *Agriculturist.*

CONTENTS.

THE NECESSITY FOR EMERGENCY FEEDS.

It has been the practice for a long time in certain parts of the arid Southwest, mostly in what is known as the Big Bend region of southern Texas, to feed sotol[1] to range stock in seasons of scarcity of the usual range feed. The custom is probably one that originated in Mexico, where this plant is used more or less extensively for human food, as well as for the production of an alcoholic beverage where, consequently, its qualities are well known.

Hitherto, the usual method of preparing sotol for stock feed has been to cut the stem off at the ground and with a machete or an ax split open the head, which is formed of the enlarged leaf bases and the thickened top of the stem. This process exposes the soft tissue of the head to the animals, and either cattle or sheep may be expected to "do the rest."

The past two seasons, 1916 and 1917, have been unusually dry in the whole of the arid Southwest from central Texas to the Pacific coast, and in consequence the normal crop of range feed did not grow. Farsighted stockmen in many cases sold off some of their

[1] Sotol is a Mexican or Indian name for a species of Dasylirion. The species found in western Texas is *Dasylirion texanum,* while the plant of southern New Mexico and Arizona is *D. wheeleri.* See descriptions of species farther on in this bulletin.

animals or moved them to other places, in order to reduce the number to be kept on their ranges to something like a proper adjustment of the numbers to the feed available. Many have fed prickly pear [1] with success when any of this kind of feed was present on their lands.

Notwithstanding the recognized necessity for a reduction in the numbers of animals upon the range, there were many men who for one reason or another were unable to sell or move their animals. Under such circumstances the only possible alternatives were to feed the animals or let them die.

The idea of feeding range stock is not new to most of the stockmen in western Texas and in southern California, but for the men in southern New Mexico and southern Arizona, who are almost without exception cattlemen, the practice is largely a new one, though many of them have heard of the use of sotol as forage, and some who have lived in Texas have practiced feeding it. Sotol occurs in only a very small part of the country where feed was scarce this past year, but in much of this area there is a greater or less amount of other species of plants that are usable.

Stimulated by the patriotic desire to avoid all possible losses of meat animals as well as probable serious financial loss, the more enterprising men began casting about for feed of one kind or another. Many of the men in Texas had already laid in a supply of cottonseed cake or meal. Some were able to buy milo maize, or kafir corn, or hay of some kind. But the supply of many of these feeds was below normal for the region because of the drought, and all were abnormally expensive, while transportation systems were much overworked. Hence the need of using all kinds of feed available on the ranges.

It is difficult to determine just who should be credited with the idea of using certain of the plants other than sotol that grow abundantly in some places in the region. The practice seems to have arisen independently in several places at about the same time, both in Arizona and in New Mexico.

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——— The "spineless" prickly pears. U. S. Dept. Agr., Bur. Plant Indus. Bul. 140, 24 p., 1 fig., 1 pl. 1909.

——— The thornless prickly pears. U. S. Dept. Agr., Farmers' Bul. 483, 20 p., 4 fig. 1912.

——— Yields of native prickly pear in southern Texas. U. S. Dept. Agr. Bul. 208, 11 p., 2 pl. 1915.

——— and Hare, R. F. Prickly pear and other cacti as foods for stock. N. Mex. Agr. Exp. Sta. Bul. 60, 134 p. 1906. Literature, p. 124-125.

——— ——— Summary of recent investigations of the value of cacti as stock food. *In* U. S. Dept. Agr., Bur. Plant Indus. Bul. 102, p. 7-18, 1 pl. 1907.

Hare, R. F. Experiments on the digestibility of prickly pear by cattle. U. S. Dept. Agr., Bur. Animal Indus. Bul. 106, 38 p., 1 fig., 1 pl. 1908.

Thornber, J. J. Native cacti as emergency forage plants. *In* Ariz. Agr. Exp. Sta. Bul. 67, p. 457-508, 8 pl. 1911.

Wooton, E. O. Cacti in New Mexico. N. Mex. Agr. Exp. Sta. Bul. 78, 70 p., 18 pl. 1911.

The first suggestion of using any of these plants for feed, of which the present writer knows, was made to him in 1914 by Mr. C. T. Turney, of Mesilla Park, N. Mex. Mr. Turney's idea was to use the tops of a species of Yucca (*Yucca elata*) locally known as soap weed, for silage.[1] Mr. Turney was cooperating with the United States Department of Agriculture on the Jornada Range Reserve near Las Cruces, N. Mex., in handling more than 5,000 cattle under the range conditions of that region. It was here, in 1915, that the first controlled experiments in the feeding of chopped soap weed to range cattle were begun. Cutting up the tops with an ordinary silage cutter was found to be difficult, and the chopped material was not altogether satisfactory, because the machine used was too light for the work. Mr. Turney asked a firm of manufacturers at El Paso, Tex., for a heavier machine, which they proceeded to design and make. This machine[2] has been in use for some time in southern New Mexico and is the first of a number since made and now in use. It is heavy enough to cut up the stalks of the soap weed, and thus the discovery was made that the stalks are better feed than the tops.

In 1916 Messrs. Cook and Johnson, of Willcox, Ariz., fed this same plant, the material being chopped into pieces of suitable size by hand, the men using axes and hatchets. A number of animals were fed in this way, but the work entailed is very hard and the feed produced is not in a very good condition, though the results obtained were fairly satisfactory. Several of their near neighbors tried the plan. Most of these men have recently bought machines to do the work and are getting better results.

In May, 1917, a man at Thatcher, Ariz., devised and built a machine for slicing soap weed which was in use for a short time. Since then some modifications of this type of machine have been introduced which have materially improved its usefulness.

In January, 1918, a machinist at Deming, N. Mex., designed and constructed a machine which shreds the stalks of this same plant.

Besides these machines, the ordinary wood-pulping "hog," such as is used for cutting up wood for paper pulp, has been tried with some success.

It will thus be seen that many people appreciated the need of such machines and that stockmen have been eager to buy them and use them. Machines of various makes are now in use on ranches all the way from Willcox, Ariz., to Marathon, Tex., and north from the Mexican boundary to Carlsbad, Engle, and Silver City, N. Mex. Considerable extension of this area to the northward in eastern

[1] Jardine, J. T., and Hurtt, L. C. Increased cattle production on southwestern ranges. U. S. Dept. Agr. Bul. 588, p. 26. 1917.

[2] See the El Paso Morning Times of Jan. 7, 1918, for the story of this machine.

New Mexico may be expected as stockmen learn that a number of the desert plants may be used in this way and they equip their ranches with the machines.

THE MACHINES.

From what has been said, it is easy to see that the essential factor in the development of this use of an emergency feed was the production of apparatus that would reduce the feed to a satisfactory mechanical condition. While hand chopping will prepare the feed for use, it is a very unsatisfactory method, because the process is slow and laborious and consequently expensive and also because the feed as prepared in this way consists of chopped-up chunks of various sizes which a greedy animal may swallow whole without chewing and which may cause choking or impaction. A number of animals have died from these causes when fed on the hand-chopped material.

Among the stockmen who fed the hand-chopped material, one or two rigged up a power pumping jack with a knife attached in such a way as to cut the stalks into sections of proper size, which were then chopped into smaller pieces with hand axes. On one ranch, a large knife, like a tobacco-cutting knife, with a long lever operated by two men, was used to cut the stalks into sections ready for the hand axes.

A few silage cutters have been used successfully, though it is necessary to chop the stems open lengthwise (they have no longitudinal grain and therefore can not be split) before they will go through the machine.

Special power-driven machines, however, were necessary to prepare these plants in sufficient quantity to meet the requirements of the situation.

Four such machines are now offered for sale by three different manufacturing companies. These machines are all modifications of a single plan. They consist essentially of a heavy cast cylinder that revolves on a horizontal shaft and carries some kind of knives or cutting teeth that pass close to a chopping block to which the material is carried by some feeding mechanism or by gravity from a hopper.

In the largest machine the knives are like those on a silage cutter or a lawn mower. Each knife is slightly longer than the cylinder and is placed diagonally across and bent around the face of it, thus giving it a shearing cut as it passes the chopping block which is parallel to the shaft on which the cylinder revolves. The plants are fed in horizontally by a mechanism driven by gears from the cylinder shaft. (Pl. I, fig. 2.) A 12 to 14 horsepower gasoline engine can drive this machine without any trouble and, if properly managed, a crew of three men may be expected to chop from 15 to 20 tons of soap weed in a 10-hour day if the plants are brought to them.

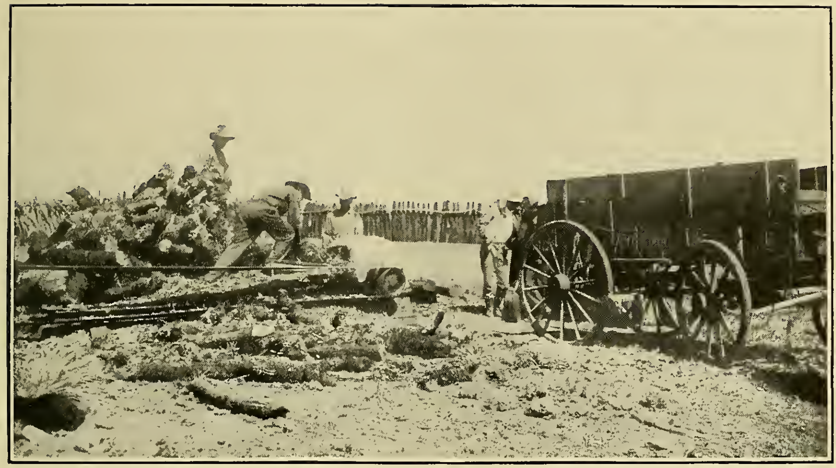

FIG. 1.—AN EMERGENCY-FEED CUTTING MACHINE IN OPERATION ON THE Z BAR L RANCH.

FIG. 2.—AN EMERGENCY-FEED CUTTER IN OPERATION ON THE HIGH-LONESOME RANCH, NORTHWEST OF LORDSBURG, N. MEX.

FIG. 1.—THE CATTLE THAT WERE BEING FED CHOPPED SOAP WEED ON THE HIGH-LONESOME RANCH, NORTHWEST OF LORDSBURG, N. MEX.

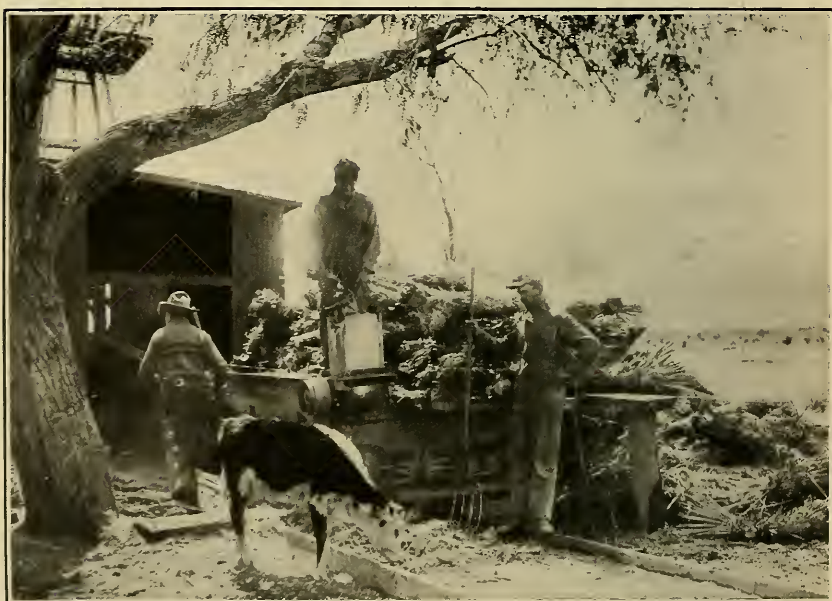

FIG. 2.—A YUCCA AND SOTOL CHOPPER IN OPERATION ON MR. J. D. PREWITT'S RANCH AT BOWIE, ARIZ.

FIG. 1.—A CHARACTERISTIC STAND OF SOAP WEED (YUCCA ELATA) IN SOUTHERN NEW MEXICO.

The yield from such an area will average 2 to 2½ tons of fresh feed per acre, but a growth of 10 or 12 years will be necessary to produce another such crop.

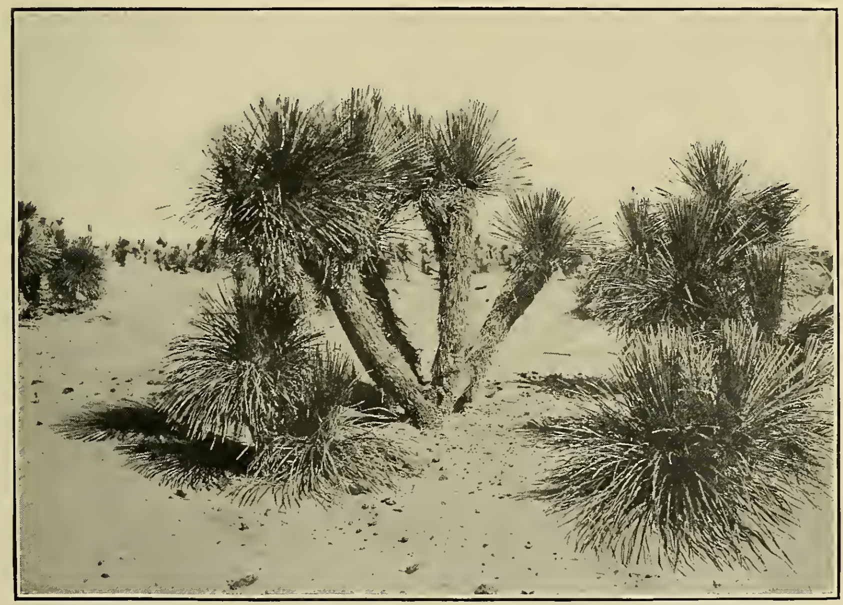

FIG. 2.—A TYPICAL LARGE SOAP WEED (YUCCA ELATA) GROWING IN A DEEP SANDY SOIL SUCH AS IT PREFERS.

FIG. 1.—OLD SOAP WEED (YUCCA ELATA) NEAR THE ARIZONA LINE, NORTHWEST OF LORDSBURG, N. MEX.

These plants are 12 to 15 feet high exclusive of the flower stalks. They are at least 50 years old. Compare this figure with figure 2 of this plate.

FIG. 2.—MATURE BEAR-GRASS (YUCCA GLAUCA) NEAR ELIDA, N. MEX.

This figure and figure 1 bring out the similarities and differences between these two nearly related species so far as they can be seen in plants that are not in bloom.

FIG. 1.—THE BLOOM STALK OF SOAP WEED.

All the yuccas have flowers more or less resembling these. The individual flowers of Dasylirion and Nolina are less than one-fiftieth the size of these.

FIG 2.—A THICK PATCH OF SOTOL (DASYLIRION WHEELERI).

Plants in full bloom, on the foothills of the Dona Ana Mountains, N. Mex.

FIG. 1.—SPANISH BAYONET PLANTS GROWING NEAR VAIL, ARIZ.

To the left is a plant of sotol.

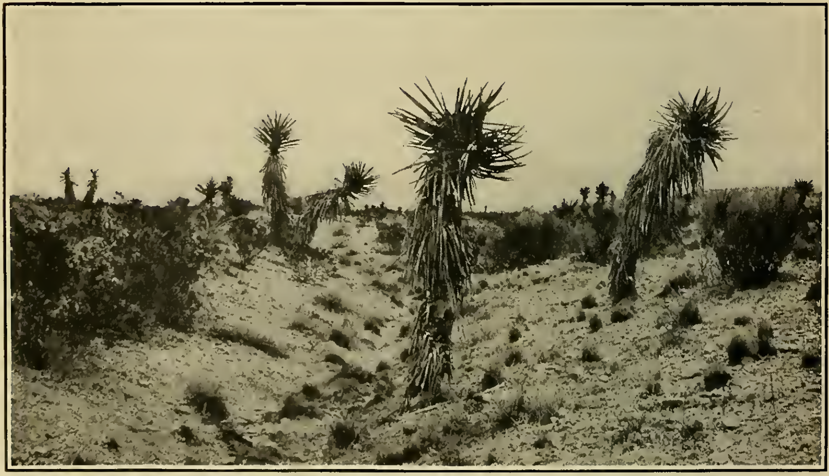

FIG. 2.—THE SPANISH BAYONET, OR PALMA (YUCCA MACROCARPA), NEAR STATE COLLEGE, N. MEX.

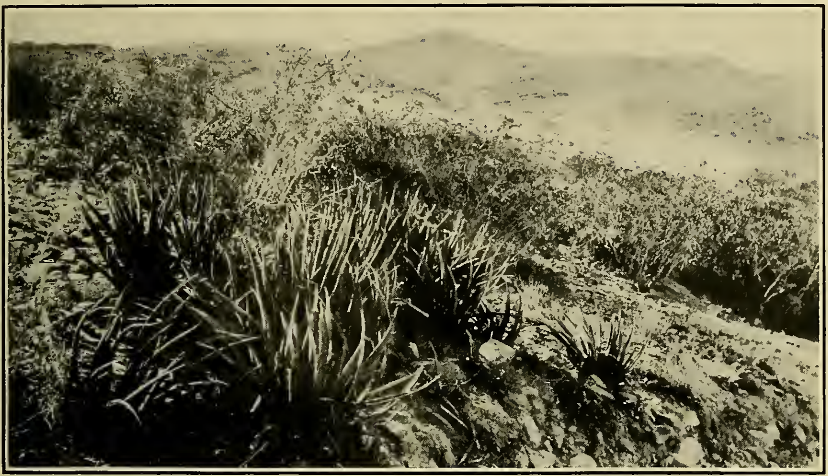

FIG. 1.—LECHUGUILLA (AGAVE LECHUGUILLA) GROWING ON LIMESTONE HILLS AT EL PASO, TEX.

FIG. 2.—THE SPANISH BAYONET, OR AMOLE (YUCCA BACCATA), IN FLOWER, SAN ANDREAS MOUNTAINS, N. MEX.

FIG. 1.—SACAHUISTA (NOLINA ERUMPENS) NEAR SONORA, TEX.

FIG. 2.—BEAR-GRASS (NOLINA MICROCARPA) IN THE SAN ANDREAS MOUNTAINS, 35 MILES NORTHEAST OF LAS CRUCES, N. MEX.

There are two machines in which the cutting is done by a set of small teeth screwed into the face of the cylinder and so arranged that each tooth strikes at a different time, all taken together cutting across the full width of the cylinder. Both these are modifications of the ordinary wood-pulping "hog," the essential differences being merely those of the size and shape of the teeth. These machines are smaller than the first one mentioned and require an engine of 6 to 8 horse-power to operate them satisfactorily, though both are actually being used with engines that furnish less power than this. They both shred the stalks of the soap weed into small pieces that cattle may eat freely without any danger of impaction. (Pl. II, fig. 2.) Each machine is fed by hand from a vertical hopper, the weight of the stalks helping to keep them against the teeth. The output from either of these machines running at about the rate which might be expected in practice is approximately 1 ton of chopped feed per hour.

The fourth machine has a set of triangular knives, something like the knives on the cutter bar of a mowing machine, bolted to the face of the cylinder, each knife being raised above the surface of the cylinder by a narrow triangular steel block about three-fourths of an inch thick, through which the bolts pass. These knives slice the stalk into sections one-half to three-fourths of an inch thick, cutting the fibers into short pieces. In its latest form the knives are diamond shaped and reversible, while the machine is fed from a troughlike hopper inclined at about 45°. In its earlier form this machine had a horizontal mechanical feed, but the makers have ceased to furnish this heavier and more expensive cutter. Machines of this kind may be expected to cut from 10 to 12 tons per day. This cutter has never received a distinctive name, but it is manufactured at Deming, N. Mex. (Pl. I, fig. 1.)

The earlier machines were constructed so they could be mounted with a gas engine on wheels and moved from place to place. Experience has shown that in most cases it is easier to set up the cutter at the corral and run it by the engine that pumps the water for the live stock. All the very poor cattle have to be fed at the watering place, because they are usually too weak to walk very far for water. The newer and smaller machines may be had with or without a frame for use on a wagon.

The Office of Forage-Crop Investigations of the Bureau of Plant Industry, United States Department of Agriculture, will be glad to answer any inquiries regarding machines and their manufacturers and to furnish any additional information in its possession regarding the use of desert plants as emergency stock feed.

The important conclusions to be drawn from the available data relative to each of these machines are (1) that they will do the work required of them; (2) that they are so constructed as to be operated easily by the kind of labor available; (3) that they may be had at such prices as stockmen can well afford to pay for the work to be done; (4) that the power required for the work is such as is supplied by the kind and size of engine frequently found on the average stock ranch or which may be purchased at a reasonable price; and (5) that the use of these machines renders available a supply of low-grade feed which will save the lives of animals that would otherwise starve. (See Pl. II, fig. 1.)

KINDS OF FEED.

As has already been stated, the feeding of sotol is not new nor is the idea of using certain other plants that have either stems or leaves (or both) that are more or less thickened. All the development of the use of prickly-pear has come about from carrying out this idea with respect to certain cacti. It is one of the purposes of this bulletin to summarize as definitely as possible the available data as to possible sources of stock feed of this kind.

One difficulty to be overcome, which is a cause of considerable misunderstanding and frequent differences of opinion, arises from the confusion of the various common names in use for the different plants and the similarities in their appearance.

The plants which may be chopped up and used as emergency feed belong to two families, embracing 4 or 5 different genera and as many as 12 to 20 different species. Almost any one of them may be very easily confused with one or more of the others that are similar in appearance. Differences which are very easily seen to exist among the flowers and fruits, the basis of most botanical classifications (Pl. V, fig. 1), are not to be seen except in the flowering season, and most people have not examined them at that time. The differences in the leaves and habits of the plants by which they can be distinguished when the plants are not in bloom or in fruit are here described.

SOAP WEED.

In the region between Pecos, Tex., and Tucson, Ariz., and south of Safford or Clifton, Ariz., and Silver City and Socorro in New Mexico, on the sandy plains, occurs in greater or less abundance a narrow-leaved yucca that is usually referred to by the English-speaking population of the region as soap weed. It is one of the commoner, and frequently the commonest and most conspicuous, of the desert shrubs. It is often called amole or by its proper Mexican name of palmilla (the little palm), and in the region about Thatcher, Ariz., it is called ooce, which is probably an Indian name for it. This is one of the two commonest yuccas of a region where there are several, and is known botanically as *Yucca elata* (the tall yucca). (Pl. III, figs. 1 and 2; Pl. IV, fig. 1.) It is called soap weed and amole because its roots (and stems) are frequently used as a soap substitute. This name soap weed is not distinctive of any species, though most commonly applied to the one mentioned, but is often applied to other plants that are used for this purpose. This confusion of usage explains how two people may disagree about certain peculiarities of soap weed; they are probably thinking and talking of two different plants.

OTHER THICK-LEAVED PLANTS.

The yuccas may be recognized when not in flower by characters which apply to all the species of the region except three. The leaves of all species are each tipped with a sharp spine, and the margin of the leaf bears one or more threadlike fibers which frequently strip back and form a loose mat of threads among the bases of the leaves. The margins of the leaves never bear any hooklike spines. In one group of three species that grow in the region of Del Rio, Sanderson, and northward in Texas the leaf margins do not have a threadlike appendage, but are thickened and horny, with very fine teeth, scarcely large enough to be seen by the naked eye, but sharp enough and hard enough to cut the hands badly.

Of the other thick-leaved plants of the region the century plants (Agave) all have sharp spines on the ends of the leaves, but the margins bear large recurved spines. Sotol (Dasylirion) has flat, strap-shaped leaves with curved, yellow, horny spines on the margin, but they are frayed at the tips. (Pl. V, fig. 2.) There are two or three species of Nolina in the region that have long, slim, nearly smooth, but tough leaves, frayed at the tips, without threads or spines, though sometimes a few very small teeth are scattered along the margin. The leaves of these plants are often as thick as they are wide, which is usually not much over one-fourth of an inch, being nearly always triangular, but sometimes nearly circular in cross section. In the region about Marathon and Sanderson, Tex., where one species (*Nolina erumpens*) [1] is tolerably abundant, the common name in use is sacahuista.[2] (Pl. VIII, fig. 1.)

BEAR-GRASS.

Bear-grass is a name that is used for two very different plants in different localities. On the Plains of eastern New Mexico and western Texas from Carlsbad northward to western Kansas and eastern Colorado, found practically always on the sandy land, the plant called bear-grass is a species of Yucca (*Y. glauca;* Pl. IV, fig. 2) that has many narrow, thin, thread-bearing leaves that are borne on a very short stem growing from a rather large root from which new heads of leaves arise whenever the old ones are cut off. The leaves are three-eighths of an inch wide or less, hardly more than one-sixteenth of an inch thick, and 18 to 30 inches long. The stem is usually not over 6 or 8 inches high. By using the same name for the two plants and failing to recognize their differences (which are not marked in plants

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[1] The variety called *compacta* by Dr. Trelease is associated with the species throughout this region.

[2] This name is also applied to a species of Spartina, a coarse grass, in the coastal-plains region of Texas.

that are not in bloom) a few people are confusing this plant with the soap weed (*Yucca elata*) already described, and differences of opinion as to the length of time it will take these plants to grow a second crop are already arising in discussions of the future prospects of this kind of feed.

In southwestern New Mexico and adjacent parts of Arizona from Silver City and Clifton southward is an entirely different plant that is known as "bear-grass." (Pl. VIII, fig. 2.) It is a species of Nolina (*N. microcarpa*) and closely resembles the sacahuista of the Marathon, Tex., region. This plant nearly always occurs on the gravelly or rocky foothills, though it sometimes spreads out over the land that is more nearly level. It is common on the hills south of Silver City, N. Mex., abundant on both sides of the railroad at Dragoon, Ariz.,[1] and a large area covered with it is found in the south end of the Animas Valley in southwestern New Mexico. A scattering growth may be expected on the foothills of the mountains associated with sotol from the region of El Paso westward.

SPANISH BAYONET, OR DAGGER.

The name Spanish bayonet (or dagger) is applied pretty generally to several broad-leaved species of Yucca and some near allies. The Spanish word palma (palm) is also occasionally used for these plants. There are several species that are hard to distinguish without flowers and fruit. Some of them are illustrated in this bulletin (Pl. VI, figs. 1 and 2; Pl. VII, fig. 2).

LECHUGUILLA.

Lechuguilla is a Mexican name for a species of Agave[2] that is quite common in the Big Bend region of Texas, especially in Brewster and Presidio Counties, south of the Southern Pacific Railway (Pl. VII, fig. 1). This plant is used as a fiber plant in northern Mexico. Animals sometimes eat it during periods of drought, but stockmen of the region are afraid of impaction from the abundant and strong fibers it contains. The plant is said to be increasing in the region mentioned, and stockmen would be glad to see it driven out, since it kills out the grass and thus reduces the available feed. Its rigid brown and black spines terminating the stiff leaves and its habit of growing thickly all over the ground make land occupied by it almost impassible for cattle or horses. However, it is easily cut with a mattock, and the large cutter shown in Plate I, figure 2, chops it into pieces that stock can easily masticate. With the fiber cut in small pieces and most of the spines chopped off, this plant will furnish considerable emergency feed, and its removal from the range will favor the grasses. It is probable that it can be cut up by a lighter

[1] Trelease refers the plants about Dragoon and other places in eastern Arizona to *Nolina caudata* Treal.

[2] *Agave lechuguilla* Torr. Other species of this genus occur in the region under consideration, but never in sufficient quantity to be important as feed. They are generally known by the name of mescal or maguey.

machine, like a silage cutter, if the knives are kept sharp. The chemical analysis indicates that this material is of about the same feeding value as the other plants here discussed.

SOTOL.

Sotol[1] is the name applied to all species of Dasylirion in the Mexican border region, as well as in northern Mexico. In south-central Arizona it is sometimes called sotoli. These plants grow only on the rocky foothills of the mountains and part way up the mountain sides. They are easily recognized by their numerous long, flexible, strap-shaped leaves, bearing yellow curved spines on their margins. Over small areas they are sometimes very abundant, but such thick patches are not common.

KEYS TO PLANTS DESCRIBED.

For convenience in identifying the above-mentioned plants when not in bloom the following artificial keys may be used.[2]

Key to the genera.

I. Leaves tipped with a more or less rigid spine.
  A. Margins of the leaves bearing a threadlike fiber or sometimes without the fiber but having a minutely toothed, horny margin .... 1. YUCCA.
    This genus contains the soap weed, one of the plants called bear-grass, the Spanish bayonet, etc.
  B. Margins of the leaves bearing conspicuous recurved gray, brown, or black spines .... 2. AGAVE.
    This genus includes the century plants, lechuguilla, mescal, and maguey.

II. Leaves usually frayed at tip, never having a terminal spine.
  C. Leaves thin and strap shaped, margins bearing small yellow curved spines .... 3. DASYLIRION
    The species of this genus are all called sotol.
  D. Leaves narrow, usually nearly as thick as they are wide, margins smooth or very minutely and sparsely toothed, sometimes tapering into a long, slender, curved or bent tip .... 4. NOLINA.
    This includes the sacahuista and another plant called bear-grass.

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[1] The spelling is Spanish though the word may be Indian, and the accent is on the second syllable. The Americans are beginning to drop the "l," put the accent on the first syllable, and apply the word to the soap weed in the Deming to Bowie district where they are not very well acquainted with the real sotol.

[2] To determine the name of a plant by the use of the key, look first at the tips of the leaves. If the leaf ends in a sharp hard spine, the plant will be found in group I; if not, then look in group II. If the plant belongs to group I, then look at the leaf margins and see whether they bear hooked spines. If they do, the plant is an Agave and is one of the group of plants to which the century plant belongs. It is necessary to take the steps in determination in the order indicated or incorrect conclusions will be reached. Thus, Dasylirion has hooked spines along the margins of the leaves, but the leaves are not spiny pointed. Always settle the question under the major subdivision first before passing to questions of the next order of rank. At the end of the series of questions will be found the botanical and common names of the plant under examination or some very near relative of it. The attempt here is not so much to be technically accurate as a botanist as it is to answer the natural questions of stockmen with a degree of accuracy sufficient for their purposes.

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Key to the species of yucca.

I. Leaves quite numerous in the head, narrow, one-half inch wide or generally less, with a thin, white, threadlike filament on the margin; fruit a dry pod that bursts.

1. Mature plant with a trunk from a few inches to several feet in length; flower stalk 5 to 10 feet high and much branched..................
1. *Yucca elata.* Soap weed, palmilla, ooce.

2. Mature plant usually without any perceptible trunk; stem, if any, at most only 6 or 8 inches high; leaves usually less than 2 feet long; flower stalk never over 3 or 4 feet high, usually sparingly branched.
2. *Yucca glauca.* Bear-grass (in eastern New Mexico).

II. Leaves less numerous, quite stiff, broad, 1½ to 2 inches wide, one-eighth to one fourth of an inch thick, with coarse woody threads on the margin; fruit more or less fleshy, at least when young. All species called Spanish bayonet, or dagger.

1. Mature plant with short trunk (a few inches high) or none, fruit large, 5 or 6 inches long, and fleshy.......3. *Yucca baccata.* Amole, datil, dagger.

2. Mature plant with trunk several feet in height; fruit smaller, 3 to 4 inches long, fleshy at first, but drying up without bursting.........
4. *Yucca macrocarpa.*[1] Palma, dagger.

III. Leaves intermediate in width and rigidity between the other two groups, margin not bearing a thread, but, being horny and with very minute teeth, is barely visible to the naked eye; fruit a dry pod that bursts open..5. *Yucca rupicola.*[2]

OTHER PLANTS AVAILABLE.

Besides the above-named plants there are several others that could doubtless be used in the same manner with equally good results. The Joshua tree (*Clistoyucca arborescens*) of the Nevada-California desert region (also called *quiote* by Spanish-speaking people), *Hesperoyucca whipplei* of the California coast region, and *Hesperaloe parviflora* of Texas east of Del Rio could be used wherever they occur in sufficient abundance. *Samuela faxoniana* of the Sierra Blanca region in Texas will probably be used along with the other plants that are available there, and they are already beginning to be used. These all look like yuccas and at one time or another have been considered to be yuccas.

DISTRIBUTION AND DENSITY.

The diagrammatic map (fig. 1) shows the regions in which the more important species occur. Each has its own soil, altitude, and expo-

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[1] This is the commonest species of this type in the region from Douglas, Ariz., to Marfa, Tex. *Yucca mohavensis* is another very similar species that grows in the Mojave Desert region of northwestern Arizona, southern Nevada, and southeastern California. *Yucca brevifolia* and *Yucca schottii* occur in the foothills of southern Arizona. *Yucca treculeana* occurs in the lower Rio Grande region from Laredo southward. None of these are ever very abundant, but all of them could doubtless be used for the purpose under discussion.

[2] Two other species, *Yucca thompsoniana* and *Yucca reverchoni*, occur associated with this species in the region from Haywood, Tex., north to San Angelo and eastward on rough hillsides along with sotol and sacahuista.

sure requirements, and the distribution of none of the species is uniform at any place. The map is as accurate as could be made from the data available and does not pretend to do more than indicate the general region where certain species may be expected to occur.

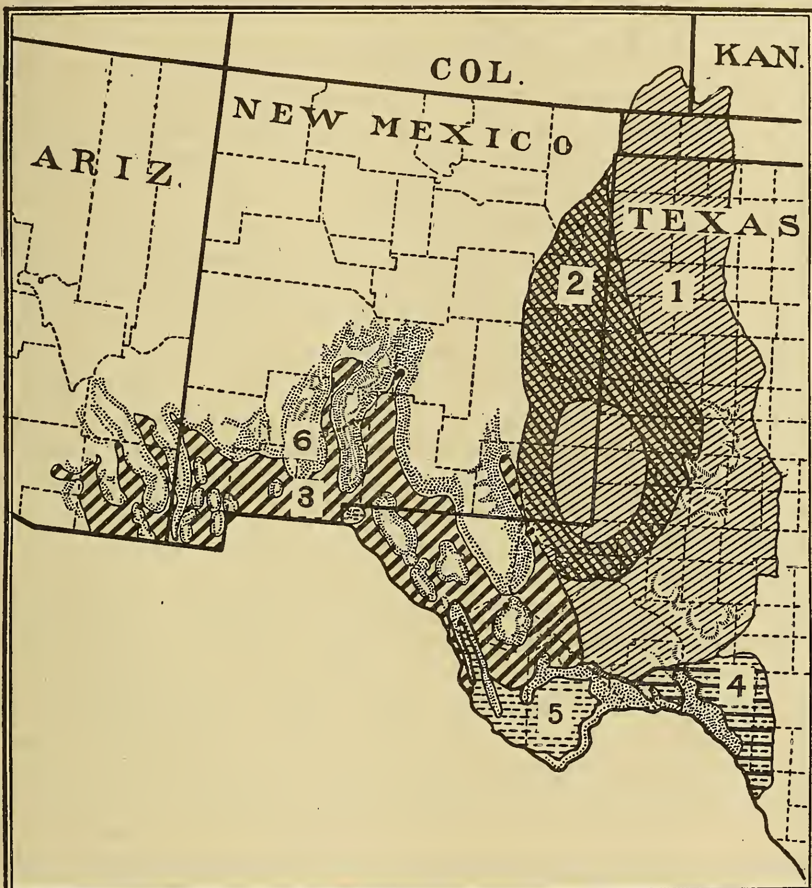

FIG. 1.—Diagrammatic outline map of the region where the emergency feeds considered in this bulletin are to be found: 1, Area where bear-grass (*Yucca glauca*) formerly was more or less abundant, but where the supply has been reduced by farming operations or where the growth is scattering; 2, area where bear-grass is now sufficiently abundant to render it important as feed; 3, distribution area throughout which soap weed (*Yucca elata*) occurs on sandy land but is not uniformly abundant; 4, distribution area of *Yucca rupicola* and its allies (other species of yucca, sotol, and sacahuista are also found); 5, area where lechuguilla (*Agave lechuguilla*) is most abundant (Spanish bayonet, sacahuista, and sotol are also found); 6, distribution area of sotol (*Dasylirion* spp.) and various daggers (*Yucca baccata* and *Y. macrocarpa*), as well as species of Nolina.

Soap weed (*Yucca elata*) and the bear-grass (*Yucca glauca*) of extreme eastern New Mexico and the Panhandle of Texas are practically always found on nearly level, sandy land. Occasionally they may occur sparingly upon tight soils or in a gravelly arroyo, but this is the exception. Sacahuista and the bear-grass (species of Nolina) of southwestern New Mexico and adjacent Arizona usually grow on soil that is moderately fine, sometimes gravelly, but generally not rocky nor very sandy. In places there are large patches of it, sufficient to feed several thousand head of cattle for several months, but the total amount of this feed both in Texas and New Mexico is quite limited.

All the other species of these curious desert plants grow on rocky hillsides and slopes where the soil is coarse talus or merely piles of stones with a little soil mixed in. Lechuguilla grows only on limestone soils, but will cover hillsides, ridges, and table-lands where the limestone is but scantily covered with soil.

Only a relatively small part (at a rough estimate not over 25 per cent) of the land in the regions indicated on the map carries a crop of the species ascribed to it. Over much of the sandy land the principal plants are grasses; on the tight soils few or none of these shrubs grow; while much of the gravelly mesa area is occupied by creosote bush or black brush with only an occasional yucca. The heaviest growth of soap weed (*Yucca elata*) is to be found in the region between El Paso and Lordsburg and in the open plain between El Paso and Alamogordo.

Exact data as to the amount of feed found on an acre or a section are not available, and estimates by different men who have been cutting it vary from 3 tons per acre down. Cuttings made over 35 to 40 sections near Newman, N. Mex., yielded from 175 to 300 tons of dry leaf heads, with an average of 250 tons per section. The man who was managing this cutting estimated the dry stalks at approximately as much more in weight per section. These plants are usually shredded and fed while fresh, and the green weight is doubtless at least twice that of the dry leaves and stalks. From these figures we reach the conclusion that in regions where these plants are tolerably abundant the yield of fresh feed averaged 1½ to 2 tons per acre. Actual weights of two loads, each consisting of 38 stalks, averaged 1,340 pounds. An acre with an average stand of the growth found on the plains northeast of Las Cruces, N. Mex., in 1914 produced 85 stalks by actual count, which would weigh about 1½ tons. These figures are obtained from land where the plants of this species were of medium to large size and fairly abundant.

Yucca glauca, the bear-grass of the Staked Plain region and northward, produces from one-fourth to 1 ton per acre of dried material, according to Mr. J. E. Wallis, of Elida, N. Mex., who had cut and baled between 3,000 and 3,500 tons (dry) of it on contract. Allowing for the loss of moisture, which would be at least 50 per cent, this species in eastern New Mexico produces from 2 tons per acre on lands carrying a heavy stand down to nothing on the tight lands.

With the exception of occasional small patches of old sotol, none of the other species produce as much feed per acre as the soap weed, and certainly none of the other species are to be found on as much land as this one.

RENEWAL AFTER CUTTING.

The soap weed (*Yucca elata*) and the bear-grass (*Yucca glauca*) both sprout readily when cut off at the ground. The best information as to the latter indicates that a new crop about as good as the original may be expected from cut-over land in about three or four years. There can be no doubt that the tall stalks of the soap weed (*Yucca elata*) are much older, however. Plants from 6 to 10 or 12 feet high are certainly 15 or 20 years old or older. Stockmen who have ridden the ranges in southern New Mexico and Arizona for many years are unanimous in estimates of this order. New heads of leaves appear at the ground, generally the next season after the old stalk is injured or killed, but it takes years to grow new tall trunks. Where they occur, these plants really constitute the desert forests, and many of them are at least 50 to 75 years old. Since the stems furnish by far the better part of the feed, it will be seen that the present method of using the plants is really but calling upon a supply of reserve feed that was not before appreciated and that its renewal is a slow process.

Experience in Texas indicates that the sotol and sacahuista do not recover when they are cut off at the root. Reports from Marathon and Sonora agree that areas which were cut over 15 years ago have not produced a new crop since and show no prospect of doing so. While actual experience is lacking with respect to the various other species mentioned here, it is highly probable that, with the exception of lechuguilla, none of them will sprout from the root when cut off. Lechuguilla sprouts readily from old stems, but the plant has a very shallow root system and it would be dug out bodily if fed, hence there would be nothing left to sprout. *Yucca baccata* has underground parts that might sprout, but it is an unimportant species, never very abundant.

Data as to the ease with which seeds will germinate are also lacking, but young seedlings are very rare in the regions where they might be expected to occur. The writer has noticed this condition many times. All the plants here considered produce abundance of seeds when they fruit, but a large proportion of the seeds are eaten in the pod by the larvæ of insects. This is especially true of the yuccas.

Under conditions that can be supplied in a greenhouse or a garden the seeds of several of the species germinate tolerably well, but such conditions do not often occur in the situations where the seeds naturally fall; hence, reproduction from seed, while possible, is but remotely probable in the open country. Moreover, if stock learn to eat the plants they will pull up the young seedlings long before they get large enough to protect themselves.

It thus appears that most of the species here listed, if used up, are not likely to return. Fortunately, the most valuable species (*Yucca elata* and *Yucca glauca*) may be expected to recover after cutting, the former slowly and the latter more rapidly, especially if the plants are not cut too close and are given an opportunity to grow.

It should be clearly understood that the supply of this emergency feed is not by any means inexhaustible; in fact, on many ranches it is scarce or very limited in amount; also that natural renewal is slow with the best species and improbable with others, while it is reasonably rapid with but one species (*Yucca glauca*). Present knowledge of the plants indicates that they should be used for emergency feed only. They should be allowed to store a supply of feed, in what might be called a natural or living silo during the favorable growing seasons, that may be used when the years of low rainfall and poor grass come—years that are sure to come when the dry part of the precipitation cycle arrives, as it does every 10 or 12 years.

QUALITY OF THE FEED.

In 1896 an analysis of sotol was published by the New Mexico Agricultural Experiment Station in Bulletin No. 17, but none of the other plants here treated were then thought of or used as feed, except as cattle occasionally chewed a few of the dry leaves.[1] In 1903 some ash analyses of three of the species listed here were published by the same station in Bulletin No. 44. In October, 1917, a press bulletin with analyses of sotol and soap weed was sent out by the same station, with comparative data for other more common feeds. On February 1, 1918, the Arizona Agricultural Experiment Station published two analyses of *Yucca elata*.[2]

The Bureau of Chemistry, United States Department of Agriculture, has been called upon to make analyses of a number of these plants at different times. The details of all are presented in Table I, all records being computed on a water-free basis. Along with these are some analyses of a few of the better known feeds, with which they may be compared. None of the ordinary feeds are exactly like these desert shrubs. They contain less water than most fresh feeds and considerably more than most dry hays. The average water content of four samples of soap weed when first prepared was 65.86, while for five samples of sotol the average water content was 60.23 per cent.

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[1] In 1898 the Texas Agricultural Experiment Station published in Bulletin No. 44 an analysis of satol from Dull's ranch, no further data being given. This is possibly a misprint for sotol.

[2] Thornber, J. J. Soap weed or palmilla (*Yucca elata*) as emergency forage. Ariz. Agr. Exp. Sta., Timely Hints for Farmers 135, 7 p., 1 fig. 1918.

A preliminary report on some feeding experiments with soap weed and sotol is made in Press Bulletin 308 of the New Mexico Agricultural Experiment Station.

TABLE I.—*Chemical analyses of different emergency feeds, with corn stover and hay comparisons.*

Name of plant, place of collection, etc.	Date of collection.	Kind of material.	Identification.	Constitutents, water-free basis (per cent). Ash.	Crude protein.	Ether extract.	Fiber.	Nitrogen-free extract.
Yucca elata:								
Willcox, Ariz.[1]	1918	Young stems	Ariz. No. 1	5.6	7.5	1.5	16.1	69.3
Tucson, Ariz.[1]	1918	Old stems	Ariz. No. 2	9.2	3.1	.9	19.6	67.2
Las Cruces, N. Mex.[2]	Oct., 1917	Heads and leaves	N. Mex. exp. sta.	6.0	6.3	1.6	30.9	55.2
	do	Stem		6.9	4.3	1.1	24.0	63.7
	1917	Silage		6.2	6.3	2.9	37.4	47.2
	Oct., 1917	Dry leaves		6.8	2.9	2.7	38.9	48.7
Jornada Reserve [3]	May 19, 1913	Flower stalk	E. O. W. 7137	7.5	18.4	2.1	26.8	45.2
Deming, N. Mex.[3]	Aug. 24, 1910	Leaves	D. G. 10090	12.1	6.5	1.5	24.9	55.0
Willcox, Ariz.[3]	May 24, 1917	do	Ranchman	5.0	3.8	.7	19.9	70.6
Deming, N. Mex.[3]	Feb., 1918	Stem	E. O. W. 7236	9.8	6.3	2.1	25.9	55.9
		Leaves and stem	E. O. W. 7237	4.6	3.1	.7	39.4	52.2
Average of all specimens.				7.1	7.5	1.6	28.4	55.4
Yucca glauca:								
Elida, N. Mex.[3]	Mar. 30, 1918	Leaves	E. O. W. 7243	8.8	6.4	2.8	32.7	49.3
		Stems and roots		7.3	5.7	.8	25.2	61.0
Yucca macrocarpa:								
State College, N. Mex.[3]	Mar. 27, 1918	Leaves and stems.	E. O. W. 7249	4.6	2.9	.6	43.1	48.8
Yucca baccata:								
Florida Mountains, N. Mex.[3]	Mar. 10, 1918	do	E. O. W. 7238	7.6	3.6	1.2	34.1	53.5
Yucca brevifolia (?):								
Near Vail, Ariz.[3]	Mar. 14, 1918	Stems	E. O. W. 7242	9.4	5.7	1.5	20.0	63.4
		Leaves		12.7	5.8	2.7	39.1	39.7
Yucca rupicola:								
Sonora, Tex.[3]	Apr. 1, 1918	Leaves and stems.	E. O. W. 7245	7.3	7.2	2.3	37.3	45.9
Samuela faxoniana:								
Sierra Blanca, Tex.[3]	Apr. 5, 1918	Leaves	E. O. W. 7248	8.5	5.5	1.7	24.5	59.8
		Stem, old part		5.6	2.8	.7	33.6	57.3
		Stem, young part		7.2	13.4	1.9	11.4	66.1
Dasylirion texanum:								
Sonora, Tex.[3]	Apr. 1, 1915	Leaves	E. O. W. 7247	3.5	5.1	1.6	41.7	48.1
		Head		3.5	6.6	1.2	20.1	68.6
		Stems		7.3	17.6	2.3	26.5	46.3
Dasylirion wheeleri:								
State College, N. Mex.	1896 [4]	Head	N. Mex. exp. sta.	4.6	4.6	2.3	24.3	64.2
	Oct., 1917 [2]	do		4.2	5.4	1.9	30.7	57.8
		Dry leaves		3.1	2.3	4.4	44.4	45.8
		Unblossomed head		5.8	11.5	2.2	28.8	51.7
		Green leaves		4.5	4.6	2.4	39.6	48.9
Florida Mountains, N. Mex.[3]	Mar. 10, 1918	Head	E. O. W. 7239	4.4	4.2	1.0	29.2	61.2
Average of all analyses.				4.3	5.5	2.4	32.9	54.9
Nolina erumpens:								
Sonora, Tex.[3]	Apr. 1, 1918	Whole plant	E. O. W. 7246	5.6	8.6	2.8	41.8	41.2
Nolina microcarpa:								
Jornada Reserve [2]	Oct., 1917	Leaves	N. Mex. exp. sta.	2.9	3.7	1.5	46.6	45.3
Agave lechuguilla:								
El Paso, Tex.[3]	Mar. 26, 1918	Whole plant	E. O. W. 7244	8.9	4.4	1.7	32.5	52.5
Averages for comparison: [5]								
Corn stover (ears removed, 183 analyses).				6.4	6.5	1.8	33.9	51.4
Prairie hay (western, 42 analyses).				8.2	8.6	2.8	32.6	47.8
Alfalfa hay (250 analyses).				9.4	16.3	2.5	31.0	40.8

[1] Thornber, J. J. Soap weed or palmilla (*Yucca elata*) as emergency forage. Ariz. Agr. Exp. Sta., Timely Hints for Farmers 135, 7 p., 1 fig. 1918.
[2] New Mexico Experiment Station, Press Bulletin 301.
[3] Analysis made in the Cattle Feeds and Grain Investigations Laboratory of the U. S. Bureau of Chemistry, under the direction of Mr. G. L. Bidwell.
[4] Goss, Arthur. Principles of stock feeding and some New Mexico feeding stuffs. N. Mex. Agr. Exp. Sta. Bul. 17, p. 21–54. 1895.
[5] Henry, W. A., and Morrison, F. B. Feeds and Feeding. . . . ed. 16, p. 633–646. Madison, Wis., 1916.

The analyses of soap weed and sotol show that the food value of the different parts of the plant varies and that the food content of the same parts of different plants also varies. This is as was to be expected. The growing parts of the plant would naturally have less fiber and more protein because they are growing, and the leaf bases and young stems would also show relatively higher food content because of their use by the plant for storage of such material against the flowering time. A change in the percentage of one constituent of necessity affects the figures for all the rest.

The average values for the 13 analyses of soap weed and 6 analyses of sotol are more nearly like those of western prairie hay (average of 42 analyses) than any other kind of feed usually fed, though they also approximate those of corn stover.

There was considerable discussion among those interested about the relative values of this feed and alfalfa hay. Assuming that they are equally digestible and that there is nothing deleterious in the soap weed, the figures given in Table I show something of the relative merits of the two feeds. From these figures alone we see that for perfectly dry material the amount of protein in 100 pounds of alfalfa is about twice as much as that in the soap weed and that the fat-carbohydrate percentages are higher in the soap weed. Both these conditions indicate higher feed value in the alfalfa. In addition to these is the condition in which the material is fed. Alfalfa is fed when air dry, and 100 pounds of hay furnishes about 93 pounds of dry matter of which between 8 and 9 pounds is crude protein. Soap weed is fed fresh cut and 100 pounds of the feed contains only about 35 pounds of dry matter, of which about 2½ pounds is protein. Thus, for every 100 pounds of alfalfa fed, an animal gets nearly three times as much feed which is at the same time twice as good feed as when he is fed 100 pounds of chopped yucca. This should answer the question very emphatically in favor of alfalfa, but at the same time it should in no way detract from the value of the soap weed as an emergency feed.

It must be clearly recognized that the soap weed and all such feeds are of low feed value and, taken alone, are feeds of very wide nutritive ratios. In other words, the amount of tissue-building food material (protein) found in these feeds constitutes only a small proportion of the total amount of the material fed, and is also small in amount when compared with the other food materials (fats and carbohydrates) present in such feeds. The fresh, moist condition of the feed when fed is advantageous, and under certain conditions it would no doubt be worth while to feed a certain amount of such material to stock on dry feed. However, under most conditions the expense of preparing the feed is such that it is not warranted unless no other feed is available at a less cost.

The distances which feeds produced on cultivated land must be transported compel the stockmen who use such feeds to seek those that are highly concentrated. The cottonseed products, meal and cake, are such feeds, and they have high protein content. They are to be had in the region and with a shorter haul than any feeds of equal value, with the exception of alfalfa. Hay and forage crops are not concentrated, and they are correspondingly hard to transport. But while the cottonseed products may be safely fed in small quantities, it is necessary that they be accompanied by sufficient roughage to give the requisite bulk and balance to the ration. They can not be fed alone for a long time or in very large quantities without serious detriment to the stock. If the dry range feed is practically all gone, the needed roughage may be supplied by soap weed or some other of the plants listed here if the plants grow on the ranch in sufficient quantity to make it possible to shred them.

But it is argued that without knowing the digestion coefficient it is not possible to tell a great deal about the value of feed from the ordinary chemical analysis.[1] From the practical standpoint, however, the answers obtained by feeders are conclusive as far as they go, though the optimistic stockman may easily overstate the results he has obtained. There is no doubt that the use of this feed saved thousands of cattle in the region in 1917. One man who was feeding 2,800 head of all kinds of cattle, from coming yearlings to cows with young calves, assured the writer that his losses had been kept down to approximately 7 per cent,[2] and that they would doubtless have been as high as 30 per cent without this feed, though he was feeding cottonseed cake besides.

One man who was feeding 400 head of cows and calves said that 13 of the cows were so weak when feeding was begun that they had to be helped up every time they lay down. They had been fed nothing else but chopped soap weed for six weeks and are now strong enough to take care of themselves.

One other extreme was that of a young cow found down and unable to get up. She would have died of thirst in a few days. The men hauled her to the watering place on the float with which they were hauling the soap weed and commenced to feed her. By using the chopped feed and a little cottonseed meal she was saved and has since dropped a calf which is alive and well.

There is no question that the chopped soap weed, sotol, bear-grass, or sacahuista will keep cattle and sheep from starving if fed in suffi-

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[1] The need of this digestion coefficient is thoroughly appreciated, and steps have already been taken to obtain this factor for both soap weed and sotol at the New Mexico Agricultural Experiment Station, which is especially equipped for this work.

[2] It is customary to figure on an average loss of about 10 per cent on open ranges.

cient quantity, because it has been done; and under certain circumstances like the present, when the saving and producing of meat is so vitally important to the whole world, the mere possibility of keeping stock from dying during the short period of feed scarcity assumes an importance out of all proportion to the possible financial loss involved. It was the appreciation of the necessity of saving not only all the meat animals that would have died but especially the breeding stock which are to furnish the next beef crop that made not only the stockmen but the makers of the chopping machines so persistent in their effective efforts. Stockmen of long experience in the arid Southwest know that it is the series of dry years that puts them out of business. They know that the dry years will be followed by wet ones and that the calf crops when there is good feed will more than pay the expense of saving the breeding herd in the dry years, if it can be done. They also know that if the breeding herd is lost there will be no calf crop, no matter how good the feed may be later; hence, the very great importance of feed on their own ranges, which may be made available to the stock at small expense and with a little work.

QUANTITY FED.

This bulletin contains no records of weights except in the case of the two wagonloads already mentioned. The other figures given rest upon the judgment of the men doing the hauling, whose estimates, however, are reasonably accurate. There was of course no uniformity of practice among the users of the feed, and the opinions as to the necessary amounts to feed ranged from 10 to 40 pounds of fresh-chopped feed per day for a mature animal. In practice, however, no one whose record was obtained fed more than 30 pounds per head per day, and over half of them fed less than 18 pounds per head per day. The feed for weaned calves and coming yearlings was 6 or 7 pounds per head and for mature animals about 18 to 20 pounds per head per day. The average feed for 11,373 head of all classes was 14 pounds per head of chopped soap weed per day.

A feed of 15 pounds of freshly chopped soap weed (*Yucca elata*) contains a little more than 5 pounds of dry matter, of which about 0.4 of a pound is crude protein, less than 0.1 of a pound is ether extract (usually called fat), 1.4 pounds is crude fiber, and 2.8 pounds is nitrogen-free extract (usually called carbohydrates). A feed of 15 pounds of average alfalfa hay would contain nearly 14 pounds of dry matter, containing 2.23 pounds of crude protein, 0.34 pound of ether extract, 4.23 pounds of fiber, and 5.60 pounds of nitrogen-free extract.

It will be seen from these figures that there is in alfalfa hay over 2½ times as much total dry matter, over five times as much crude protein, more than four times as much ether extract, and twice as much nitrogen-free extract as is to be found in an equal weight of freshly chopped soap weed. In other words, 15 to 20 pounds of freshly chopped soap weed is a daily ration that will barely sustain life in the animal, and it needs some concentrate that has a large percentage of protein to go with it in order to make the animal grow or improve in condition.

MECHANICAL CONDITION OF THE FEED.

The soap weed when prepared by any of the machines is cut into slices one-half to three-fourths of an inch thick and 2 or 3 inches each way or is torn into small shreddy pieces an inch or two long. The fibers, which are very numerous in both leaves and stems, are cut in pieces never more than 1 or 2 inches long, except that the leaves are frequently torn off the head and but partly chopped into pieces. It is the usual practice to cut down the stalks, haul them to the choppers, shred, and feed all during the same day. It is not necessary that this practice should be followed, as the stems retain their moisture a long time. It was impossible by any ordinary inspection to tell much difference in the moisture content of shredded material from fresh stalks and from those that had been cut a month before shredding.

The material is quite wet when freshly shredded, is noticeably sweet to the taste (with a distinct bitter aftertaste), and is in such shape that cattle or sheep can eat it readily. Cattle learn to eat it in a very short time and seem to like it. They will go ahead of the wagons to the feeding grounds, and calves soon learn to slip through gates to get to the machine when it is at work.[1] Very little of the soap weed has been fed to sheep so far, though it is a common practice to feed sotol to them in Texas. Certain advantages that have not yet been well tried are doubtless to be gained by the use of these yuccas for sheep, upon which definite data are wanting.

Most of the men who are using this feed burn off the dead leaves before cutting the stalks, leaving only the tuft of green leaves at the top. In one instance, where it was necessary to haul the stalks more than 2 miles to the feeding place, the herd had been divided into two parts. One part, composed of the stronger animals that could easily walk to and from the water, was held on the ground where the soap weed was growing. The green tops (leaves) of the plants were cut off with the axes and left scattered upon the ground for these animals to eat. The stems, which look like so many sticks of wood, were hauled to the corral and shredded for the other part of the herd.

[1] The chopped or shredded feed sours and heats very quickly if left in a pile. Small piles left lying for some days ultimately mildew and spoil. Cattle eat the soured material freely.

This method avoids the necessity of handling and hauling a large part of the feed and makes the work of handling and shredding the remainder easier. It has given satisfactory results. It is probably not altogether wise to burn off the dry leaves, as they contain some feed value that should not be wasted, but they make the shredding operation much more difficult, and the feed value in the dry leaves may not be worth the additional labor[1] necessary to pass them through the machine.

In most cases additional feed, usually cottonseed cake, was being fed to the animals. This is as it should be, since the shredded feed is nothing but a low grade of roughness comparable to corn stover (ears removed) or range-grass hay.

STOCK LOSSES FROM USING THIS FEED.

A particular effort was made to learn whether or not the chopped feed was in any way responsible for losses of any kind among the stock fed. Scouring was reported from a few herds, but it was never of any importance and was overcome by adding dry feed to the ration. In a few cases this result was obtained by grinding up the old dead leaves of the plants with the rest of the feed, instead of burning them off.

A few cases of bloating were reported when animals had been fed quite heavily with the chopped soap weed. No cases of abortion were found, though all the feeders were asked about it. Some cases of impaction were found and some choking, but in all cases of loss from either of these causes the feed was hand chopped, and the trouble arose from the mechanical condition of the feed rather than from any other cause. One source of loss was the chilling which occurred at night when the temperature fell. Cattle weak and poor from starvation would lie down and get chilled and never get up. With one herd the men stayed with the animals on one cold night and kept them moving about to prevent losses of this kind. Such losses arose from lack of feed instead of the use of this kind.

The total losses directly attributable to properly shredded soap weed were negligible.

COST OF FEEDING SOAP WEED.

In getting together the material for this bulletin the writer interviewed many different men who had fed or were feeding sotol, sacahuista, bear-grass, or soap weed. He saw all of the various kinds of machines at work on ranches. He obtained 13 complete reports from men who were chopping soap weed to feed to cattle in Arizona, New

[1] Some of the men who were chopping the soap weed by hand cut the stalks and piled them before burning off the dead leaves. They found that the heat tended to cook and soften the stems, thereby making the work of chopping easier.

Mexico, and Texas. The number of cattle that these 13 outfits were feeding aggregated almost 10,000 head. The details of investment and expense connected with these outfits are shown in Table II.

TABLE II.—*Expenses of maintenance of outfits for shredding soap weed and cost of feeding the prepared product.*

State and record.	Kind of machine.[a]	Engine.	Investment.				Expenses per month.						Number of animals fed.	Cost per month per animal.
			Chopper.	Engine.	Teams, etc.	Total.	Wages.	Board.	Horse feed.	Fuel and oil.	Repairs and depreciation.	Interest.		
New Mexico:														
No. 1	A	10 H. P.	$280	$275	$750	$1,305	$210	$105	$60	$40	$26	$11	1,040	$0.44
Texas:														
No. 2	B	14 H. P.	618	600	1,600	2,818	405	250	60	75	44	24	2,000	.43
No. 3	B	12 H. P.	600	545	400	1,545	205	75	25	6	13	13	400	.84
No. 4	C	10 H. P.	104	300	500	904	135	90	30	9	8	8	600	.47
No. 5	B	14 H. P.	615	433	260	1,308	30	10	10	3	11	11	800	[b].10
New Mexico:														
No. 6	B	14 H. P.	600	600	1,000	2,200	40	14	6	9	18	15	200	.51
Arizona:														
No. 7	B	12 H. P.	560	300	640	1,500	240	175	60	30	13	13	450	1.18
No. 8	D	7 H. P.	150	350	250	750	200	66	20	26	6	6	383	.85
No. 9	Silage cutter.	12 H. P.	75	250	400	725	50	20	30	5	6	6	200	.59
New Mexico:														
No. 10	A	12 H. P.	375	500	1,200	2,075	295	105	165	75	15	15	1,200	.56
No. 11	B		530	267	925	1,722	160	60	105	62	14	14	1,600	.26
No. 12	A		360	385	450	1,195	120	75	90	7	10	10	600	.52
No. 13	D	Automobile.	155	150	450	755	60	30	76	101	8	6	200	[c]1.40
Total			5,007	4,970	8,825	18,802	2,150	1,075	337	448	192	154	9,673	
Average			385	382	679	1,447	165	83	57	34	15	12		.49

[a] The Office of Forage-Crop Investigations of the Bureau of Plant Industry will be glad to answer any inquiries regarding machines and their manufacturers.

[b] This figure is quite small because the animals were young and were being fed only 5 or 6 pounds of chopped feed per day.

[c] This figure is very large on account of the character of fuel it was necessary to use in the engine, which was bought at a very high price. Most of the other gas engines used distillate. This engine had to have gasoline. These figures correct each other in the average.

It will be seen that depreciation and interest charges have been made against the entire value of the investment that is in any way used for the preparation or feeding of the soap weed. Included in this investment is the value of teams, wagons, and harness, as well as saddle horses, and sometimes gas engines, that are normal equipment of the ranch and which are used for other purposes. To the extent that they are used for other purposes during the period when feeding is being done, the charge becomes an overcharge to the feeding cost and the results obtained are to that extent in excess of the truth. It is safe to say that the average cost of 50 cents per head per month for feeding the soap weed is a fair average upon which to estimate where the haul is not too great. And no stockman will hesitate to incur such an expense to save his stock. As will be seen, all the various kinds of machines in use are represented. There was no attempt to select any special kind. Every user of any kind of machine from whom the writer could get definite information was asked for the results of his experience. Thirty more or less complete records were obtained in this way, and those which gave conclusive evidence with respect to machine-chopped soap weed are included in Table II. A number of them recounted the experience of men who were cutting sotol or bear-grass by hand.

There is absolute unanimity of opinion that soap weed, sotol, bear-grass of either kind, or sacahuista if fed in sufficient quantity and given to the stock before they get very weak from starvation will save them in every instance.

Stockmen of the region all recognize the advantage of the machines. One man who had used one of them for some time, in conversation with a neighbor, asked if his friend had a machine. The latter replied that he had not yet bought one, and the experienced man said, "Well, buy two."

Records of the sale of 80 machines up to March 31, 1918, were obtained from the makers, and orders for several more had already been received.

The total number of stock being fed one or another of these feeds in 1918 whose owners were interviewed by the writer was 16,298 besides 885 that had been fed hand-chopped material in 1917. It was the general opinion of the men who were feeding that from 75 to 90 per cent of these weaker animals would have died if they had not been fed. The animals that were being fed constituted from 30 to 100 per cent of the different herds to which they belonged. Almost all of these men were feeding some cottonseed cake or meal (they expressed various differences of opinion as to which is better) if they could get it. But several said their stock were already beginning to go down on cake alone when they commenced feeding soap weed, and the animals at once showed improvement.

The additional expense of feeding cake or meal may be easily calculated from the amount fed per day and the price of the feed at the ranch. This price varied this year from 2½ to 3¾ cents per pound, and the amount fed varies from one-half pound for young stock to 2 pounds for mature breeding animals, with an average of about 1 pound per head per day.

IMPORTANCE OF EMERGENCY FEEDS.

The best measure of the importance of this subject is shown by the numbers of animals involved. These numbers give some conception of the possible losses that may be avoided by the feeding. The only figures available for Arizona and New Mexico are the United States Department of Agriculture reports of range cattle and sheep for the various counties where these feeds occur. (See Table III.) These figures are furnished by the field agents of the Bureau of Crop Estimates.[1]

[1] Mr. L. M. Harrison for Arizona and Dr. R. F. Hare for New Mexico.

The figures for Texas given in Table III are taken from the Report of the State Comptroller for 1916, the latest published. It is not intended to suggest that these emergency feeds are of equal importance to all of these stock, and in the present state of our knowledge it is impossible to give even an estimate of what percentage of the total number of animals here listed have been or are likely to be in any way affected. It is safe to say that a large percentage of cattle that otherwise would have died were saved by this means in the following counties: Arizona—Cochise and Greenlee; New Mexico—Grant, Luna, Dona Ana, Otero, and Eddy; Texas—El Paso, Culberson, Jeff Davis, Presidio, Reeves, Pecos, Brewster, and Terrell. It is certainly true that the actual total number of animals saved is large, even though the percentage of the total number of animals in the region is not large. In the past it has been not uncommon for cattlemen in this region to suffer losses amounting to 30 per cent or even 40 per cent of their cattle in years of extreme drought, such as the present period is. If the use of these emergency feeds results in reducing the losses to nothing more than normal. thousands of head of stock will have been saved.

TABLE III.—*Estimated number of cattle and sheep in certain counties of Arizona, New Mexico, and Texas.*

Counties.	Cattle.	Sheep.
Arizona, 1917:		
Cochise	114,000	9,000
Greenlee	38,000	....
Graham	83,000	....
Santa Cruz	29,000	....
Pima	71,000	....
Pinal	50,000	8,000
Total	391,000	17,000
New Mexico, Jan. 1, 1918:		
Grant	140,000	6,000
Luna	40,000	20,000
Sierra	50,000	2,000
Dona Ana	30,000	8,000
Socorro	150,000	440,000
Otero	40,000	25,000
Lincoln	50,000	180,000
Eddy	70,000	70,000
Chaves	90,000	200,000
Roosevelt	60,000	5,000
Curry	30,000	1,000
Quay	50,000	50,000
Total	800,000	1,007,000
Texas, 1917:		
El Paso	45,312	1,335
Culberson	34,917	4,700
Jeff Davis	51,876	....
Texas—Continued.		
Presidio	41,934	2,510
Brewster	63,809	7,600
Reeves	29,369	715
Loving	4,623	....
Winkler	11,959	....
Pecos	71,366	66,525
Terrell	18,826	67,406
Valverde	33,232	227,695
Bailey	22,337	....
Cochran	6,349	1,975
Hockley	18,223	....
Yoakum	16,322	5
Terry	18,879	209
Dawson	20,000	1,000
Andrews	27,788	....
Martin	55,493	27
Ector	19,061	62
Midland	29,938	51
Crane	10,645	....
Upton	23,776	4,758
Reagan	17,940	15,630
Crockett	52,871	90,825
Schleicher	40,907	50,478
Sutton	42,510	142,012
Edwards	39,860	90,711
Kinney	26,799	34,311
Total	896,812	810,540

ARGUMENT FOR FEEDING RANGE STOCK.

There are no more loyal citizens in our Nation than the western stockmen. Nothing is needed to stimulate their patriotic endeavors except to point out clearly to them the relation of their business to the war, and most of them already understand it perfectly. The United States Food Administration has blazoned its slogan "Food will win the war" from one ocean to the other and from Canada to Mexico; but most people think only of the crop farmer as the producer of food, although meat is one of the most important of the foods. No higher kind of loyalty and service can be rendered by stockmen than the use of their experience, equipment, and effort in the production of the maximum quantity of this necessary kind of food. Soldiers can not fight without an abundance of strong food, and food can not be purchased for them, no matter how much money we have, if it is not produced in sufficient quantities. Every cow that dies is herself just so much meat lost, and with her death there ends a continuing stream of meat-producing animals which can not be started flowing again. Hence, it is vitally important to save all animals, but especially the breeding stock.

But while reasons of this higher type will appeal to stockmen in general, they are by no means the only arguments in favor of saving cows. Experience has shown that it is ordinarily good management to feed range stock a small amount of concentrated feed during ordinary years, and especially in seasons of drought and consequent poor range feeds.

Suppose that in any given year, without additional feed, the loss of breeding cows on the range is 10 per cent, or that out of every 100 cows, 10 will die. Suppose the rate of increase is 70 per cent of the breeding cows.[1] If no feeding is done, at the end of the year, out of each 100 cows there will be left 90, and they will have 63 calves. If they are fed well enough to reduce the losses to 2 per cent, there will be 98 cows left, and they will produce 68 calves. If the cost of the feeding has been the value of 8 cows, the stockman has 5 more calves per 100 cows by the one method than by the other. If the cost has been less than that amount, the difference in his favor is greater. Besides this, his animals are all in better condition. If the calves have been weaned at six months and fed a small amount of concentrates and the breeding cows and bulls have also been fed, all of the stock are in better condition, the calves bring a better price as yearlings, and the next year's crop is larger and of better quality, because of the physical condition of the breeding stock and also because there will be eight more cows per hundred left in the herd. Stockmen all agree that animals that have once been fed are much tamer and more easily handled than before, and that this is an important factor in all work done with them thereafter.

All of the above applies to the ordinary or usual conditions. In proportion as the rainfall of any season is below the average, the feed for the next year is bound to be reduced, and after two seasons of

[1] This is the average for one well-managed ranch for a period of 12 years, and it is certainly above the average for the ordinary range.

diminished production the feed left on the range is not only scanty, but is of the very poorest quality. If the range is fully stocked when the dry years come (as is usually the case, since the previous years have generally been years of more than average production), it is absolutely necessary to do one of three things—reduce the number of animals on the area, feed them some kind of material they can not get for themselves, or let some of them die of starvation. The amount of reduction necessary is very difficult to determine, and the necessity for doing it usually is recognized only after the stock commence to go off in quality and therefore in selling value. Feeding the stock maintains or improves their quality and numbers, and prevents forced selling, but cuts into the net receipts. However, it is much the least of the three evils, and while the expense involved is nearly always greater the longer and more widely distributed the drought may be, the increased selling prices which usually accompany such conditions compensate more or less for the increase in expense

Range stockmen who can obtain at a reasonable price a concentrated feed like cottonseed cake that contains a high percentage of protein, and who have their ranges fenced, have been feeding for a number of years. The principal factor which has prevented New Mexico and Arizona cattlemen from following in the way others have led is their lack of legal control of their range lands. It is a common custom in the open-range country to water all the animals that come to the watering places. But it would be very difficult to feed one's own stock and keep stock of other brands away from the feed as long as they run together on the range. In particular cases stock of different owners have been and are now being fed together just as they are now watered, but adjustments are hard to make and are apt to lead to misunderstandings, especially where tempers and confidence are already strained.

No one advance step could be taken which would benefit this business so much as some legislation that would give the southwestern stockman legalized control of the land he uses and thereby allow him to fence his range.

SUMMARY AND CONCLUSIONS.

It has been demonstrated by trial on a large scale that several desert shrubs, some of which have not been used until recently, are valuable emergency feed for range cattle and sheep in times of extreme drought, if properly prepared.

The preparation consists of chopping or shredding the stems and leaves of these plants by machines that have recently been designed and produced. Hand chopping of the material is possible, but it is slow and laborious and the product is not very satisfactory. The machine-chopped material is satisfactory in every way.

Several different kinds of machines are now being manufactured, any one of which will do the work required and can be handled readily by the kind of labor available on the average stock ranch.

The cost of the necessary equipment, from $1,000 to $2,500 (depending on the number of animals to be fed), is such that it is within the reach of the average stockman who needs it. A much smaller initial expense is usually sufficient, since most of the ranches are already supplied with one or more gas engines and all the horses and wagons necessary for the work.

The chemical analyses of these feeds and the experience of the men who are feeding them agree in showing that the feed is of low nutritive value and is to be considered as roughage, comparable to range-grass hay. If fed alone it may be expected to keep stock from starving; if fed with concentrates a properly balanced ration may be worked out.

The customary practice among users of the feed is to give young stock 6 to 12 pounds of chopped soap weed a day with one-half to three-fourths of a pound of cottonseed cake or meal. Mature stock are given 20 to 40 pounds of soap weed and 1 to 2 pounds of cottonseed cake per day. Of the chopped feed alone, 20 to 25 pounds per day will save stock from dying. With a pound of cottonseed cake in addition, a fairly well-balanced living ration is produced.

Only two of the species of the plants here discussed may be expected to renew themselves if cut off. The bear-grass of the New Mexico–Texas Plains region (*Yucca glauca*) will produce a new crop in three or four years. Soap weed (*Yucca elata*) will doubtless need 10 to 15 years to produce another crop equal to that now being removed. All the other species will probably be destroyed if cut off at the ground for feeding purposes, unless steps are taken to insure a new crop.

The average cost of feeding about 20 pounds of chopped soap weed per animal is about 50 cents a month, or 1⅔ cents a day. With the addition of cottonseed cake, when worth $67 per ton at the ranch, stock can be kept in good condition and sometimes improved for about 5 cents per day per animal at the present prevailing prices of labor, fuel, oil, etc.

The argument for the emergency feeding of range stock rests primarily upon a basis of war-time need of meat, but it can easily be shown that it is a perfectly good economic policy. Stockmen in the region under consideration would doubtless have acted much as they have, with respect to this method of saving their stock, even if the war-time incentive had not existed; but they would probably have adopted this method much more slowly. Such delay would have resulted in much greater losses of animals and income than will now be sustained, and war-time selling prices will tend to compensate for such expenses as may result from the policy adopted.

These emergency feed plants are all well adapted to the climatic and soil conditions of the region in which they grow and are capable of withstanding the most prolonged droughts which occur in that region. They grow vigorously during favorable seasons and less so during unfavorable ones, but as long as they grow they are storing up food in what is in reality a living, self-filling silo. There is reason to believe that the feed is in its best condition at the very time that it is most needed, i. e., in the period of excessive drought. The feed is fresh and may be used at any time. The "silo" will refill itself in many cases if given time. Careful consideration of the subject leads to the judgment that these plants should be used only for emergency conditions, and that they should be allowed to grow during favorable seasons.

YOU WILL REALIZE, as I think statesmen on both sides of the water realize, that the culminating crisis of the struggle has come and that the achievements of this year on the one side or the other must determine the issue. It has turned out that the forces that fight for freedom, the freedom of man, all over the world as well as our own, depend upon us in an extraordinary and unexpected degree for sustenance, for the supply of the materials by which men are to live and to fight, and it will be our glory when the war is over that we have supplied those materials and supplied them abundantly, and it will be all the more glory because in supplying them we have made our supreme effort and sacrifice.—*From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.*

IN THE FIELD OF AGRICULTURE we have agencies and instrumentalities, fortunately, such as no other Government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them, if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed.—*From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.*

THE FARMERS OF THIS COUNTRY are as efficient as any other farmers in the world. They do not produce more per acre than the farmers in Europe. It is not necessary that they should do so. It would perhaps be bad economy for them to attempt it. But they do produce by two to three or four times more per man, per unit of labor and capital, than the farmers of any European country. They are more alert and use more labor-saving devices than any other farmers in the world. And their response to the demands of the present emergency has been in every way remarkable. Last spring their planting exceeded by 12,000,000 acres the largest planting of any previous year, and the yields from the crops were record-breaking yields. In the fall of 1917 a wheat acreage of 42,170,000 was planted, which was 1,000,000 larger than for any preceding year, 3,000,000 greater than the next largest, and 7,000,000 greater than the preceding five-year average.

But I ought to say to you that it is not only necessary that these achievements should be repeated, but that they should be exceeded. I know what this advice involves. It involves not only labor but sacrifice, the painstaking application of every bit of scientific knowledge and every tested practice that is available. It means the utmost economy, even to the point where the pinch comes. It means the kind of concentration and self-sacrifice which is involved in the field of battle itself, where the object always looms greater than the individual. And yet the Government will help, and help in every way that is possible.—*From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.*"

IT WAS FARMERS from whom came the first shots at Lexington, that set aflame the Revolution that made America free. I hope and believe that the farmers of America will willingly and conspicuously stand by to win this war also. The toil, the intelligence, the energy, the foresight, the self-sacrifice, and devotion of the farmers of America will, I believe, bring to a triumphant conclusion this great last war for the emancipation of men from the control of arbitrary government and the selfishness of class legislation and control, and then, when the end has come, we may look each other in the face and be glad that we are Americans and have had the privilege to play such a part.—*From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.*

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BULLETIN No. 729

Contribution from Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. July 24, 1918

SUITABLE STORAGE CONDITIONS FOR CERTAIN PERISHABLE FOOD PRODUCTS.

APPLES, POTATOES, SWEET POTATOES, ONIONS, CABBAGE, EGGS, FROZEN EGGS, POULTRY, BUTTER, AND FISH.

INTRODUCTION.

FOR a number of years the Department of Agriculture has been accumulating information concerning the factors which influence the keeping of various perishable farm products in storage. Some of this information has been published in various bulletins of the department, but much of it has not been made available in convenient form for the use of those operating storage warehouses. Recently the Federal Reserve Board requested the Department of Agriculture to furnish it with information as to "proper storage conditions," "length of storage" and "percentage of shrinkage in storage" for each several perishable commodities which might be considered sufficiently staple to receive the benefit of the preferential rate of rediscount in connection with loans made by member banks against warehouse receipts for such products "properly graded, packed and stored in weather-proof and responsible warehouses." This information has been prepared on apples, potatoes, sweet potatoes, onions, cabbage, eggs, frozen eggs, poultry, butter and fish and for convenience it has been tabulated in the form of a folding chart or table. (See envelope in back cover of this bulletin.)

The data contained in this chart represent the results of investigations and observations made by various workers in the Department of Agriculture. While the information given is not complete and may not, in all cases, represent ideal conditions of storage, it gives methods and conditions which thus far have been found to produce the most satisfactory results.

GENERAL CONSIDERATIONS.

The function of the storage warehouse is to preserve the product, so as to extend its season of distribution to the consumer. This is accomplished by providing certain conditions of temperature, moisture and ventilation which arrest the deteriorating processes and retard the development of decay-producing organisms. The warehouseman is responsible for the quick cooling of the product after it is placed in storage as well as for the maintenance of proper temperature and humidity conditions. Too much emphasis cannot be given to the matter of holding even temperatures in storage rooms. Fluctuations in the temperature shorten the storage life of fruits and vegetables, and cause deterioration of such products as fish and poultry. As a guide in maintaining uniform temperatures an accurate thermograph record should be kept. The thermograph, or recording thermometer, should be corrected when necessary with an accurate mercury thermometer.

The relative humidity of the air in storage rooms has an important relation to the keeping quality of the product. When the humidity or moisture content of the air is too low there is deterioration through the increased loss of moisture by the product, causing shrinkage or wilting; when it is too high moisture may be deposited on the product, making conditions favorable for the growth of molds and bacteria. Most of the common fruits and vegetables require a high humidity and low temperature in storage, although a drier atmosphere is desirable for certain products, as in the case of sweet potatoes and onions. In common storage houses, special methods for producing and maintaining a high relative humidity are necessary.

The period during which perishable products will keep in good condition usually depends as much on the treatment they receive before being placed in storage as on the conditions under which they are held in storage. In many cases the responsibility rests as much with the producer or handling organization as with the storage warehouseman. Varieties, stage of maturity and soundness are among the considerations which are discussed more fully elsewhere. Containers used in storing food products should be clean and strongly made. In storing they should be so arranged as to permit of free and unobstructed air circulation through and around all containers.

It is often difficult to determine the probable storage life or possible storage period of a perishable food product. The best methods for handling and the most suitable storage conditions vary with the different products. The storage life of the product is governed primarily by the extent to which carefully established methods of handling and storage have been followed. Frequent and thorough inspection of the product in storage is essential to avoid losses from deterioration and decay resulting from improper methods of handling to which commercial stocks often are subjected.

Under the column headed "Storage period" in the table, it is not intended to fix absolute storage limits, or the time at which stored perishable food products must be placed on the market. It is intended rather to indicate the storage period which experience has shown to be generally safe for the various products, and after which, in some cases, decline in market value is likely to begin. The storage period refers to the length of time the product, when properly handled, may be safely held if placed in storage in its normal season.

ESSENTIALS OF SUCCESSFUL STORAGE.

A brief consideration of the fundamental factors governing the successful handling and storage of the food product involved will help to make clear the data presented in the table. The following discussion of the proper methods of handling and the warehouse conditions adapted to the successful storage of these products is intended merely to supplement and explain the information contained in the table.

APPLES.

There is a wide variation in the storage quality of the different varieties of apples and of the same variety grown in different regions. The results of commercial experience usually indicate the relative storage season of different varieties in a given region.[1]

The inherent keeping qualities of apples in storage are definitely related to the cultural and orchard sanitation practices of the grower, who is responsible for the production of sound, properly matured fruit. To have good keeping qualities, apples should be fully grown and well colored. When properly matured and colored they are less likely to scald and are in better condition generally to be held in storage for the maximum period. Apples that from a storage standpoint are overripe, whether they have ripened on the trees or while awaiting delayed storage, have passed their prime condition and may be expected to deteriorate quickly in storage.

Apples should be handled in all the operations of picking, grading, packing and hauling with that degree of care necessary to prevent serious bruising, skin punctures or other mechanical injuries. To insure soundness and good keeping quality, apples must be properly grown, carefully handled in harvesting and packing and stored as quickly as possible after they are picked.

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[1] Ramsey, H. J., and others. The handling and storage of apples in the Pacific Northwest, U. S. Department of Agriculture, Bulletin 587. 1917.

A uniform temperature of 31° to 32° F. and a relative humidity of from 85 to 90 per cent are accepted as standard for the storage of apples. The usual humidity of refrigerated storage rooms is about 85 per cent.

Apples in cold storage should be inspected frequently in order that they may be removed and sold while they are still in good condition.

POTATOES.

Potatoes for storage should be "practically free from frost injury and decay and free from serious damage caused by dirt or other foreign matter, sunburn, second-growth, cuts, scab, blight, dry rot and other diseases, insects or mechanical means" as described in Markets Document No. 7: Potato Grades Recommended by the United States Department of Agriculture and the United States Food Administration.

In order to reduce the danger of deterioration from disease and from exposure to atmospheric changes, potatoes should be placed in storage as soon as practicable after being harvested. When stowed in bulk in either common or cold storage, potatoes should be piled not deeper than six feet, and the bins or compartments should be constructed with slat sides and bottoms to provide ample ventilation. They should not be stowed on earth floors. Each bin should contain not to exceed 60,000 pounds of potatoes. When stowed in crates or bags, the containers should be so piled as to permit unobstructed circulation of air on all sides.

The temperature of storage rooms should not be lower than 35° nor higher than 40°. In cellars or common storage houses the ventilators should be of ample size to permit of quick cooling in the autumn to a temperature of 40° or lower. The relative humidity of the storage rooms should be from 80 to 90 per cent to prevent shriveling or softening of the potatoes, but it should not be high enough to cause a deposit of moisture on the potatoes. Daylight should be entirely excluded from the storage room unless the potatoes are to be used for seed.

In properly constructed and well managed common storages, potatoes which are sound and mature when stored in the autumn should keep in a good merchantable condition from four to six months. Under less favorable conditions earlier deterioration may be expected which may require the removal and marketing of the product within three or four months. In sections where a sufficiently low temperature cannot be maintained, potatoes can be held in common storages for only short periods without danger of serious deterioration. When common storage is used, frequent inspection is necessary to avoid holding them beyond their prime market condition.[1] In cold storage, potatoes may be held

[1] Stuart, William. Potato storage and storage houses. U. S. Department of Agriculture, Farmers' Bulletin 847. 1917.

in prime condition for six months or longer. However, it is important to avoid temperatures below 35° because of the pronounced sweetening effect of such low temperatures upon the flavor of the potatoes.

SWEET POTATOES.

To keep well in storage, sweet potatoes should be free from serious damage caused by frost, heat, bruises, cuts, scars, cracks, decay, dry rot, or other disease, insects, or mechanical means. They should be dug during periods of dry weather and left exposed to the air a sufficient length of time to remove the surface moisture. Then they should be quickly placed in storage and subjected to the curing process. Sweet potatoes may be stored in bins, crates or hampers. When stowed in crates or hampers they should be so stacked as to allow ample ventilation. When bins are used they should be so constructed as to provide adequate ventilation on all sides and under the floor.

The temperature of the house at the time of filling and during the curing period should be maintained at about 85° with ventilation so managed as to drive off the moisture-laden air. The curing process will require from seven to twenty-one days, depending upon weather conditions. When thoroughly cured the sweet potato will present a bright, clear, dry surface, smooth and velvety to the touch.[1]

After the curing period, the ventilation should be so handled that the temperature is gradually lowered to 50° to 55° F. The temperature should be maintained uniformly at this point throughout the storage season by ventilation and occasional heating if necessary. A dry condition of the air in the storage house is absolutely essential to the successful storage of sweet potatoes. If properly cured and of sound stock, carefully-handled sweet potatoes can be kept in good marketable condition for three to six months.

ONIONS.

Onions should be well ripened and thoroughly cured in the field, in drying sheds or on slat trays before they are placed in storage. Decay and deterioration result from the storage of immature, soft, or "thick-necked" onions and from imperfect curing, bruising or other injuries caused by improper methods of handling in harvesting or drying.

When in good condition for storage, onions are well cured, hard, free from loose skins or mechanical injuries caused by rough or careless handling. They should be stored in slatted onion crates or in shallow slatted bins and should be cooled to a temperature of 32° to 36° as

[1]Thompson, H. C. Storing and marketing sweet potatoes. U. S. Department of Agriculture, Farmers' Bulletin 970. 1918.

quickly as possible after they are placed in storage. They should be stored in frost-proof ventilated cellars, in well-insulated, above-ground storage houses, or in cold storage houses. In common storage adequate means of ventilation should be provided for the quick cooling of the product and for maintaining a uniform temperature during the storing season.

CABBAGE.

Cabbage should be stored at a temperature of 32° to 35° in a well-ventilated, frost-proof cellar, a common storage house, or in cold storage. The heads should be solid, practically free from injuries caused by insects and diseases and the loose leaves should be removed from them.

Cabbage should be handled carefully in harvesting, sorting and storing in order to avoid early deterioration and decay of the product in storage. The heads should be placed one layer deep on slatted shelves, so arranged as to provide ample ventilation at the sides, floor and ceiling of the storage room. To prevent excessive wilting and consequent shrinkage, a relative humidity of 80 to 90 per cent should be maintained, but moisture should not be deposited on the leaves. The storage cellar or house should be provided with ventilators of ample size for the quick cooling of the product after it is placed in storage.

EGGS IN THE SHELL.

Only large eggs that are fresh and have clean, whole shells should be used for long holding in cold storage. The net weight of a case (30 dozens) of "storage-packed" eggs should be at least 42 pounds. The quantity of eggs on the market in March, April and May is greater and the quality better than those for sale in the summer months. The former are preferable for storage purposes. Commercially they constitute the majority of eggs stored.

The eggs should be packed in new, odorless cases with medium or heavier fillers (3 pounds, 3 ounces to the case). In making the cases 3-penny cement-coated nails should be used. The package should have odorless cushions at both the top and bottom and the lid should be securely fastened with six nails at each end to protect the eggs from damage.

The egg storage rooms should be dry, scrupulously clean and free from all odors. They should be maintained at temperatures of 29° to 32° F. The lowest limit of safety at which eggs may be held for short periods is 28° F. and the highest 33° F. To facilitate the circulation of air about the eggs, it is advisable to place strips of wood about two inches thick under the cases on the floor and half-inch or thicker strips between the cases in the stacks.

If eggs are fresh and have clean, whole shells they may be successfully preserved in cold storage for nine or ten months. In trade practice the deliveries of eggs out of cold storage begin in the late summer and continue through the winter. In only exceptional seasons are eggs left in storage after the first of March.

In commercial stocks withdrawn from storage between November and March those prepared from spring eggs lose by candling an average of 12 to 18 bad eggs per case, and those put up from summer eggs 18 to 42 bad eggs per case. The presence of cracked and leaking eggs in the package because of oversight or carelessness in the original grading or because of breakage before delivery to cold storage rooms, furnishes a considerable number of the bad eggs. In the summer stocks, heated eggs are an additional cause of bad eggs.

The net shrinkage in weight of eggs in case lots varies from approximately 3 to 4 ounces per month or about 30 to 40 ounces after a storage period of ten months. The shrinkage is due to the evaporation of moisture from the eggs.

FROZEN EGGS.

Frozen eggs are used in large quantities by bakers, noodle manufacturers and manufacturers of salad dressing and ice cream. This product is prepared from small, dirty, cracked, shrunken and heated eggs and also from current receipts. These eggs are not suited for storage in the shell, except for short periods. If removed properly from the shell and frozen promptly, they will retain their initial condition for a year or longer. No attempt should be made to use eggs of questionable quality, for a low grade product is bound to result and shipment into interstate commerce would be in violation of the Food and Drugs Act.

The preparation of frozen eggs is an economic industry. It withdraws from the market surplus quantities of edible eggs of a grade below firsts and makes them available the year around. The firms which use them can obtain eggs at a lower price than if they depended upon those in storage in the shell, and as frozen eggs are ready for use as soon as thawed, they are more convenient to use in large quantities than are shell eggs. Frozen eggs are put on the market in the form of whites, yolks, whole eggs or a mixture of white and yolks. A thirty-pound tin can is the ordinary package.

Plants preparing frozen eggs should have facilities on the premises for prompt freezing at a temperature of 10° F. or lower. When shipments are made over long distances to warehouses for long storage, good refrigerator cars properly iced and salted must be used. The packages should be so stowed in the car that they arrive at their destination in a frozen condition. They should be unloaded promptly and delivered to the cold storage holding rooms hard frozen. When withdrawn from storage they should be received by the baker or other customer still in a hard frozen state.

The standardized rooms, equipment and methods of operation, essential for the preparation of a product of uniform, good quality have been fully described in publications of the Bureau of Chemistry.[1]

DRESSED POULTRY.

Poultry going into cold storage must be fresh. It must be absolutely free from any visible or olfactory evidences of decomposition. Poultry for storage should be good for its grade. Well-fleshed birds keep better than thin birds.

The poultry should be "dry picked" and "dry packed." While "ice packed" poultry is sometimes held in cold storage and "scalded" poultry is frequently so handled, the type of dressing in each case is conducive to more rapid aging. Poultry which has been in contact with ice should never be cold stored.

Poultry should be packed in clean, well-made wooden boxes, usually 12 birds to the box, in either a single or a double layer. The box should be lined with a parchment or other suitable paper or each bird should be wrapped in paper. The box should be tight, not slatted, and not stripped. The habit of freezing barrel-packed chickens and fowls should be discouraged.

Dressed poultry is held in cold storage in a hard frozen condition. If poultry is accepted by the warehouse to be frozen as well as held, it should be placed in a "sharp" freezer, that is a freezer carrying a temperature below 5° F. for at least 48 hours. The boxes must be staggered or slatted and the stacks must be low and small enough to permit air circulation. If shelves constructed from brine-filling piping, such as used for fish, are available, the boxes of poultry should be placed on them. Through this method the period required for freezing is cut about one-half.

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[1] Pennington, M. E. Practical suggestions for the preparation of frozen and dried eggs. U. S. Department of Agriculture, Bureau of Chemistry, Circular 98. 1912.

Pennington, M. E. A bacteriological and chemical study of commercial eggs in the producing districts of the Central West. U. S. Department of Agriculture, Bureau of Chemistry, Bulletin 51. 1914.

Pennington, M. E. A study of the preparation of frozen and dried eggs in the producing section. U. S. Department of Agriculture, Bulletin 224. 1916.

Jenkins, M. K., and Hendrickson, Norman. Accuracy in commercial grading of opened eggs. U. S. Department of Agriculture, Bulletin 391. 1918.

Jenkins, M. K. The installation and equipment of an egg-breaking plant. U. S. Department of Agriculture, Bulletin 663. 1918.

Hard frozen poultry should be held at temperatures below 15° F. in rooms which are clean, dry and fairly constant in temperature.

Dressed poultry, properly prepared for storage, fresh, properly frozen and held, will maintain its quality for twelve months. While longer periods have not shown a loss in "wholesomeness," the loss in palatability is pronounced.

BUTTER.

Butter that is to be held in cold storage for several months should be made from cream of limited acidity. The cream should be pasteurized, cooled at once, and churned without further ripening. The kind of flavor that develops is determined almost entirely before the butter goes in storage. Butter containing a low percentage of salt keeps better than butter containing a higher percentage of salt.

The butter containers should conform to those styles regularly used in commerce. They include the 63 pound tub, the 63 to 78 pound cubes, and standard boxes for one pound prints.

To prevent the development of mold during the period prior to storage when the wooden tubs and cubes are used, the interior of the packages should be properly paraffined. A sprinkling of salt should be placed over the contents before adjusting the cover. When standard boxes for prints are used, the butter should be placed in the storage as quickly as possible. Storage rooms should be clean and free from all odors.

Deterioration and consequent change of flavor takes place much more rapidly when fresh-made butter is exposed to relatively high temperatures. Therefore this product, when intended for a long storage period, should be placed in the regular storage temperatures as quickly as possible, both to assure the keeping quality while in storage, and after it has left storage for the movement to the consumer.

Butter should be stored at 2 degrees Fahrenheit and below, to secure the best results. While butter stored at higher temperatures may not become unwholesome, changes which reduce its commercial value take place more quickly.

Care should be exercised in the stowing of the packages in the storage rooms so that a free circulation of air beneath and through the pile is permitted. This is particularly true of cube and box packages, which should be separated by one inch dunnage. It is also necessary that the stowing be done in such a way that separate lots may be available for easy inspection.

FISH.

Only fish in prime condition should be frozen. As the time between catching and freezing should be reduced to a minimum, it is well to locate fish freezers at or near the fishing grounds. Fish which have been shipped long distances from the landing point by express or freight packed in ice should not be selected for freezing.

Fish should be washed clean before freezing. Whether they should be frozen "gutted" or "in the round" depends upon the variety of the fish, the size of the fish, and the character of the feed.

Small and medium sized fish are placed in pans to be frozen. Large fish are frozen separately. Very small fish and fish for bait may be "stacked" for the initial freezing.

Freezing should be done at the lowest obtainable temperatures. Generally the temperature of the sharp freezer is between —5° to —15° F. The pans of fish are set on shelves made of refrigerator pipes carrying brine or ammonia. Pan fish should be solidly frozen in 24 hours or less. The holding temperature for fish should be between 0° and 10° F.

Frozen fish should be "glazed," that is, coated with a thin layer of ice formed by passing them a few times through a tank of cold water. Frozen, glazed fish are preferably stored in wooden boxes containing 120 to 160 pounds. When fish are stacked in the holding freezer, or placed in bins and covered, they are glazed by spraying with water. Fish stored more than three months should be reglazed every three or four months during the entire storage period.

Fish can be held without loss of quality for at least twelve months. Some species have been held in good condition for two years.

UNITED STATES DEPARTMENT OF AGRICULTURE

SUITABLE STORAGE CONDITIONS FOR CERTAIN PERISHABLE FOOD PRODUCTS

(This table should be used in connection with the text of Bulletin No. 729).

PRODUCT.	HANDLING FACTORS.		WAREHOUSE REQUIREMENTS.						OTHER CONSIDERATIONS.		
	PRE-STORAGE HANDLING AND CONDITION WHEN PLACED IN STORAGE.	VARIETIES AND GRADES.	A—CONSTRUCTION.	B—TEMPERATURE.	C—HUMIDITY.	D—STOWING.	E—CONTAINERS.	F—INSPECTION.	STORAGE PERIOD.	SHRINKAGE.	REMARKS.
APPLES.	Apples should be picked when well matured but not over-ripe. In all the operations of picking, packing and hauling they should be so handled as to avoid bruising, skin punctures and other mechanical injuries; and they should be so graded as to be practically free from serious injuries caused by insects, diseases or mechanical means. It is essential that they be handled promptly from the orchard to the storage room and cooled quickly.	Only varieties which have a recognized storage period of three months or more should be considered.	Cold storage houses should be so constructed and equipped as to maintain practically uniform temperature and humidity conditions throughout the storage season. Common storage houses should be sufficiently insulated to prevent freezing, and should be provided with the necessary inlet and outlet vents to permit adequate ventilation and temperature regulation.	Cold storage temperature range should be 31° F. to 32° F. for the storage of apples. Common storage temperature should be maintained at from 31° F. to 36° F. after the initial cooling of the fruit.	Humidity range, 80 to 90 per cent.	Apples should be stowed with sufficient spacing to permit of free air circulation, and to render each lot readily accessible for inspection and withdrawal.	Containers shall be clean, strongly built barrels, boxes or crates, and when packed for market shall be plainly marked with the grade, variety and the grower's or packer's name.	All lots of apples should be inspected when received for storage by a qualified inspector. Subsequent inspections of representative packages of all lots should be made at intervals of 15 to 30 days, depending on the variety and condition of the fruit as indicated by previous inspections.	The usual cold storage period for winter varieties of apples is from three to six months, depending upon the variety and condition of the fruit when stored.	The shrinkage in cold storage is from 2% to 5%. In common storage the shrinkage is variable.	Attention is directed to the fact that a delay of one or more weeks between the picking and storing of apples greatly reduces the storage period of the product and results in early deterioration. The successful storage of apples is as much dependent upon the treatment they receive before being placed in cold storage as the conditions under which they are held in storage. See Department Bulletin No. 587.
POTATOES.	Potatoes should be well matured, and graded to conform to the specifications of the United States standard grades. Seed stock should be certified by a competent inspector.	All varieties harvested in autumn keep well in storage.	The building should be so constructed and insulated as to prevent fluctuations in temperature. Means for ample ventilation should be provided and all unnecessary light should be excluded.	Temperature range from 35° F. to 40° F.	Humidity range, 80 to 85 per cent.	When stowed in bags, boxes or crates, potatoes should be so piled as to permit free air circulation. Bulk potatoes should not be stored to a greater depth than 6 feet nor more than 60,000 pounds in a single compartment. They should be carefully handled to avoid unnecessary injuries.	Potatoes may be stored in clean burlap bags, barrels, boxes or crates; or when in bulk they should be stored in ventilated bins.	Potatoes should be inspected by a qualified inspector when received for storage, and again within 30 days. The frequency of the inspections thereafter will depend upon the condition of the potatoes as determined by previous inspections.	The usual storage period is from three to six months, depending upon the section of the country in which the storage is located, the type of the storage house and the condition of the stock. Allowing for a high percentage of deterioration, potatoes may be held in storage for a much longer period.	When potatoes are stored, in containers or in bulk, as specified in Column 6, the shrinkage may amount to about 7%, although it varies greatly.	Potatoes are usually stored in cellars and common storages, but are sometimes held in cold storages. See Farmers' Bulletin No. 847.
POTATOES (SWEET).	Sweet potatoes should be well developed, carefully handled to avoid bruising, and should be practically free from damage caused by disease, insect or mechanical injury. They should not be allowed to become chilled or frosted, and when placed in storage the surface should be dry and practically clean.	All varieties grown on a commercial scale.	The building should be so constructed that all light is excluded, and moderate changes in outside temperature will not quickly affect inside temperatures. Wood construction is preferable, and ample means for ventilation control should be provided.	While the potatoes are being stored, and for a period of ten days to two weeks thereafter, or until the potatoes are cured, a temperature of from 80° F. to 90° F. should be maintained. Thereafter, a uniform temperature of as nearly 55° F. as is practicable should be maintained. Ventilation and artificial heat are necessary to control temperature and moisture.	The percentage of humidity should not be so high that moisture is deposited on the walls of the storage house.	When stored in bins, the potatoes should be carefully poured from basket or crate into the bin. To allow free circulation of air, the bins should have slatted sides and floor, and at least 4 inches of air space on all sides. The bin floor should be raised 2 inches or more above the house floor. When stowed in crates, baskets or hampers, the containers should be stacked so as to allow circulation of air, and to avoid the crushing or breaking of the packages and the bruising of their contents.	Sweet potatoes are usually stored in bins, but may be stored satisfactorily in substantial crates, baskets or hampers which permit of a free air circulation.	The potatoes should be thoroughly inspected by a qualified inspector at the time they are put in the storage house, within 15 days after the beginning of the storage period and from 15 to 30 days thereafter.	The safe storage period is about four months. Under the most favorable conditions and good management sweet potatoes may be kept six months.	The shrinkage from loss of moisture is from 8% to 10% in bins, and somewhat higher in packages. An additional shrinkage of 5% should be allowed for decay.	It is recommended that sweet potatoes be not considered properly stored until they have passed through the curing period. See Farmers' Bulletin No. 970.
ONIONS.	The onions should be well ripened, dry and thoroughly air-cured when stored. Onions intended for storage should be practically free from damage caused by disease, insects or mechanical injury, and from other stock commercially known as culls.	All common varieties of onions, except those of the Bermuda type.	The building should be so constructed and insulated as to prevent fluctuations in temperature, and means for ample ventilation should be provided.	In cold storage the temperature range should be from 32° F. to 36° F. In common storage the same range of temperature should be maintained as nearly as possible, but with the proper ventilation, onions will keep well in common storage at higher temperatures.	Low humidity is desirable.	Onions should be stowed in suitable receptacles, as indicated under "Containers," and should be stacked in such a way as to permit of free air circulation throughout the lot.	The best containers are slatted crates, although baskets, hampers and bags are used successfully.	Thorough inspection should be made when the onions are placed in storage, and at intervals not exceeding 30 days. The frequency of the inspections thereafter will depend upon the condition at the previous inspection.	The usual storage period of onions with proper ventilation is six months.	The shrinkage should not exceed 10% or 12%.	See Farmers' Bulletin No. 354.
CABBAGE.	Cabbage must be of solid heads, practically free from injuries caused by insects and diseases. Heads should be cut with but few, if any, loose leaves adhering, and carefully handled from field to storage house. Special care should be used to avoid bruising and other mechanical injuries.	Danish Ball Head, or sorts with similar form and texture.	Well ventilated, frost proof root cellar or warehouse type of construction, with ample intake and outlet vents for quick cooling and ventilation, and equipped with slatted shelves supported on staging, so that the heads may be stored one layer deep, with at least 15 to 18 inches clear space around the walls of the building. The ceiling should be so constructed as to prevent drip on the product.	Temperature range, 32° F. to 36° F.	The humidity should be maintained as high as possible without actual deposition of moisture on the product.	Cabbage should be stored on slat shelves in single layers. The height of the staging and the number of shelves will be determined by convenience and dimensions of the building.	Containers are not generally used.	Cabbage should be inspected at intervals of from 15 to 30 days.	The storage period for cabbage extends from November to April—five or six months.	The shrinkage in cabbage is quite variable.	Stoves should be provided in common storages to prevent freezing in cold periods. See Farmers' Bulletin No. 433.
EGGS.	Eggs should be moved quickly from the producer to the warehouse. They should be carefully sorted and candled, so that none showing mechanical defects or noticeable deterioration is included in the storage stocks. No washed eggs should be stored.	The grades should conform to those generally adopted by the wholesale trade, until United States standards are promulgated.	Cold storage houses should be so constructed and equipped as to maintain practically uniform temperature and humidity conditions required for successful storage throughout the storage season.	Temperature range, 29° F. to 32° F.	Humidity range, 82 to 85 per cent.	Egg cases should be stowed so that separate lots may be easily inspected, and with ½ inch to 1 inch dunnage between the cases to insure space for free air circulation.	Eggs should be packed in clean, odorless, wood cases. Fillers should be of new No. 1 or medium straw or wood pulp board with flats over top and under bottom. Padding must be kiln-dried excelsior, cork shavings or corrugated straw or wood pulp board on top and bottom of each case. No pine excelsior should be used. The cases should be plainly marked with the grade.	Inspection of eggs should be at intervals of from 15 to 30 days, and the storage house should have daily attention from a competent warehouseman skilled in the handling of such structures and commodities.	The storage period for eggs should not exceed 12 months.	The shrinkage depends upon the humidity, and should not be more than 5.5%. Shrinkage should be calculated from net weight of products.	Rooms must be clean and odorless. See Bureau of Chemistry Circular No. 64.
FROZEN EGGS.	Eggs should be removed from shell in chilled, sanitary surroundings, and frozen immediately on dish shelf sharp freezers.	One grade for food. One grade for manufacturing purposes.	Same as for eggs.	Temperature range, 0° F. or below to 10° F. above.	The usual humidity at the temperature of storage.	Protect eggs from heat leakage at doors and elevator shafts.	Thirty-pound tin buckets are most common. The use of smaller tin cans is now increasing, due to wider use of this product.	Inspections of frozen eggs should be made about every 30 days.	No change in composition up to 24 months. After 12 months egg thickens slightly. Whites near top of can may become pink, due to iron under tin. Egg not injured as food thereby.	The shrinkage is not of commercial importance.	See Department Bulletin No. 51. Department Bulletin No. 224. Bureau of Chemistry Circular 98.
POULTRY.	Poultry should be dry picked, dry cooled, and dry packed at temperatures ranging from 30° F. to 35° F. for from 18 to 24 hours, then frozen at 6° F. or below.	The classes and grades should conform to those generally adopted by the wholesale trade, until United States standards are promulgated.	Same as for eggs.	Preferred temperature, 0° F. to 10° F. Admissible temperature, 12° F. to 14° F.	Same as frozen eggs.	Poultry should be so stowed that separate lots may be inspected easily, and protected from injury by heat leakage at doors and elevator shafts.	All poultry should be packed in clean, strongly built, odorless boxes, lined with parchment or other suitable paper, and should be plainly marked to indicate the grades and classes. Barrels are still admissible, especially for turkeys, but are less desirable than boxes.	All lots of poultry should be inspected by a qualified inspector when received for storage, and at intervals of 30 days or longer, depending upon the conditions found at the previous inspections.	The storage period for poultry should not exceed 12 months.	The shrinkage varies from 1% to 3%.	Water-cooled or ice-packed poultry should not be stored for long periods. Scalded birds deteriorate more rapidly than dry-picked. Drawn poultry should never be stored. See Bureau of Chemistry Circulars Nos. 64 and 70.
BUTTER.	Butter should be placed in cold storage within ten days after it is manufactured. When storage facilities are not available during this period, the product should be held in a temperature below 40° F.	The grades should conform to those generally adopted by the wholesale trade, until United States standards are promulgated.	Same as for eggs.	Temperature, 2° F. or below.	Same as frozen eggs.	Packages of butter should be so stowed as to permit a free air circulation beneath the pile, and so stacked that separate lots may be inspected easily. Cube and box packages should be separated by 1 inch dunnage.	Packages should conform to the regular commercial styles, including 63-pound tubs, 63 to 78-pound cubes and standard boxes of 1-pound prints.	All lots of butter should be inspected by a qualified inspector when received for storage, and at intervals of 30 days or more, depending upon the quality and condition of the lots at previous inspection.	The storage period for butter should not exceed 12 months.	In general, the shrinkage will run from ½% to 1%.	See Bureau of Animal Industry Bulletins Nos. 84 and 148.
FISH.	Fish should be placed in storage in a fresh condition, as indicated by their physical appearance.	Practically all kinds used for food.	Same as for eggs.	Hard frozen and glazed at temperature of —5° F. or below, and stored at 0° F. or below to 10° F., depending on the kind. For holding less than six months it is admissible to store at 12° F.	Same as frozen eggs.	Fish should be stowed as compactly as possible.	Fish are stored in boxes and in bulk.	Inspection of fish should be made at intervals of 30 days or more by a qualified inspector.	The storage period for fish should not exceed 12 months.	The shrinkage is not of commercial importance.	Boxed fish should be reglazed in three to six months. Stacked fish should be spray-glazed every three months or more frequently. See Department Bulletin No. 635.

Compiled by L. C. Franklin, C. W. Mann, and W. M. Scott, Specialists, Bureau of Markets, U. S. Department of Agriculture. 1918.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 730

Contribution from the Bureau of Entomology,
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPERS. December 24, 1918

I. THE GRAPE CURCULIO.[1]

By Fred E. Brooks,

Entomologist, Deciduous-Fruit Insect Investigations.

CONTENTS.

INTRODUCTION.

In many localities in the eastern part of the United States the grape curculio, *Craponius inaequalis* Say (Pl. I, *A—D*), may be classed as the most destructive insect attacking the grape. From some cause or causes which are not entirely clear, the insect is markedly local in its occurrence and within the bounds of its general range appears annually in destructive numbers in some localities whereas it remains practically unknown to grape growers in other districts near by. In places where it is abundant it may be expected to destroy each year from 35 to 100 per cent of fruit on all grapevines that do not receive protection of some kind.

The adult curculio is small and inconspicuous and a grape grower will frequently lose within a short time an entire crop of fruit, that had promised well, without being able to determine the nature of the enemy that caused the loss. He will know only that the grapes while

Note.—Acknowledgment is due Mr. C. R. Cutright, who was employed temporarily by the Bureau of Entomology to assist with the present investigation.

[1] *Craponius inaequalis* Say; suborder Rhynchophora, family Curculionidae, tribe Ceutorhynchini, subtribe Coeliodes.

growing became suddenly wormy and were ruined. Fortunately losses from this pest are easily preventable when an intelligent use is made of available means of control. The present bulletin gives an account of an investigation of this species that was carried out principally in a badly infested locality in Central West Virginia during the years 1916 and 1917.

ECONOMIC HISTORY.

This curculio seems first to have been noted as an enemy of the grape in the vicinity of Cincinnati, Ohio, in the year 1853 (2).[1] Walsh (5) states that it ruined fruit at Cobden, Ill., in the period 1863 to 1865 and at Hudson and Marietta, Ohio, from 1863 to 1867, and that in 1867 16 acres of grapes at Big Hill, Ky., were destroyed. He states also (4) that it was destructive at Carbondale, Ill., from 1864 to 1867. In 1890 Riley (15) quotes a correspondent from London, Ky., who said that the grape curculio was doing more damage than all else combined. In 1891 Webster (16) found the insect in Franklin County, Ark., and learned that it had been increasing there for at least 10 years and that it had become almost impossible to obtain crops of fruit without bagging the clusters. Brooks (30) quotes correspondents who showed that in West Virginia it was generally distributed and very destructive to grapes during the years 1899 to 1905.

SYNONYMY.

The grape curculio was first described in 1831 by Say (1) under the name *Ceutorhynchus inaequalis*, from specimens collected in Indiana, where, he states, many beetles were collected in the spring, resting upon a newly constructed fence. Le Conte (8), in his revision of Say's work, placed the species in the genus Coeliodes, but later (11) erected for it the genus Craponius. The synonymy, therefore, is as follows:

Ceutorhynchus inaequalis Say, 1831 (1).
Coeliodes inaequalis (Say) Le Conte, 1869 (8).
Craponius inaequalis (Say) Le Conte, 1876 (11).

COMMON NAMES.

On account of the larva's habit of attacking the seed as well as the pulp of the fruit, the common name "grape-seed weevil" was applied to the species by early writers. At present the common name "grape curculio" is in general use.

[1] Numbers inclosed in parentheses refer to "Bibliography," p. 16.

DISTRIBUTION.

The grape curculio has been recorded from the New England States (33) to Minnesota (25) and south to Missouri (7) and Florida (33). Within this range there are records of its occurrence in the following States: Arkansas, Florida, Illinois, Indiana, Kentucky, Minnesota, Missouri, New York, North Carolina, Ohio, Pennsylvania, Tennessee, and West Virginia.

FOOD PLANTS.

The adult curculios may be found upon the foliage and the larvæ within the fruit of probably all kinds of wild and cultivated grapes that grow in the localities where the insect is found. There are no records of either the adults or larvæ attacking under natural conditions the leaves or fruit of plants other than the grape. During the present investigation frequent search was made for the feeding marks of the beetles on the foliage of various kinds of plants, but they were not found elsewhere than on grape, nor were the beetles or the larvæ found about any other fruit. Brooks (30) states that beetles in confinement, when deprived of other food, fed on apple and cherry leaves and that one such female deposited an egg in the fruit of Virginia creeper (*Ampelopsis quinquefolia*). This egg hatched but the larva died at the end of two days.

RECENT INJURIES.

During the present investigation the following records were made showing the destructiveness of the curculio at French Creek, W. Va.: On August 14, 1916, several clusters of fruit were picked from an unsprayed Concord grapevine. The clusters bore 163 berries and of these 161 contained curculio stings. At least one-half of the berries had already dropped from the clusters on account of being infested with curculio larvæ. On August 18 of the same year the entire crop of fruit from another unsprayed Concord grapevine was gathered. The vine produced 2,382 fruits and of these 2,274, or 95.47 per cent, showed curculio injury and 108, or 4.53 per cent, were sound. Probably half the grapes originally on the clusters had dropped as a result of infestation, and were not counted.

On August 23, 1917, about 50 grapevines of different varieties growing about farmers' homes in the locality were examined. Counts showed that from 40 to 95 per cent of all unprotected fruit had been ruined by the curculio, the average loss being about 70 per cent.

RESISTANCE OF CERTAIN GRAPES TO CURCULIO ATTACK.

Opportunity was taken to note the extent of curculio injury to about 25 different varieties of cultivated grapes and to three species of wild grapes. The wild species were the fox grape (*Vitis labrusca*), the "pigeon" grape (*V. aestivalis*), and the "frost" grape (*V. cordifolia*). Under similar conditions one variety of cultivated grape will suffer about equally with another. Frequently a discrimination will seem to be shown by the curculio between varieties, since the fruit of one vine may be attacked more extensively than that of another in the same locality. Such discrimination, however, is usually due to the particular locations of the vines rather than to any varietal peculiarities. The fruit of vines trained on the side of a house or of those growing in isolated positions in a field will escape injury to a far greater extent than will that of groups of vines trained on wire, fence, or trellis. Of the wild species the fox grape suffers about equally with the cultivated varieties, the "pigeon" grape to a less extent, and the "frost" grape is very rarely attacked. The immunity from attack of this last species is probably due to its small size and to the fact that it develops much later in the season than do the other species.

THE LIFE CYCLE IN BRIEF.

The beetles appear upon grape foliage in the spring and feed for ten days or two weeks on the upper epidermis and parenchyma of the leaf before beginning to deposit eggs within the young fruit. The larvæ (Pl. I, *H*) from the eggs feed upon the pulp and seeds of the fruit until full grown when they leave their feeding place and pupate within pellet-like earthen cocoons (Pl. I, *J*) located at or just beneath the surface of the ground. In about three weeks the beetles issue from the cocoons and go to the grape foliage, where they feed rather freely on the upper surface of the grape leaves until cool weather in the fall drives them into hibernation.

A few relatively unimportant departures from the foregoing rule are recounted later in this paper.

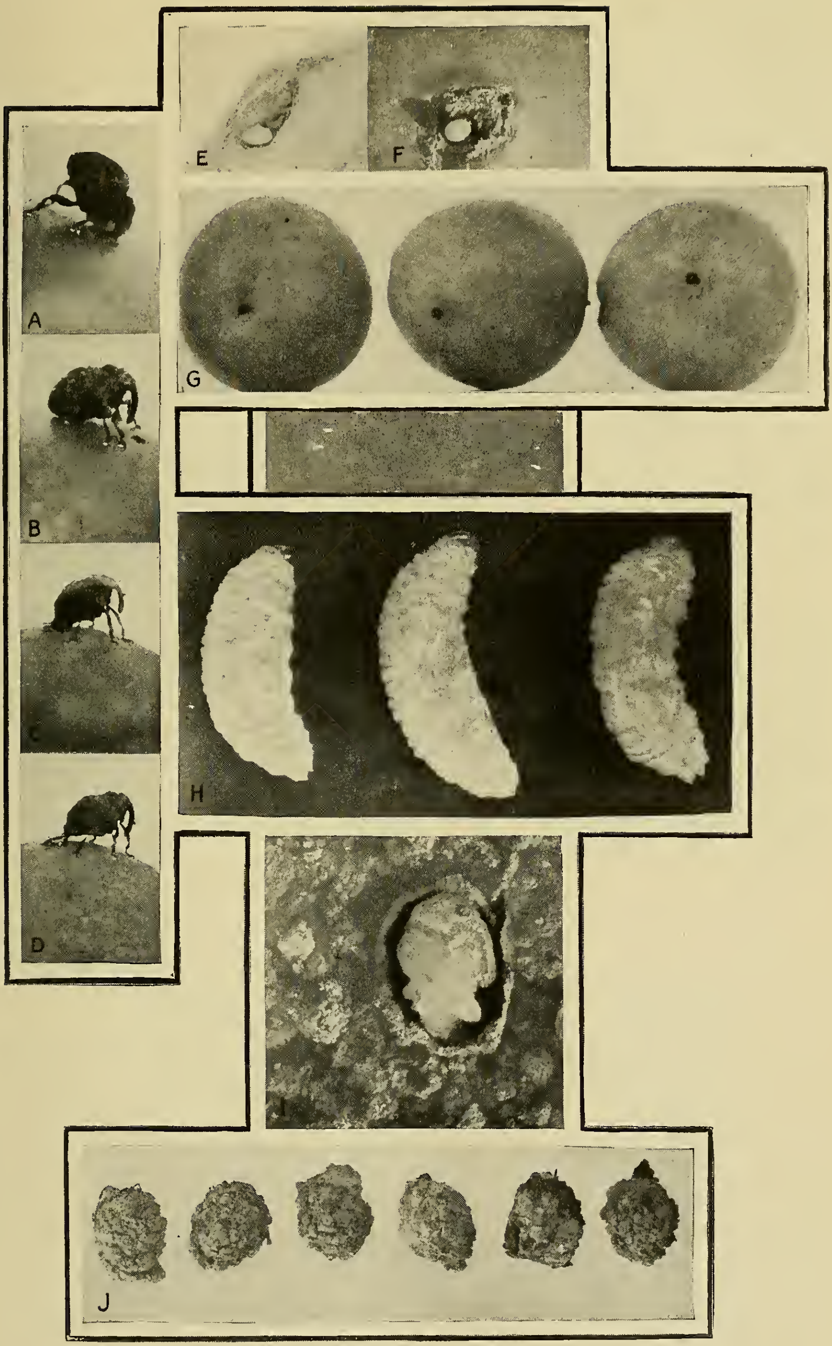
DESCRIPTION.

THE EGG.

The eggs (Pl. I, *E*, *F*) are rather uniformly oblong elliptical in shape. The surface is smooth and opaque, white when first deposited, but turning to yellowish on the second and third days. The average measurement of 10 specimens was 0.46 by 0.71 mm. The egg is attached to the wall of a roomy cavity which the female beetle with her snout excavates from the pulp of the grape through a small hole made in the skin.

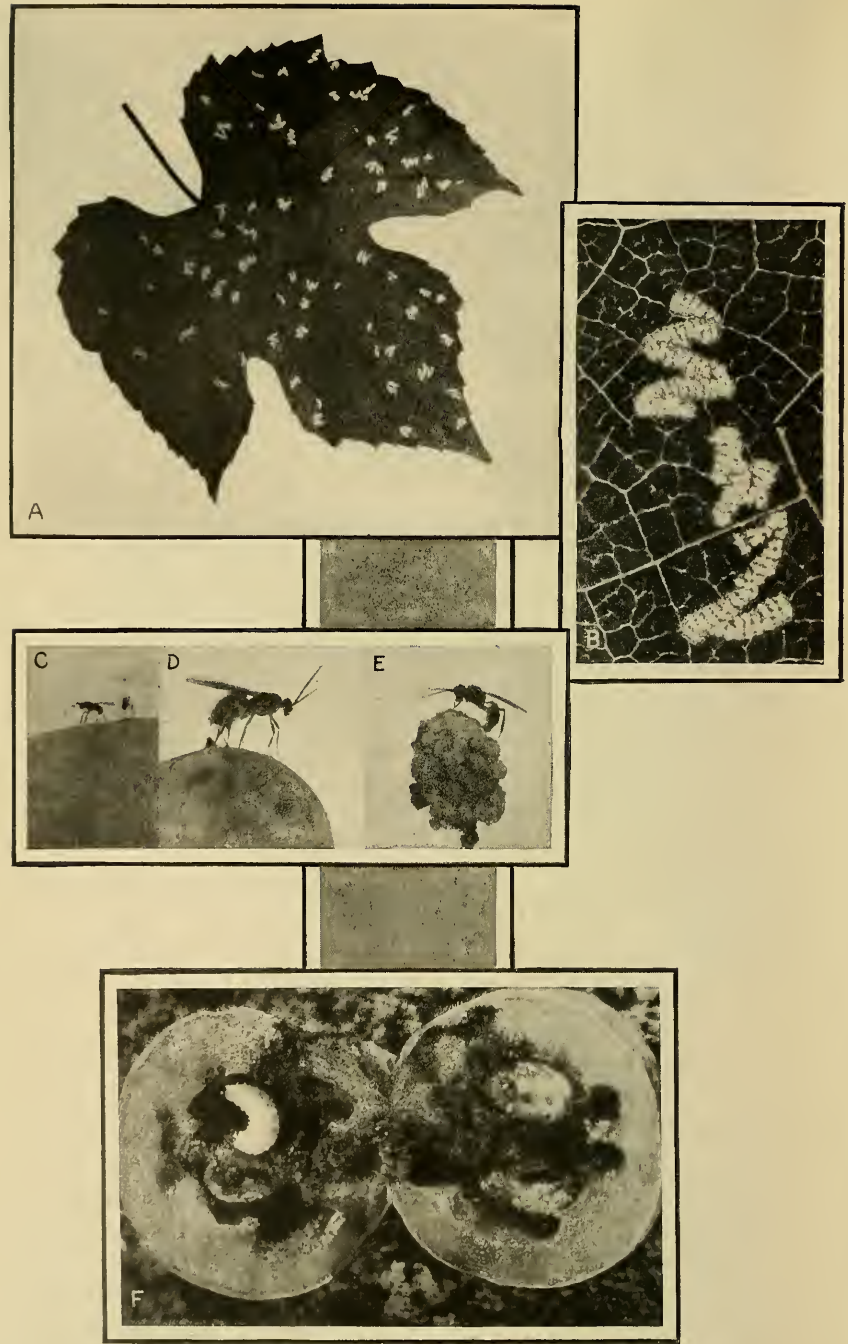
THE LARVA.

The legless, fusiform, curved larva (Pl. I, *H*; Pl. II, *F*) is white with light brown head, the body usually being clouded with the dark-colored contents of the alimentary canal. The average length is 7 mm. and



THE GRAPE CURCULIO.

A, Grape curculio excavating egg chamber; B, beetle resting by puncture in grape; C, beetle ovipositing; D, beetle sealing egg chamber; E and F, curculio eggs in natural position in grape; G, egg punctures in grapes after being sealed; H, larvæ; I, pupa in cocoon in soil; J cocoons. All enlarged. (Original.)



THE GRAPE CURCULIO AND ITS PARASITES.

A, Feeding marks of curculios in grape leaf, natural size; B, feeding marks, greatly enlarged; C, *Anaphoidea conotracheli* in act of ovipositing; D, *Microbracon mellitor* ovipositing in infested grape; E, *Stiboscopus brooksi* ovipositing in curculio cocoon; F, grape cut open to show injury by curculio larva. All enlarged except A. (Original.)

the width, at the widest point, 2 mm. The body is sparsely covered with short, fine hairs.

THE PUPA.

The pupa (Pl. I, *I*) is short, stout, and yellowish white, with the eyes and tip of rostrum reddish and with other dark markings developing as the adult stage is approached. The length is 3 mm. and the width 2 mm. The head and body are sparsely covered with long, stiff hairs. The pupa occupies a small, spherical cocoon formed of grains of earth, the cell having a delicate membranous lining.

THE ADULT.

The beetle (Pl. I, *A–D*) is short, robust, 3 mm. in length by 2.5 mm. in width, the snout being half as long as the body. The color, when fresh from the cocoon, is almost black, fading with age to chocolate brown. The surface is coarsely sculptured with prominent, acute tubercles on the thorax and elytra and the entire body is clothed with minute, whitish, scale-like hairs.

HABITS AND ACTIVITIES OF THE BEETLES.

At about the time Concord grapevines are blooming the grape curculio beetles emerge from hibernation and appear upon the grape leaves. Within the geographical range of the species the date of the first appearance of the beetles on the vines will vary considerably, according to season and locality. In West Virginia the dates of their first observed appearance on the vines are as follows:

Year.	Date.
1904	June 1
1905	May 25
1916	June 14
1917	June 2

Blatchley and Leng (33) record the beetles from central Florida from February 11 to April 13. At first the beetles are somewhat inactive and an individual may remain on a single leaf for a week or more at a time, feeding at intervals on the upper surface and sheltering during unfavorable weather on the underside. Feeding on the exposed part of the foliage is engaged in rather freely from the first appearance of the beetles in the spring until the fruit is ripe, thus rendering the beetles susceptible to arsenical sprays at any time while the fruit is on the vines. Food is also taken in a limited way from the bark of the fruit stems and the females devour the tissues removed in making their egg punctures (Pl. I, *G*) in the fruit. The immature grapes probably never are attacked by the beetles primarily for food, but the ripe fruit is sometimes punctured for this purpose.

The beetles frequently rest on the leaves for long intervals without motion and, even when eating or crawling about, their movements are so slight or so slow as not to attract attention. In appearance a beetle on the vines resembles more closely a small lump of brown earth than any form of animate life. While collecting, the writer has frequently mistaken them for the pellets of excrement dropped by sphinx caterpillars on the grape leaves. When disturbed they do not run or fly directly but leap to a considerable distance and either take wing while in the air or fall to the ground, simulating death. When caught and held closely in the hand they give forth a squeaking note pitched on an exceedingly high key. This note is heard also during sexual attempts of the male.

FEEDING MARKS.

The feeding marks on the leaves (Pl. II, *A*) are situated on the upper surface and extend only through the epidermis and parenchyma. Usually they are in the form of a slightly curved line, averaging about 2 mm. long by 0.5 mm. wide, or of from 2 to 10 such lines, joined at the ends to form acute angles. Under magnification the lines show distinct cross figurations. (Pl. II, *B*) These marks on the leaves usually may serve as the best means of determining the presence of the curculio in any locality, since in badly infested districts, especially in the autumn, the foliage is thickly specked with them. The health of the vine is not impaired to any appreciable extent by even great numbers of the marks, but this feeding habit is otherwise important as furnishing an easy means of control.

Careful measurement of 50 feeding marks showed that the average area covered by each was 3 square millimeters. In order that some idea of the individual feeding capacity of the beetles might be gained, 24 pairs were confined in jars and supplied daily with fresh grape leaves and fruit. Every morning counts were made of the marks on the leaves eaten by each pair. This was continued from July 9 to September 30, a period of 84 days. On the last-named date feeding was discontinued, all the beetles having died or entered hibernation. Table I shows the results of these counts.

TABLE I.—*Number of feeding marks made in grape leaves by 24 pairs of the grape curculio during the period from July 9 to Sept. 30, 1917.*

Pair No.	Number of feeding marks.	Pair No.	Number of feeding marks.
1	1,128	13	1,333
2	1,404	14	1,225
3	431	15	1,180
4	1,076	16	1,127
5	1,084	17	1,139
6	1,292	18	688
7	704	19	1,180
8	1,233	20	1,222
9	1,311	21	1,297
10	874	22	1,201
11	1,164	23	1,549
12	1,413	24	972
		Total	27,227

The records in Table I cover only a portion of the active life of the beetles, and it is certain that the specimens under observation had been feeding on the grape foliage for at least four weeks just prior to July 9, the day of the first record. It is also reasonably certain that at least a part of the beetles had fed for a time during the previous autumn before going into hibernation. On the day of the first record 280 feeding marks were made and the period of greatest feeding activity extended from that date to August 10. This was likewise the period of greatest egg production. On July 30 the beetles made 1,085 feeding marks, which was the maximum number, and on July 31 they deposited 244 eggs, which was also the maximum number. As is shown by Table I, the total number of feeding marks was 27,227, an average of slightly over 567 for each individual. The aggregate leaf surface eaten over by each beetle averaged slightly more than 2½ square inches and the total surface eaten by all the beetles would cover an area nearly four times the size of the printed portion of this page.

RELATIVE FEEDING CAPACITY OF THE SEXES.

During the egg-laying season the food consumed by a female in excavating her egg chambers is considerable, often surpassing daily in weight that of the insect itself. It was thought possible that the amount of fruit pulp eaten in this operation would result, for the time at least, in a decreased amount of leaf feeding by the females and render them less susceptible to arsenical sprays than are the males. Experiments, however, showed that the females do not decrease their leaf feeding during the oviposition period, and that, on the contrary, during days when egg production is heaviest leaf feeding may increase rather than diminish.

For a period of 14 days, from August 8 to August 21, 3 male and 3 female beetles were confined in cages separately and supplied daily with fresh grape leaves and fruit. During the period the males made 251 feeding marks, an average of 83.66 each, while the females made 313 marks, an average of 104.33 each. In addition, the 3 females excavated 125 egg chambers. The individual female which laid the greatest number of eggs made, also, the greatest number of feeding marks, the numbers being 54 eggs and 172 feeding marks. In another experiment, while 5 males were making 1,875 feeding marks an equal number of females under the same conditions made 2,185 feeding marks and excavated 717 egg chambers. It is thus seen that the opportunity for killing the females by poison sprays applied to the foliage during the egg-laying season is at least as good as for killing the males.

EGGS AND OVIPOSITION.

The eggs are placed singly in cavities eaten out of the fruit, the cavities averaging slightly more than 1 mm. deep by 2 mm. wide. (Pl. I, *E*, *F*) The wound is relatively large, and, even in cases where the eggs do not hatch, the hardening of the tissues about the cavity, which take place during the healing process, ruins the fruit for all purposes except that of juice extraction.

In ovipositing the female selects with some care a point, which may be at any place on the surface of the grape, and makes a small opening through the skin with her snout. Without changing her position on the grape she then excavates through the small opening all the pulp within convenient reach of the snout, the completed cavity extending back beneath the body of the beetle. (Pl. I, *A*) All the pulp removed is swallowed, and excrement is voided in small quantities during the operation. When the cavity is finished the beetle turns around, as though on a pivot, and places the tip of the abdomen over the opening in the skin. (Pl. I, *C*) On several occasions as the beetle was in the act of turning, a section of the grape was cut away by the observer so as to expose the lower end of the egg chamber, thus permitting oviposition to be watched from within through a hand lens. This showed, immediately following the appearance of the tip of the abdomen at the opening, a slender ovipositor extended and moved about touching the sides of the chamber. The ovipositor was then withdrawn into the body, but a few seconds later it was suddenly extruded to its full length and pointed rigidly forward, and at this time the movement of the egg could be seen passing down the duct. The tip of the abdomen at the moment was in contact with the wall of the chamber at the point farthest from the opening in the skin, and the egg was ejected and attached at this point (Pl. I, *E*), after which the ovipositor was slowly withdrawn into the body.

After the egg is deposited the beetle ejects a mass of excrement over the opening in the skin (Pl. I, *D*), presses some of the more solid matter of the excrement into the opening with the tip of the abdomen, and then moves away. This excrement soon dries and seals the cavity (Pl. I, *G*). Frequently the female is attended by a male during the preparation of the egg chamber and the work is interrupted by copulation. Table II shows how the time was observed to be divided in six instances where the duration of the different steps was recorded.

TABLE II.—*Time spent in oviposition by the grape curculio.*

Beetle No.	Minutes excavating.	Minutes copulating.	Minutes ovipositing.	Total minutes.
1	7	22	3	32
2	16	0	7	23
3	17	17	3	37
4	18	18	3	39
5	12	13	2	27
6	24	16	2	42
Average	15.6	14.3	3.3	33.3

There are occasional but rare departures from the method of procedure in egg laying as just described. For example, two or three egg chambers were found containing two eggs each, and on one occasion a female was observed to complete her egg chamber and then deposit an egg on the grape near the puncture. She then pushed the egg into the opening with her snout and sealed the chamber in the usual manner. A few eggs were found in excavations in the fruit stems, but the larvæ which hatched from them were not able to subsist on the food at hand.

OBTAINING EGG RECORDS.

For obtaining egg records a large number of beetles were collected from grape foliage early in the season and confined with food in cages. As fast as they could be found mating in the cages they were removed and confined by pairs in glass tumblers. The tumblers were covered with cheesecloth and the beetles provided daily with fresh leaves and fruit. Twenty-four pairs were thus obtained and kept in an open insectary throughout the season. So far as could be determined, by comparing the activities of the beetles in the glasses with those of beetles in the field, egg laying proceeded in the insectary in a normal manner.

Every morning counts were made of the eggs deposited during the preceding 24 hours. Table III shows the result of these counts and is believed to represent with fair accuracy the individual egg-laying capacity of the beetles.

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TABLE III.—*Egg-laying record of 24 female grape curculios.*

Date.	Beetle No.—																								Total.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
July 3	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
5	1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	7
6	6	1	0	2	0	3	0	0	1	0	0	0	0	0	3	0	0	0	2	0	3	0	2	0	23
7	4	2	4	2	4	3	1	1	5	0	0	0	3	0	1	0	2	3	3	0	2	1	0	0	41
8	5	4	2	4	3	6	3	4	4	1	3	5	3	0	4	0	7	4	4	3	3	5	5	4	86
9	4	4	3	4	0	5	4	3	4	1	0	0	5	3	5	1	0	5	1	1	3	0	0	5	61
10	5	1	0	7	6	4	0	3	4	2	0	1	2	3	4	2	7	3	3	1	4	2	4	3	71
11	4	4	3	6	3	10	0	2	4	0	0	2	7	4	4	0	5	5	4	4	2	7	1	3	84
12	4	5	3	6	4	6	7	5	5	1	3	5	5	3	0	3	7	4	2	4	4	3	5	3	97
13	8	6	4	7	2	7	6	4	5	2	4	1	4	1	5	3	5	4	5	0	4	4	4	6	101
14	7	5	4	9	4	9	9	7	6	5	4	4	6	6	5	6	6	5	7	6	7	7	4	5	143
15	8	5	3	6	7	10	3	5	6	5	4	5	8	6	5	6	6	6	6	6	4	3	5	4	132
16	9	9	5	6	10	9	6	8	7	4	6	8	7	6	7	5	8	7	6	7	6	8	6	5	165
17	6	7	5	8	5	9	4	6	6	5	4	7	8	5	6	6	8	4	6	6	5	6	5	5	142
18	6	5	4	5	6	9	9	4	4	5	4	8	6	7	5	6	4	6	5	5	3	8	5	3	132
19	7	8	3	8	9	9	9	7	7	7	8	5	9	9	9	9	5	4	4	10	8	6	8	6	174
20	10	5	6	12	11	11	9	9	7	8	4	11	11	8	8	8	5	8	7	6	7	6	8	5	190
21	7	9	6	13	8	11	9	5	6	8	8	9	7	11	8	7	8	8	7	7	6	11	9	5	193
22	10	8	6	8	8	11	10	8	7	9	6	8	10	7	7	9	9	8	9	9	5	5	9	6	192
23	9	9	7	10	10	12	5	8	8	8	6	10	11	8	9	5	9	7	6	10	6	7	10	5	195
24	9	10	5	14	10	12	12	10	10	7	8	10	11	10	11	12	4	10	7	10	6	12	12	7	229
25	9	7	9	10	10	10	7	8	7	9	8	10	11	9	9	9	10	8	9	8	5	8	9	6	205
26	12	10	8	14	12	12	11	9	8	9	7	10	9	9	8	7	9	8	9	11	6	10	11	7	226
27	9	8	8	9	12	12	12	7	8	10	5	10	13	11	10	10	10	8	7	9	5	8	11	4	216
28	8	8	2	12	7	10	7	4	0	4	8	8	5	6	6	6	5	7	6	10	4	5	7	5	150
29	10	8	10	12	11	13	12	10	12	10	4	11	8	12	12	11	11	7	8	12	6	8	13	2	233
30	10	8	6	10	11	8	12	9	8	8	9	10	13	9	8	9	8	12	9	10	7	11	9	10	224
31	12	12	6	16	14	15	10	7	6	8	6	12	12	9	12	13	11	8	8	11	7	11	13	5	244
Aug. 1	9	8	7	14	10	14	12	9	7	4	9	7	14	11	10	11	12	10	10	11	8	12	8	6	233
2	10	9	6	9	11	11	5	5	6	1	7	8	9	5	7	8	6	5	7	8	5	6	11	6	171
3	6	5	4	8	6	6	3	6	4	0	3	6	6	8	4	4	4	4	5	4	5	5	8	4	118
4	6	7	4	8	5	7	4	3	5	0	6	4	6	7	6	1	8	4	7	6	4	6	8	4	126
5	12	8	6	10	10	10	9	8	6	0	6	10	9	8	8	1	9	7	8	7	7	12	8	1	180
6	8	7	5	12	8	12	8	7	5	0	2	7	8	7	7	0	10	5	4	8	5	8	7	2	152
7	5	7	4	8	9	7	5	2	5	0	8	6	6	5	8	0	6	4	10	6	6	3	8	4	132
8	6	6	5	8	6	8	7	3	5	0	4	7	6	7	3	2	7	6	5	5	4	3	4	3	120
9	7	5	3	8	8	8	6	3	4	0	4	7	7	6	6	1	7	5	6	5	2	7	9	4	128
10	3	4	4	6	4	7	5	4	5	0	1	4	4	4	4	0	4	5	4	4	3	4	4	3	90
11	5	4	2	6	4	6	4	4	4	0	3	6	5	5	4	1	3	3	4	6	2	4	4	2	91
12	4	5	5	9	9	6	1	1	5	0	3	7	7	8	2	4	8	7	3	6	3	8	3	7	121
13	4	3	4	9	4	8	7	2	2	0	2	5	6	3	2	0	6	6	4	6	3	6	2	4	98
14	2	7	3	8	5	8	7	1	1	0	2	8	6	6	0	1	6	4	4	5	4	6	1	2	97
15	3	3	3	8	2	6	3	1	3	0	2	5	3	5	1	0	4	4	4	6	2	7	0	2	77
16	0	5	2	6	3	10	3	3	6	0	0	7	5	6	0	2	5	5	0	4	0	6	0	1	79
17	2	4	4	8	4	5	3	2	5	0	1	5	3	7	0	0	4	6	6	3	2	6	0	2	82
18	0	1	2	3	2	2	1	0	0	0	0	2	3	2	0	0	0	4	1	5	1	5	0	0	34
19	0	3	2	2	2	4	1	1	4	0	0	4	2	4	1	0	2	4	1	2	0	9	0	2	50
20	0	0	2	3	0	1	1	2	3	0	2	0	2	2	0	0	1	4	2	4	0	9	0	0	38
21	0	0	0	3	2	2	0	1	1	0	0	0	1	2	0	0	0	4	3	2	0	5	0	0	26
22	1	0	1	0	0	0	0	1	0	0	0	0	1	3	0	0	0	5	0	2	0	5	0	0	19
23	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	1	2	0	7	0	1	18
24	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	2	0	3	0	0	9
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	4
26	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	0	0	2	0	0	0	1	0	0	7
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3
28	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	1	0	0	1	0	0	1	7
29	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	5
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Sept. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	295	269	202	378	301	386	274	223	245	141	185	286	313	285	248	191	282	283	249	285	196	321	262	180	6,280

As indicated in Table III, the total number of eggs laid by the 24 females was 6,280. The minimum number laid by an individual was 141 and the maximum number 386, the average for the 24 beetles being 261.66.[1] The first eggs were deposited on July 3 and the last on September 5, oviposition by all the beetles covering a period of 65 days. The greatest number of eggs laid by a female in a single day was 16, and this record was made in only one instance. Another beetle laid 15 eggs in a day and there were six cases in which 14 eggs were laid in a day. The period of greatest egg production was from July 13 to August 12, 81.9 per cent of the eggs being deposited between these dates. The maximum number of eggs for one day was 244; these were produced on July 31.

ACTIVITY OF THE BEETLES AT NIGHT.

During the progress of the investigation it became apparent that the beetles were ovipositing and feeding on the leaves to some extent during the night, and, to obtain data on this point, 5 pairs of beetles were confined in cages in the insectary on July 19 and kept under observation until August 3, a period of 14 days. The beetles were provided with fresh grapes and leaves three times daily, at 5 a. m.,[2] 12 m., and 7 p. m., the duration of the forenoon period being 7 hours, that of the afternoon period 7 hours, and that of the night period 10 hours. Each time the grapes and leaves were changed in the cages counts were made of the eggs and leaf-feeding marks produced during the period just ended. The counts showed a total of 455 eggs produced by the 5 females for the entire period. Of this number 85 were deposited during the forenoon period, 148 during the afternoon period, and 222 during the night period. The average was 16.6 eggs for each of the 14 hours of daylight and 22.2 eggs for each of the 10 hours of darkness. Feeding on the leaves was more active by day than by night. The 10 beetles during the daylight periods made 1,072 feeding marks, or an average of 78 for each of the 14 hours of daylight, and 376 during the night period, or an average of 37.6 for each of the 10 hours of darkness.

TIME REQUIRED FOR EGGS TO HATCH.

About 50 eggs deposited on July 17 hatched on July 23 and an equal number deposited on July 21 hatched on July 27, the period of incubation in both cases being 6 days. Differences in temperature probably would produce a variation of a day or two in the length of this period.

All the eggs of a female that had been separated from males for 33 days were found to be fertile, although in nature copulation continues at frequent intervals until the end of the egg-laying season.

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[1] It is interesting to note that the average number of eggs laid by 30 females from which a record was obtained in 1905 (30) was 257.46, a difference per individual for the two lots of beetles of only 4.2 eggs.

[2] All references to clock time refer to "Standard time."

ACTIVITIES OF THE LARVÆ.

The young larvæ begin to feed on the grape berry before they are free from the eggshell and within a few minutes after emergence from the shell burrow out of sight within the pulp. On the second or third day they attack the seed and on the fourth day practically all the larvæ are located within the seed cavity of the grape berry. Later they leave the seed cavity and continue to feed on the pulp, soon converting the interior of the grape into a discolored mixture of pulp and excrement. (Pl. II, *E*)

Larvæ reached full growth and issued from the grapes in from 13 to 25 days after the deposition of the eggs. Table IV shows the number that appeared on each day.

TABLE IV.—*Number of days elapsing from deposition of eggs by the grape curculio to issuance of larvæ from the grapes.*

Number of days in grape	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of larvæ issuing	2	5	51	71	29	37	17	10	11	7	1	3	3

According to Table IV, allowing 6 days for the eggs to hatch, the larvæ remain in the grapes from 7 to 19 days, the average time being from 10 to 12 days.

The larvæ squeeze through small holes which they make in the skin of the grape berry and seek at once for places in which to pupate. Most of the larvæ leave the grapes during the morning hours, although a few continue to appear during the afternoon. On August 4, 1917, 57 larvæ dropped from a basket of infested grapes suspended in the vineyard over a container. At the end of every hour the larvæ in the container were collected and counted. The results are shown in Table V.

TABLE V.—*Time of day in which larvæ of the grape curculio leave grape berries.*

[Standard time.]

	A. M.								P. M.		P. M. to A. M.
Hours of day	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–4
Number of larvæ	0	2	7	17	13	5	2	5	5	1	0

Table V indicates that more than one-half of the larvæ leave the grapes to pupate between the hours of 7 and 9 in the morning. Most of the cocoons are constructed on the surface of the ground except in cases where the larvæ follow cracks or other openings into the soil. They are frequently placed under fallen leaves or other small objects and are sometimes attached to straws or stones lying on the surface of the ground.

THE PUPA PERIOD.

Small lots of larvæ which had just issued from grapes were placed in jars containing earth on August 1 and 2, 1917. From these larvæ 46 beetles developed, of which 37 emerged on the eighteenth day and 9 on the nineteenth day. This and other observations indicate that in the warmer part of the summer the beetles issue, on an average, about 18 days after the construction of the cocoon. The larvæ that leave the grapes late in August and in September pupate and remain within the cocoon until the spring following, when they issue as beetles at about the time the wintering beetles are emerging from hibernation.

THE BEETLES IN THE FALL.

The young beetles that appear late in summer spend all the remaining warm days of the season on the grape foliage. They feed rather freely and can be distinguished very readily from the old beetles which are still on the vines by their fresher appearance and darker color. Many of the beetles that appear from hibernation or from wintering pupæ in the spring live through the entire season and enter hibernation again in the fall. Of the lot of 48 beetles kept in glass tumblers for the purpose of obtaining egg records throughout the summer of 1917, 36 were still alive on October 4. At that time the 36 beetles were placed in a large jar containing dry, decayed wood and soon thereafter they hid away in the wood fragments and became dormant. There is considerable mortality among the beetles soon after they appear upon the vines in the spring, and the probability is that most of the beetles that die at that time are the individuals that have survived two winters.

NATURAL ENEMIES.

PREDACIOUS FORMS.

At the time the grape curculio larvæ leave the grapes and crawl over the ground in search of suitable places to pupate, they fall an easy prey to ants and other enemies. In the summer of 1917 a small red ant, determined by Wheeler as *Solenôpsis molesta* Say, was observed in great numbers feeding on larvæ beneath infested grapevines. Another ant, determined by Wheeler as *Aphaenogaster fulva* Roger, subspecies *aquia* Buckley, variety *picea* Emery, was present in less numbers and was observed attacking the larvæ. A small ground-dwelling spider, as yet undetermined, was seen to pounce upon a curculio larva and was caught as it hurried with its load beneath a stone. The larva of a rove beetle, *Philonthus brunneus* Gravenhorst, and the following species of ants are recorded as attacking the curculio larva: *Camponotus pennsylvanicus* De

Geer, *Myrmica punctiventris* Roger, *Lasius americanus* Emery, *Cremastogaster lineolata* Say, and *Solenopsis debilis* Mayr.

PARASITES.

In August, 1916, it was found that many of the curculio eggs were being destroyed by a minute hymenopterous parasite, determined by Girault as *Anaphoidea conotracheli* Girault Pl. (II, *C*), a well-known egg parasite of the plum curculio, *Conotrachelus nenuphar* Herbst. This parasite is about half a millimeter in length and is barely visible to the naked eye. The legs and bases of antennæ are light brown and the rest of the body is black. In 1917 this parasite was again abundant and was observed frequently ovipositing in the curculio egg punctures in grapes. When a fresh puncture was made by the grape curculio several of these egg parasites would collect about it and could be seen through a lens, thrusting their ovipositors through the skin of the grape into the curculio eggs in the egg chamber. Males usually were present and copulation would take place while the females were struggling with one another for a desired position over the egg chamber. Adult parasites issued in from 10 to 13 days after their eggs had been deposited within the eggs of the grape curculio. When the mature parasites leave the host eggs they sometimes enter the pulp of the grape and mine through it to the surface, making a threadlike burrow half an inch or more in length. The exit hole of the parasite in the skin of the grape is usually near to the original puncture of the curculio.

In determining the extent of parasitization by this species, about 50 curculio beetles were confined on July 24, 1917, in a wire-screen cage over a live branch of grapevine bearing 8 bunches of sound fruit. Two days later the cage and curculios were removed and the punctured grapes left exposed for six days to the attacks of the egg parasites. A later examination showed that 134 curculio eggs had been deposited in the grapes and of these 53, or 39.5 per cent, had been parasitized. The oviposition period of the curculio is sufficiently long for the development of four or five successive generations of the parasite. This may account for an apparently constant increase in the percentage of parasitized curculio eggs as the season advances.

Another parasite, *Microbracon mellitor* Say (Pl. II, *D*) was observed frequently ovipositing in infested grapes on the vine and on the ground. The larva of this species attacks the larva of the curculio externally and devours it, after which it constructs within the grape a small, dirty-white cocoon from which the adult parasite escapes within a few days. A third hymenopterous parasite, *Stiboscopus brooksi* Ashm. (Pl. II, *E*), attacks the curculio while within the cocoon. This parasite is about 4 mm. in length, the ovipositor being one-third as long as the body. The head and thorax are shining black, the abdomen brown, the tips of antennæ dark brown, and the bases of antennæ and the legs light brown. It runs rapidly over the ground under infested grapevines, frequently crawling beneath fallen leaves and into openings in the ground in search of curculio cocoons. When one is found the parasite manifests much excitement and runs about over the cocoon, with both antennæ and ovipositor applied to the surface, in search of a vulnerable point of attack. When such a point is located the ovipositor is thrust viciously to its full length within the cocoon, after which the insect remains quiet for a few seconds while the egg is being deposited. The parasitic larva destroys the curculio within the cocoon and issues as an adult within a short time. Both this species and *Microbracon mellitor* were abundant in the locality where the present investigation was carried out. A single specimen of still another parasite, which has been determined by Mr. R. A. Cushman as *Triaspis curculionis* Fitch, was reared from the grape curculio in 1917.

METHODS OF CONTROL.

SPRAYING.

The long period during which the curculio beetles feed freely on the upper surface of the grape leaves renders them peculiarly susceptible to arsenical sprays. In several cases practically complete freedom from attack was obtained by applying two sprays of lead arsenate at a strength of 3 pounds of the paste to 50 gallons of water, the first just after the blossoms had dropped and the second three or four weeks later. In August, 1917, a count of several thousand fruits of different varieties of grape from sprayed vines showed that only a little more than 1 per cent of the fruit was infested, while on unsprayed vines in the same locality from 75 to 90 per cent of the fruit was punctured.

On July 26 a Concord grapevine was sprayed with lead arsenate at a strength of 3–50. As soon as the spray was dry a branch of the vine bearing leaves and several bunches of sound fruit was inclosed in a wire-screen cage in which 50 male and female curculio beetles had been placed. Four days later, when the cage was removed, all the beetles were dead. The grapes which had been in the cage contained 8 eggs and there were about 50 feeding marks on the leaves, indicating that the death of the beetles resulted from a small amount of feeding. At about the same time another grapevine was sprayed with a tobacco extract containing 40 per cent of nicotine as sulphate at the rate of 1 pint to 800 gallons of water, and a fruiting branch inclosed with 40 beetles. At the end of 4 days 38 of the beetles were still alive in the cage, 119 eggs had been deposited in the fruit, and 1,136 feeding marks had been made on the leaves.

It is possible to destroy the beetles by spraying with arsenicals at any time during the growing season of the fruit, or in the fall after the fruit has been gathered. Preferably, however, a spray shuold be applied in the spring soon after the blossoms have dropped and another three or four weeks later. This is the season when other grape insect pests and fungous diseases are to be dealt with and the sprays can be prepared and applied for combined results. As has been pointed out, the beetles are feeding on the foliage for 10 days or more before oviposition begins and practically all may be killed by spraying before any injury is done to the fruit.

BAGGING.

Inclosing the clusters of fruit when about one-fourth grown in 1-pound or 2-pound paper bags affords complete protection against the curculio. The ordinary paper bags kept by grocers are sufficient for this purpose. The bags should be slipped over the clusters and the mouth pinned or otherwise fastened securely around the stem. The bags usually remain intact until the fruit is ready for gathering, and the grapes within ripen perfectly. This method of protecting the fruit, however, is much slower and more expensive than is spraying, and for protecting the fruit from the curculio the results are very little, if any, better than would be obtained by spraying.

OTHER METHODS OF CONTROL.

Cultivation of the soil under infested grapevines destroys the curculios to some extent by breaking up the cocoons and exposing the pupæ, or by burying the cocoons so deeply in the soil that the beetles on emerging from the cocoons are unable to work their way to the surface.

A measure of benefit also may be obtained by gathering and destroying the punctured fruit and by collecting the beetles by jarring them from the vines in the early morning or on cloudy days upon sheets spread on the ground beneath the vines.

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II. THE GRAPE ROOT-BORER.[1]

By FRED E. BROOKS, *Entomologist, Deciduous-Fruit Insect Investigations.*

CONTENTS.

INTRODUCTION.

The studies of the grape root-borer (*Memythrus polistiformis* Harris) described herein were conducted principally at French Creek, W. Va., during the summers of 1916 and 1917. Conditions there were favorable for the investigation, since the insect occurred abundantly and over a hundred badly infested grapevines were at the entire disposal of the investigator. Wild grapes of the species *Vitis labrusca, V. cordifolia,* and *V. aestivalis* abounded also in the locality, affording an opportunity for observations as to native host plants.

The grape root-borer in all its stages is peculiarly inconspicuous, and there is a possibility that the species is a more widespread and serious enemy of grapes than has been commonly supposed. The eggs (Pl. III, *E*) are small and dark-colored and are so placed by the female moth that they escape notice, the larvæ (Pl. III, *A, B*) feed exclusively on the roots and throw no castings to the surface of the ground, pupation takes place within the soil, and the adults (Pl. III, *C, D*) so closely resemble wasps of the genus Polistes that the casual observer does not distinguish between them and true wasps. Grapevines are rarely killed outright by the borers, but, on becoming infested, usually linger for years, making meager annual growth and bearing reduced crops of fruit (Pl. V). There is a probability that many vineyards suffer seriously from this insect while persons in charge of the vines remain unaware of the true cause of the trouble.

NOTE.—The author wishes to acknowledge the assistance of Mr. C. R. Cutright, field assistant in the Bureau of Entomology, in conducting the investigation described herein.

[1] *Memythrus polistiformis* Harris; order Lepidoptera, family Aegeriidae.

ECONOMIC HISTORY.

The grape root-borer is a native of the eastern part of the United States, and doubtless bred originally in the several species of wild grapes indigenous to that region. It was first described in 1854 by Harris (1, 2),[1] who recorded injury by the species in North Carolina. In 1867 Walsh (3) wrote of the species at some length and reported injury in Kentucky, Missouri, North Carolina, and Ohio. He quotes a correspondent who said he had noted injury by the root-borer in Missouri for 20 years. Riley (4), in 1871, mentioned the destructiveness of the species in Kentucky and recorded capturing the moths in Missouri. In 1873 Glover (5) reported, on the authority of a correspondent, that 5,000 vines, representing 107 varieties imported from Paris and planted at Albemarle, N. C., were lost as a result of attacks by this borer. Lugger (6) states that a single moth of this species was seen flying about a wild grapevine in Minnesota in 1898. Holland (7), in 1903, mentioned the range of the moth as extending as far north as Vermont. Brooks (8), in 1907, wrote of serious injury by the species in central West Virginia.

GEOGRAPHICAL DISTRIBUTION.

The grape root-borer has been recorded as occurring in the States of Kentucky, Minnesota, Missouri, North Carolina, Ohio, West Virginia, and Vermont. It very probably will be found in other States, where the inconspicuousness of the insect and its work have resulted so far in its being overlooked.

FOOD PLANTS.

Grapevines, so far as known, are the only plants attacked by this insect. Apparently all the common cultivated varieties of the eastern part of the country suffer about equally in this respect. Vines of the fox grape, *Vitis labrusca,* growing in a vineyard, were found to be attacked almost as extensively as Concord and other cultivated sorts, although vines of the same species growing in woods were not injured seriously. Vines of *V. cordifolia* and *V. aestivalis* were not observed to be attacked. The Scuppernong, a variety of the Southern fox grape, *Vitis rotundifolia,* is said by a correspondent of Glover (5) to have withstood attacks.

RECENT INJURIES.

During the past 10 years the writer frequently has observed serious injury by the grape root-borer in a few sections of West Virginia. Vines have been seen in other localities which had every appearance of being infested, but, since the borers can be found only by digging

[1] Numbers in parentheses refer to "Literature cited," p. 28.

to the vine roots, no examination was made and positive evidence of their presence is lacking. A number of old vines are known that have been infested constantly for at least 10 years. In cases where these vines have been pruned, cultivated, and fertilized a strong annual growth of wood is still made and the crops of fruit are satisfactory. Infested vines when neglected, however, in all cases observed have practically ceased growing and died by degrees over a period of several years.

NATURE OF INJURY.

Injury to grapevines by the root-borer is due exclusively to the burrows made by the larvæ in the roots (Pl. III, *A*, *B*), and is usually in the nature of severe root-pruning. The newly hatched larvæ enter the ground in the vicinity of grapevines and penetrate the soil in search of roots, attacking them wherever found. Usually roots smaller in diameter than an ordinary lead pencil are not made a place of permanent attack. Those half an inch in thickness, and often those that are larger, are girdled or eaten entirely off, only a stump of live root being left to help sustain the vine. Frequently all the main roots of a vine will be severed at varying distances from the root center. In such cases the remaining root stumps hasten to send out branch roots, the vigor and extent of growth of the branches depending largely upon the cultural care the vine is receiving at the time.

DESCRIPTION.

THE EGG.

(Pl. III, *E*.)

The egg is 1.1 mm. long by 0.7 mm. wide, chocolate brown, oblong ovate, and flattened; one end is slightly truncate, and a broad furrow extends longitudinally on one side. The surface, except in the furrow, is finely and distinctly reticulate.

Eggs hatch in from 18 to 23 days.

THE LARVA.

(Pl. III, *A*, *B*.)

When first hatched the larva is dingy brown and about 2 mm. in length. After the first or second molt the color changes to white. The head is brown and the body is distinctly segmented and covered sparsely with short, stiff hairs. Full-grown specimens are from 35 to 40 mm. in length. The larva stage covers a period of nearly two years.

THE PUPA AND COCOON.

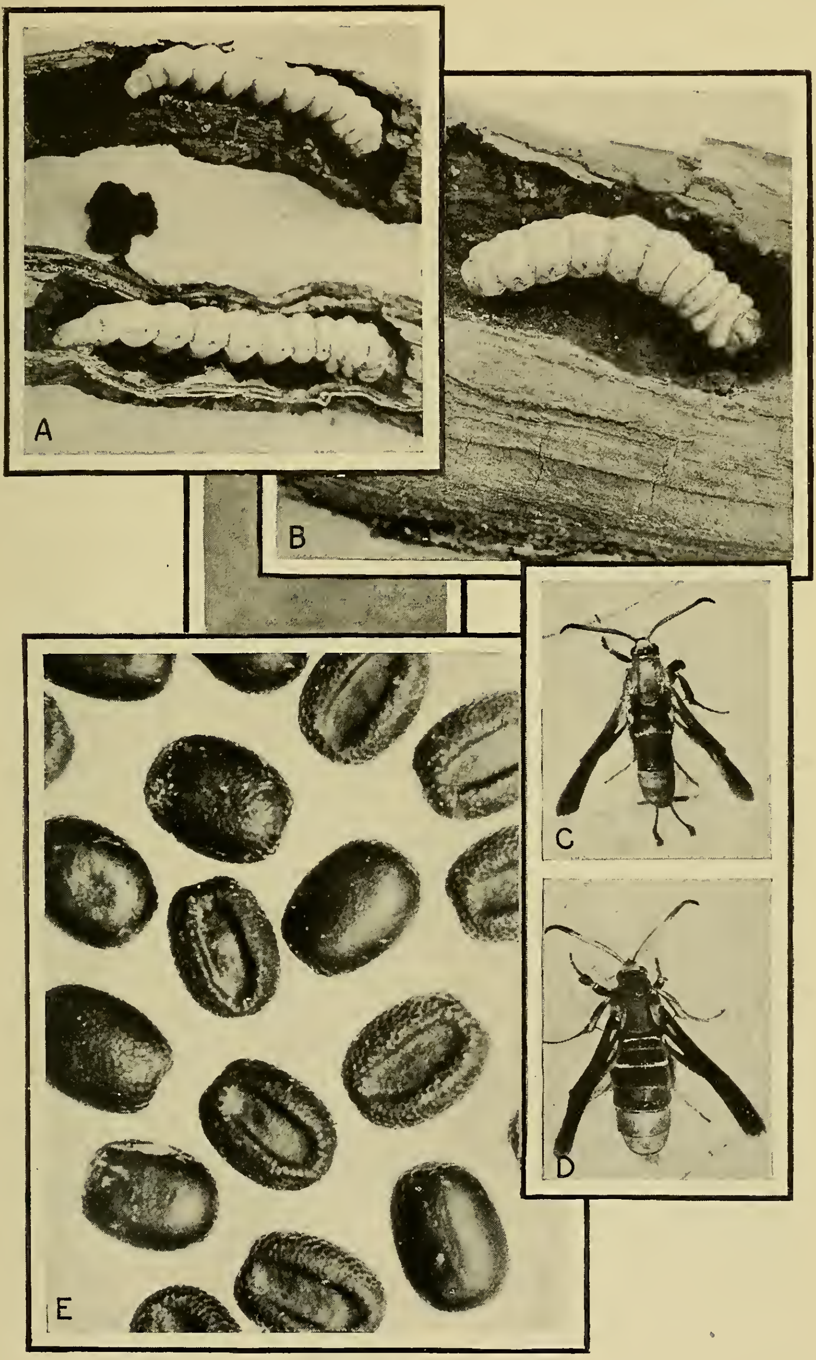
(Pl. IV, *A*, *B*.)

The pupa is dark brown, with bands of a lighter shade encircling the abdomen. Its average length is 20 mm. It occupies a cocoon at the surface of the ground, usually directly over the point in the root where the full-grown larva ceased feeding. The pupa is characteristic of its family, being spindle shaped, the males having 14 and the females 13 rows of strong reflexed dorsal spines, the cremaster consisting in each of 8 stout spines surrounding the anal end. The cocoon is from 20 to 30 mm. in length and stands perpendicularly in the soil with the anterior end just at the surface of the ground. It is composed of frass and grains of earth held together with a parchment-like lining of brown silk. Usually, although not always, more grains of earth than of frass enter into the composition of the outer part of the cocoon. The pupæ and cocoons of the females average longer and stouter than those of the males. When the moth is ready to issue it works half the length of the pupa out of the cocoon and escapes from the pupa case through a slit in the back, leaving the empty case projecting above the ground. (Pl. IV, *B*.) The insect occupies the cocoon for a period of about four weeks.

THE ADULT.

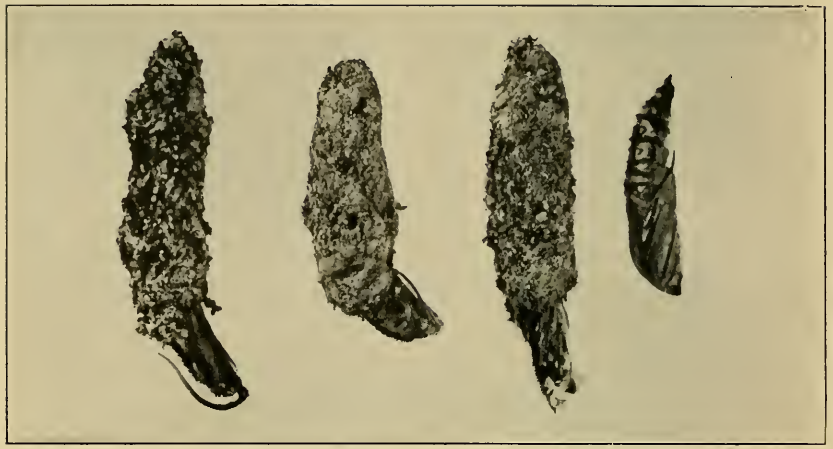
(Pl. III, *C*, *D*.)

The mature insect is a handsome, wasplike moth, the males of which are from 12 to 18 mm. in length, and the females from 18 to 20 mm. The general color of both sexes is dark lustrous brown. The fore wings are brown and the hind wings transparent bordered and veined with brown. The abdomen is encircled at the posterior margins of the second and fourth segments with conspicuous bands of orange and lemon colored scales, the lemon scales predominating in the front band and the orange in the other. There are spots of metallic yellow scales at the base of the wings. The legs are reddish brown. The antennæ of the males are brown, marked with metallic colors and are delicately pectinate; those of the female are brown for a third of the length at the base, the rest metallic purple and bronze. The female has a small orange-colored tuft on each side of the tail and the male has two such tufts on each side, the middle pair being more than twice as long as the others. The scales with which the moths are covered rub off easily and old specimens rarely show all the markings described above.



THE GRAPE ROOT-BORER.

A, B, Larvæ feeding in grape roots (A, natural size; B, enlarged); C, male moth, slightly enlarged; D, female moth, slightly enlarged; E, eggs, greatly enlarged. (Original.)



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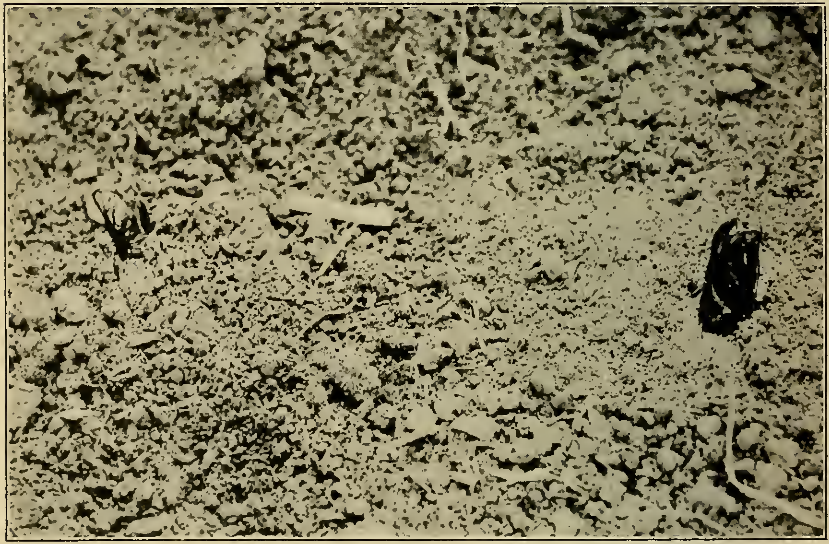

B

THE GRAPE ROOT-BORER.

A, Pupa, cocoons, and empty pupa cases; B, empty pupa cases projecting from ground under grapevine. Slightly enlarged. (Original.)

THE GRAPE ROOT-BORER.

Old grapevine showing small growth and light crop of fruit due to injury. (Original.)

ACTIVITIES OF THE MOTHS.

It has been stated that in North Carolina the moths are on the wing from the middle of June until the middle of September (3) but observations indicate that in West Virginia the period of flight is not so long. Table I shows the dates on which moths were first and last seen in three different years in West Virginia.

TABLE I.—*Period moths of the grape root-borer are on the wing, West Virginia.*

Year.	First seen.	Last seen.	Number of days on wing.	Average number of days.
1907	July 24	Aug. 10	18	
1916	July 20	Aug. 17	29	23.3
1917	July 25	Aug. 17	24	

The records set forth in Table I show that in the locality where the present investigation was made the moths are probably on the wing a little less than 30 days, instead of 90 days, as reported from North Carolina.

The moths issue from the cocoons on bright, warm days, usually about the middle of the forenoon. Of 11 females observed, all left the cocoons between 9 a. m.[1] and 11 a. m. The males after issuing rest for a while on some object near the discarded cocoon and then take flight, but the females are less active and usually remain quietly near the place of emergence several hours to await the coming of the males. Several females that were kept under observation were seen to elevate their genitalia, evidently sending forth a scent to attract males. Almost instantly after this act was begun by the female a swarm of males would appear and copulation would soon take place. Usually the pair would remain connected for 2 or 3 hours, and on the morning following egg laying would begin. In one case observed copulation lasted 2 hours and 45 minutes and in two cases 3 hours and 40 minutes each. Two or three of the females did not attract and receive the males until the morning following their emergence from the cocoons. One group of excited males that gathered around a female contained a single male of the squash-vine borer, *Melittia satyriniformis*. This moth grasped the female and attempted to pair with her after she had united with a male of her own kind.

In ovipositing the females make short flights, alighting on the canes or leaves of grapevines, or, more frequently, on grass, weeds, or straws under or near the vines, and deposit in each place one or more eggs. Sometimes four or five eggs will be placed together and at other times the female will crawl over the surface of a leaf or along a

[1] References to clock time refer to standard time.

grape cane or weed stem, pausing every few inches to deposit an egg. No attempt is made to conceal the eggs, except that the moth occasionally will move along the margin of a leaf and bend her abdomen over the edge, placing eggs on the underside. The eggs are attached very feebly, and the rain or wind soon dislodges them and they fall to the ground before hatching. One female kept in a cage produced 555 eggs and several others more than 400 each. About a week is required by the female in which to deposit her quota of eggs. Females caught in the vineyard while ovipositing and placed in bottles continued to drop eggs with scarcely any intermission resulting from the changed conditions.

As has already been mentioned, there is a close resemblance in the moths to the comb-building wasps of the genus Polistes. The gravid females are somewhat more deliberate in flight than are the wasps, but the males dart about on the wing in a manner that is very wasp-like. The males have a habit of resting for long periods in exposed positions about the vines, and when approached or disturbed frequently flutter their wings rapidly, giving off a buzzing sound that still further increases their resemblance to wasps. Rarely the female also will engage in this buzzing performance.

Bottles in which females had been kept in the insectary, and in which they had been seen to elevate their genitalia, were several times taken to the vineyard after the females had been removed. When uncorked, males would appear almost immediately, evidently attracted by the scent, and would even enter the bottles in search of the females.

LARVAL ACTIVITIES.

The larvæ hatch from eggs that at the time are almost invariably scattered over the ground in the vicinity of grapevines. After hatching they at once burrow into the soil and attack the larger grape roots whenever found. It is possible that they subsist on small roots and root fibers while searching for their permanent places of attack, but undoubtedly many of them perish before finding roots to their liking. They enter the roots wherever they come in contact with them, either close to the vine or far out toward the extremities. In one case a larva was found that had penetrated a foot of stiff clay soil and attacked a root at a point 19 feet from the vine.

The ability of the larvæ to penetrate the ground to a considerable distance was shown by placing a large number of hatching eggs on the surface of soil that had been placed to a depth of 9 inches over some sections of grape root in the bottom of a wooden box. Twenty days later the grape roots were removed and the bark found to be filled with young borers. The borers had mined an inch or more in the bark, some of the burrows encircling the roots and others extending parallel with the grain of the wood.

As the larvæ increase in size the burrows become large and irregular in outline, and roots that are half an inch or less in diameter usually are eaten off or injured so severely that the outlying section dies. Very large roots may withstand the combined attacks of several borers without being killed. Such large roots are usually eaten most extensively along the underside.

The larva passes the winter in a roomy chamber at the end of its burrow, the chamber being sometimes, although apparently not always, lined with a very thin web of silk. Feeding is not continued through the winter, but is resumed as soon as the soil becomes warm in the spring.

When full grown the larva makes an open passage from its feeding place upward through the soil to the surface of the ground, where the cocoon is constructed. The larva in some way transports from the root considerable frass for use in making the cocoon. Evidently after the cocoon is begun the larva passes back and forth frequently from the cocoon to the root, probably feeding on the root at intervals and voiding the frass while working at the cocoon. Pupation takes place in June and early July.

NATURAL ENEMIES.

No parasites of this species are known. During the present investigation ants were seen carrying the moth eggs, but what disposition they made of them was not observed. In a previous study of this species (8) the writer found the larva of a firefly beetle (*Photuris pennsylvanica* De Geer) which had broken into a root-borer cocoon and was devouring the pupa. The crested flycatcher (*Myiarchus crinitus*) was observed to catch several moths on the wing.

METHODS OF CONTROL.

This species does not lend itself readily to any of the common insecticidal methods of control; neither is the worming process, so often used against various borers attacking fruit trees, of practical application against this species. The borers feed in the roots over so wide an area that digging for them as a practicable method of destruction is out of the question and even soil fumigants are, for the same reason, of doubtful value.

Thorough cultivation of the soil around the vines during June and July is of some benefit in destroying the larvæ and pupæ in the cocoons. By far the most valuable practice, however, is the application of such cultural methods as would induce in a healthy vine a vigorous and rapid growth. It was found that even badly infested vines, when carefully pruned, sprayed, fertilized, and cultivated, made a normal wood growth and bore satisfactory crops of fruit. The borers, by killing the terminals of so many of the roots, greatly restrict the feeding area of the root system, and it becomes necessary to use fertilizers rather freely within a few feet of the vine, where most of the roots are located. The use of fertilizers and the application of the other cultural methods mentioned become increasingly important as the root injury increases.

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III. EXPERIMENTS IN THE CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.[1]

By B. R. Leach, *Scientific Assistant, Deciduous-Fruit Insect Investigations.*

CONTENTS.

INTRODUCTION.

During the seasons of 1914 and 1915 a series of experiments on the control of the root form of the woolly apple aphis (*Erisoma lanigerum* Hausmann) was conducted in Virginia, the work being based on the results obtained by French investigators in the employment of carbon disulphid and sodium cyanid in solution against the grape phylloxera. The opportunity also was afforded of obtaining data on the use of kerosene emulsion and on the effect of deep planting as preventives of woolly apple aphis injury.

Little work appears to have been done by American entomologists in the employment of carbon disulphid and sodium cyanid in solution as a control for soil-inhabiting insects. The data obtained as a result of the experiments herein reported are presented in the hope that other experimenters will have opportunity to carry out further tests along these lines. Much additional information concerning these treatments is desirable, especially that which may be acquired through experiments carried on under a variety of climatic, crop, and soil conditions.

THE USE OF CARBON DISULPHID IN WATER.

EARLY RECORDS.

The use of carbon disulphid in water was first proposed by Cauvy,[2] of France, in 1875.

It was found that a solution containing from 0.5 to 1.2 per cent of carbon disulphid will kill the grape phylloxera in 24 hours. The

[1] *Eriosoma lanigerum* Hausmann; order Hemiptera, suborder Homoptera, family Aphididae.
[2] Bourcart, E. Insecticides, Fungicides and Weedkillers. p. 74. London, 1913.

advantages claimed for the method are that it is harmless to the vine, even in full vegetation, and that by its use a uniform distribution of the carbon disulphid in the soil is effected. It is stated, however, that the disadvantages of this treatment are the enormous amount of water required and the high labor cost.

No record has been found of the use of this method in the United States.

EXPERIMENTAL WORK WITH THIS METHOD.

Realizing the possible merits of this method of applying carbon disulphid, a series of determinative experiments was carried out during the seasons of 1914 and 1915. The resulting data, herewith presented, include an account of the preliminary work to determine the factors influencing this water treatment and a report of the large-scale operations in the field in which this method was utilized, based on the knowledge acquired in the preliminary experiments. In conclusion, a discussion of the advantages and disadvantages of the treatment is given.

Preliminary Experiments.

PREPARATION OF THE BASIN.

In applying quantities of liquid for the control of soil-inhabiting insects, such as the root form of the woolly apple aphis, it is necessary, in order that the material may be effective, to prepare a basin around the base of the tree for the reception of this liquid in order that it may be spread evenly over the soil surface, and to insure permeation and absorption by the soil.

In preparation for the reception of the carbon-disulphid solution the basin should be made as shallow as possible, to prevent exposure of the roots. If the roots are exposed, the gas in solution is prevented from acting upon the aphids thereon, and the treatment is thereby rendered incomplete. The bottom of the basin should be absolutely level, with the soil heaped up around the edges to confine the liquid to the area undergoing treatment.

In order to simplify the placing of the liquid, strips of galvanized iron, shown in Plates VI and VII, were utilized. These strips were 12 feet in length and 5 inches in width, providing for a circular basin 4 feet in diameter. After leveling the ground about the base of the tree one of the strips of galvanized iron was placed with the ends overlapping 3 or 4 inches (Pl. VI) and the dirt heaped up around the outer edges. This gave a level basin for the reception of the liquid and confined it to the area to be treated.

AMOUNT OF LIQUID REQUIRED IN THE TREATMENT AND THE INFLUENCE OF SOIL TYPE AND SOIL MOISTURE.

The success of this treatment depends on the one essential, that sufficient liquid be used. Experiments carried out for the purpose of obtaining data on this point demonstrated the general efficiency of three-fourths of a gallon of liquid per square foot of soil area treated. This is equivalent to about one and two-tenths inches of water.

This quantity of liquid, in the majority of cases in moist soils, and regardless of the soil type, will penetrate to reach the aphids infesting the roots at the lower levels. This condition is due to the difference in the depth of infestation in the various soil types by the woolly aphis. In general it may be said that the root infestation by this insect occurs at greater depths in light soils—for instance, the shale loams—than is the case in heavy soils, such as the clay loams. On the other hand, a given quantity of liquid will be absorbed to a greater depth by a light soil than by a heavy soil. It may be said, therefore, that a given quantity of liquid will penetrate a given soil in proportion to the depth of the aphis infestation in that soil. For this reason a standard recommendation can be made as to the quantity of liquid required for all soil types.

The treatment may be used in either dry or moist soil, but is less laborious in the latter. If the ground is well drained, the best results are obtained after a heavy rain, when the soil is saturated, since a given quantity of liquid will penetrate deeper in moist soil than in dry soil, thereby resulting in a more thorough control.

When the liquid is applied to dry soil, most of the liquid (when used at the rate of three-fourths gallon per square foot) is taken up and retained by the first few inches of dry top soil. In order to insure the death of the aphids in the lower levels of the soil under these conditions it is necessary to use a much larger amount of liquid per square foot of area treated, with a consequent increase in labor and cost.

THE PREPARATION OF THE LIQUID AND DETERMINATION OF MOST EFFICIENT DOSAGE.

When carbon disulphid is added to water, and the mixture is allowed to settle, the carbon disulphid drops to the bottom of the container and collects in a single large globule. By agitation with a broad paddle the carbon disulphid may be broken up into globules which diffuse to every portion of the liquid. Some of the carbon disulphid goes into solution while the remainder forms a mechanical mixture with the water.

The small amount of carbon disulphid dissolved in water necessary for the success of this method is remarkable. The following experiment will illustrate this point: A one-fourth inch stream of water at 60° F. was led to the bottom of a column of carbon disulphid 18 inches in depth, contained in a glass cylinder, and allowed to diffuse upward through the carbon disulphid, thereby taking up the carbon disulphid in solution. This solution was immediately collected and placed in sealed bottles until used at the rate of three-fourths gallon per square foot for the control of the root form of the woolly apple aphis. This extremely dilute solution, although less than 1 to 1,000, gave perfect control.

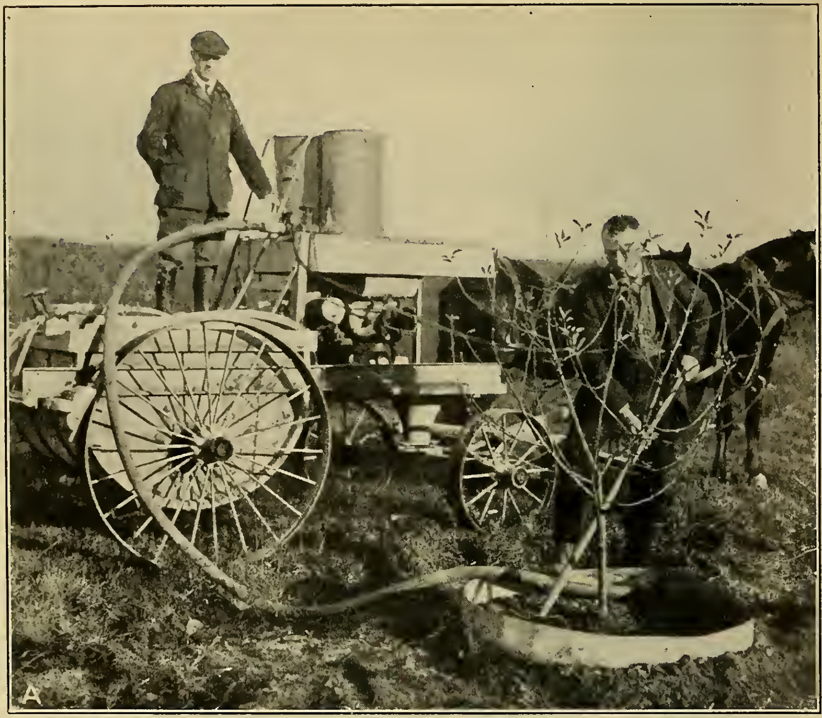
In consideration of the foregoing data, a dosage at the rate of one-half ounce of carbon disulphid to 4 gallons of water was rated as the most efficient, and this was verified subsequently in practice. One-half ounce of carbon disulphid is more than can be dissolved in 4 gallons of water at ordinary temperatures. When the liquid is agitated, the portion of the material not entering into solution forms a mechanical mixture with the water. A margin of safety is thereby secured which insures the success of the treatment. *Under no circumstances is it necessary to employ a stronger dosage than the foregoing.* In fact, when larger doses are used the excess carbon disulphid drops to the bottom of the container, despite agitation, thereby resulting in an uneven strength and consequent danger of injury to the roots.

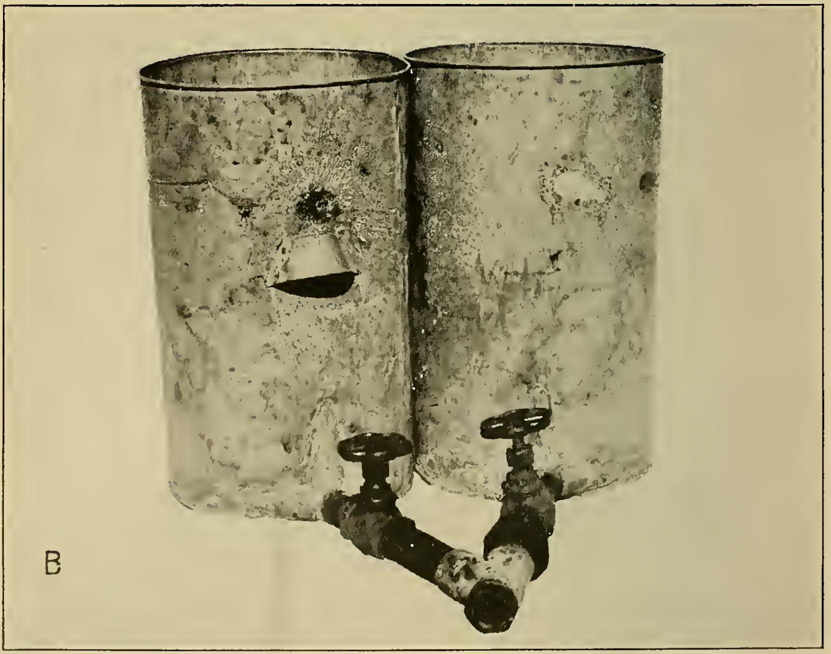
THE DIFFUSION OF THE LIQUID AND CONTAINED GAS IN THE SOIL.

During the course of the work the question arose as to whether the carbon-disulphid gas given off from the water diffused laterally beyond the point in the soil attained by the water itself, and a series of experiments was carried out to determine this point. Figure 1 shows the method employed. The soil treated with the liquid was confined to the circular area 4 feet in diameter within the galvanized-iron strip *D*. The galvanized-iron strip may therefore be taken to represent the line of demarcation between the soil within the strip, directly subjected to the action of the liquid, and the soil outside the strip which remains in its natural state of dryness, except for any possible lateral diffusion at this immediate line of demarcation between the two. At points *A*, *B*, and *C*, respectively, 2, 4, and 6 inches from the strip, screen-wire cylinders containing apple roots infested with the woolly apple aphis were placed in the ground previous to the application of the liquid. When examined 5 days later, the aphids at *A*, *B*, and *C* were alive and breeding. This experiment was carried out in (1) light and (2) heavy soils, both in dry and in moist condition, with the same results. On several occasions the examination of treated trees showed that aphids on the roots located just outside the treated area had escaped, thus corroborating the results of the specific experiments previously outlined. It is apparent, therefore, that the carbon-disulphid gas in the solution does not diffuse laterally through the soil beyond the point reached by the liquid.

CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A basin for the reception of carbon-disulphid solution, using a strip of galvanized iron. (Original.)





CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A, The employment of a power-spraying outfit and auxiliary tanks for the application of carbon-disulphid solution in orchard practice; B, the auxiliary tanks. (Original.)

INJURY TO THE TREE.

Apple trees in the first year of growth were treated at the height of the growing season with varying dosages of carbon disulphid in water.[1] One ounce of carbon disulphid to 4 gallons of water caused considerable injury, as evidenced by the drying of the foliage, but did not kill the tree, while 2 ounces to 4 gallons of water killed the tree in three days.[2] Since one-half ounce of carbon disulphid to 4 gallons of water is ample for control there is no necessity for increasing the strength.

In the same way apple trees in their second year of growth were treated with varying dosages of carbon disulphid in water.[1] One ounce carbon disulphid to 4 gallons of water caused no injury, 1½ ounces caused considerable injury, and 2 ounces killed the tree outright in 10 days.[3]

The increased resistance of the older trees is explained by the greater area involved by the root mass, a large part of which was not subjected at all to the fumes of the carbon disulphid.

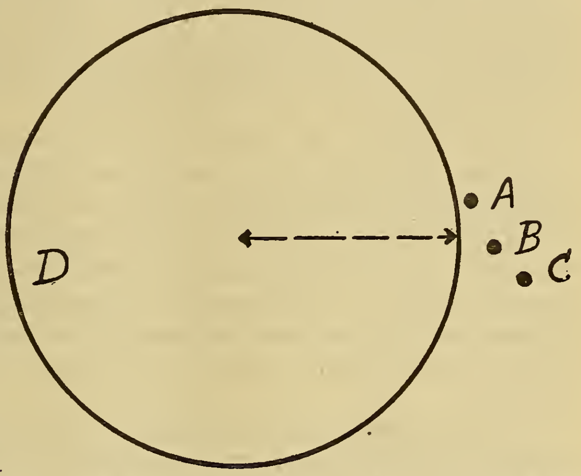


FIG. 1.—Diagram illustrating method of determining the lateral diffusion through the soil of carbon disulphid in water. For explanation see p. 32. (Original.)

During the extended field tests about 500 apple trees of varying ages were treated at the rate of one-half ounce of carbon disulphid to 4 gallons of water and no apparent injury resulted.

Injury to the tree by carbon disulphid in large doses is first indicated by a drying of the foliage. This, however, is merely direct evidence that the small roots and rootlets have been injured, thus cutting off the normal supply of water to the leaves and causing them to turn brown. With medium doses rootlets killed by carbon disulphid are rapidly replaced by the otherwise unimpaired root system. With the dosages of one-half ounce to 4 gallons of water the rootlet injury is negligible, and no killing of the foliage or check in growth will result.

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[1] Liquid employed at rate of three-fourths gallon per square foot of soil area treated (p. 31).
[2] Diameter of treated areas in these tests 30 inches.
[3] Diameter of treated areas in these tests 48 inches.

THE BEST TIME OF APPLICATION.

Trees were treated at intervals throughout the season to determine the effect of carbon-disulphid solution when applied at the varying stages of seasonal development. With the possible exception of early spring, when the trees are producing their initial foliage, no noticeable injury was observed. Treatment at this time appeared to delay the process of leafing out. With this treatment it is a question of securing ideal conditions of soil moisture, and not essentially a question of season.

Large-Scale Treatments, Using the Liquid Method.

As a result of the foregoing work experiments involving large numbers of trees were undertaken. These large-scale operations required the employment of a 200-gallon power-spraying outfit and the special galvanized-iron tanks shown in Plate VII. The method of preparing and disposing the solution was as follows:

Having half filled the spray tank with water, the required amount of carbon disulphid, at the rate of one-half fluid ounce to 4 gallons of water, was poured into the tank and the agitation started and continued while the remainder of the water was being run into the tank. The agitation was continued while the outfit was being driven from the source of water supply to the location of the trees to be treated, and by this time the water in the tank was evenly charged with carbon disulphid in solution and in suspension as a mechanical mixture.

The tree basins for the reception of the liquid having been previously prepared, the material was run out through the tanks placed on the top of the engine hood (Pl. VII, *A*) to the basins about the trees. In order to secure accuracy in measuring the liquid, the heights in these tanks representing 4 and 8 gallons were indicated by black circles painted on the inside.

These two auxiliary galvanized-iron tanks (Pl. VII, *B*), having a capacity of 12 gallons each, were connected by a 2-inch Y-pipe to the discharge hose, each of the two arms of the Y-pipe being furnished with a globe valve. The liquid was pumped through a 1-inch hose directly from the 200-gallon tank, and could be directed into either of these two auxiliary tanks at the will of the operator. While one tank was being filled the liquid in the other was being run into a tree basin simply by opening the globe valve belonging to that tank. When empty, the valve was closed and the tank again filled, and during this process the contents of the other tank in turn were emptied into a prepared basin. The process was so regulated that no interruptions were necessary, and 200 gallons of liquid could be disposed of in from 15 to 20 minutes.

A crew of three men was required—a driver, a man to operate the filling and emptying of the tanks, and a man to distribute the water evenly over the surface of the basin.

One tank of 200 gallons was sufficient for the treatment of from 20 to 25 trees, and with a crew of three men it was possible to dispose of one tank an hour, depending on the distance from the water supply.

ADVANTAGES OF THIS METHOD.

The advantages of this method are as follows: When properly agitated every portion of the combination solution and the mechanical mixture contains the same amount of carbon disulphid. When it is poured onto the soil it sinks through the earth, carrying the carbon disulphid to every part of the soil penetrated by the liquid. This results in an even distribution and none of the aphids escape. With this method no portion of the soil receives too much or too little of the fumigant, but just enough to do the work.

DISADVANTAGES OF THIS METHOD.

The greatest disadvantage of this method is the amount of labor in handling the large quantity of water required, the employment of several horses and men being necessary for this purpose.

The difficulty, when ordinary labor is employed, of preparing the basins properly for the reception of the liquid, so as to insure an even distribution of the liquid over the soil area to be treated, is a second disadvantage. On hillsides it is almost impossible to insure the even distribution of the liquid over the surface of the basin.

On some trees, in some soils, the area of infested roots is so extended that treatment of a basin 4 or 5 feet in diameter will not reach all the aphids, and since three-fourths gallon per square foot is required for success, the amount of water necessary for the treatment of an area greater than the foregoing practically limits its use to small trees with restricted root area.

USE OF SODIUM CYANID IN SOLUTION.

EXPERIMENTS ON VINES IN FRENCH VINEYARDS.

Among the substances tried against the phylloxera in France was sodium cyanid in solution. Bourcart [1] records the experiments of Mouillefert as follows:

The stocks were stripped to a depth of about 15 centimeters, with a radius of 30 to 35 centimeters (12 to 14 inches), the soil being rather dry. After pouring on the cyanid solution the soil was replaced at the foot of the stocks and thoroughly packed. The dose varied from 20 to 25 grams per stock, dissolved in 10 liters (2.2 gallons) of water. Wherever the solution had penetrated, the phylloxera and their eggs

[1] BOURCART, E. Insecticides, fungicides, and weedkillers. p. 135. London, 1913.

were dead, but at a depth of 40 to 50 centimeters (16 to 18 inches), as well as between the stocks in a radial direction, even by using five times more water, the result was incomplete.

EXPERIMENTS AT WINCHESTER, VA.

Having prepared the basins as described for the use of carbon disulphid in solution, using 8 gallons of liquid to a 4-foot basin, one tree was treated with the solution at the rate of one-half ounce to 4 gallons of water, and the second tree at the rate of 1 ounce to 4 gallons. The aphids within the treated area were killed.[1]

PREPARATION OF THE SOLUTION.

Sodium cyanid is very soluble in water, and it is therefore not necessary to exercise the same degree of care in preparing the solution as is the case when using carbon disulphid. In the initial experiments outlined above the correct amount of sodium cyanid was weighed out and stirred into the water contained in 2-gallon pails. In the more extended field experiments the material was dissolved in a 200-gallon spray tank and run into the basins through the auxiliary tanks described under the "Use of carbon disulphid in solution."

DOSAGE EMPLOYED.

Experiments were carried out in which from one-fourth to 2 ounces of sodium cyanid to 4 gallons of water were used, and as in the case of carbon disulphid it was found that one-half ounce of sodium cyanid to 4 gallons of water was the most satisfactory.

THE EXTENT OF THE LATERAL AND VERTICAL DIFFUSION OF THE GAS BEYOND THE RANGE ATTAINED BY THE LIQUID.

The particular experiment (p. 32, fig. 1) made to determine whether the fumes of carbon disulphid diffused laterally beyond the range of the liquid was repeated with sodium cyanid. The results were the same in both instances, namely, the fumes of sodium cyanid do not diffuse laterally beyond the point attained by the liquid in its diffusion.

Experiments and observations made during the course of the work confirmed the opinion of Mouillefert, recorded above, that the gas from the dissolved cyanid did not diffuse evenly or produce aphid mortality to the lowest depths attained by the liquid in the case of carbon disulphid.

No difficulty was encountered in killing the aphids at shallow depths when the liquid was used at the rate of three-fourths gallon per square foot of soil area, but the aphids forming the deeper infestation invariably escaped. This was the case even in moist, light soils, where the foregoing quantity of water will penetrate to a considerable depth.

[1] The aphid infestation on these trees was shallow.

CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A deeply planted tree with root system exposed; top almost dead. Note the partial success of the root system in attaining the upper soil levels. (Original.)

INJURY TO THE TREE.

The trees used in the following experiments were of 1-year growth in the nursery and were planted in the spring, three months prior to the experiments outlined below, which were carried out during the height of the growing season.

4 ounces of sodium cyanid to 4 gallons of water killed the tree in 48 hours. The foliage turned brown and dried.

2 ounces of sodium cyanid to 4 gallons of water killed the tree in 7 days.

1 ounce of sodium cyanid to 4 gallons of water injured the tree, as indicated by the browning of the foliage to some extent, but it did not kill the tree, which resumed growth later in the season.

One-half ounce of sodium cyanid to 4 gallons of water produced no apparent injury nor did it check the growth. Trees treated with this dosage remained normal during the following two years and made a satisfactory growth.[1]

During the following summer, when this block of trees was in its second year of growth, trees other than the ones used in the dosage tests outlined above were treated, with the following results:

4 ounces of sodium cyanid to 4 gallons of water killed the tree in 8 days.

2 ounces of sodium cyanid to 4 gallons of water injured the foliage to some extent but did not kill the tree.

1 ounce of sodium cyanid to 4 gallons of water produced no apparent injury nor was there any check in growth.

One-half ounce of sodium cyanid to 4 gallons of water produced no apparent injury.[2]

It will be observed that the resistance of the apple to sodium cyanid in solution, as in the case of carbon disulphid, depends on the age of the tree. During the extended field tests about 500 apple trees of various ages were treated at the rate of one-half ounce to 4 gallons of water with no apparent injury. In excessive doses the same type of injury occurs as results from the employment of large doses of carbon disulphid.

ADVANTAGES AND DISADVANTAGES OF THE METHOD.

The only advantage possessed by sodium cyanid as compared with carbon disulphid is its ready solubility in water. On the other hand, its uncertainty in producing aphid mortality in the lower soil levels, together with the extremely poisonous nature of the material, precludes its use in practice.

USE OF KEROSENE EMULSION.

PRELIMINARY EXPERIMENTS.

Kerosene emulsion has been recommended repeatedly as a remedy for the root form of the woolly aphis. Experiments were therefore carried out to determine its efficiency and also to determine what takes place when the kerosene emulsion is introduced into the soil.

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[1] See footnotes 1 and 2, page 33.
[2] See footnotes 1 and 3, page 33.

For this latter purpose the following apparatus was devised: A series of pinholes was made in the bottom of a pail and the latter then filled with earth, well tamped down, and the soil scooped out slightly and heaped up against the inside of the pail so as to furnish a miniature basin for the reception of the liquid. The soil column thus prepared was approximately 7 inches in depth. Into the basin on the surface of this column was poured 10 per cent kerosene emulsion at the rate of three-fourths gallon to the square foot of soil surface, and a drip pan placed immediately beneath the pail in order to catch the drippings from the soil column. The following conclusions were arrived at as a result of this and several other similar experiments:

A. The first inch of surface soil separates out and retains all the soap in the emulsion, together with some of the kerosene content.

B. The first 4 inches of the soil retains almost all the remainder of the kerosene.

C. The drippings from the soil column 4 inches in depth consist of clear water with a slight trace of kerosene.

FIELD EXPERIMENTS.

Experiments carried out in the field, in which 3-year-old apple trees infested with the woolly aphis were used, corroborated the results obtained in the laboratory. The basins for the reception of the kerosene emulsion were prepared as outlined for the application of carbon disulphid in water, and the material was used at the rate of three-fourths gallon per square foot of soil treated. The majority of the aphids within 8 inches of the surface were killed as a result of the treatment, but those at lower levels escaped. Furthermore, the trees were very severely injured as a result of the application of the emulsion. The following spring, seven months after the treatment, the foliage presented a weak, yellowish appearance, and practically no new growth. The rootlets were badly injured and were not replaced that season by new growth.

The mechanical and unstable character of kerosene emulsion, together with the cost and labor required in preparing the quantity necessary for soil treatment, renders this method of little value.

DEEP PLANTING.

Theories have been advanced from time to time in the literature to the effect that by planting the apple tree deeper in the soil than is normally done the aphis infestation will be prevented. Evidently it is presumed that the aphids will be unable to live at the lower depths in the soil occupied by the root systems of these deeply planted trees. Furthermore, it is taken for granted that the root systems will grow normally at these depths.

The writer fortunately was enabled to make observations and photographs of the effects of deep planting, as carried out by a grower at

Winchester, Va., his object being to prevent the ravages of the woolly aphis. Following this idea he planted 200 trees, the first tier of main roots being 18 to 24 inches below the surface of the ground in a stiff clay soil. The second year after planting some of the trees began to show signs of distress, while others were growing normally. The third year some were dead, others nearly dead, and others growing normally.

An examination of the root systems showed the following conditions:

1. The root growth on the dead trees was poor. The roots had made an unsuccessful attempt to reach the upper layers of the soil. No new tiers of roots had been pushed out at a higher level in the soil.
2. The trees in a subnormal condition had succeded in pushing a few roots up to the top layers of the soil (Pl. VIII).
3. The deeply planted trees which were growing normally had succeeded in pushing the majority of their roots up to the surface layers of the soil.

When trees are planted deeply only a portion of them will succeed in pushing their roots up to the surface layers of the soil. The trees which do not succeed in accomplishing this eventually die. Deep planting is unnatural, injures the tree, and does not prevent aphis infestation.

SUMMARY.

Carbon disulphid, in solution at the rate of one-half ounce to 4 gallons of water and applied at the rate of three-fourths gallon per square foot of soil, will control the root form of the woolly aphis under suitable soil conditions. The liquid is best applied by preparing shallow basins about the tree and should be applied only when the soil is in a moist condition. The solution is best prepared by pouring the carbon disulphid into the water and agitating vigorously. The carbon disulphid thereby breaks up into small globules, some going into solution and the remainder forming a mechanical mixture with the solution. The gas diffuses laterally and vertically only as far as the liquid penetrates and therefore every square foot of infested soil must be subjected to the action of the solution in order to insure complete control. When used at the foregoing rate the carbon disulphid produced no injury to the roots of apple. The treatment may be made at any time during the growing season except during the period of two or three weeks in the spring when the trees are budding out.

In orchard practice the solution is best applied by using a power spraying outfit and two auxiliary tanks.

The advantages of this method are, first, the even diffusion of the liquid and complete aphid mortality in the soil area treated and, second, the safety with which the disulphid can be used. The dis-

advantages of the method are, first, the huge amounts of water required, with consequent high cost of labor; second, the difficulty, on any but level ground, of preparing basins with level floors, thus insuring the proper distribution of the liquid over the area to be treated; and, third, the wide area of infested roots on older trees, every square foot of which must be treated with the liquid. This last condition precludes the use of carbon disulphid except on small trees with restricted root areas.

Sodium cyanid at the rate of one-half ounce to 4 gallons of water did not kill the woolly aphis in the lower soil depths even when a superabundance of solution per square foot was employed. No injury to apple roots resulted when the material was employed at this strength. The only advantage this material possesses, as compared with carbon disulphid, is its ready solubility in water. On the other hand, its uncertainty in producing aphid mortality in the lower soil levels, together with the extremely poisonous nature of the material, precludes its use in practice.

When kerosene emulsion is applied to the soil it disintegrates into its component parts; the first inch of surface soil retains the soap and some of the kerosene content; the first 4 inches of the soil retains almost all the remainder of the kerosene. Kerosene emulsion, therefore, does not kill the aphids in the lower soil levels and the cost of preparing the quantity necessary for soil treatment renders it of little value. The application of this material to apple roots, in the writer's experience, results in severe injury to the tree.

Deep planting will not prevent woolly aphis infestation and results in the death of many trees so planted, due apparently to the inability of the root systems to function properly under these conditions.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 731

Contribution from the Bureau of Entomology,
L. O. HOWARD, Chief.

Washington, D. C. ▼ July 19, 1918

RECENT EXPERIMENTAL WORK ON POISONING COTTON-BOLL WEEVILS.[1]

By B. R. Coad,

Entomological Assistant, Southern Field-Crop Insect Investigations, Bureau of Entomology.

CONTENTS.

EARLY ATTEMPTS AT POISONING THE WEEVIL.

Practically since the advent of the Mexican cotton-boll weevil innumerable attempts have been made to control this pest by the use of poisons. The results, however, were always discouraging. The best that could be secured apparently was a very slight degree of control which would seldom pay for the expense of treatment. As a result it was generally conceded that the weevil could not be poisoned profitably under cotton-field conditions. This was attributed to the fact that the weevil derived its food from deep punctures which it made into the cotton squares and bolls, thus ingesting very little of the external plant tissues upon which the poison would be found. On account of this feeding habit of the weevil the idea prevailed that the only possible method of poisoning would be one which would so distribute the poison on the plant that small amounts would be eaten during the process of starting the punctures through the external tissues. For this reason all experiments were aimed toward getting a poison which could be driven inside the

[1] In the development of power machinery for applying the poison Mr. Elmer Johnson, of the Bureau of Public Roads, has been of inestimable assistance.

bracts surrounding the cotton square and on to the bud itself. In addition, a considerable portion of the experiments included principally treatments very early in the season before the squares had appeared. At this stage of growth the prime objective was to drive the poison into the terminal bud which forms the tip of the young cotton plant and which is the favorite weevil food before squares are formed. As has been mentioned, however, the results secured from all these attempts to poison the weevil were, generally speaking, very dubious and gave no apparent reason for hope for the successful poisoning of the weevil.

THE WATER-DRINKING HABIT OF THE WEEVIL AND ITS BEARING ON POISONING.

During the seasons of 1913 and 1914 the writer conducted a number of biological investigations on the boll weevil from which an intimation was obtained of the possibility of utilizing certain newly discovered features in an attempt to poison the weevil. It seemed quite obvious that there was no hope of successfully poisoning weevils if full dependence were placed on the amount of poison they would secure in the course of their feeding. These studies, however, demonstrated very clearly the importance of water to the continued existence of the weevil. It was found that under cage conditions they drank water very regularly and it seemed reasonable to assume that under field conditions they would secure this apparently essential moisture by drinking from the rain or dew collected in droplets on the leaves of the cotton plants. With this idea in view, the writer decided to conduct experiments in which the attempt would be made to poison the water which the weevils would drink.

THE POISONING TESTS OF 1915.

The first tests of this nature were instituted in 1915 and have been continued to date by the various agents of the Delta Laboratory of the United States Bureau of Entomology under the direction of the writer. The majority of these tests were located in the vicinity of Tallulah, La., which is in typical delta territory and normally subject to an exceedingly heavy degree of weevil injury due to the great humidity and excessive rains which prevail. For the purpose of these experiments of 1915, triplicate series of plats were surveyed on three different plantations near Tallulah. Each of these series consisted of five plats of about one acre each, as nearly uniform as possible in all conditions affecting their production of cotton. In each case the two end plats were given four, five, and six applications of poison, respectively. It was soon evident that this poisoning was exerting a very decided control on the weevils, as the weevil infestation was considerably reduced in the poisoned plats and these plats continued blooming much later in the season than did the adjoining unpoisoned ones. When the cotton was picked from these plats rather surprising results were secured. Every poisoned plat yielded more than the untreated checks, but the most pronounced feature was the much greater increase in yield with the larger number of poisonings. With four applications a gain of about 15 per cent was secured; with five applications this gain was increased to about 35 per cent, while with six applications it was increased about 70 per cent. In other words, a single extra application over four more than doubled the gain, while two extra applications over four increased the gain between four and five fold. As all applications were started at the same time and the extra treatments consisted simply of a continuation that much later in the season, this seemed to point out very significantly the importance of late-season applications.

POISONING EXPERIMENTS IN 1916.

The results of these experiments were certainly definite and significant, but it was considered possible that they might have been due to some peculiar conditions prevailing during that season and that they could not be duplicated during another year. Consequently the experiments during the season of 1916 were planned largely to check the results secured during 1915, with the important change that provision was made for a wider range in the periods of application. In 1916 the applications in the different experiments extended from the first appearance of the weevils in June until about the 1st of September. On the whole the results in 1916 were just as definite as were those of 1915, and the greater importance of the late-season applications was very plainly demonstrated. In this connection a detailed description of a few of the tests is of interest.

Probably the most spectacular test of the season and the one which aroused the most interest was conducted in a cut of abandoned cotton. Poor drainage and excessive rains during May and June had prevented cultivation of this cut, and on the 25th of July there were no prospects whatever of a crop. The plants were only about 10 inches high and had been so heavily infested by the weevils that there had been no blooms since June. Thus an opportunity was afforded to determine what could be accomplished by poisoning under the most extreme conditions imaginable. An attempt was made to work the cotton out about the 1st of August and a small plat in the center of the cut, only six-tenths of an acre in size, was poisoned. This poisoning was continued during the month of August and surprising results were secured. The weevil infestation decreased rapidly in the poisoned plat and the plants soon started blooming and continued to bloom practically until frost in spite of the fact that all surrounding cotton was very heavily infested with weevils and undoubtedly hundreds, if not thousands, were moving into the poisoned cotton daily. When the cotton matured a remarkable sight was presented. The unpoisoned cotton showed practically no open bolls, while the poisoned plat to the very last row was practically white with open cotton. This is illustrated in figures 1 and 2, which show different views of the dividing line between the poisoned and unpoisoned cotton shortly after the first killing frost. When the cotton was picked it was found that the unpoisoned plats yielded 45 and 65 pounds of seed cotton per acre, respectively, while the poisoned plat yielded about 500 pounds per acre. This, of course, did not constitute a good yield of cotton but was very remarkable in view of the opportunity which this cotton had had to produce a crop.

FIG. 1.—View showing dividing line between poisoned and unpoisoned cotton on Algodon Cut No. 1 October 30, 1916, Tallulah, La. Beginning of additional unpoisoned cotton can be distinguished at upper right-hand corner of view.

This test was particularly interesting because of the severe conditions which prevented the unpoisoned cotton from making any production, because the plants were so small, and because it was possible to poison the last row of the treated plat effectively without allowing the poison to drift on to the adjoining check row. For this reason the line of demarcation between the plats was much more pronounced than usually was possible.

Additional tests during the same season located in better cotton frequently gave larger gains in production per acre, but of course the percentage of gain was not so large. In one case of poisoning during the month of July a gain of about 600 pounds of seed cotton per acre was secured. Figures 3 and 4 show a comparison of the typical picking in the poisoned and check plats, respectively, in this test. In this case the cotton was so luxuriant that the dividing line could not be shown in a single picture, but the two views given in these illustrations were selected by a disinterested planter as being typical of the two plats. Probably the most interesting feature of this test was the fact that there were 22 days of rain during the month when the applications were made. This seemed to indicate that successful results could be secured from poisoning in spite of excessively rainy weather and tended to allay the fear that dry weather would be essential to successful results.

FIG. 2.—Another view showing dividing line between poisoned and unpoisoned cotton on Algodon Cut No. 1, October 30, 1916, Tallulah, La. View looking in opposite direction from that shown in figure 1.

In another case a portion of a cut of new ground practically surrounded by heavy timber was poisoned. This was very heavily infested with weevils, but the poisoned plat yielded about 1,700 pounds of seed cotton per acre as compared with about 900 for the check. The treatments in this case were practically confined to late July.

In all about 15 experiments were conducted during 1916, and the total results showed definitely that it was possible to poison the weevils profitably under certain conditions. Again, the increased value of late-season applications was obvious, for, as a general rule, the early-season applications gave only slight gains with a very doubtful profit whereas the late-season applications all showed pronounced profits.

EXPERIMENTS IN 1917.

EXPERIMENTS AT TALLULAH, LA.

At the beginning of the season of 1917 it was recognized that the experiments to date had merely demonstrated the possibility of poisoning weevils successfully, and that all phases of the economic use of the poison remained still to be worked out. Consequently a very elaborate series of experiments was inaugurated in that season, and about seventy-five tests were started in the neighborhood of Tallulah, each one intended to determine some particular point of importance. These consisted of studies of the comparative efficacy of different poisons, the time of day of application giving the best results,

Fig. 3.—Typical view of opened cotton in poisoned plat on Algodon Cut No. 2, second picking, October 12, 1916, Tallulah, La. For comparison with figure 4.

the most profitable season of application, the proper interval between applications, the requisite amount of poison per acre, and many other similar questions, all of which would have to be answered before definite general advice as to the use of the poison could be given. The early studies had shown that under certain conditions poisoning was profitable, but it was apparent that any change in these conditions might easily result in a much lower gain, if not in an actual loss, and it was essential to determine thoroughly the possibilities and limitations of boll-weevil poisoning before releasing any information for public use. Unfortunately for the experimental work, the season of 1917 in the vicinity of Tallulah was most remarkable for the light degree of weevil damage. This was due to a peculiar combination of seasonal conditions and resulted in an almost complete absence of weevil damage in all of the cotton in which tests had been planned. In other words, the yield of cotton in these cuts was just the same as if no weevils had been present. Of course weevil-control experiments could not be conducted under such conditions and the majority of the Tallulah experiments had to be given up for the season. Nevertheless, a dozen or more cuts were located immediately adjoining timber where a somewhat heavier degree of infestation was experienced, and in these cases the rule prevailed that the heavier the infestation, the greater the gain due to poisoning. These results, of course, fully confirmed those of the preceding two years, but the necessary postponement of many experiments still left many

FIG. 4.—Typical view of opened cotton in check plat on Algodon Cut No. 2, second picking, October 12, 1916, Tallulah, La. For comparison with figure 3.

gaps in the information essential to outlining a general procedure for weevil poisoning.

Figure 5 illustrates something of the results secured in one of the more heavily infested cuts near Tallulah. This photograph was taken to show the difference in the amount of top cotton produced by the poisoned and unpoisoned plats, and shows only the second picking. A considerable gain had already been secured at the first picking, and in the total a gain of something over 50 per cent was secured.

EXPERIMENTS IN ARKANSAS AND MISSISSIPPI.

In addition to the experiments just detailed, a number were conducted in the North Delta, in Chicot County, near Lake Village, Ark., and in Washington County, near Scott, Miss. At both of these points a heavier infestation was produced by different seasonal conditions, and pronounced results were secured from the poison. In every case the experiments were conducted on comparatively small areas, subject to a continual influx of weevils from surrounding untreated cotton, but in spite of this a very definite weevil control resulted from poisoning. The open cotton in every case showed a definite gain to the last row of treatment. The gains per acre ranged from 250 pounds to 1,007 pounds of seed cotton. Views of two of these tests are shown in figures 6, 7, and 8.

It is, of course, impossible to estimate how much larger these gains would have been if entire cuts or entire plantations had been

FIG. 5.—View looking across rear end of poisoned cotton on Mound Plantation Cut No. 2, with poisoned cotton on right of view and unpoisoned on left; second picking only, October 23, 1917, Tallulah, La.

treated, and thus the inflow of weevils from unpoisoned cotton prevented, but it is clear that these gains secured on small plats were very conservative. In fact, this was brought out well by one large-scale treatment described below.

A LARGE-SCALE TREATMENT.

About the middle of August the writer was requested to attempt the control of the weevil on a large section of an Arkansas plantation. This cotton was on very fair land, but had not been planted until well along in May. Weather conditions then retarded it greatly and it did not start setting a crop until about the latter part of July. About the middle of August a fair crop of bolls was present, but the plants were large and leafy and the weevils had multiplied so rapidly that one of the heaviest infestations ever witnessed by the writer prevailed. Blooming had practically ceased and the weevils had cleaned up the squares so thoroughly that they were attacking the bolls in enormous numbers and all bolls, even to the largest present, were being riddled with punctures. It seemed probable that on one section no bolls would be left to open. It was, of course, too late to attempt to set a new crop by poisoning, but an effort was made to save the bolls then present on the plants. For this purpose large-scale treatments were continued from August 23 to about September 1, several hundred acres in all being treated. At the beginning of the work a series

Fig. 6.—View along dividing line between poisoned and unpoisoned cotton in Lake Vista Cut No. 2, with poisoned cotton to left of view; second picking only, October 26, 1917, Scott, Miss.

of counts showed that 86 per cent of the squares in the cotton which was to be poisoned had been weevil-punctured. This cotton was given a single poisoning and, about 10 days later, it was found that the weevil infestation in these same cuts had been reduced so that only 36 per cent of the squares were punctured. During the same period the infestation in the adjoining unpoisoned cotton had been increasing steadily. Practically all of the poisoned cuts started blooming again at this time and a number of them reached what is ordinarily termed the "flower-garden" stage of blooming, five to seven blooms per plant on a single day being not at all rare. In starting this treatment it had been anticipated that several applications would be necessary to produce the desired result, but the effect of the single application was so pronounced that it seemed unnecessary to repeat it. The weevils had been so reduced that only 36 per cent of the squares were punctured, and although thousands of weevils were being bred out from the squares on the ground or were coming in from other plantations every day, it was still obvious that the weevils would greatly reduce their attack on the bolls until they had caught up with the squares then present, and that this period would be long enough to allow the bolls to become sufficiently hardened to avoid weevil damage. Owing to the necessity of poisoning considerable areas in this case and to the inability to leave unpoisoned plats as checks, it was of course impossible to determine the exact

FIG. 7.—View down center of check plat, Isola Cut No. 1, on October 26, 1917, showing cotton available for second picking; Scott, Miss. For comparison with figure 8.

benefit derived from the treatment. Rough comparisons, however, based on yields of surrounding cuts, made it obvious that a considerable gain had been secured and it was evident that the poisoning was a very profitable operation.

LABORATORY AND OTHER EXPERIMENTS.

Numerous other field experiments might be detailed to add weight to the results secured, but the ones described have been selected as illustrating the different methods followed and the different conditions experienced, and are surely sufficient to illustrate the effectiveness of the poison. In addition to these field tests a number of laboratory studies were conducted at the same time to check the results in the field. These were conducted under cage conditions and were for the purpose of comparing the effectiveness of different poisons and different methods of poisoning.

IMPORTANCE OF MOISTURE IN POISONING.

One interesting feature of the foregoing tests was the apparent necessity of the presence of moisture if any considerable degree of weevil mortality were to be caused by the poison. It was found that only a very light mortality would result from tests where the plants were kept absolutely dry after poisoning; but as soon as moisture was introduced the mortality increased tremendously. This evi-

FIG. 8.—View down center of poisoned plat, Isola Cut No. 1, on October 26, 1917, showing cotton available for second picking; Scott, Miss. For comparison with figure 7.

dently validated the conclusion that at least a major portion of the success in poisoning was due to ingestion by the weevil while drinking.

RELATIVE EFFECTIVENESS OF DIFFERENT ARSENICALS.

In the course of these experiments quite a number of different poisons were utilized and it was found that nearly all arsenicals were effective to a certain degree but that most of them were not sufficiently effective to be satisfactory. At the outset the ordinary triplumbic form of lead arsenate was utilized. It was found, however, that this was not sufficiently toxic to the weevils to warrant its use and the newer dihydrogen form of lead arsenate proved to be vastly more toxic. This was utilized in practically all of the experiments of 1916, but additional tests demonstrated that a high grade of calcium arsenate was still more effective. This contains a much higher percentage of arsenic pentoxid than any other arsenical utilized and has the great advantage of being much cheaper than lead arsenate. In addition, a number of tests of various mixtures of these arsenicals and dilutions of them with different carriers were conducted. This work is still in the experimental stage and it is difficult to prophesy just what the results will be. It is obvious, however, that either a dihydrogen lead arsenate containing not less than 32 per cent of arsenic pentoxid or a calcium arsenate containing at least 42 per cent of arsenic pentoxid will produce an effective control if utilized properly. It also seems probable that it will

FIG. 9.—Hand dust guns in operation, showing method of use; Tallulah, La., July 15, 1916.

be possible to dilute these considerably with some cheap carrier such as lime, though this has not been definitely determined as yet.

DENSITY OF THE POISON.

Fully as important as the actual composition of the chemical is its physical condition. When the experiments were first started, practically all of these chemicals were prepared only in a density of about 40 cubic inches per pound. It was evident, however, that a much finer powder would afford a greater distribution per pound, and also that a finer powder was apparently more readily taken up by the dew and held in suspension for the weevils. Consequently these poisons were prepared in density ranging from 80 to 160 cubic inches per pound and proved much more effective in that form.

TIME OF APPLICATIONS.

WHEN TO BEGIN POISONING.

The technique of application is obviously much more important than the actual poison utilized, if a poison of satisfactory degree of toxicity be selected. As has been mentioned, very doubtful profits were shown by early-season applications, and the most definite gains resulted from treatments made while the infestation was at its height. This is evidently due to a combination of conditions which need not be discussed in detail here, but which caused an application made at the time the weevils were doing their maximum injury to the crop to be far more effective in their control. This time, of course,

FIG. 10.—Power dusting machine in operation at Tallulah, La., April 26, 1917, showing type of dust fog developed.

varies considerably under different conditions and in different seasons, but is usually the time when the cotton manifestly slackens in blooming, and, while the experiments are not yet completed to the point of outlining definitely just when the most effective season of application will be, it will probably be found to be at about this time.

INTERVAL BETWEEN APPLICATIONS.

The time interval between applications is another important point which must be determined but concerning which comparatively little is known as yet. In most of the tests conducted so far the applications have been repeated at weekly intervals more as a matter of convenience than for any particular reason, but it seems probable that about once a week will constitute an effective application.

TIME OF DAY.

Another question of importance is the time of day for application. It is, of course, well known that much more effective poisoning with dry dust can be conducted while the dew is on the plant, as the poison not only clings to the plant better but has much less tendency to drift away from the cotton. A number of tests have been conducted in an attempt to secure some information on this score but were so hampered by the light infestation of 1917 that definite conclusions are not warranted. It is evident that more effective poisoning usually can be done from about 4 p. m. until about 9 a. m. than at other times, although fairly successful results have been secured from applications made throughout the day. It will probably be found that it is advisable to poison as much as possible during the evening, night, and early morning, and to plan to poison during the day only in case of emergency.

MACHINERY FOR APPLYING THE POISON.

The machinery for the application must, of course, vary according to the requirements of different conditions. A very satisfactory hand gun of the type shown in operation in figure 9 was already on the market and was largely utilized in the experiments described. This gun, however, will cover only about 4 or 5 acres a day, and it was, of course, necessary to develop machinery adapted to larger areas. For this purpose a power machine has been developed somewhat of the type shown in figure 10. These have been increased in efficiency until now nearly 200 acres per day can be covered by a single machine. In addition, efforts are being made to develop an intermediate type of machine which can be sold comparatively cheaply and which will be adapted to the man planting 50 to 100 acres of cotton, and cover 20 to 30 acres per day.

AMOUNT OF POISON PER APPLICATION.

The amount of poison required per application has depended so far more on the requirements of the machinery utilized than on the amount necessary for thoroughly dusting the cotton. As a general rule experimental applications have averaged about 5 pounds per acre, but it is apparent that this amount is excessive, and with further improvement in the machinery it will be possible to accomplish an effective poisoning with a much smaller amount.

NUMBER OF APPLICATIONS.

The number of applications necessary undoubtedly will vary. This must depend entirely on the conditions prevailing within the particular cut under consideration. In most of the experiments conducted so far from three to five applications were made but, as has been shown, the effectiveness of these was considerably reduced by the fact that they were on such small plats. In the only case in which experiments on a very large scale were conducted, the effect of a single application was as pronounced as is ordinarily secured from about three applications on a small plat, due, of course, to the constant migration of weevils into the small plat.

COST OF TREATMENT.

The cost of treatment will, of course, vary widely. In the strictly experimental tests conducted so far it has averaged usually about $1 an acre for each application. It must be recognized, however, that it will be possible to reduce this considerably when applications are made on a larger scale, and, with improved machinery, a further reduction will result from the lessened poison requirements. In addition, the probability that it will be possible to utilize carriers and thus further reduce the amount of poison required per acre renders the cost subject to a still greater reduction. It should be remembered, also, that very rarely will it be necessary to poison an entire plantation to control the weevil infestation. The weevils on emerging in the spring will always concentrate near the hibernation quarters in which they spent the preceding winter. They remain rather closely at these points until they have multiplied sufficiently to threaten a shortage in the local food supply. For this reason a great part of the cotton is not seriously infested with weevils until some time after midseason and often not until well along in August. Of course the control measures adopted must depend on conditions on each plantation, but by concentrating on the more heavily infested cuts just before the weevils become sufficiently abundant to start movement to the remainder of the cotton it will be possible not only directly to benefit the cotton treated, but to protect the remainder of the plantation by preventing the weevil migration. In this way the cost of the treatment for a comparatively few acres will be borne by the benefit derived by the entire plantation. In this connection it probably will often prove advisable to give several applications to the more heavily infested cuts and perhaps only a single application to the remainder.

NECESSITY FOR FURTHER EXPERIMENTAL WORK.

In conclusion it should be emphasized that the present bulletin is merely a "progress report" and the writer does not wish to be construed as in any way advising the general use of these poisons for boll-weevil control. There are now too many doubtful points, especially as regards the technique of application; and, as has been shown, the technique of application largely determines the benefits derived. At the present stage of the investigation it is impossible to outline a definite plan of procedure for the poisoning of weevils under all conditions, and much more experimental work will be required before such a plan can be proposed. With the present lack of information on so many important points, any attempt to poison the weevil by the inexperienced may very easily result in actual loss.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 732

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ November 14, 1918

SMYRNA FIG CULTURE.

By G. P. Rixford, *Physiologist, Crop Physiology and Breeding Investigations.*

CONTENTS.

THE SMYRNA FIG INDUSTRY.

The United States is annually importing from Asia Minor and the countries of southern Europe from 19 to 20 million pounds of dried figs of a value of nearly a million dollars. About two-thirds of the tonnage and nine-tenths of the value consist of figs of the Smyrna type. The area in the Southwestern States and California is equally as well adapted to the fig industry as is the Meander Valley of Asia Minor and is more than extensive enough to produce many times the quantity imported into this country. At the present time the annual production of Smyrna figs in California, which is almost the total yield in this country, is not far from 2,000 tons. The imported figs can not be bought for less than 17 or 18 cents a pound wholesale, whereas there is a good profit in growing such figs for one-half that price. When American-grown Smyrna figs can be put on the market at 15 cents a pound retail, the consumption will be greatly increased. The field will therefore be a promising one for many years to come.

The pollination of Smyrna fig flowers by the fig insect *Blastophaga psenes* is one of the most obscure and complicated processes known to botanists. Caprification was little understood and even considered unnecessary by most of the leading botanists and horticulturists of Europe almost up to the beginning of the present century. They believed it to be the result of ignorant superstition on the part of the inhabitants of Asia Minor. They did not believe that the fig and caprifig were the female and male forms of a single diœcious species, but persisted in classifying them as two separate species. This belief was generally adhered to until the indispensable necessity of caprification was demonstrated in 1885 by Dr. Gustav Eisen, of Fresno, Cal. (8).[1] Therefore, it is not strange that the operation was little known and appreciated even by people familiar with the growth of common figs.

ORIGIN OF SMYRNA FIG CULTURE.

The fig family (Moraceæ) is one of the largest in the vegetable world. Botanists have identified and described more than 600 species, mostly tropical evergreens, frequently of gigantic size, often climbers or epiphytic. Very few of the species produce edible fruits, but many yield other useful products. One of them, *Ficus elastica*, is an important rubber producer.

All of the leading cultivated figs belong to the species *Ficus carica*. Two or three other species producing edible fruits may be mentioned here, but they are of little importance. Among them is the *Ficus sycomorus* of Egypt, the fruit of which is consumed by the natives of that country. Another, *Ficus roxburghii*, native to the lower slopes of the Himalaya Mountains in northern India, produces a fruit of very large size, in massive clusters, but of not very high quality. *Ficus pseudocarica* of northeastern Africa (the Italian colony of Eritrea and Abyssinia) produces a small, dark-colored, sweet, quite palatable fruit, the capri form of which is receiving considerable attention in California.

The original home of the cultivated fig (*Ficus carica*) conforms closely to that of the olive. Alphonse de Candolle (2) sums up the subject in a few words, as follows: "The result of our inquiry shows, then, that the prehistoric area of the fig covered the middle and southern parts of the Mediterranean Basin, from Syria to the Canaries." The fig has been cultivated in these regions from the earliest

[1] The serial numbers in parentheses refer to the "Bibliography," pp. 41-43.

historical times. The extreme ease with which it can be propagated from cuttings, its resistance to heat and drought, its early bearing, its value as human food, and the ease of its culture had in the early ages much to do with its wide dissemination.

INTRODUCTION OF SMYRNA FIGS INTO THE UNITED STATES.

Regarding the first introduction of the Smyrna fig into the United States, it may be mentioned that a detailed account by the writer of this bulletin was reprinted by Dr. Gustav Eisen (11, pp. 67–69) in 1901. For present purposes a synopsis will be sufficient.

Believing that the soil and climate of California were perfectly adapted to the growth of Smyrna figs, the writer, who was at that time business manager of the Evening Bulletin of San Francisco, Cal., induced the proprietors of that journal to make an appropriation of funds to undertake the introduction from Asia Minor of the genuine Smyrna fig of commerce. In January, 1880, the assistance of E. J. Smithers, then United States consul at Smyrna, was enlisted in aid of the enterprise. A remittance was made to cover the expense of forwarding a small shipment of 500 cuttings, including a few caprifig cuttings. This shipment reached San Francisco on June 8, 1880, but owing to defective packing, a considerable portion of the wood had rotted and the season was so far advanced that the cuttings made but a feeble growth, although the greatest care was taken with them. However, 200 of them were saved and showed promise of becoming thrifty trees.

About this time Mr. Smithers arrived in San Francisco en route to Chinkiang, China, to which consulship he had just been assigned. He stated that at the time the shipment was made he and the dragoman of the consulate at Smyrna had caused to be planted 4,000 cuttings, which had meantime become rooted trees and could be purchased at from 8 to 10 cents each, the usual price of trees in Asia Minor. Rather than disappoint the county subscribers of the paper who were expecting the promised trees that season, it was then determined to import the whole lot. Funds were therefore forwarded to an American merchant in Smyrna with instructions to purchase the trees referred to and ship them at once. About the first of April, 1881, instead of the trees, a letter dated February 16 came to hand, from which the following paragraph is taken:

> I have had Mr. ——— at my office, who says that the 4,000 cuttings he had planted and to which your order refers (on E. J. Smithers' suggestion) have by this time grown up into strong young trees from 4 to 6 feet high, and he is offered $1 per tree at the nursery at Aidin. He says he can not afford now to part with them at anything under $1.25 each, from this port (first cost).

The prices mentioned in the letter discouraged further negotiations for this lot. However, correspondence was kept up with the agent during the summer, and in September, 1881, orders were sent to make a large shipment of cuttings which it was found could be had at a reasonable price from one of the best orchards in the Meander Valley, the most important fig district of Asia Minor. Every precaution had been taken to assure the safe arrival of this consignment, even by shipping moss from New York in which to pack the cuttings. The cases on arrival in New York were repacked before being shipped across the continent by the southern route, as the season was midwinter.

The shipment consisted of 14,000 cuttings, including several varieties of the best Smyrna figs. It weighed several tons and arrived in excellent condition. W. B. West, of Stockton, James Shinn, of Niles, Gov. Leland Stanford, of San Francisco, and Dr. J. D. B. Stillman, of Lagona, Cal., had shares in the importation, but the San Francisco Bulletin Company had the larger portion and paid the greater part of the expense. A large number of cuttings were distributed to 3,000 county subscribers of the Bulletin, while the individual shares went to the different partners in the enterprise. Gov. Stanford planted most of his cuttings on his ranch near Vina, Cal., now the property of Stanford University. The trees resulting from this importation are now growing in all parts of California and other Southwestern States. Some have attained gigantic size, a number recently measured by the writer having trunks 3 feet in diameter.

CLASSIFICATION OF CULTIVATED FIGS.

The cultivated varieties of *Ficus carica* include more than 100, most of which have been successfully established in the Southern and Southwestern States and California. The Lob Ingir variety, the Turkish name of the common Smyrna fig (fig. 1), is unique in requiring pollination in order to bring its fruit to perfection. Linnæus and other botanists as early as 1744 reached the conclusion that the capri fig is the male form and all the common varieties, including the Smyrna, the female forms of a diœcious species. The caprifigs are male, because they contain male or staminate flowers; the common varieties and Smyrnas are female, because they contain only female or pistillate flowers. These fertile or female figs may be again divided into two classes, namely, the Smyrna figs, the flowers of which must be pollinated in order to mature fruit, and the other large class, frequently called the Adriatic class, the fruits of which reach maturity without pollination. The latter race includes most of the varieties cultivated in all fig-growing countries. Some of the best and most extensively grown in this country are the Adriatic, Brunswick, Barnissotte Black, Barnissotte White, Dottato or Kodato, White Genoa, Gentile, Large Black Douro (one of the largest in cultivation), Mission or California Black, Pastellière (Eisen says if he could plant only one blue variety it would certainly be this fig), Black

San Pedro, and Versailles. In the Gulf and Atlantic Coast States the kinds most generally grown are the Celeste, Magnolia, Lemon, Brunswick, Ischia, and Brown Turkey.

The common cultivated figs are of two kinds, the caprified or Smyrna figs and the common cultivated figs which do not require

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Fig. 1.—Lob Ingir (Smyrna) figs. The large fig is fully mature, the others partly so. (Nearly natural size.)

caprification. Until recent years only varieties of the latter kind were known in America. The figs of the Smyrna type do not set any fruit at all unless the flowers are pollinated, that is, unless the fig trees are caprified. Ordinary fig trees of the noncaprifying varieties produce fruit perfectly well by themselves wherever the climate permits. The culture of Smyrna figs on the contrary necessitates the simultaneous culture of caprifigs which harbor the fig insect and bear the pollen necessary to fertilize figs of the Smyrna type.

The fig is not a fruit in the sense in which we regard the apple, peach, etc., but is what is known to botanists as a receptacle, upon the inner surface of which are arranged hundreds of unisexual flowers. At the apex of the receptacle is an opening called the eye, which in the young fruit is closed by a number of scales or imbricated bracts. The blossoms are therefore effectually cut off from the outer world, and as the female flowers can not be supplied with pollen by the wind and can not pollinate themselves, dependence must be had on the fig insect (*Blastophaga psenes*).

Fig. 2.—Mature mamme (winter) and young profichi (spring) caprifigs. The mamme figs are the larger ones. (Nearly one-half natural size.)

CROPS OF THE FIG TREE.

All of the female fig trees, both of the Smyrna class, the fruit of which never matures without pollination, and most of the other large class, which does not require pollination, have two well-defined crops. The first pushes from the old wood and appears in spring, ripening in July and August. In Spain these fruits are called *brebas* and in France *figues fleurs* or *figues d'été*. The next, which is the main crop, called in Spain *higos* and in France *figues d'automne*, springs from the axils of the leaves of the new wood and ripens in summer and fall.

The male or caprifig tree has two well-defined crops and a third which is in doubt by some authorities (figs. 2 and 3). To these for convenience the Neapolitan names *profichi* (spring crop), *mammoni* (summer crop), and *mamme* (winter crop) have been applied. The mamme crop forms in autumn on the wood of the current season and the Blastophaga from the preceding mammoni oviposits in them when they have reached the size of filberts. By December these mamme fruits are the size of small walnuts and change but little during the winter. The insect hibernates in them in the larval condition and will endure a temperature of 14° or 15° F. without injury. As the weather becomes warm in spring, the insects develop rapidly and are ready to issue in April (fig. 4), when the spring (profichi) crop on the same or other capri trees is in a receptive condition. This crop grows in clusters on the old wood at the extreme ends of the branches and, unlike the mamme, which is nearly spherical, is much

FIG. 3.—Mammoni (fall) caprifigs. (About one-half natural size.)

larger and usually has a pronounced neck. It is produced in enormous numbers, many times greater than any other crop, a wise provision of nature, as it is the one which is most abundantly supplied with pollen and also the one which is exclusively used to pollinate the main Smyrna fig crop. The late summer crop of the capri tree, known as mammoni, unlike the others, pushes from the axils of the leaves on the new wood and matures from August to the middle of November. This crop serves to carry the Blastophaga through the late summer and fall months. The Blastophaga from these mammoni figs oviposit in the winter crop and thus the cycle of the yearly life of the insect is completed.

Doubts have been expressed as to the existence of three distinct crops of caprifigs, and with good reason, for at times and in some climates belated mammoni hibernate with the mamme. H. G. Solms-Laubach says that in Europe there is no sharp distinction between

FIG. 4.—Mature profichi caprifigs with Blastophaga about ready to issue. (About two-thirds natural size.)

the mammoni and the mamme crops and that fruits of the former crop which do not mature in the fall remain as mamme over winter. They both occupy the same position on the branch, both developing on the new wood. The chief difference between the two is that the former contains a well-defined cluster of staminate flowers, while in the mamme with rare exceptions no male flowers have been observed except in *Ficus pseudocarica*, which regularly bears pollen in the winter-generation caprifigs. These hibernating mammoni figs are so similar in form and general appearance to the mamme figs that without cutting them open it is difficult to tell them apart.

To summarize, the necessity of sheltering the fig insect the whole year round leads to the curious result that the caprifig trees bear through the winter on their bare branches the so-called winter generation or mamme caprifigs, from which issue in spring the fig insects, which thereupon lay their eggs in the enormously abundant spring generation of caprifigs or profichi. These profichi, which mature in June, are used to caprify the Smyrna figs, which at this season have myriads of young fruits just ready for the Blastophaga to enter. The caprifig trees also bear a somewhat scanty crop of summer-generation fruit called mammoni, which furnishes a breeding place for the fig insect and carries it over from season to season.

After late summer the fruits on the caprifig tree become irregular, and all sizes of fruits can be found on the tree at the same time; and generally the fig insects can be found issuing at any time from September to November. As winter comes on and the growth of the caprifig tree becomes slower, a few tardy fruits set, which hang on through the winter, constituting the winter generation or mamme crop noted already.

ABILITY OF THE CAPRIFIG TO CARRY THE WINTER CROP.

Probably more caprifig varieties are now established in California than are to be found in any other country in the world, owing in part to the enterprise of the late W. B. West, of Stockton; Mr. Van Lennep, of Auburn; George C. Roeding and G. N. Milco, of Fresno; Felix Gillett, of Nevada City; and largely to the United States Department of Agriculture. Here may be found most of the best varieties from the Smyrna district of Asia Minor, many from Greece, Italy, and the islands of the Mediterranean, and especially from the States of northern Africa, besides a host of seedlings of American origin.

Probably every Smyrna fig grower has observed the difference that exists in the ability of different varieties of caprifigs to carry through the winter crop. Many kinds never produce a winter crop, though they generally yield the spring or profichi crop in great abundance. Still others produce so few winter figs that they are of little use in perpetuating the Blastophaga. Some fail to bear a mammoni (summer) crop, or the figs push at a time that leaves a hiatus in the successive generations of the insects. Such trees can not produce a mamme crop unless they have the assistance of better trees, for it is well known that the mamme figs dry up and fall unless oviposited in by insects of the mammoni generation. It is a curious fact that the egg of the Blastophaga is just as essential to make the caprifig hold on and mature as is the pollen to do the same for the Smyrna fig. This fact was observed in California by E. A. Schwarz, of the Bureau of Entomology, United States Department of Agriculture, as mentioned in the proceedings of the meeting of the Entomological Society of Washington, D. C., December 6, 1900 (45, p. 503).

Careful investigations extending over a period of several years indicate that the ability of a tree to support successfully the mamme crop through the winter is more a question of variety than of climate. Several instances are known where in the frosty portions of the San

FIG. 5.—The Samuel Gates Milco caprifig tree, 10 miles west of Modesto, Cal., which has carried the Blastophaga since 1868, unaided by any other tree.

Joaquin Valley, Cal., single isolated trees near Modesto and Lathrop, unassisted by others in the neighborhood, have carried the different crops uninterruptedly for more than 40 years (fig. 5). The possession of such trees by the grower is of supreme importance.

THE FIG FLOWERS.

Count H. G. Solms-Laubach and Dr. Paul Mayer, the German botanists; Olivier, the Frenchman; Gasparrini, Gallesio, and Pontedera, the Italians; and later Dr. Gustav Eisen are all agreed that there are four kinds of flowers in the fig. It may seem presumptuous to take exception to these authorities, but it is nevertheless a fact, easily demonstrable with the abundant material now accessible in

California, that there are really but two kinds of fig flowers, namely, pistillate and staminate, although it may be advisable to separate the pistillate flowers into two kinds—those of the caprifig, called gall flowers, and the ordinary flowers of all the female figs. These authors enumerate the four kinds as the male and female of the caprifig, the regular female flower of the Smyrna, and lastly the female flowers of the Adriatic class, which some of them contend have imperfect stigmas and can not be pollinated, and therefore call them mule flowers. Careful investigations by the writer have failed to disclose such flowers. Pontedera and Gallesio call them fico mula and fico semimula, a few of the latter being susceptible of pollination and the former not at all. This idea has become so fixed in the minds of some horticulturists that they are calling this class of figs "mule figs," a positive misnomer and entirely unwarranted by the facts.

The staminate flowers of the caprifig are arranged in a zone or cluster at the upper part of the fig, just within the eye. The remainder of the receptacle is filled with gall flowers which are perfect female flowers, the pistils of which are modified for the purposes of the female Blastophaga. The styles of these flowers are short and thick compared to those of the Smyrna and other female figs and are provided with a duct, down which the fig insect pushes her ovipositor into the ovary, where she deposits the egg. As evidence that these are female flowers, careful examination discloses the fact that these styles are surmounted usually by forked stigmas, the surfaces of which are provided with the usual cells or glands and the viscous coating to which the pollen grains adhere. With sufficient magnifying power the pollen tubes can be seen pushing their way from the surface of the stigma down through the cellular tissue into the ovary. The gall flowers of all caprifigs are alike except for slight variations in the shape of the stigmas.

As further evidence that all the gall flowers in the caprifig are perfect female flowers, some of the persistent stigmas from ovaries containing fertile seeds in a mammoni fig and others from galls containing fully developed Blastophaga in the same fig were placed side by side under the microscope and were found to be identical in cellular structure and in every other respect. The writer is therefore satisfied that the stigmas of the flowers of the mammoni caprifigs are equally as susceptible to pollination as are those of the female figs, and in fact are so pollinated, but fail to produce more than a few seeds, for the reason given in this bulletin under the heading "Caprifig seeds." (See p. 15.)

FIG POLLINATION.

When the Blastophaga enters the spring crop of the caprifig, the stamens are in an undeveloped condition and the anthers will not be ready to discharge their pollen until about two months later—

that is, at the time when the next generation of insects is ready to issue. It is, therefore, impossible for a fig to pollinate itself. Here, then, is a striking instance of one of nature's methods of preventing self-fecundation.

In the regular female flower of the Smyrna fig the style is long and slim, two or three times longer than the style of the flower of the caprifig, and this is the reason that it is unsuited for the purpose of the insect. It is divided at the summit usually into two stigmas,

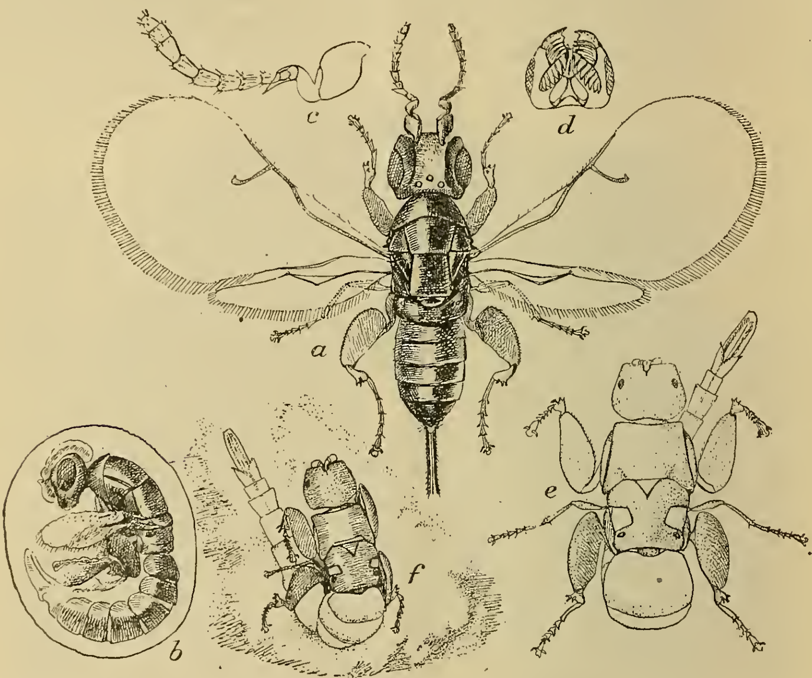

FIG. 6.—*Blastophaga psenes: a,* Adult female with wings extended, seen from above; *b,* female not yet entirely issued from pupal skin and still contained in gall; *c,* antenna of female; *d,* head of female from below; *e* and *f,* adult males. (All greatly enlarged.)

and they appear to be identical with those of the flowers of the Adriatic class, to which belong all those figs which reach an edible condition without pollination. The stigmas of the latter, some authors say, are mostly malformed and can not be fertilized.

LIFE OF THE BLASTOPHAGA.

The beneficent insect upon which depends absolutely the whole Smyrna fig industry is a small species of very strange structure (figs. 6 and 7). The female, a little less than an eighth of an inch in length, is black in color, is provided with wings, and in a favorable wind has been known to fly several miles. The male is wingless, is amber or brownish yellow in color, and somewhat resembles a small grub. After many unsuccessful attempts, the insect was sent over to the United States from northern Africa in 1899 by Walter T. Swingle, of the United States Department of Agriculture. Success was due to avoiding methods which had previously often failed by confining the efforts to the winter generation and by the ingenious device of wrapping each caprifig in tin foil to prevent evaporation. It was discovered later, however, that the Blastophaga was already here, having been accidentally introduced with fig trees from southern Europe about 1865, but this did not become known to orchardists until 1908, having been, so far as known, confined to an isolated tree 10 miles west of Modesto and one or two others in the vicinity of Lathrop, Cal. (50, 54).

In California the insect, which hibernates in the larval form during the previous few months, reaches maturity in April. The male leaves the gall first. He moves about the interior of the fig, and, finding a gall containing a female, gnaws a hole through the cortex of the ovary at the base of the style and fertilizes the female while she is still in the gall. The gravid female enlarges the opening and sometimes makes another, usually at the base of the style, probably because it is the point of least resistance. In from 22 to 48 hours she leaves the gall, reaching the open air through the cluster of male flowers, the anthers of which at this time have burst and are shedding large quantities of pollen. Her body is moist and sticky and she is frequently so loaded with pollen that she is unable to fly until she divests herself of much of it in the same way that the common house fly strokes its body with its legs.

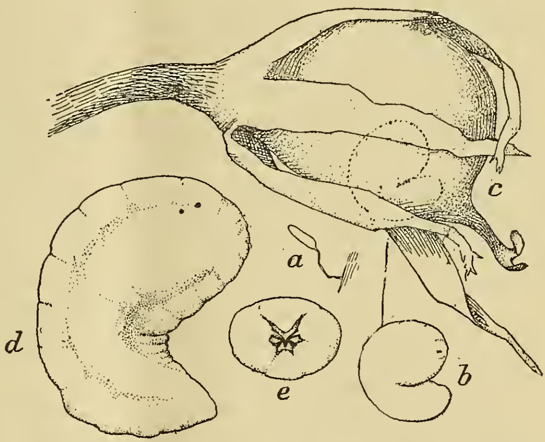

FIG. 7.—*Blastophaga psenes: a*, Egg; *b*, young larva; *c*, outline of young larva in gall; *d*, full-grown larva; *e*, mouth of full-grown larva. (All enlarged.)

After being relieved of part of the load, she flies to the nearest fig, and if it be in the right condition she immediately seeks the opening at the apex. At this time the figs are hard and from a quarter to three-quarters of an inch in diameter and the eye is closed by the overlapping scales. Some authors assert that with her powerful mandibles she is obliged to cut away a portion of one of these scales to effect an entrance; but this is unnecessary, as she is able to push her head under the thin edges and after a struggle of sometimes five minutes or more pushes down the zigzag way to the interior of the fig, generally leaving her wings behind.

While one insect is probably sufficient to fertilize a fig, it is not unusual where they are very abundant, as at the Maslin orchard at Loomis, to find a dozen or fifteen in one small fig and as many more in a struggling mass trying to effect an entrance; often the cluster of wings can be seen radiating from the eye like the plumes of a miniature feather duster. If the caprifig from which the insect has issued has been hung in a Smyrna tree, she enters a Smyrna fig and then finds she has made a mistake, as the flowers are of such shape that she can not oviposit in them, and after wandering about in a vain effort to dispose of her eggs, in this way doing her useful work of fertilizing the female flowers, in most cases she crawls out. When the weather is warm, say 90° to 100° F., the insects are very active and come out of the caprifig with a rush. The writer has seen 40 issue in one minute. The issue takes place almost entirely in the forenoon, unless a cold windy morning is succeeded by a hot sun in the early afternoon, when a considerable number appear. The movement depends much upon the weather. During cool windy mornings very few issue, but if the next morning is warm, calm, and sunny a great rush occurs. The insects continue to issue from a single fig for a week or ten days if the weather is favorable, and from the figs of various capri trees for two to three weeks. After the females have left the fig most of the males soon follow, and, being wingless, drop to the ground like the females which have lost their wings in entering the Smyrna figs.

Every Smyrna fig not entered by the Blastophaga dries up and falls from the trees. In a few days the caprified fig undergoes a remarkable change. It begins to increase rapidly in size, becomes smooth by a lessened prominence of the ribs, and loses its pea-green color, assuming a decidedly pruinose tinge, this being true also of the caprifig.

PROPORTION OF MALE AND FEMALE INSECTS IN CAPRIFIGS.

The writer has taken some pains to determine the proportions of the sexes of the Blastophaga in caprifigs, and has found from actual count of the insects of several varieties that the proportion runs from two-thirds to three-quarters females. The number of galls in good sound caprifigs, according to size, runs from 500 to 1,600. A medium-sized mamme caprifig has been found to contain 1,015 healthy galls; good Milco profichi caprifigs have been found to contain 1,200 to 1,600. After the female insects leave the caprifig most of them live only 24 hours, though a very few will be found alive at the end of 48 hours. It is doubtful whether they eat at all. After the female has fulfilled the object of her existence, namely, providing for the future generations of her species, she dies.

OVIPOSITION BY BLASTOPHAGA.

If the Blastophaga has entered a caprifig, a crop of which should at the time be in receptive condition, she finds no difficulty in depositing her eggs. Authors differ as to the technique of the operation. The German botanist Count H. G. Solms-Laubach says she pushes her ovipositor down through the duct in the style and thus places the egg in the ovary. Dr. Cunningham, the English botanist, in his memoir on the fertilization of *Ficus roxburghii* (5), says, "The deposition must apparently take place, not in the style, but by means of penetration of the upper surface of the ovary." Another author says, "Should the fig entered prove to be a caprifig, she lays as many eggs at the base of as many male flowers as she can find and then dies."

Careful investigations by the writer confirm the view of Solms-Laubach. This view must be correct; otherwise the insect would be able to oviposit in the Smyrna and other edible figs (which she never does), and thus give us a collection of insects instead of seeds.

After the insect reaches the interior of the caprifig she moves about over the mass of stigmas; curving the posterior portion of the abdomen under and forward, she thrusts the ovipositor repeatedly down between the flowers, seeming to be guided entirely by the sense of feeling rather than sight. Finally, after eight or ten attempts, she succeeds in pushing it down through the central duct of the style and rests for a minute or two while the egg is being ejected.

When the insect is wandering over the flowers the ovipositor does not appear longer than the sheath. This apparently misled Dr. Cunningham, who states that the ovipositor is too short to reach the ovary through the style. When an entrance to the style is effected, the ovipositor is extended, telescopelike, to three times the usual length, which enables the insect to deposit her egg well down in the ovary. The style is white and translucent, and as the egg-laying instrument is yellow or amber colored it is plainly visible with a microscope of moderate power when pushed down into the ovary. Within two or three hours after oviposition in a flower the stigma and style turn brown, rendering it easy by opening a fig to determine that the work has been well done.

CAPRIFIG SEEDS.

The mammoni crop of the capri tree is the only one which has been observed to produce seeds, and then only in small numbers. The obvious reason for the presence of seeds is that this crop is pollinated by the Blastophaga of the preceding profichi crop. The profichi crop itself yields no seed, because the mamme figs preceding it have no viable pollen, although the pistils are provided with receptive stigmas.

Gasparrini (17) found 20 seeds in 40 mammoni figs and reached the conclusion that not more than one flower in 2,000 is a perfect female flower, all the others being gall flowers, incapable of fertilization. The writer has found as many as 75 fertile seeds in one fig, and from a large number of mammoni seeds plants have grown at the United States Plant Introduction Garden, Chico, Cal. From careful observations he has been forced to the conclusion that all gall flowers are perfect female flowers and susceptible of pollination and that most of them are pollinated, but if the Blastophaga deposits an egg in the ovary the resulting larva prevents the development of the ovule and no seed is formed. The seeds therefore found in the mammoni figs are from those flowers in which the insect failed to oviposit.

SEEDS ACCOMPANIED BY SECRETION OF SUGAR.

There seems to be some connection, not yet well understood, between the seed and the secretion of sugar and coloring matter. The pedicels and floral envelopes of the seeds in mammoni figs are succulent, sweet, and generally of a pink color, while all parts of the gall flowers containing Blastophaga are white and quite dry, the difference in appearance being so marked that the seeds can readily be picked out with a pair of forceps from the mass of galls by their succulence and pinkish color.

CAPRIFICATION.

The term caprification is derived from the word *capri*, the name by which the male or pollen-bearing fig is known, and is applied to the process of hanging the caprifigs in the Smyrna trees. The details of the process are somewhat obscure and complicated, and it is not strange that it is little understood by the public in general, though known to the inhabitants of Asia Minor more than two thousand years ago. Theophrastus, who wrote about 350 years before Christ, describes the process as practiced at that time exactly as it is used at the present day in this country.

Undoubtedly the cultivated fig was originally a diœcious species having about equal numbers of male and female trees. Through centuries of culture, varieties of the female figs have been developed which will produce fruit without caprification, but such figs never produce fertile seeds. Figs of the Smyrna type absolutely require fertilization to set fruit at all, and such fruits produce an abundance of fertile seeds, which undoubtedly add to the flavor and quality of the dried Smyrna figs. In orchard practice it is not necessary to have, as in the state of nature, approximately one half of the trees male and the other half female. One or two caprifig trees per acre of fig orchard is sufficient to supply an abundance of caprifigs to fertilize the whole orchard.

It is well known that the flowers of the fig are inside the receptacle which becomes the fruit. Caprifig trees look exactly like ordinary fig trees and bear fruits which look like figs, the only difference being that instead of producing seeds the caprifigs are fitted with small galls just about the size of seeds, in which the fig insect develops. The caprifig differs from the Smyrna and other female figs in having a cluster of male or staminate flowers just within the eye. As the Smyrna, unlike common fig varieties, can not reach maturity unless the flowers are supplied with pollen and the fig can not pollinate itself, dependence must be had on some outside agency. This agency is the fig insect (*Blastophaga psenes*). The spring (profichi) crop of the capri or male tree is used for this purpose. In California and other Southwestern States the insects begin to issue in the warm valley from the 10th to the 20th of June and continue often until well into July.

In leaving the fig the female insect passes through the zone of male flowers, thereby dusting herself all over with the fertilizing pollen, which she then carries to the young fruits of the Smyrna fig. The fig insect can live only a few hours outside of the caprifig. In fact, only a portion of the male insects as a rule leave the caprifig at all, and the females leave only to deposit eggs for the next generation. In other words, the fig insect is restricted absolutely to the caprifig and can breed nowhere else. This means that the caprifig tree must furnish a succession of generations of fig fruits in which the fig insect can multiply; that is, as one crop of caprifigs ripens the next crop must be ready to receive the insect. This proper adjustment of crops does occur in some few caprifig varieties, but in many others the adjustment is not so close, as explained elsewhere.

It only remains to state that the fig insect is unable to breed in the Smyrna fig itself. The fig insect merely carries pollen from the caprifig fruit and is not able to lay her eggs in the minute flowers which line the Smyrna fig fruit, because the styles of these flowers are too long to permit the egg to be placed properly.

Briefly, then, caprification consists in suspending in the Smyrna fig tree in June a few chaplets or baskets of caprifig fruits of the spring generation or profichi fruits of the caprifig tree which contain myriads of minute fig insects (*Blastophaga psenes*). The minute winged female insect in issuing from these caprifig fruits becomes dusted with pollen, which she carries into the young and receptive fruits of the Smyrna fig. Once inside the Smyrna fig fruit, the female insect wanders around trying to find a suitable flower for oviposition. All she accomplishes is to dust thoroughly the stigmas of the fig flowers with pollen, thereby insuring the setting and ripening of the fruit, but she does not succeed in ovipositing in the Smyrna fruit.

No other horticultural industry is so intimately tied up with a specific insect as is Smyrna fig culture, which is, indeed, absolutely impossible without the beneficent help of this minute creature.

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APPLICATION OF CAPRIFIGS TO SMYRNA TREES.

Various methods are employed in suspending caprifigs in the Smyrna trees. The figs may be strung on strings or raffia by means of a coarse needle into which the string is threaded. These chaplets of four or five figs each are then suspended in the Smyrna branches, preferably in the shady parts of the tree. Another method is to put the caprifigs into cornucopia-shaped baskets made of coarse galvanized-wire cloth. These baskets may be used year after year, or may even be left suspended in the trees.

Some experienced growers find that it pays to suspend small pans filled with moist sand in the trees, into which the caprifigs are pushed, stem down, two-thirds of their length. This prevents the fig from drying out and permits all the Blastophaga to escape.

WHEN SMYRNA FIGS ARE RECEPTIVE.

Smyrna figs are in a receptive condition from the time they are the size of filberts to that of small walnuts, say from five-eighths of an inch to about an inch in diameter. At this time the fig is glossy, with prominent ribs. Soon after caprification it becomes smooth and loses its gloss. (See fig. 8.) On cutting open such a fig a few hours after it has been entered by the insect the styles and stigmas of the flowers will be observed to have turned brown from injury caused by the Blastophaga. The best evidence, however, to indicate that the fig has been entered by the insect is the presence at the eye of the wings which have been left behind in effecting the entrance. These will be visible for a day or more if the weather is not windy.

SEVERAL APPLICATIONS OF CAPRIFIGS ADVANTAGEOUS.

Dr. Eisen has shown that a number of applications of caprifigs to each tree greatly increases the crop, for the reason that when the caprifigs are first hung in a Smyrna tree only a part of the figs are in a receptive condition. In warm weather these caprifigs are exhausted of most of the insects in four or five days. Meantime, other Smyrna figs have pushed and have reached a receptive condition, and another supply of caprifigs at this time will be required for their pollination. Three or four such applications four or five days apart will be found to increase greatly the setting of fruit. As the Smyrna crop depends absolutely upon the supply of insects it is found that a liberal application of caprifigs is desirable. For trees 4 to 6 years of age, 10 or 12 figs for each will be found sufficient, while for trees from 8 to 12 years old the number should be doubled. One experienced grower in the San Joaquin Valley, whose trees are about 12 years of age, informs the writer that he greatly increases his crop by applying as many as 50 to 150 caprifigs to each tree.

CAPRIFICATION NOT AN EXPENSIVE OPERATION.

Occasionally fig growers raise objection to the cultivation of Smyrna figs on account of the trouble of caprification, but as there is no other way of raising them the grower must submit to the slight handicap if he wishes to produce dried figs of high quality. It has been found from experience that one man can caprify about 40 acres. His time will be consumed for a period of about three weeks. Mr. George C. Roeding, of Fresno, Cal., says that the cost of the work in his large orchard does not exceed 2 cents per tree, or from $1 to $1.50 per acre.

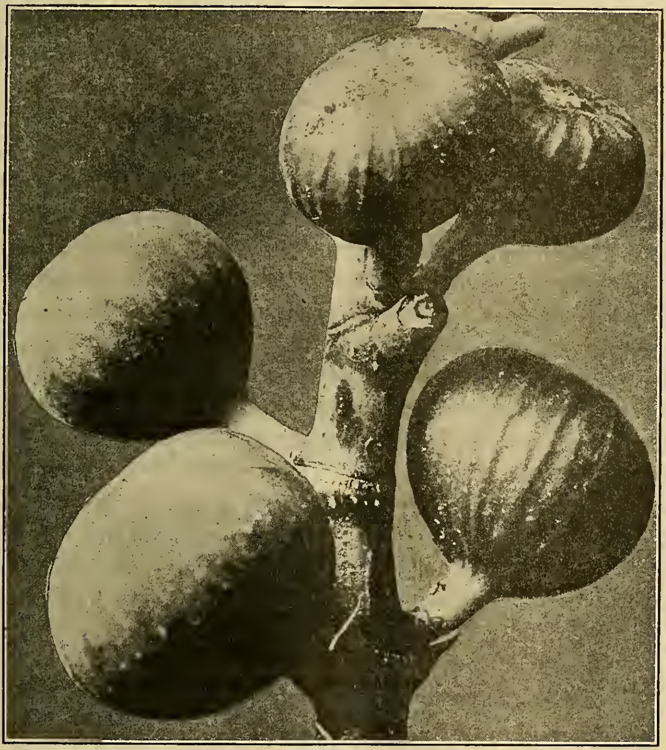

FIG. 8.—Change in appearance of figs due to caprification. Two caprified figs are shown on the left, three uncaprified ones on the right.

WHEN TO GATHER PROFICHI CAPRIFIGS.

The proper condition for gathering profichi caprifigs is easily ascertained by opening a few figs and looking for the appearance of the male, as previously mentioned, but is readily indicated by a slight softening of the fig.

Experience has developed some methods of handling profichi figs that are worth mentioning. The spring generation of Blastophaga commences to issue from about the tenth of June to the first week in July, the time depending upon the locality and the weather, warm weather hastening development and cool weather retarding it. At this time the weather is very warm in the great valley of California. If large quantities of figs are to be gathered, a considerable saving is effected with no harm to the insect by letting them fall to the ground when detached from the branches, but the figs must not be allowed to remain on the hot ground in the sun longer than a few minutes. With a temperature of 90° F. many insects will be killed in half an hour, and most of them in an hour. In an hour and a half every one of them will have succumbed. The figs in the shade of the tree or those attached to the branches are not affected except at very much higher temperatures. It is therefore necessary to pick up the figs from the ground about as fast as they are thrown down by the men in the trees.

CAPRIFICATION OF COMMON FIGS.

To show how erroneous is the conclusion of some authors that the pistillate flowers of the Adriatic class of figs are malformed and can not be pollinated, it may be mentioned that the writer by applying the Blastophaga to the so-called "mule" figs of more than 50 varieties found that in every instance heavy fertile seeds were produced and in as large proportion as in the Smyrna fig. From these seeds, thousands of plants have been grown at the United States Plant Introduction Garden, Chico, Cal. From such cross-pollinated seeds some interesting and valuable varieties are being secured. The breeder does not have long to wait for results, since most of the seedlings bear fruit at the age of 2 and 3 years.

A striking instance of the fertilization of common figs occurred at Loomis, Cal., where Mr. Andrew Ryder, a prominent fruit grower, had grafted a portion of an Adriatic tree with Smyrna scions. The Smyrna set quantities of fruit, and wishing to secure a crop the owner hung in the tree caprifigs containing Blastophaga ready to issue. Some of the insects entered the Adriatic figs on the ungrafted part of the tree. The writer secured three mature Adriatic figs which showed by their abnormally large size that they had been entered by the insects. These three figs contained by actual count 4,800 heavy fertile seeds, or an average of 1,600 for each fig—certainly a good crop for a "mule" fig which, according to some writers, will not breed.

Experience is showing that the time may come when it will be worth while to caprify all of the common figs, that is, those varieties which otherwise reach an edible condition without pollination. A caprified fig is a more nearly perfect fruit than an uncaprified one. The fruit is considerably increased in size, and the seeds contain plump kernels which give a delicious nutty flavor, not apparent in uncaprified figs. Dr. Eisen was the first investigator to make the suggestion.

CAPRIFIG PLANTATIONS.

As the caprifig crop occasionally suffers from frost in the flat regions of the great valley, it is suggested that the fig growers of a locality combine and plant a caprifig orchard of a few acres in some frost-free foothill region. In this way the cooperators would insure themselves a steady supply of caprifigs at little cost.

All Smyrna fig growers appreciate the fact that there would be considerable advantage if caprifigs containing the insect could be had for a period of a month or six weeks, thereby insuring the pollinizing of more figs and an increase in the crops. With our present varieties of caprifig trees the caprifying season covers a period of only about three weeks. The only way by which this period can be extended with capri varieties now cultivated seems to be by planting the capri trees in cool localities where the proximity of the sea or other influences retard the ripening of the figs and the development of the Blastophaga. In such localities as Loomis, Fresno, Indio, and Mecca, Cal., and Phoenix, Ariz., the insects from the profichi crop begin to issue from about the 10th to the 20th of June, while in localities within the influence of the ocean breezes, such as the cooler portions of Sacramento and San Joaquin Counties, the period of issue is a week or ten days later, and at Niles, Alameda County, Cal., on the eastern shore of San Francisco Bay, the time of issue is as late as July 25 or the beginning of August. A cooperative caprifig orchard could be so located as to supply the Smyrna fig growers with pollinizing material for the latest figs that could ripen before the advent of the fall rains.[1]

THE SEEDLING FIG ORCHARD AT LOOMIS, CAL.

Back in 1886, while a spirited discussion regarding the necessities of caprification was going on in California, E. W. Maslin, then of Loomis, Cal., sent to H. K. Thurber, a leading importing merchant of New York City, for a box of the finest imported Smyrna figs. The seeds of these figs were planted by the gardener at the State Capitol, Sacramento. The resulting seedlings were planted by Mr. Maslin on his ranch at Loomis in 1887. These trees grew thriftily and in the course of three or four years began to set fruit, nearly all of which failed to mature for lack of pollination, the fertilizing insect, Blastophaga, not then having been introduced into that part of the State.

The Blastophaga were first colonized on George C. Roeding's trees at Fresno, and in the following year, 1901, they were established in the Maslin orchard, at Loomis, where the trees matured fruit for the first time. The fruiting of the trees demonstrated that about half of them were caprifigs and the other half of the female or edible type. This result was naturally to be expected, as the Smyrna fig is the female form of a diœcious species.

[1] This would be a desirable undertaking for an association of fig growers, such as was formed at the Fig Institute at Fresno, Cal., January 4 and 5, 1918.

From this time a careful study of the trees and product was made, with the result that a number of new varieties of decided promise were found. Two of a new Smyrna class were discovered in 1908 by A. H. Brydges. These attracted attention from the fact that the fruit withstood uninjured two soaking rains which spoiled that on adjoining trees. The preservation of the fruit under these trying circumstances was due to the fact that the eye of the majority of the fruits is stopped by a drop of hardened, pellucid juice which effectually excludes rain, filth, beetles, and flies which might carry into the fig the germs of fermentation. This prevents souring, and it also prevents the entrance of insects which deposit eggs resulting in wormy figs. (See "Descriptions of varieties," pp. 36–37, Rixford variety.)

The Maslin fig orchard has played an important part in the development of the fig industry in California. At the fruit-growers' convention, at Stockton, in December, 1910, reports were current that a number of fig growers in the San Joaquin Valley were digging up their bearing Smyrna trees, owing to the difficulty of obtaining caprifigs containing Blastophaga to pollinate their fruit. Walter T. Swingle and the writer proceeded to Ceres, where most of the destruction of trees had occurred, and called a meeting of growers who could be quickly reached by telephone. There were 12 or 13 growers present, who were admonished not to destroy any more trees, as the United States Department of Agriculture had taken a lease on the Maslin orchard, containing 72 capri trees, and would furnish the entire crop to the growers at the bare cost of gathering and shipping the fruit, namely, 50 cents per box containing 160 to 175 figs. The growers next season availed themselves of the opportunity to the extent of over 600 boxes, 96,000 figs, with the result that no more fig trees were destroyed. In addition to devoting the entire crop of caprifigs of the orchard to the growers, cuttings from the best trees were offered gratis to anyone who desired to avail himself of the privilege. Besides several fine Smyrna varieties, the orchard contains several of the finest capri varieties in cultivation. Of the capri varieties, several bear the largest caprifigs ever seen in this country, with correspondingly large numbers of Blastophaga from the ample gall zones and having large staminate clusters with abundance of pollen. They possess, besides, a vigor and hardiness that has never failed to carry the mamme crop safely through the hardest frosts of California winters. Detailed descriptions of these will be found in another part of this bulletin.

HARVESTING AND CURING.

The fig ripens and dries on the tree and when it falls all of the small and medium-sized fruits are sufficiently cured to keep, while those of large size require further exposure to the sun for a day or two, either on the ground or on wooden platforms. In some respects the normal climate of the great interior valley of California is superior to that of Asia Minor, where summer dews are prevalent and fall rains sometimes injure the crop.

It is a good practice to gather the figs very often, say two or three times a week. One successful grower who puts up an exceedingly fine product gathers the figs every day. One reason for this is that the eye of a caprified fig is usually quite open and the longer it remains on the ground the more likely it is to be visited by beetles that leave eggs inside the fig, causing a wormy product.

Sulphuring is not necessary to improve the appearance of Smyrna figs, as it is for the Adriatics and some other varieties. Some

P30025A–CP.

FIG. 9.—Drying grounds at Fresno, Cal. In the foreground figs are being dried on platforms, while to the left are stacks of trays already dried.

growers think that spreading the figs out on trays and stacking them so as to keep them out of the direct rays of the sun to finish up the drying makes them lighter colored.

The first operation after the figs are gathered from the ground is to rinse them in clear water and spread them out on wooden platforms, such as are used for drying raisins, until the surplus moisture has evaporated (fig. 9). They are then dumped into boxes. In the raisin region sweat boxes are used for the purpose. They should be pressed down into a solid mass and should remain in that condition until ready to be packed or sold to the packer. The product is thereby greatly improved, as the overdried fig absorbs moisture from the underdried, thus equalizing the whole mass. This process also causes the skin of the fig to absorb moisture and sugar from the interior pulp and this renders it pliable and tender.

PACKING FIGS.

Most growers pack the figs in clean cotton bags, in which condition they are sold to the packers, but others find they can add several cents per pound to the value of the product by doing their own packing. Many figs are packed in 5-pound and 10-pound boxes and many more in fancy cartons holding from one-half to 1 pound each. The expense of fitting up a packing house is inconsiderable, the appliances required being a kettle set in a furnace for heating boiling water or brine, forms for packing the figs in half-pound or 1-pound bricks, and a press to apply pressure to the packed product. The bricks which go into the cartons are wrapped in waxed paper, which tends to retard drying out.

P80025B—CP.

FIG. 10.—Processing house. The dipping vat is shown in the center.

The packing operations begin by exposing the figs to boiling brine for a minute or two in wire baskets or by means of a prune dipper where it is done on a very large scale (fig. 10). The brine is made with from 3 to 4 ounces of salt to the gallon of water. Care should be taken not to make the brine so salt as to be apparent to the taste in eating the fig. The object of the process is to destroy by heat the eggs of any insect that may have entered the fig while it was lying on the ground and also to help retain the moisture and prevent drying out, as it is well known that salt absorbs moisture to some extent. Some growers put their figs through a sizing machine at a certain stage of the work, separating the fruit into about three grades. The smaller and also any defective fruit, including split figs, finds a ready market ordinarily at 2 to 4 cents a pound, and is used by manufacturers of pastry products.

The medium and large fruits are packed by themselves, making two to three grades with names to suit the fancy of the packers. Those intended for ornamental cartons are flattened out between the fingers of the operator, the eye end is turned under and then the fig is split from apex to stem and spread out to the width of the form in which the brick is packed, being arranged in layers until the form is filled. The bricks are put under the press and thus compacted into a solid block. These blocks or bricks are wrapped in wax paper and placed in fancy cartons upon which the producer's name or brand is embossed or are packed in layers in 5-pound and 10-pound wooden boxes.

Another style of packing, called "lacoum" in Smyrna, in which each fig is pressed by hand into a square shape and then packed into rows in the cartons, is described and illustrated in Dr. Eisen's bulletin (11).

SHIPPING FRESH FIGS.

The consumption of fresh or undried figs in the city markets is building up a trade of considerable importance. The large populations, especially of peoples from southern Europe, who count the fruit in this condition as an almost indispensable luxury, have all brought to this country their liking for fresh figs, which demands that fruit growers cater to this trade. The Smyrna fig is so superior to the common varieties that when the supply is sufficient at reasonable prices, the markets can take large quantities of the fruit in this form.

Only the choicest fully mature specimens of uniform size should be shipped. Such fruit appeals to everybody. The usual method of packing now in use is in wooden boxes about 12 by 16 inches in size and corresponding in depth to the size of the largest figs, holding about 8 pounds. The fruit carries best when packed in a single layer, the boxes being lined with white paper and the rows of figs separated by strips of the same. No doubt egg boxes, in which each fruit would be out of contact with its neighbor, would be ideal carriers.

If a plan not too expensive could be devised by which ripe figs could be laid down in eastern cities, a large trade in Smyrna figs could be built up. Experiments have been made which have met with some success. A shipment of 50 boxes sent from Ceres, Cal., in an iced fruit car was sold readily in Chicago at 20 cents a pound. A smaller lot, shipped in a pony refrigerator from Indio, Cal., reached New York City in perfect condition and brought $4.62 per 1-layer box of 7 or 8 pounds. In each case the consignee asked for more. The best results were had with the pony-refrigerators, but the cost of express charges on the pony and the necessary weight of ice are almost prohibitory. Fresh Smyrna figs are so much superior to any ever seen in eastern cities that they would meet with an active demand at reasonable or even high prices. Here, then, is a field that ought to engage the attention of experimenters, not only in the Southwest, but also in the South Atlantic and Gulf Coast States.

SMYRNA FIG CULTURE IN THE SOUTHERN STATES.

Many varieties of Adriatic figs are already successfully cultivated throughout the great coastal plain from Texas to the Carolinas, chiefly for home consumption, canning, and preserving. The home fruit garden usually contains a few thrifty trees, which provide for the owner liberal supplies of fresh figs from the middle of July to well into September. The varieties now in most general cultivation are Celeste, Magnolia, Ischia, Brunswick, and Brown Turkey. The first mentioned is the favorite in Louisiana, especially in the neighborhood of New Orleans.

The Smyrna fig on the Pacific coast is equally as frost resistant as any of the varieties mentioned. In fact, some of the oldest and largest fig trees seen by the writer in the Southern States are of the Smyrna type. These trees, it is surmised, are accidental seedlings from imported Smyrna figs and include the capri, or staminate, as well as the Smyrna, or pistillate, trees, located at various widely separated points. Through the lack of fig insects to pollinate their fruits no crop is ever secured from such scattered Smyrna trees, the figs dropping when about half grown. On this account, Prof. Reimer (39), of the North Carolina Agricultural Experiment Station, advised that all such seedlings in North Carolina be cut down and replaced by varieties that do not require caprification. A caprifig tree was discovered and identified in the business section of San Antonio, Tex., through the assistance of E. B. Pauly. Other old Smyrna fig trees were located with the assistance of George E. Murrell, the horticulturist of a railway company. Prof. Boudousquie, of Spring Hill College, Mobile, Ala., has half a dozen capri trees, 6 years old, at Battles Wharf, on the east shore of Mobile Bay. Capt. Lawrence, at Fairhope, in the same neighborhood, has grown Smyrna figs with varying success for several years by using caprifigs containing fertilizing insects, these caprifigs being sent to him from California, but has not succeeded in establishing a colony of Blastophaga on his capri tree, perhaps because it is not of a good variety.

On Dauphin Island several old fig trees 8 to 10 inches in diameter had suffered severely from a hurricane at the time the writer examined them, but showed no injury from frost. To the warm waters of the Gulf of Mexico is due the immunity of the locality from frost.

At Brunswick, Ga., a large capri tree was found at the home of Mrs. L. M. Russell. The tree is supposed to be 18 years old. It is 5 feet in circumference 6 feet from the ground and has a spread of 35 to 40 feet. At Savannah a large Smyrna fig tree was discovered on the premises of Mrs. S. D. Richards. This tree has a trunk 10 inches in diameter. Capt. S. G. Stoney, president of the Charleston County Agricultural Society, C. F. Nevins, and M. L. Bissell rendered valuable assistance in locating these trees. At Augusta, Ga., R. C. Berckmans is growing many varieties of figs and was able to give the writer much valuable information on the subject. From these investigations it is apparent that there exists no climatic obstacle to the growing of Smyrna figs in the Southern States.

Besides ascertaining the climatic fitness for the successful growth of Smyrna trees, a further important step looking to successful Smyrna fig culture has been taken. Colonies of the fig insect have been established at two points in the South. A colony was established in the old capri tree at San Antonio, Tex., in 1917, and in two trees at Brunswick, Ga. The insects sent in caprifigs from the Department of Agriculture's orchard at Loomis, Cal., were placed in the San Antonio tree by E. B. Pauly, where they established themselves and seemed to thrive in spite of a fall in temperature to 25° F.; but later a drop to 13° F. exterminated the whole colony. The capri trees at Brunswick, Ga., belonging to Mrs. L. M. Russell and George H. Cook carried their crop through the winter of 1917–18 without injury, and the fig insects entered the spring crop of caprifigs, causing a full setting of fruit. Mrs. Russell sent a few of her figs to San Antonio and reestablished the colony on the old tree at that point.[1]

A serious obstacle to the fig industry in the South is the prevalence of wet weather during the ripening period, causing most varieties to sour and also preventing the fruit from drying on the trees, as it does everywhere in California.

Sufficient evidence has been accumulated as to the possibility of Smyrna fig culture in the Southern States to justify experimenting with this type of fig. Even if the crop can not be dried without artificial heat, it is probable that owing to its greater sugar content the Smyrna fig will resist the tendency to sour and for this reason will prove to be suitable for shipping in a fresh state to the northern and other city markets.

It should be borne in mind, however, that success in growing Smyrna figs is absolutely dependent upon the presence of caprifig trees colonized with the fig insect. Until it has been demonstrated that the insect can be carried successfully through several seasons it will not be advisable to undertake commercial plantings of figs of the Smyrna type. There are, however, many scattered chance seedlings of the Smyrna type already in existence the fruit of which now goes to waste. Experiments should be conducted in caprifying their crops if female trees or in establishing the fig insect in them if they happen to be caprifigs. The summer or main crop of edible figs of the Smyrna type should be setting in late May or early June, when they are ready for caprification; the profichi or main crop of the caprifig tree should be setting in March, when the fig insects may best be introduced.

[1] Caprifigs from the Russell tree at Brunswick placed in the Richards tree at Savannah (Smyrna type) on June 1, 1918, caused a large crop of excellent figs to mature, the first fruits ever secured from this old tree.

STARTING A SMYRNA FIG ORCHARD.

In starting a fig orchard the selection of the best varieties adapted to the locality is a matter of supreme importance. It can not be too strongly impressed upon the beginner that his main dependence in planting the orchard should be upon the Lob Ingir, the standard Smyrna fig of the world and the variety universally grown commercially in the Meander Valley of Asia Minor. (See fig. 1.) Sometimes planters are advised to put out the Adriatic, under the mistaken idea that it is a heavier bearer than the former. Experience has demonstrated that if the Smyrna is liberally supplied with caprifigs the

FIG. 11.—A fig tree of the Stanford variety. The fruit does not split in ripening, as in the case of other figs, and it ripens about two weeks earlier than that of the Lob Ingir.

reverse is the case. The eastern cities are flooded with the inferior Adriatic figs, the repulsive acid taste of which, derived from the sulphur used in bleaching, is giving California dried figs a bad reputation. Shippers should realize that they are doing irreparable injury to the fig trade by putting this inferior fruit upon the market. It must be apparent to anyone who has sampled the Adriatic fruit now found in quantities in the eastern cities that a great fig trade which will successfully compete with the imported Smyrna fruit can not be built up with this inferior Adriatic fruit.

If the planter desires to experiment in a small way, some of the varieties described in another part of this bulletin may be tried.

Perhaps among these the Stanford variety (fig. 11), on account of its earliness and nonsplitting character when ripening, is one of the most promising.

Almost any grower of Lob Ingir figs in California can supply cuttings at a nominal rate when pruning his trees. This enables a fig orchard to be started at a very small cost; though, if preferred, trees can now be obtained from most nurserymen.

One of the indispensable requirements of successful Smyrna fig growing is a carefully selected assortment of capri trees. Since the undertaking is absolutely dependent on the Blastophaga, it is evident that varieties must be selected that experience has shown are capable

FIG. 12.—The original Milco caprifig tree, Niles, Cal.

of sustaining all three caprifig crops and all three generations of the fertilizing insects.

The first consideration is to secure capri varieties which never fail to carry a good winter (mamme) crop in spite of frosts and adverse conditions. This insures insects for an abundant spring (profichi) crop and must be followed by a good summer (mammoni) crop. As an abundant supply of good caprifigs at the proper season is the ultimate object of the capri plantation, four or five of the best kinds should be planted at the rate of two good trees to each acre of Smyrnas. In this list the grower can not be too earnestly urged to include the Milco caprifig, which has proved itself to be one of the best to carry all the crops of the caprifig to perfection (fig. 12).

Sometimes it is thought advisable to plant capri varieties first, for the reason that they usually fail to carry the mamme crop through the winter until they have reached the age of 4 or 5 years. As the capri trees produce the other two crops as early as the Smyrna, the difficulty may be avoided by securing from older orchards mamme caprifigs early in April to caprify the spring crop of the capri trees, thus providing a supply of profichi for caprifying the Smyrna crop of the young trees.

MAKING AND ROOTING CUTTINGS.

A fig orchard may be started by planting cuttings directly where the future trees are to stand, as is done in Asia Minor, but the almost universal practice in California is to plant the cuttings in nursery rows where they can be supplied with the necessary moisture until rooted. Cuttings taken from terminal branches and about 10 to 12 inches in length are preferable. In taking the cutting it should be cut through a node rather than between nodes, for the reason that between the nodes the pith is quite large and when planted leaves a hole in the bottom of the tree, while at the node the stem is solid.

In putting out the cuttings in the dry climate of California and other Southwestern States it is important that they be planted deeply, leaving not more than half an inch above the surface. If any large proportion of the cutting projects above the ground, the evaporation from the bark is such that the absorption below, there being no roots, will be insufficient to supply the loss of moisture and many of the cuttings will die.

The trees should be planted not less than 30 feet apart, and at the time of planting should be cut down to within about 2 feet of the surface. The ground should be plowed deeply and well pulverized, and if any hardpan exists it should be loosened by exploding a half stick of dynamite where each tree is to stand. The trees should be liberally irrigated until they are well established, but irrigation should not be continued later than the beginning of August. Anything that tends to keep up the circulation of the sap, preventing the wood from thoroughly ripening, renders the young trees liable to injury by frost.

Smyrna fig trees will give a few figs the third year. The fourth year, if they do well, should furnish a crop that will pay all the expenses of cultivation. From that time on, the crop and profits will increase for a generation.

ADAPTATION TO CLIMATE.

The fig endures about the same degree of cold as the olive. If not long continued, a minimum of 12° to 14° F. above zero is not injurious to mature trees, but this appears to be about the limit. Young trees if in a succulent condition would be badly set back if not killed at such temperatures. The cultivated fig (*Ficus carica*) delights in a dry, warm climate, but thrives also in a moist one, but not in the moist Tropics. The Smyrna fig, by far the best type in cultivation, is more exacting than the Adriatic class in the relation between climate and fruit production, as its crop of fruit is absolutely dependent on the fertilizing insect (*Blastophaga psenes*) and its culture on a commercial scale is therefore confined at present to regions where the winters are sufficiently mild to permit the mamme or winter insect-bearing crop to live through without injury.

While figs for fresh consumption can be grown successfully in moist and cool coastal regions, fig drying can be successfully carried on only in regions where the weather from the end of August and continuing through September and October is sufficiently warm to ripen the crop. This season of the year should be free from rains. A great commercial industry will always be confined to the production of dried figs; therefore, at this season of the year dry, sunny weather is indispensable.

PRESERVING MAMME CAPRIFIGS.

The discovery was made a few years ago by Henry Markarian, of Fresno, Cal., that mamme caprifigs gathered in December before the advent of severe frosts and packed in layers in damp sand or damp sphagnum moss and placed in outhouses or cellars where they may be protected from excessive cold can in this way be carried through the season of cold weather. It appears that the figs contain sufficient latex and the ovaries sufficient protoplasmic matter to feed and develop the insect to maturity, and all that is required is moisture enough in the packing material to prevent drying out. It is found that the insects reach maturity about the same time as those left on the tree.

Repeated experiments by the writer have shown that the period of issue can be regulated to a considerable extent by adjusting the temperature of the room or building where the figs are kept. A slight increase in the temperature hastens the development, and a corresponding lowering of the temperature retards it. In one instance figs were gathered on December 19, and the insects began to issue early in April. Some of these figs were sent from San Francisco to a location in southern Texas. The receiver reported the arrival of the figs in good condition and the insects began to issue on April 13 and entered the figs of his profichi crop. From these experiments it is evident that detached caprifigs can be successfully carried through winters in storage where the temperature is so low that the figs on the trees might be destroyed, thus making it possible to grow Smyrna figs in regions where frosts would otherwise interfere with success.

SOIL REQUIREMENTS.

The soil requirements of the fig are less exacting than those of climate. The size and quality of the fruit, however, are affected to a considerable extent by the character of the land on which it is grown.

Some varieties, like the Mission, seem to thrive on almost any kind of soil from light sand to heavy adobe. It is pretty well settled, however, that the best Smyrna figs are grown on quite heavy soil rather than light sand. The water requirements of the fig are less than those of most other fruit trees. Still, it demands above all well-drained land and some irrigation. It does not succeed, for instance, on land where the Bartlett pear thrives. Next to a well-drained, compact loam, a rich sandy loam is best, and a good dressing of stable manure will always repay the cost of application in the increased size of the fruit. A good percentage of lime in the soil is important. Some growers contend that lime reduces nematode infestation to a considerable degree.

CULTIVATION AND IRRIGATION.

The fig tree responds to good care and culture as readily as any other fruit tree. The orchard should be cultivated after every irrigation, and toward the end of the season it is well to have the ground under the trees mellow in order to avoid a hard surface upon which the ripe figs fall. Many orchards in California, especially on deep bottom land, produce good crops entirely without irrigation, while on shallower soil a good supply of water is necessary. A prominent grower at Fresno says that he raises large crops by a heavy irrigation in May or the beginning of June and another when caprifying at the end of June.

PRUNING.

The fig requires less pruning than any other fruit tree. After setting and cutting back to about 2 feet from the ground the aim should be to produce an open, symmetrical top, so as to admit plenty of sunshine and at the same time shade the trunk to prevent sunburn; still the branches are to be kept up out of the way of the cultivators. Many planters use tree protectors to shade the trunk until the tree top offers the necessary shade. In the beginning the top should be started with three or four branches, which are to be the framework of the future tree. The after treatment will require little more than the removal of chafing branches and the suckers which start from the ground at the base of the trunk. The main idea to be kept in mind is that the ripening crop requires plenty of air and sunshine.

GRAFTING.

Occasionally it will be found convenient or advisable to change inferior varieties to Smyrnas by grafting. Any of the ordinary methods employed on other fruit trees can be used. The only point of importance is always to use for scions 2-year-old wood. It may be from one-fourth to three-fourths of an inch in diameter. If 1-year-old wood is used, not more than one-fourth to one-third of the grafts will grow, while if 2-year-old wood is used and the work carefully done 95 per cent of them will grow. This is the experience of A. H. Brydges, a skillful horticulturist and caretaker of the demonstration fig orchard of the Department of Agriculture at Loomis, Cal.

Experienced fig growers are now thoroughly convinced of the superiority of Smyrna figs over any other kind as a profitable crop, and in many places they are grafting over their Adriatic trees to Smyrnas, thus about doubling the value of the product. If the tree to be changed is large, it is best to take two years for the work, as to remove the whole top in one season often proves too much of a shock to the parent tree. If the grafts do well, they will produce some figs the second year.

FREEDOM FROM DISEASES AND INSECT PESTS.

The fig possesses several advantages over other deciduous fruit trees. One is that little thinning is required to produce large-sized fruit, as is necessary with peaches, apricots, etc., since the size of the crop can be regulated by the number of caprifigs applied. The crop is never cut off by late spring frosts, for the reason that it pushes long after the last frosts occur. Up to the present time the fig tree in California has also been virtually free from insect pests and diseases, so that spraying has never been necessary.

A few cases of fungus on Adriatic and Mission trees have been reported, but they are not regarded as serious. A blackish smut or fungus sometimes is found in dried figs. Its appearance is not unlike the smut in cereals, and it can usually be detected by a discoloration of the skin. It may also be detected when no outward discoloration occurs by squeezing the figs, which ruptures the inclosing membrane and forces out the spores in a dark dustlike powder. As the spores are blown about by the wind, it is important that all affected figs be immediately destroyed by burning or depositing them in a receptacle containing a weak solution of formalin or corrosive sublimate, or even hot water. All refuse figs and trash from the orchard should be cleaned up and burned.

Large fig-eating beetles, known as June bugs, are troublesome in parts of Arizona, but have not been observed in California. Nematodes, minute worms infesting the roots, are found in many localities, but as yet they have not become a serious pest.

A small spotted beetle (*Carpophilus hemiplerus*) works in souring and fermenting figs, prunes, etc., and is really a packing-house insect. The little fly which frequents souring figs is the well-known vinegar fly. These insects can be abated to a considerable extent by cleaning up and burning the refuse leaves and decaying fruit from the orchard.

THE SPLITTING OF FIGS.

In certain seasons a few of the ripening figs split upon the tree. While this is an injury to some extent, it is not a very serious one. There seems to be a difference of opinion as to the cause. Some growers are firmly of the opinion that it is caused by too many Blastophagas, or, in other words, by overpollination; others think that it is due to too much irrigation. The writer, however, is convinced that these are not the principal causes, but that the cause is principally climatic. If damp weather, not necessarily rain, occurs during the ripening period, it seems to stimulate the circulation of the sap and gorges the fruit with juice until the pressure is such that the tender skin fails to resist and the fig splits open. If, however, this period of dampness is followed by warm, sunny weather, such figs dry without souring, the split closes up, and they are readily disposed of at 2 to 4 cents per pound, which pays for gathering and caring for them. The proportion of figs that split rarely exceeds 25 per cent; nearly always the proportion is much less.

Trees have been observed standing on the banks of irrigating ditches where the supply of moisture was continuous and showing less split figs than trees in the same orchard that received only occasional irrigation. It appears that when the ground has become too dry and water is then applied a stimulation in the circulation of the sap is caused and is almost invariably followed by more or less splitting, while if the supply of moisture has been continuous few, if any, splits occur. The splitting of oranges and prunes is attributed by many to the same cause.

FIG BREEDING.

Fertile seeds can be secured from all kinds of our cultivated figs by caprification and the breeder can readily perpetuate by vegetative propagation desirable hereditary characteristics in his seedling trees. It has been found from experience, however, that about one-half of such seedlings are capri or staminate trees. The process is exceedingly simple. A twig is selected with a number of figs from three-eighths to three-quarters of an inch in diameter (the receptive size in most varieties) which have not been entered by the insects. Drop into a paper bag a caprifig with Blastophaga ready to issue and tie it tightly over the twig, and the insects will do the rest. At the end of two or three weeks remove the paper bag and replace it with one of mosquito netting for protection against birds and to prevent the ripe dried fig from falling to the ground.

DESCRIPTIONS OF VARIETIES.

For the purposes of this bulletin it is deemed sufficient to describe those Smyrna fig varieties that are promising or have already assumed importance in the fig industry. Of the hundred or more caprifig varieties, either imported or originated from seed in this country, it is deemed sufficient to describe only those which from their desirable qualities are of permanent interest to Smyrna fig growers. Dr. Eisen (11) describes briefly 20 of the Smyrna fig and caprifig varieties. These descriptions, as well as those by George C. Roeding, have been drawn upon to a considerable extent, while those of seedling varieties which have originated in California are from the studies of the writer at the Loomis orchard and other localities where these varieties are in cultivation. The attempt is made in the descriptions, when practicable, to give sufficient details to enable the reader to identify the variety.

SMYRNA VARIETIES.

Lob Ingir.—The Lob Ingir (fig. 1) known also as Erbeyli, Calimyrna, etc., is the great commercial fig of the Meander Valley, Asia Minor, commonly called Smyrna, after the port from which it is exported to all parts of the world. The tree is a vigorous grower; leaves very large, up to 8 by 10 inches, with generally five lobes, a few with three, and occasionally entire; lobes separated by broad, deep sinuses, obtuse toward apex, finely to coarsely serrate, dark glossy green and rough above, lighter and smooth beneath; petioles and veins greenish white; the former about half the length of the blade; stipules pointed, brown when falling; fruit medium to very large, flat or onion shaped, up to 3 inches in diameter, flat at apex; skin very thin, color light pea green when immature, delicately pubescent, fading to delicate light lemon yellow at maturity, with scattered whitish dots, some of which are elongated; thin, medium to short neck; stem very short; eye large, open, bordered by whitish protruding scales a little lighter than the skin, surrounded by a dark ring or iris, ribs conspicuous from apex to stem, branched, smoothing out as the fruit ripens; seeds large but not very abundant; pulp pink when unripe, deepening to dark amber at maturity; flesh thin, white or greenish white. The sweetest and most luscious fig for consumption fresh and unequaled as a dried fruit. Introduced into this country from Asia Minor by the writer, a small shipment arriving in 1880 and 14,000 cuttings during the winter of 1881–82.

Kassaba.—Introduced from Asia Minor in 1882; tree vigorous, an upright grower, outer branches drooping under a heavy load of fruit; leaves very large, up to 8 by 10 inches, nearly all three lobed; lobes broad toward apex, blunt, making a right angle; sinuses shallow, one-fourth depth of blade, lobes occasionally overlapping; upper surface light glossy green, slightly rough to the touch, smooth and lighter beneath; edges fine to coarsely serrate; petioles and veins greenish white, tomentose, the former one-fourth to one-third the length of the blade; stipules pointed, light green; fruit pyriform, lopsided, truncate; color pea green, fading to lemon yellow at maturity, lighter toward apex; ribs prominent, branched, wider apart toward neck, extending almost from apex to stem; skin with delicate whitish bloom and faint whitish dots; neck short, stout, stem very short; eye medium, open, bracts pinkish and not protruding; pulp pinkish red, darkening to brown at maturity, flesh rather thick before maturity, tinged with green which penetrates a sixteenth of an inch from the skin; seeds medium to large, but not numerous.

Blowers.—Tree thrifty and vigorous, of upright growth; leaves very large, mostly three lobed, a few with five lobes, dark glossy green, rough above, lighter below, veins and petioles yellowish green, edges of lobes dentate; petioles about one-third the length of blade; fruit medium, globose, flattened at apex; ribs irregular, prominent, and darker than skin between; skin lemon yellow, covered with scattered whitish dots; neck small, bent to one side, longer than in the Lob Ingir; stem medium length; pulp pink before and dark amber after maturity, intensely sweet, good flavor; eye medium, open.

This variety was derived from cuttings of the writer's importation from Smyrna in 1882, planted on the ranch of the late R. B. Blowers, Woodland, Cal. Turkish name unknown; named "Blowers" by Dr. Gustav Eisen.

Eisen.—A seedling of the Maslin orchard at Loomis, Cal., from the best type of imported Smyrna figs. The tree is unfortunately located near a swampy spot in the orchard and is not in normal condition. Grafts have been inserted in better localities where the fruit is showing high quality.

The following description is from vigorous, thrifty grafts. Leaves medium to large, mostly five lobed; lobes bluntly pointed, edges coarsely serrate; upper surface dark, glossy green, rough, smooth beneath, sinuses variable from shallow to deep, with no overlapping of lobes; petioles greenish white, one-third the length of blade, veins a shade lighter, covered with soft tomentum; stipules light green; fruit large to very large, 2 to 2¾ inches in diameter, onion shaped like the Lob Ingir; neck thin, short; stem very short; ribs prominent from apex to neck, often branched; skin very thin and delicate, covered with white dots which remain till maturity; color greenish yellow, changing to translucent amber when dry; occasionally the delicate skin cracks, showing the white flesh within; pulp juicy, light amber, more transparent than the Lob Ingir and extending to very near the skin, leaving the flesh very thin; flavor sweet and rich. A large portion of the crop at Loomis is self-sealed like the Rixford. Cuttings in small numbers have been distributed to the best fig localities, and if its high quality at Loomis is sustained at other places it will prove to be a valuable addition to the list of desirable figs. Named in honor of Dr. Gustav Eisen.

Hilgard.—Large, thrifty tree, spreading top, trunk knobby, 2½ feet in diameter. At 3 feet from the ground it divides into four large branches. Leaves three to five lobed, many entire, glossy green above, rough, light green below; sinuses shallow, lobes acute, edges finely to coarsely serrate; petioles one-fourth to one-third the length of the blade, covered with very short tomentum or glabrous; veins a lighter shade; fruit medium in size, lemon yellow, skin covered with minute whitish dots and very delicate bloom, flat or onion shaped; ribs irregular, branched, extending from apex to stem, smoothing out at maturity; eye open, bracts pink, with a dark circle surrounding; neck very short or none; stem very short; pulp rosy red, deepening to dark amber at maturity; seeds medium sized, not very numerous. This seedling tree of the Maslin orchard at Loomis is almost immune from splitting, while fruit on adjoining trees splits badly. This is a very sweet and excellent flavored fig. Named in honor of the late Prof. E. W. Hilgard.

Rixford.—A seedling raised from the best imported Smyrna brand, planted by E. W. Maslin in 1886 on his ranch at Loomis, Cal. The tree is vigorous, thrifty, and the largest in the Maslin orchard of 172 trees; drooping habit with a spread of branches over 50 feet and diameter of trunk 2 feet; leaves large, up to 8 by 8 inches, light green above without gloss, three to five lobed, a few entire, finely to coarsely serrate, sinuses shallow, not more than one-third the length of blade; petioles one-third to one-half the length of blade, and with veins whitish green, smooth, covered with short, soft tomentum; stipules pointed, whitish green. Fruit medium sized, up to 1½ to 2½ inches, round-obtuse, somewhat flattened at the apex, neck small, short, bent to one side; stem very short; ribs prominent from apex to neck, smoothing out at maturity; skin thin, color lemon yellow, greenish toward the apex, with scattered white dots from center to neck, some elongated; eye small; bracts short, white, surrounded by dark ring at maturity; pulp deep red, changing to brown amber when mature and dry. In a large portion of the figs the eye is sealed as they ripen by the gradual hardening of a drop of pellucid gum, effectually excluding filth and beetles and other insects. They do not sour, as germs of fermentation are also excluded. Very sweet and fine flavor, but with the fault at Loomis in some seasons of splitting badly. One of the earliest varieties in the Maslin orchard, frequently maturing as early as the first week in August. Described and named by Walter T. Swingle, of the United States Department of Agriculture.

Stanford.—A large, thrifty tree with dense top (fig. 12). Leaves medium to large, three to five lobed or entire, sinuses shallow and broad, lobes bluntly pointed, edges finely to coarsely serrate or wavy; dark green, rough, without gloss on upper surface, smooth beneath, with soft tomentum, petioles one-half to one-third the length of blade and with veins greenish white and tomentose; fruit medium, a little smaller than the ordinary Lob Ingir, turbinate or globular; neck small, very short; stem medium to short; ribs not very prominent, irregular, extending from eye to neck, color lemon yellow, with greenish tinge at maturity; eye very small, surrounded by dark ring, scales whitish; pulp bright rosy red, dark amber at maturity; flesh white, tinged with green.

This variety consists of four giant trees growing on rich bottom land of the Stanford University ranch at Vina, Cal., in a row with ordinary Lob Ingir trees. These trees were grown from cuttings imported from Asia Minor by the writer in 1882. The fruit ripens a week or ten days earlier than that of other Lob Ingir trees and seems to be immune from splitting. During the four years that the variety has been under observation not a single split fig has been found on either tree, although the usual percentage of split fruit was found on the ordinary Lob Ingir trees in the same row. The manager of the ranch permitted the United States Department of Agriculture to take 500 cuttings each year for four years for free distribution. The value of the variety will soon be demonstrated from these widely distributed cuttings. The writer proposes to name the variety "Stanford," in honor of the late Gov. Leland Stanford, founder of Leland Stanford Junior University.

West.—Another of the seedling trees of the Maslin orchard, raised from the best imported Smyrna figs, has been named in honor of the late W. B. West, of Stockton, Cal., who imported a great many varieties of figs from southern Europe and did much for the fig industry in California. It is a large, thrifty, open-top tree, with long-jointed wood and drooping branches, and with a clean, smooth trunk 16 inches in diameter a foot from the ground. Leaves very large, deeply three to five lobed, with coarsely serrated edges, glossy green above, under surface smooth, covered with soft, short tomentum; petioles one-third to one-half the length of blade; fruit medium to large, pyriform; color greenish yellow, retaining the green tint toward the neck up to full maturity; pulp pinkish just before maturity, changing to dark amber when fully ripe. One of the sweetest and best all-round figs in the Maslin orchard. Skin very thin and almost immune from splitting. It bears a fair first crop. It is now being tested in many localities from extensive distributions made by the United States Department of Agriculture.

Wilson.—A clean, thrifty tree of spreading habit. Leaves large, shining, dark green above, lighter and tomentose beneath, mostly three lobed, a few entire; lobes obtuse, sinuses broad, shallow; lobes coarsely to finely serrate, or with wavy edges; petioles large, greenish white, half as long as the blade, slightly tomentose or glabrous; veins same color as petioles; stipules light green, tipped with brown; fruit medium to large, ribs conspicuous; skin thin, delicate, light green, inclined to crack in ripening, covered with scattered whitish dots, pruinose toward the stem; neck very short and thick; stem medium to short; eye medium, open; scales reddish brown, disclosing rosy red pulp within, which darkens to chocolate brown when dry; seeds small, amber color; flesh thin, white. It makes a very good dried fig, rich, but not equal in quality to the Lob Ingir. The variety was imported by the United States Department of Agriculture in 1891 and named by Dr. Gustav Eisen in honor of James Wilson, at that time Secretary of Agriculture.

Bardakjik.—Tree a compact, low-spreading grower, with thick, closely jointed branches, leaves very large, five lobed, sinuses shallow. Fruit handsome, medium to large, pyriform, with short neck and long stem. Color light grayish green, covered with small gray dots, especially toward the neck, ribs distinct; eye small, scales not protruding, apex flat; skin very thin and delicate, cracking at full maturity, showing the white flesh beneath; pulp a rich brilliant red, seeds small and numerous. A first-class table fig, grown exclusively for that purpose in the Smyrna district of Asia Minor. Roeding says that scattering trees are to be found in gardens near Smyrna and in the foothills a few miles from the city. They are always caprified, but not so systematically as in the fig district proper.

CAPRI VARIETIES.

Milco.—Tree vigorous, symmetrical, spreading, dense top, clean, smooth trunk and branches (fig. 5); leaves medium to large, three to five lobed, dark glossy green above, lighter below, lobes bluntly pointed, finely to coarsely dentate, sinuses shallow; petioles half the length of the blade and with the veins hairy; stipules pointed, green, turning brown when falling; profichi fruit medium to large, turbinate, lopsided; neck short and stout; stem short, but increasing in length on those figs growing toward the end of the old wood; ribs prominent when young, smoothing out as the size increases; quite firm when the insects are ready to issue; color dark green, lighter toward the stem, assuming a reddish brown at maturity; eye small, with pinkish scales. This caprifig is unique in having a few male flowers scattered among the gall flowers; cluster of stamens not large; gall zone well developed and generally filling the cavity of the receptacle; flesh greenish white, with band of dark violet stain. The profichi crop, with its generation of Blastophaga, matures later than most varieties. There is little doubt that the variety was imported from Italy by the late W. B. West, of Stockton, under the name Verdoni, but was exploited by G. N. Milco, whose name became attached to it.

The Milco is an early bearer and one of the most valuable figs in cultivation. It carried its annual crop of fruit and fig wasps for 40 years on the old Gates tree, 10 miles west of Modesto, Cal., and on others in the vicinity of Lathrop, Cal., unaided by other trees in the neighborhood.

Loomis.—A very thrifty, open-topped tree; leaves three to five lobed, a few entire; lobes broad toward the apex and obtuse, sinuses shallow, edges finely to coarsely serlate; petioles half the length of the blade and with veins greenish white, slightly tomentose; upper surface glossy green and very rough, under surface lighter and smooth. Foliage holds later than most trees. Stipules purplish brown when falling. Mamme crop good, up to half an inch to 1½ inches in diameter. The figs of the profichi crop are very large, up to 2½ inches in diameter, and have a distinct neck and prominent ribs. This tree never fails to carry a good mamme crop, and it produces one of the earliest profichi crops in the orchard.

Newcastle.—Knobby trunk with spreading top, thrifty; leaves rough glossy green with three to five lobes, mostly five, sinuses broad, half the depth of tle blade, no overlapping of the lobes, margins coarsely serrate and lobes acute, petioles short, one-half the length of the blade, creamy white; leaves slightly glossy, green and rough above, lighter green beneath; petioles and veins slightly tomentose; carrying a fair mamme crop from three-quarters of an inch to 1¼ inches in diameter. Mammoni crop fair, containing many seeds. Produces an early profichi crop. Tree vigorous and holding foliage late.

Mason.—A thrifty, spreading tree, dense top, clean, smooth trunk; leaves with three to five lobes, smooth surfaces, upper side dark green, under side a little lighter, sinuses deep, one-half to two-thirds the length of the blade, edges finely serrate to wavy, points of the lobes obtuse; petioles one-third to one-half the length of the blade, veins slightly tomentose. A splendid and very early caprifig, never failing to carry a mamme crop through the winter. Profichi figs large, with enormous staminate cluster and a long season.

Ficus pseudocarica.—Introduced into California by Dr. Franceschi, of Santa Barbara. Thrifty tree, spreading habit, young wood pink, covered with short dense tomentum; leaves medium sized, with three and five lobes, sinuses broad and shallow, one-quarter to one-third the depth of blade, lobes acute pointed, glossy green above, lighter below; petioles and veins pinkish, covered with soft tomentum; petioles half the length of the blade; stipules greenish pink. Figs of the mamme crop three-eighths to one-half an inch in diameter, long, slim neck, stem very long, greenish red; profichi figs small, one-half to five-eighths of an inch in diameter, coppery red, long stem and neck, ribs prominent, color reddish toward sun; eye small, raised above surface, scales red. This caprifig, a native of northeastern Africa, is peculiar in that figs of the mamme crop always contain stamens and can be used to caprify first-crop Smyrnas, a fact noted first by Walter T. Swingle, of the United States Department of Agriculture.

Bleasdale.—Large spreading tree, dense top, clean trunk about 1½ feet in diameter; leaves dark glossy green, rough, mostly three, a few five lobed, many entire, large, up to 8 by 8 inches, lobes obtuse, sinuses broad and shallow, half the depth of the blade, edges finely to coarsely serrate or wavy; carries a good mamme crop from three-fourths of an inch to 1½ inches in diameter; petioles medium to long, up to one-half to two-thirds the length of the blade, petioles and veins greenish white and slightly tomentose. Figs of the profichi crop green and firm when the insects issue; rather late; abundant staminate cluster and large gall zone. One of the most valuable seedling capri trees of the Maslin orchard, never failing to carry a good mamme crop through the winter, with a very large profichi crop in the spring. Named for the late Dr. John Bleasdale, a prolific writer on the fig.

Roeding No. 1.—A thrifty tree of low, spreading habit, long-jointed wood, leaves dark green without gloss, lighter shade below, three and five lobed, some entire, sinuses broad, shallow, edges coarsely serrate or wavy, petioles one-third to one-half the length of the blade and with the veins covered with soft tomentum. Profichi figs pyriform, small, neck long, few and not pronounced ribs, skin dark dull green, with whitish dots, orifice large, flesh stained purple, gall flowers numerous, staminate flowers producing abundance of pollen. Profichi figs a week earlier than Roeding No. 2. The first Blastophaga were established in this country in the profichi crop of this variety from the importations of Mr. Walter T. Swingle in April, 1899. [Chiefly Mr. Roeding's description.]

Roeding No. 2.—Thrifty, erect growth, with slender limbs and long-jointed wood; leaves medium to large, three and five lobes, dark green, smooth, sinuses medium depth, one-half that of the blade, lobes often overlap, edges of lobes wavy; petioles long, one-half to two-thirds the length of blade and the veins greenish white, covered with soft tomentum; lobes bluntly pointed. Profichi fruit medium, almost globular; short stem and neck; ribs distinct, but not prominent; skin smooth, waxy, greenish yellow; apex flat, eye medium, slightly raised; gall flowers numerous. Mamme crop usually wanting or very small; profichi crop abundant. Valuable, Mr. Roeding says, as lengthening the season for caprifying the Smyrna fig, but not reliable by itself, as it does not carry a mamme crop through the winter.

Roeding No. 3.—Tree thrifty, straggling growth, of dwarfish habit; leaves medium, three and five lobes, glossy green, rough above, lighter beneath, lobes broad toward the apex, bluntly pointed, sinuses broad and half the length of the blade, no overlapping of lobes, edges coarsely serrate or wavy; petioles and veins greenish white, covered with short tomentum. Profichi fruit medium sized up to 3 inches long, turbinate, neck and stem short; ribs conspicuous from apex to neck; skin light shining green, thickly covered with whitish dots; eye large, protruding from a sunken apex; good gall zone and staminate cluster; meat thick, stained with purple. The earliest of the Roeding varieties and perhaps the most valuable, as it usually carries the mamme crop through the winter.

OPPORTUNITIES IN THE INDUSTRY.

At the present time the annual production of dried figs in California amounts to about 6,000 tons, one-third of which are of the Smyrna type and the remainder chiefly Adriatic and Mission, the Adriatic including by far the largest quantity. The reason for this is that the Adriatic was extensively planted many years before the Smyrna was introduced. In a few instances Adriatic figs are still being planted under the mistaken idea that they are more prolific bearers than the Smyrna variety. One prominent grower in the San Joaquin Valley who has orchards of both Smyrna and Adriatic finds that by a liberal supply of caprifigs he gets a ton to the acre more from the Smyrna than from the Adriatic variety, while the former sells for about double the price of the latter. At the present time he is engaged in grafting his Adriatic trees to the Smyrna variety. The fig plantings at present are confined almost entirely to the Smyrna type and it is only a question of a few years before the markets of this country will be supplied with home-grown Smyrna figs.

The cutting off of the supplies of figs from Asia Minor and the countries of southern Europe by the war has so raised the prices as greatly to stimulate the planting of figs in this country. It is a reasonable estimate that 10,000 acres of Smyrna fig trees have been planted in the central San Joaquin Valley alone during the last two years. When these large plantings come into bearing, this country will be independent of importations from Smyrna, and dried figs by the carload will be as evident in commercial movements as raisins are at the present time.

To show the increasing demand for the best figs, the purchasing agent for the eating houses and the newsboy trade on one of the large railroad systems of the country in 1913 contracted with a leading packer for 80,000 half-pound cartons of California-grown Smyrna figs, and the supply proved insufficient. In 1914 he contracted for 100,000 packages, and the supply was still insufficient. In 1915 he contracted for 120,000 packages. This buyer never handles any other figs as long as the California-grown Smyrna supply holds out.

A 4-year-old Smyrna fig orchard ought to produce sufficient fruit to pay all the expenses of cultivation, and from that age will yield increasing crops indefinitely. The owner of one 20-acre orchard 9 years of age in 1914 reported a net yield of the value of $115 per acre. The owner of a 40-acre orchard in the same locality, 13 years old, reported an income of $250 per acre. However, it should be mentioned that part of the last-mentioned crop was shipped to city markets undried. Appearances at the present time indicate that it will be but a few years before the 15 or 16 million pounds of figs annually imported from Smyrna will be supplied by the home-grown product.

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IN THE FIELD OF AGRICULTURE we have agencies and instrumentalities, fortunately, such as no other Government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal-reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed.—*From President Wilson's Message to the Farmers' Conference at Urbana, Ill., January 31, 1918.*

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 733

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. ▼ September 6, 1918

LENGTH OF COTTON LINT, CROPS 1916 AND 1917.

By W. L. Pryor, *Cotton-Crop Specialist.*

CONTENTS.

DISTRIBUTION OF VARIETIES PRODUCED.

The data from which figures relating to long-staple cotton and the comments which follow are the result of an inquiry made in December, 1917. Reports were obtained from the regular crop reporters of the Bureau of Crop Estimates, including the aids of the field agents and of the cotton-crop specialist of the bureau in the following States: Mississippi, Texas, Arkansas, Oklahoma, South Carolina, Louisiana, Arizona, and California. This information was supplemented by special reports from buyers, exporters, and dealers, from seed breeders and from special investigations of several field agents and the cotton-crop specialist of the Bureau of Crop Estimates. In many sections of several States reporters were unable to obtain definite data, for only in districts where the growth of staple cotton has been recognized for several years is attention paid to the length of lint. In recognized staple-producing sections, cotton is ordinarily bought and sold on types showing quality of staple, color, and trash content. Elsewhere many buyers make no effort to determine length and character of the staple. Where the latter custom obtains, it is not to be wondered at that the farmer knows but little of the length of lint grown on his plantation. Neither is it strange, where the price for all cotton, regardless of the length of fiber, is approximately the same, that farmers grow varieties which produce the most lint. It is for this reason that the notorious "half-and-half" cotton and other short-lint varieties are being largely planted in many sections. West of the Mississippi River this very short-lint cotton has gained favor among some farmers in the past few years, and until buyers refuse to purchase except at a considerable reduction in price as compared to the longer-lint varieties, it probably will continue to be planted.

The Department of Agriculture has repeatedly warned farmers against planting cotton of the "half-and-half" and other extremely short-stapled varieties. Among the reasons given are the following:

The lint of the "half-and-half" variety is of poor character, irregular, wasty, and very short, a large portion of the samples examined being less than seven-eighths of an inch in length of staple. Cotton less than seven-eighths of an inch is untenderable on future contracts made under the provisions of the United States cotton futures act, and therefore buyers will penalize it whenever discovered.

Cotton of less than seven-eighths inch staple is of approximately the same spinning value as the bulk of the cotton of India. On economic principles, the American product should be maintained on a higher level of intrinsic worth than that of India in order that the American crop may not be forced to compete in the markets of the world with the cotton of India.

Cotton of less than seven-eighths inch staple is inferior to the average American quality, and localities that produce such cotton in appreciable quantities soon establish reputations for an inferior product. The price of all cotton in such markets will suffer on account of the poor reputation of the market.

Competent cotton buyers discriminate against extremely short staple whenever such cotton is discovered. They should be equally careful to discriminate in favor of cotton of good staple. The farmer who produces inferior cotton is likely to find that his product brings a price materially lower than quotations would indicate as its true value. The seller commonly looks upon such discrimination as a penalty, while the buyer considers that he is paying the full value for an inferior commodity.

As the variety of seed planted is the primary factor in determining length of staple, and as there are early maturing prolific varieties which produce a staple of at least an inch in length, no farmer or community is justified in planting an inferior variety or in expecting the full market price for a debased article of commerce.

The States above named produced a total of 7,909,000 bales (500 pounds gross weight) of cotton, of which 1,264,000 bales, or 16 per cent, is reported as 1⅛ inches or longer in length of staple. In all probability these figures, if applied to actual measured length of lint, are too high. It is likely that much cotton sold as 1⅛-inch lint, but really shorter, is included in the report. This is true also of the figures shown for the previous years in comparison. It is estimated that the remaining cotton States, with a total production of 3,377,000 bales in 1917, and in which no close investigation was made, produced about 90,000 bales of long staple, not including 85,000 bales of Sea Island and Egyptian cotton grown in the States of Georgia, Florida, South Carolina, Arizona, and California. Of the total crop of staple cotton, 2 per cent, or 226,000 bales, including Sea Island and Egyptian, stapled better than 1¼ inches in length.

DAMAGE TO CROP FROM WEATHER AND INSECTS.

The cotton season of 1917 was not considered a very favorable one. The crop got a late start, the early part of the spring not being propitious for early seed germination. In much of the cotton-producing area of Texas and Oklahoma a severe and damaging drought extended throughout almost the entire season. Smaller areas in other States also suffered from drought. Boll worms did severe damage in portions of north Texas and Oklahoma, and boll-weevil damage covered a larger territory than in former years. However, in the older weevil-infested areas of Louisiana and Mississippi the damage was not so great as for the past several years. While the acreage in these States as compared to former years was considerably reduced, the crop planted showed the heaviest yield since the first weevil infestation. A killing frost, extending over more than half of the cotton belt early in October, caught many immature bolls and caused great loss in quality, though the weather during the winter was very favorable for gathering "bollies," or frostbitten, immature bolls. Owing to the high price prevailing for cotton in the fall and winter of 1917, "bollies" were gathered more carefully than in former years. Heretofore the bolly crop has come almost entirely from the States of Texas, Oklahoma, Arkansas, Tennessee, and Missouri, but during the past season considerable quantities of "bollies" were gathered in the States farther east. As a result, the bolly crop this year amounts to several hundred thousand bales more than in any recent year. The first of this cotton to move brought from 5 to 10 cents per pound under prices prevailing for middling cotton, but this margin subsequently increased. Even at that, it paid the farmer well to harvest the frostbitten cotton. The large proportion of bolly cotton in several of the States materially lowered the average price received for the crop.

SEA ISLAND COTTON.

The sea-island cotton crop of 1917 was 71,000 bales, against a crop of 93,000 bales in 1916, a reduction of 23.7 per cent. This was largely because of weevil infestation, the pest having reached approximately all the sea-island producing sections of Georgia and Florida. In the latter State in 1917 sea-island and other cotton was planted far down the peninsula and splendid yields secured. In South Carolina the yield was reduced somewhat by the early frost in October.

Sea-island cotton is bringing phenomenally high prices, and every effort is being made by farmers to produce it wherever it will grow and maintain its length and strength of fiber. Only a comparatively small portion of the cotton-producing area of the United States is adapted to the growth of this variety, which, requiring a longer maturing season, is especially susceptible to boll-weevil damage. Experiments were conducted in southern Louisiana the past two seasons with both sea-island and Egyptian cotton; the quantity produced was small, and it is still in the experimental stage, with a slightly increasing acreage.

QUALITIES REQUIRED FOR SPINNING.

The heavier-producing and well-recognized staple-producing sections of the country show an increase in production. This was because of the premiums previously paid for extra-length cotton and for the reason that early maturing strains have been propagated in recent years which have been found to be about as early and prolific as the shorter varieties of lint. Length of staple does not always determine spinning quality. Buyers pay a considerable premium for cotton combining both length and strength of fiber over cotton of considerable length but of poor strength. For this reason certain localities in which years of experience have demonstrated the power to produce this extra-quality staple receive a considerable premium over new staple districts or over sections where weather conditions tend to unfavorably affect the length or strength of fiber from year to year. Spinners, being satisfied with results from a certain section, offer premiums for cotton from the same point of origin year after year. Mills are willing to pay an extra price for "hard cotton" or "extra-hard cotton." Ordinarily there is less waste in spinning this cotton, and it is sometimes used to mix with soft lint to lessen spinning waste and to improve the strength of the fabric. After a mill finds by actual experience that cotton from a certain section invariably meets its requirements, that from other sections apparently just as good is view with suspicion until it is thoroughly tested. In some sections $1\frac{1}{16}$-inch cotton brings a premium over $1\frac{1}{8}$-inch cotton grown in other sections of the same States.

The style and hardness of staple of equal length is very important to the Manchester and American mills, and the man who passes on staple should be a good judge of staple cotton, taking into consideration that even, smooth staple cotton is worth considerably more than uneven cotton.

DIFFERENCES IN CLASSIFICATION OF COTTON ACCORDING TO LENGTH OF STAPLE.

There is a considerable difference between the American and Liverpool ideas as to length of staple. Much of the Texas crop, which averages around $1\frac{1}{16}$ inches, is sold in Liverpool on types variously described as "good $1\frac{1}{8}$," "full $1\frac{1}{8}$," "hard $1\frac{1}{8}$," etc., when most of this cotton would probably not staple over $1\frac{1}{16}$ inches, American standard, or measured by rule. Because of this great confusion in stapling, the millimeter standard is gaining ground, as there is a general understanding of what is meant, for instance, by 32-millimeter cotton, whereas a reference to $1\frac{1}{8}$-inch cotton brings forth the query, "What kind of inch-and-one-eighth?" It is for this reason that the millimeter standard is gaining friends, especially by the exporters of staple and many of the cotton manufacturers.

Every market has a different classification and understanding of staples. Staple cotton is generally bought on the basis of samples, really, the staple being judged from types supplied by the seller or from the seller's own "marks," it being understood that the seller may call the staple whatever he chooses. One trade name for extra-length cotton is "Benders." This is supposed to be heavy-bodied, strong, staple cotton, running from $1\frac{1}{16}$ to $1\frac{3}{16}$ inches or better in staple. This cotton is called Benders from the fact that it was originally grown in the river bends of the Mississippi. Of recent years factors have sold much cotton for Benders that never grew near a river. The test for this cotton is body and strength of fiber, with a staple running not less than $1\frac{1}{16}$ inches in length.

EGYPTIAN AND DURANGO COTTON.

The States producing the largest amount of extra-staple cotton in the order named are Mississippi, Texas, Arkansas, Oklahoma, South Carolina, and Louisiana. These six States produced in 1917 92.4 per cent of the total staple crop, not including Egyptian and Sea Island cotton. Georgia, Tennessee, Missouri, and in fact all of the cotton States produce small quantities of staple cotton. Arizona and California together produced 27,000 bales of the Egyptian and Durango varieties in 1917.

In California, Durango cotton was damaged by a shortage of water in the Imperial Valley during August, and the production was only 23.2 per cent of the total crop as against 30 per cent last year. Egyptian cotton is growing in favor in California, the crop in 1917 being upward of 1,000 bales. This crop was grown mostly in the Palo Verde Valley and near Yuma. Considerable Egyptian cotton, because of the great premium offered for it, will be grown in the Imperial Valley of California in 1918.

In Arizona, Egyptian cotton is now being grown exclusively in the Salt River Valley, the high premium being received for this crop forcing out the shorter varieties. In addition, Egyptian cotton is being grown to a considerable extent in the Yuma Valley. The total production of Egyptian cotton in Arizona in 1917 was 13,000 bales. Owing to the high premium received by the grower of the Egyptian variety, which enters into competition with Sea Island cotton grown in the Atlantic States, where the crop is seriously menaced by the progress of the boll weevil, great interest is being taken in Arizona and California lands which will produce this type of cotton. The effort is being made to increase the production of Egyptian cotton to make up for the probable reduction in the Sea Island crop, which it is feared will result from the continued advance of the boll weevil into Sea Island territory. It is very probable that the 1918 crop of Egyptian cotton in Arizona and California will be much larger than any grown heretofore. There is at last a sufficient quantity of planting seed of the Yuma and Pima varieties developed in Arizona to plant a large acreage of Egyptian cotton. The acreage planted in short cotton heretofore in Arizona will be largely planted to Egyptian in 1918.

LOCATION OF AREAS OF THE PRINCIPAL PRODUCTION OF EXTRA-LENGTH COTTON.

The areas of the principal production of extra-length cotton—that is, where year after year the lint retains its uniform length and strength of fiber, texture, etc.—are well known to the trade. Cotton from these long-established staple sections always brings a premium over that grown in areas not so well known or where the season has a marked influence on the quality of the staples. The most important of these areas are the alluvial sections of Mississippi, between the Mississippi and Yazoo Rivers, known as the Delta; and similar soils in Arkansas along the Arkansas, Mississippi, and other large streams; in eastern and northwestern Louisiana; in northeastern Texas and eastern Oklahoma. In South Carolina there is much extra staple grown in the northeastern portion of the State in the counties of Darlington, Marlboro, Florence, Chesterfield, and a number of others. Mississippi and Arkansas showed a heavy increase of production of staples in 1917. In fact, all of the staple-producing areas showed an increase except Louisiana, where there was a slight falling off.

AVERAGE PRICE RECEIVED BY GROWERS.

The average price received by growers for upland long-staple cotton in 1917 varied considerably. In the sections where much of the extra-length staple was above 1⅛ inches, the average price received was considerably higher than in those sections where the bulk of the crop was scant 1⅛. Prices for cotton above 1¼ inches in length are more uniform than for cotton from 1⅛ to 1¼ inches. In Mississippi, Arkansas, and South Carolina the average is much higher than in Texas and Oklahoma, where not so much attention is paid to length and where the bulk of the crop will run from 1 inch to 1⅛ inches in length. These prices are those prevailing about December 1, and, while they represent the price differences for long and short staple prevailing at that time, they do not represent the averages for the entire crop. Prices for staples around December 1 were considerably higher than later in the season. The planter realized a good price for his extra-length cotton, but much of it is now being held at a loss by factors at concentration points.

YIELD PER ACRE.

Extra-length cotton shows a heavier yield per acre than short cotton. This cotton is planted on the most fertile lands and is raised largely by the best class of farmers. Planted on the same class of soil and cultivated alike, short cotton will yield more lint per acre than long. Extra-length cotton usually requires from 100 to 300 pounds more of seed cotton to make a 500-pound bale than short cotton.

COTTON VARIETIES COMMONLY GROWN.

The following are the principal varieties reported as most generally grown in the different important staple-producing States:

Producing length of over 1¼ inches.—Sea Island in South Carolina, Georgia, and Florida; Egyptian of the Pima and Yuma varieties in Arizona and California; Webber 49, Adair, Pemiscott, Mississippi Silk, Hartsville, Florodora, Foster, Keenan, and Coulette.

Producing length of 1⅛ to 1¼ inches.—Columbia, Columbia Big Boll, Black Rattler, Foster, Webber and Webber 49, Express, Florodora, Allen Silk, Mississippi, White Seed, and Durango.

Producing length under 1⅛ inches.—Triumph, Mebane, Kings, Lone Star, Simpkins, Rowden, Cleveland, Big Boll, Trice, Moneymaker, Mortgage Lifter, Peterkin, Half and Half.

Estimated length of cotton lint, crops of 1917 and 1916, in the principal staple-cotton producing States showing proportions, yield, and selling price of different lengths.

[In percentages and in equivalent 500-pound, gross weight, bales. Bales in thousands, i. e., 000 omitted.]

State.	Proportion of total crop composed of long staple, short staple, Sea Island, and Egyptian.					
	Cotton ginned.		Long staple, 1⅛ inches or over.			
	1917	1916	1917	1916	1917	1916
	Bales.	*Bales.*	*P. ct.*	*P. ct.*	*Bales.*	*Bales.*
South Carolina	1,236	930	11.5	9.0	142	84
Mississippi	903	811	49.7	38.0	449	308
Louisiana	638	443	4.0	7.0	26	31
Texas	3,124	3,725	7.6	5.0	237	186
Arkansas	973	1,134	24.0	17.0	234	193
Oklahoma	958	823	17.0	11.0	163	91
California	56	44	23.2	30.0	13	13
Arizona	21	8	1.0	43.0	....	4
All other States	3,377	3,519	2.7	2.8	90	99
United States	11,286	11,437	12.0	8.8	1,354	1,009

Proportion of total crop composed of long staples, short staples, Sea Island, and Egyptian.

State.	Short staples under 1⅛ inches.				Sea Island or Egyptian.			
	1917	1916	1917	1916	1917	1916	1917	1916
	P. ct.	*P. ct.*	*Bales.*	*Bales.*	*P. ct.*	*P. ct.*	*Bales.*	*Bales.*
South Carolina	88.1	90.1	1,089	843	0.4	0.3	5	3
Mississippi	51.3	62	454	503	....	....	....	....
Louisiana	96	93	612	412	....	....	....	....
Texas	92.4	95	2,887	3,539	....	....	....	....
Arkansas	76	83	739	941	....	....	....	....
Oklahoma	83	89	795	732	....	....	....	....
California	75.4	70	42	31	1.4	....	1	....
Arizona	35	57	7	4	63	....	13	....
Georgia	....	....	....	....	2.0	3.5	38	64
Florida	....	....	....	....	74	63	28	26
All other States	95.3	97.2	3,207	3,331	....	....	....	....
United States	87.3	90.4	9,832	10,336	.8	.7	85	93

Proportion of crop over 1¼ inches in length and that 1⅛ to 1¼ inches, seasons of 1917 and 1916.

[Not including Sea Island and Egyptian. Bales in thousands, i. e., 000 omitted.]

State.	Over 1¼ inches.				1⅛ to 1¼ inches, inclusive.			
	1917	1916	1917	1916	1917	1916	1917	1916
	P. ct.	*P. ct.*	*Bales.*	*Bales.*	*P. ct.*	*P. ct.*	*Bales.*	*Bales.*
South Carolina	2.9	1.5	36	14	8.6	7.8	106	73
Mississippi	5	3	45	24	44.7	35	404	284
Louisiana	0.5	1.0	3	4	3.6	6	23	27
Texas	0.5	....	15	....	7.1	5	222	186
Arkansas	2.5	1.3	25	15	21.5	15.7	209	178
Oklahoma	0.8	....	8	....	16.2	11	155	90
California	....	....	....	....	23.2	30	13	13
All other States	0.3	....	9	....	2.4	10	81	95
United States	1.2	1.3	141	....	10.8	8.3	1,213	946

Yield of lint per acre, long staple above 1¼ inches, 1⅛ to 1¼ inches, inclusive; under 1⅛ inches, Sea Island and Egyptian.

State.	Long staple above 1¼ inches.	Long staple 1⅛ to 1¼ inches.		Short staple under 1⅛ inches.		Sea Island and Egyptian.	
	1917	1917	1916	1917	1916	1917	1916
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
South Carolina	240	259	156	197	155	136	125
Mississippi	160	190	133	132	117	....	....
Louisiana	170	236	166	232	176	....	....
Texas	191	168	160	133	159	....	....
Arkansas	163	168	200	185	209	....	....
Oklahoma	169	174	163	175	153	....	....
California	....	182	275	246	275	163	....
Arizona	....	200	232	225	450	224	....
Georgia	....	....	160	....	....	122	130
Florida	....	....	80	....	....	115	123
All other States	162	170	....	156	....	....	....
United States	184.9	174.8	160	161.3	163	136.6	128

Average price per pound received by growers about Dec. 1.

State.	Long staple, 1¼ inches or over.	Long staple, 1⅛ to 1¼ inches.		Short staple, under 1⅛ inches.		Sea Island and Egyptian.	
	1917	1917	1916	1917	1916	1917	1916
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
South Carolina	41.2	36.8	25.3	28.2	19.3	72.8	49
Mississippi	44	35.5	25	28.4	19.4	....	....
Louisiana	43.1	33.2	24	26.7	19	....	....
Texas	49	29.8	20.5	26.9	19	....	....
Arkansas	43.5	34.9	23	28.1	19.1	....	....
Oklahoma	38.1	28.9	19.6	26.6	19	....	....
California	....	36	26	28.8	20	71	....
Arizona	....	34	....	29	19	72	49
Georgia	....	....	....	....	....	72.1	46
Florida	....	....	....	....	....	71.9	46
All other States	44.5	33.5	....	28.1	19.3	....	....
United States	43.4	33.5	....	27.6	19.1	72	46.1

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 734

Joint Contribution from the Bureau of Markets, CHARLES J. BRAND, Chief, and the Bureau of Plant Industry, WM. A. TAYLOR, Chief.

Washington, D. C. ▼ November 13, 1918

NEMATODE GALLS AS A FACTOR IN THE MARKETING AND MILLING OF WHEAT.

By D. A. Coleman, *Scientific Assistant in Grain Standardization* and S. A. Regan, *Grain Supervisor.*

CONTENTS.

INTRODUCTION.

Wheat, as grown and harvested, contains numerous impurities, and much of it on reaching the merchant or miller contains foreign materials. As the buyer can not be expected to pay wheat prices for such material, a dockage or deduction is made commensurate with the amount and kind of foreign material present. Some of the impurities are readily removed from wheat, whereas others, which can be removed only with difficulty, such as cockle, wild peas, vetch, onions, rye, and ragweed seed, remain in the wheat and become serious factors in milling and baking operations. At many local points only one penalty is placed on the load of wheat, the dockage embodying all the factors likely to influence the future sale and milling of the wheat.

When wheat is to be purchased on grades as established by the Secretary of Agriculture under the United States Grain Standards Act,[1] this dockage determination is first made by an appropriate set of sieves in order to determine the quantity of wheat present. A grade is then given the sample on this dockage-free basis, taking into consideration such factors as moisture, weight per bushel, damaged kernels, foreign material other than dockage, as well as presence of

[1] U. S. Dept. of Agriculture Service and Regulatory Announcement (Markets), No. 33: Official grain standards of the United States for wheat, and official grain standards of the United States for shelled corn. 1918.

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smut, live insects, and odors. The list of foreign material other than dockage now is quite large, and any further addition must be viewed with some concern on the part of the merchant or miller.

A comparatively new source of foreign material not previously encountered in marketed wheat has lately come to the attention of the Department of Agriculture; this, if not controlled, will figure conspicuously both as dockage and foreign material other than dockage in grain. This is a black, misshapen gall resulting from the infection of wheat heads by the nematode *Tylenchus tritici* (Steinbuch) Bastian. This foreign material, as far as known, has not been recognized by grain inspectors in the commercial grading of wheat. Investigations up to the present time indicate that the disease has a rather limited distribution and there is as yet little evidence to indicate whether it will prove to be a serious factor in wheat growing in other parts of the country.

On account of the number of places where this disease seems to be established, it was thought necessary to bring the disease to the attention of merchants, millers, and wheat growers in order that they might easily recognize it, have some knowledge of its present distribution, its importance as a factor in affecting market grades and milling quality; also to give some information concerning its control in order that it may be eliminated efficiently and quickly as a serious pest in wheat.

PREVIOUS OCCURRENCE OF THE DISEASE.

This disease has been known as a serious pest in Europe since 1745. Has been found in Australia, Austria-Hungary, Germany, Holland, Sweden, Switzerland, and very recently in China. Previous citations as to its occurrence in this country are few. Bessey[1] has noted related forms in various grasses, but did not observe any form attacking wheat. Johnson[2] seems to have first noted its distribution in this country, having found it near Modesto, Cal., in May, 1909. He also reported finding it established in the States of West Virginia, New York, and Georgia. Byars[3] and Fromme[4] have reported it from China and Virginia, respectively.

PRESENT DISTRIBUTION.

The importance of this disease as a factor in the marketing and milling of wheat first came to the attention of the Bureau of Markets by a request for identification as a troublesome foreign material

[1] Bessey, Ernst, A. A nematode disease of grasses. Science N. S. 21, 391, 1905.

[2] Johnson, Edward C. Notes on a nematode disease in wheat. Science N. S. 30, 576, 1909.

[3] Byars, L. P. *Tylenchus tritici* on wheat. Phytopathology, vol. VII, 56–57, Feb., 1917.

[4] Fromme, F. D. *Tylenchus tritici* on wheat in Virginia. Phytopathology, vol. VII, 452–453, Dec., 1917.

in some Virginia wheat. Observations showed the exhibits to be nematode galls resulting from plants infected with the nematode disease of wheat. These findings were confirmed by the Bureau of Plant Industry.[1]

Further inquiry throughout the State of Virginia revealed the fact that this single occurrence was not an isolated one, but that the disease was established in various sections of the State in such magnitude as to affect seriously not only yields per acre but also the market grades and milling quality of wheat containing such material. At the present time these galls have been found in wheat

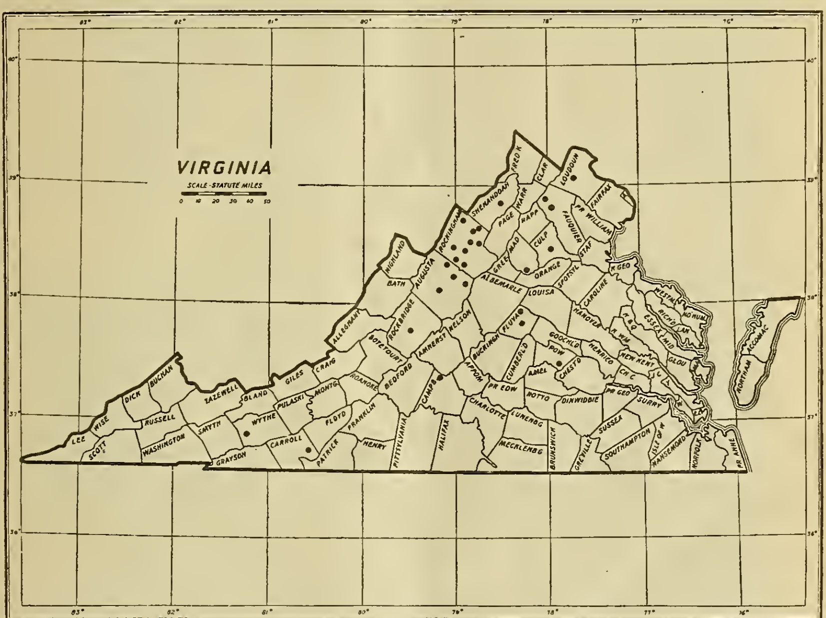

Fig. 1.—Showing places in the State where the diseased kernels have been found either in wheat or in screenings.

or wheat screenings from merchants or millers in the vicinity of Bridgewater, Crofton, Charlottesville, Culpeper, Dayton, Dovesville, Edinburg, Grottoes, Harriston, Harrisonburg, Leesburg, Lacey Springs, Lexington, Linville, Lynwood, Lynchburg, Marshall, Mount Solon, Mount Crawford, New Market, Purcellville, Port Republic, Powhatan, Rural Retreat, Timberville, Union Mills, Weyers Cave, and Woodstock, in the State of Virginia.

Through the courtesy of the Food Administration Grain Corporation approximately 3,500 samples of wheat have been analyzed from all the important wheat-growing sections in the United States. The results of these observations are given in Table 1.

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[1] In this connection acknowledgment is made of the work of Mr. L. P. Byars of the Bureau of Plant Industry.

TABLE I.—*Results of the analyses of commercial wheat samples for the presence of nematode galls.*

State where grown.	Number of samples.	Per cent of samples showing gall.	State where grown.	Number of samples.	Per cent of samples showing gall.
Arkansas	1	0	Nebraska	23	0
California	266	Trace.	New Jersey	1	0
Delaware	8	0	New York	44	0
Georgia	3	0	Ohio	204	0
Kentucky	1	0	Oklahoma	....	0
Illinois	172	0	Oregon	4	0
Indiana	91	0	Pennsylvania	127	0
Iowa	3	0	North Dakota	193	0
Maryland	201	0	South Dakota	83	0
Michigan	85	0	Virginia	108	11
Minnesota	163	0	West Virginia	52	0
Mississippi	1	0	Wisconsin	1	0
Missouri	223	0	Not known	1,000	0
Montana	163	0			

No samples were found outside of the States of California and Virginia having wheat infected with these nematode galls, and it would seem at the present writing that the disease is confined mostly

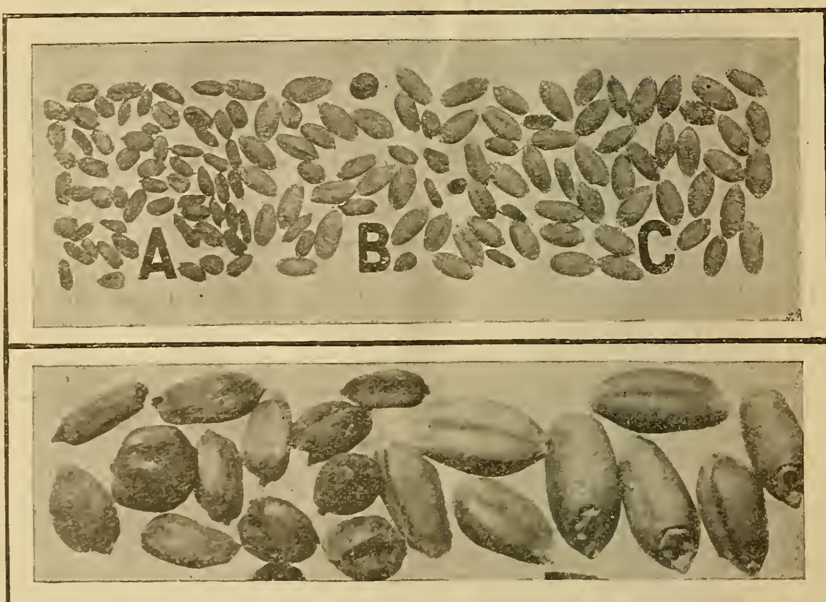

FIG. 2.—*A*, Nematode galls; *B*, wheat containing an admixture of galls; *C*, wheat for comparison with *A*. Lower, galls and wheat enlarged 3×.

to the State of Virginia. Eleven per cent of the samples of the Food Administration from Virginia showed the galls to be present to a greater or less degree. One of the California samples had galls present in the dockage determination separation.

DESCRIPTION OF THE GALLS AND DISEASED PLANTS.

The galls which have been photographed and are shown in figure 2 in comparison with sound wheat are irregular in shape, shriveled, and wrinkled. Usually they are shorter and broader than sound wheat kernels, but sometimes are equal in size, or again may be very narrow and needlelike. Very small galls, the size of wild buckwheat, are also found frequently. It is not uncommon to find several of them tightly cemented together.

In color the galls vary from a light gray to a jet black. Usually they are dark brown but may also be mottled to some extent.

The covering of the gall is very thick, making up some 95 per cent by weight of the entire gall. It incloses a yellowish-white powdery

FIG. 3.—A transverse section of the nematode gall, showing worms and outer thick husk. ×35

substance, which, when moistened with water and placed under a magnifying glass, is seen to disintegrate into small thread-shaped worms about two-tenths of an inch in length and two-thousandths of an inch in width and slightly decreasing in size at each end. Figure 3 is a transverse section of one of the galls magnified to show the thick covering and the inner powdery substance composed mostly of small worms.[1] Figure 4 is a photograph of one of the nematodes or eel worms highly magnified to show its structure.

The galls, upon falling to the ground, decay under favorable moisture and temperature conditions. The nematodes then escape, and,

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[1] The Bureau of Markets wishes to express its gratitude to Miss B. H. Silberberg, Bureau of Chemistry, for the photomicrographs of figures 3 and 5.

migrating through the soil, attack the wheat seedlings, penetrating between the leaf sheaths, causing them to become wrinkled, distorted, and swollen. The larvæ so adjust their zone of infection that almost all remain near the young growing portion of the plant. In this way, as the plant grows they are elevated toward the flowering parts. When the plant blossoms, the larvæ, which up to this time appear not to have taken nourishment, enter the flowering parts, from which they obtain food. Here they develop sexuality, pair, lay eggs, and die. These eggs hatch and produce larvæ. When the wheat plant matures these larvæ become coiled and dried up, forming the inner yellowish-white portion of the black gall as is shown in figure 5. The nematodes have great tenacity of life, and in many respects are analogous to the well-known *Trichinae* of pork. They bear a temperature of 125° F. and are also very resistant to frost and low temperature.

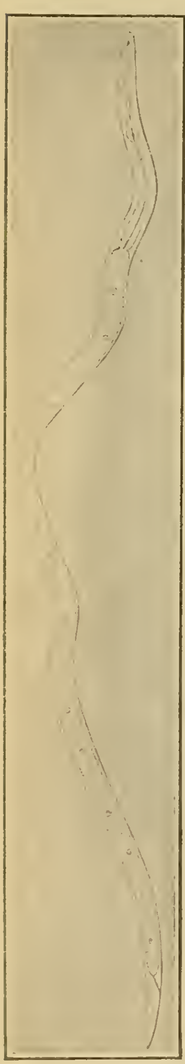

FIG. 4.—The nematode *Tylenchus tritici*. ×150

Heads infected with the nematode disease resemble heads infected with the stinking smut of wheat. They are usually thicker and shorter than normal heads, the glumes of the spikelet are spread somewhat, and in place of the normal seed, dark galls, incapable of germination and full of larvæ, are to be found.

Information gathered from those whose crops of grain have been infected with this disease is to the effect that it is easily recognized in the field on account of the darker green appearance of the heads and their somewhat longer maturing period. The plants are smaller, having a blighted and blackened appearance. Sometimes only one side of the spike is affected, while the other side is normal. There may also be some sound grains in the infected spikelet, and in some instances the head may not be infected at all, the only apparent infection being the formation of tumor-like or abcess-like elevations on the leaves of the plant. Figure 6 shows the similarity between wheat heads infected with the nematode disease and with the stinking-smut disease of wheat in comparison with an unaffected wheat head.

Soil conditions seem to have an important bearing on the disease. Spots in fields which become water-logged, or parts of the field where trash has accumulated, show the greatest percentage of infected plants.

Farmers and mill operators who were questioned about this disease stated that it had been known to them for varying periods of from 5 to 20 years. They had known it under such names as hard smut, cockle, bin-burned wheat, frosted kernels, and immature wheat. As a matter of fact these galls are quite different. In figure 7, where they are pictured in contrast, they can be easily distinguished from bin-burned wheat, frosted wheat, smut, and corn cockle.

Smut can be distinguished readily from these galls by crushing under the thumb. Smut balls can be crushed in the hand and leave the hand covered with a mass of black, evil-smelling material. It is almost impossible to crush nematode galls on account of their hardness. Some

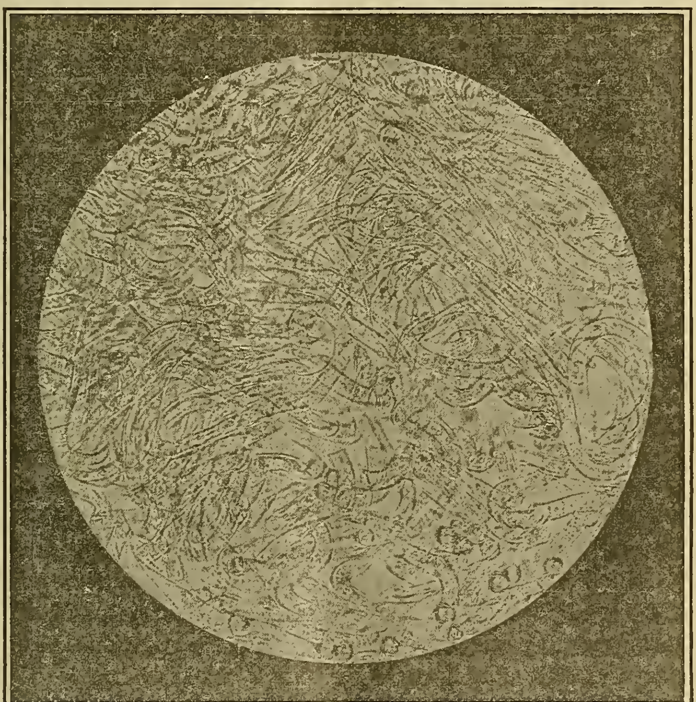

FIG. 5.—A portion of the inside of the gall magnified to show the coiled nematodes.

conditions of smut, i. e., hard smut, may be mistaken for these galls, but if cut open will at once show the absence of the inner yellowish-white portion, which is a distinguishing feature of the nematode galls.

Cockle is easy to distinguish because of the spiny appearance of its seed coat. Bin-burned wheat frequently has been confused with these galls. It may be distinguished from nematode galls, however, because the shape of the bin-burned wheat kernel remains intact in spite of the decoloration. This is not true of nematode galls, which are very irregular in shape. The powdery substance present within the gall is not found in bin-burned wheat.

A FACTOR INFLUENCING MARKET GRADE AND MILLING QUALITY.

In samples of grain obtained from millers and farmers throughout the State of Virginia these galls were found in amounts varying

FIG. 6.—Showing the comparison between heads infected with the nematode disease and the stinking-smut disease of wheat. *A*, head infected with nematodes; *B*, sound head; *C*, head infected with stinking smut.

from 0.1 per cent to 25 per cent. As a grading factor this is extremely important, as the galls must be classed as foreign material and calculated as dockage if they can be removed readily from the wheat, or as foreign material other than dockage if they can not be removed in the determination of dockage.

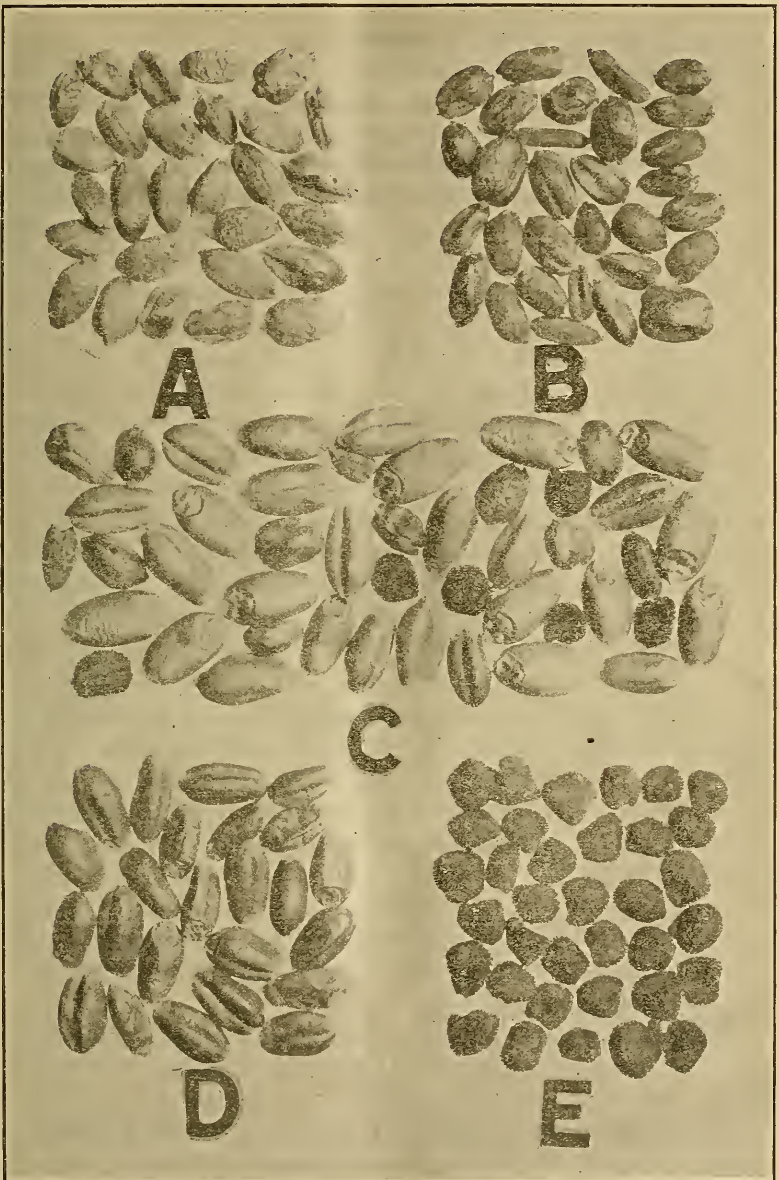

FIG. 7.—*A*, Smut balls; *B*, nematode galls; *C*, wheat containing smut, corn cockle, bin-burned wheat, and nematode galls; *D*, bin-burned wheat; *E*, corn cockle.

The estimation of the foreign material in wheat is generally made in one of two ways.[1] It may be made by means of sieves such as

[1] U. S. Dept. of Agriculture, Farmers' Bulletin 919. The application of dockage in the marketing of wheat. 1917.

are described as in use by the Department of Agriculture under the United States Grain Standards Act, or it may be estimated by means of the so-called wild-oat kicker.

Experiments were made to remove nematode galls as separable foreign material (dockage) in the grain-standardization laboratory of the Bureau of Markets by both methods. Using the oat-kicking machine, only about one-eighth of the total percentage of the galls were removed as easily separable foreign material, the others remaining behind in the sound wheat. By means of the standard sieves, i. e., the fine-seed sieve, the buckwheat sieve, and the small chess sieve, a somewhat greater percentage was removed. Even with these three sieves, however, from 65 to 70 per cent of the galls remained in the wheat as foreign material other than dockage.

Experiments were also made to remove the galls by vigorous fanning. By this method, with a fan revolving 850 times per minute, a still larger percentage was removed. Nevertheless 40 to 45 per cent of the total galls remained. With still harder fanning a greater quantity no doubt could be removed, but this would result in the removal also of a greater quantity of sound wheat.

Mills equipped with wheat washers and driers which are specially devised to clean smutty wheat can eliminate these galls almost entirely by floating them out, as they are lighter than sound wheat, with a specific gravity of 0.8125.

From a grading standpoint the presence of these galls in the grain also reduces the weight per bushel, an important item in determining the grade of grain. It is readily seen that a farmer with such galls in his load of wheat will be subjected to heavy penalties. First, the separable foreign material is assessed as dockage, and later the grade may be reduced because of the remaining foreign material other than dockage.

Knowing the pathological significance of these kernels, the question might also be raised whether such wheat should not be regarded as similar to wheat infested with garlic, onions, weevil, or smut, and placed in a class by itself.

The amount of flour which can be obtained from a bushel of wheat is of prime importance to a miller, since flour is the most valuable mill product. Any impurity which reduces the yield of flour obtained in milling wheat or lowers the quality of the flour has a direct bearing on the milling value and should receive consideration in the grading of the wheat. Any factor which appreciably injures the color of flour will result in a product of low grade or in a reduction of the purchase price.

Chemical analysis of the nematode galls by the Bureau of Chemistry is given below in comparison with an analysis of sound wheat berries. For comparative purposes both have been reduced to the water-free basis.

TABLE 2.—*Chemical analysis of nematode galls in comparison with sound wheat berries.*

Chemical constituents.	Nematode galls.	Sound wheat.
	Per cent.	*Per cent.*
Ether extract	6.9	2.06
Crude fiber	22.2	2.68
Protein	21.3	13.70
Ash	3.4	2.06
Nitrogen-free extract	46.2	79.00
Pentosans	20.4	....
Sugars	....	....
Acidity, c. c. $\frac{N}{1}$ alkali per kilo	110 c. c.	12 c. c.
Dry gluten	None.	11.8
Moist gluten	None.	28.8

An examination of the chemical analysis of the nematode galls shows that the nitrogen-free extract, which in the normal wheat berry consists mostly of starch grains, has been greatly reduced. On the other hand, the crude fiber, crude protein, ash, and fat have been largely increased. The normal acidity of the whole wheat berry has likewise been raised ten times above that present in sound wheat. It would seem that the percentages of these other components of the wheat berry had increased at the expense of the lesser amount of nitrogen-free extract, or carbohydrate. Microscopic tests for starch grains showed them to be almost completely absent. Whether the nematodes consumed the starch or whether their presence in the plant resulted in physiological disturbances precluding starch formation is difficult to say.

The fact that the nematode galls contain no starch is very important. The lack of starch grains will necessarily result in a lower flour yield from any given quantity of wheat, with the nematode galls present. The presence of the galls in wheat will increase the percentage of the lower-grade flours, because black specks, which are portions of the gall coat, remain in the flour and discolor it.

Comparative milling and baking tests on a sample of wheat containing galls as obtained on the market with the same sample from which the galls were removed by hand picking is given in Table 3. This work was done at the grain-standardization milling and baking laboratory at Fargo, N. Dak.

TABLE 3.—*Milling and baking test of nematode gall infected wheat.*

Operation.	Wheat and galls.	Wheat galls removed.
Milling test:		
Weight per bushel—		
Uncleaned..........pounds..	56	56
Scoured..........do....	61	61.5
Screenings..........per cent..	5.5	5.5
Mill products—		
Straight flour..........per cent..	72.7	73.9
Shorts and low grade..........do....	14.0	12.3
Bran..........do....	14.5	14.0
Gain..........do....	1.2	.3
Moisture at tempering..........do....	9.8	9.8
Before..........do....	9.8	9.8
After..........do....	14.6	14.1
Baking test:		
Flour used..........grams..	340	340
Water used..........cubic centimeters..	180	180
Weight of loaf..........grams..	483	484
Volume of loaf..........cubic centimeters..	2,080	2,010
Color..........	79	93
Texture..........	94.5	93
Crumb..........	Dark gray.	Gray.
Remarks..........	([1])	None.

[1] Noticeably unpleasant odor present throughout process.

Mr. L. M. Thomas, who conducted the tests at Fargo, writes:

With ordinary cleaning machinery, where the separation of foreign material is accomplished by means of sieves and air currents, only a very small percentage of the nematode masses can be removed from the wheat. In the case of the sample milled, the original contained 2.7 per cent of infected kernels. After cleaning the sample by the process used in preparing all our samples for milling, the sample still contained 2.5 per cent of infected kernels, or 92.6 per cent of those in the original sample. The most satisfactory method perhaps of removing these nematode masses would be by floating them away from the wheat. In mills equipped for washing wheat, this could easily be done, but where there is no washing and drying system it is doubtful if any appreciable number of these infected kernels could be removed.

The results of the milling test also show slight variations. Less flour was obtained from the sample containing galls than from the hand-picked samples. The flour from this sample contained black specks resulting from the breaking up of the galls. There was likewise a correspondingly increased amount of shorts and low-grade flours. The baking test also brought out slight differences. The loaf made from the flour containing the ground-up galls was quite inferior in color and had a dark-gray crumb. Throughout the baking process a noticeably unpleasant odor was present with this sample. The texture and volume of both loaves, however, were not affected to any extent.

The temperature of the water used in tempering these samples was 62° F. In the tempering of samples for milling on the small experimental mill there is no application of heat or steam. In commercial mills there would often be a slight application of steam to the wheat just before it enters the rolls, the object being to toughen the bran.

It was thought that this temperature would be sufficient to kill all the larvæ, but Mr. Thomas states that it is quite unlikely that the small amount of steam used would penetrate any deeper than the outside coats of the berry. Of course, during the baking process, all larvæ would be killed, which were not killed in the milling operation. They are still present in a macerated condition, and it would seem for sanitary reasons that they should be removed.

Notice has also come to the attention of the Department of Agriculture that some farmers mill their own flour from this infected wheat. Knowing the content of these galls, this practice is repulsive, and it is recommended that in the future, wheat for home milling be carefully inspected for the presence of these nematode galls, and that they either be removed by floating or that such wheat be rejected or diluted with sound wheat until a negligible amount of galls is present.

METHODS OF CONTROL AND DISTRIBUTION.

It is apparent that if this disease is allowed to increase it will become a serious factor in the marketing and milling of wheat, and, therefore, known methods for its control should be made public at the present time.

Apparently, no previous extensive experiments have been carried out for the purpose of controlling this disease in this country. No doubt the prime essentials for effective control are clean seed and crop rotation. Past experiments indicate that the nematodes must have either the gall or the host plant present as a protection, otherwise they do not live long in the soil in the active state. Also, it seems to have been shown that, of the common field crops, this nematode seriously attacks wheat only. It would seem, then, that a crop rotation of two or more years would be effective in practically ridding a field of this pest.

The use of clean seed, either by the buying of new seed from outside sources or by the planting of seed which has been properly cleaned, has been shown to reduce the infection in a number of instances throughout the infected area.

A number of ways for cleaning the infected grain have been tried and suggested. Bessey suggests that grain containing these galls be given the hot-water treatment, as carried out for the stinking smut of wheat, in order to kill the nematodes. Cobb[1] mentions winnowing. Steeping in a .2 to 5 per cent solution of sulphuric acid for one-half to two hours as a means of ridding seed of these organisms has also been suggested.

It has been the experience of several farmers, as well as that of the Grain Standardization Laboratory, that the bluestone treatment for

[1] Cobb, N. A. Cited by Johnson.

smut, i. e., seed immersed in a solution of copper sulphate (1 pound of copper sulphate to 4 gallons of water) for three minutes is not an effective method for killing the nematodes, because in this length of time the solution does not pass through the hard covering of the gall.

The modified copper-sulphate treatment of soaking the seed for 12 hours in a solution of the strength 1 pound of bluestone to 25 gallons of water has not proved successful in killing these worms.

Experiments show that soaking seed in 0.6 per cent sulphuric acid for 24 hours is an efficient method of killing the contents of the gall. This sulphuric-acid treatment is so subject to variations in the hands of an inexperienced operator that it can not be recommended for treatment of seed infected with these galls, however, as the germination of the seed is greatly decreased.

The hot-water treatment for smut, which is described in Farmers' Bulletin 507,[1] and which consists essentially of immersing seed for 10 to 15 minutes in water at a temperature of 135° F., has likewise proved successful in killing the nematodes. This test, however, unless properly carried out, is also liable to injure the sound seeds and for this reason can not be recommended without reservation.

The most feasible method of removing the source of infection from sound wheat seems to be by floating the galls out in cold water. The nematode galls are lighter than sound wheat kernels, and this difference in weight is made use of in their separation. A suggested method follows:

Have two tubs or half barrels, one set above the other so that the overflow containing the galls will fall into the lower tub. Cover the lower tub with cheese cloth to catch the galls but let the water run through. Fill the upper tub with water to overflowing. Next pour the infected wheat into the top barrel slowly at the same time stirring vigorously. The galls and light chaff will rise to the top and float off when assisted by hand or skimmer, and will be caught on the cheesecloth over the lower tub. When vigorous stirring brings up no more galls pour or drain off the water. Air drying is accomplished quickly and easily if the wet grain be spread out to dry on a canvas or on a clean barn floor. The dampened grain should not be allowed to lie in a heap as the kernels will not dry out regularly; some will sprout and danger of heating is present.

The seed may be planted as soon as it will run freely in a drill or may be dried thoroughly and stored for future use. Experiments carried out by this method have resulted in the removal of over 99 per cent of the galls. It is recommended that the grain be allowed

[1] Johnson, Edward C. The smuts of wheat, oats, barley, and corn. U. S. Dept. of Agriculture, Farmers' Bulletin 507. 1912.

to remain in the water for only as long as absolutely necessary for a thorough removal of the galls or the germination will be affected.

To summarize, clean seed obtained from outside sources, or seed cleaned by means of floating the galls out of the infected wheat with water, combined with crop rotation, seem to be the most effective methods of controlling this disease at the present time. Experiments in which the Bureau of Markets is cooperating are now being conducted by the Bureau of Plant Industry on additional methods for controlling this disease, the results of which will be reported in the future.[1]

The disease propagates easily. This has been brought out several times from the investigations carried on throughout the infected area. One method of propagation is the planting of infected seed wheat. For example, one particular crop which contained these galls was sold for seeding purposes. Without exception the next season every farmer who purchased this seed had an infected crop regardless of the fertile condition of the soil. Farmers who planted their own infected seed harvested each year a greater proportion of galls. The highest proportion of galls to sound wheat coming to the attention of the Department of Agriculture was 25 per cent.

Some of the mills which do a seed-cleaning business as a side line return the screenings to the owners to be used for feed. If these screenings contain nematode galls and are given to fowls and stock for feeding purposes they constitute an important means of spreading the disease. Feeding experiments[2] indicate that the gall is not digested in all cases, but finds its way into the manure intact. When this manure is spread over the land the land is thus inoculated with these nematode galls, and if wheat is again planted two sources of infection, the seed and manure, are acting to supply infectious material for the young seedling. It is apparent that such screenings should be burned even at chance of losing some feed. The material removed from infected wheat by floating should also be burned as a precaution against further distribution of this disease.

Further experiments on this disease from a milling, grading, and distribution standpoint are now being carried forward by the Bureau of Markets in order that a better knowledge of the commercial importance of this material as a foreign material in wheat may be obtained.

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[1] U. S. Dept. of Agriculture, Office of the Secretary, Circular 114. A Serious eelworm or nematode disease of wheat. 1918.

[2] Marcinowski, K. Parasitich und semiparasitsch an Pflanzen lebende Nematoden. K. Biol. anst. F. land un forstw. Arb. bd., 7 hft. 1, p. 1–192, pl. 1, Berlin, 1909.

SUMMARY.

The results of this preliminary investigation show that a disease of wheat comparatively new to this country and to the grain trade is established in certain areas of the United States, particularly in certain sections of Virginia. This disease not only reduces yields per acre but also seriously affects market grades and milling qualities of marketed wheat, on account of the presence in the grain of a peculiarly misshapen black gall, which can be removed only with difficulty and which is the resting place of the invading organisms.

The presence of the galls in a parcel of wheat reduces the market grade in several ways. Its presence reduces the test weight per bushel because of its lighter weight. It also increases the amount of dockage and particularly the amount of foreign material other than dockage in any given lot of infected grain.

Flour yield from such infected wheat is reduced, and the percentage of low-grade flour and shorts is increased. Ordinary wheat-cleaning machinery will not remove these galls successfully, although machinery for washing and drying wheat will no doubt be successful.

The best known methods of control are crop rotation and clean seed. To kill the nematode larvæ, infected seed may be treated by the hot-water treatment used for the control of smut to kill the nematode larvæ. The easiest method and the least dangerous practice to obtain clean seed is to float the galls away from the sound wheat by means of water.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 735

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ November 15, 1918

FARM PRACTICE IN GROWING SUGAR BEETS IN THE BILLINGS REGION OF MONTANA.[1]

By S. B. Nuckols, *Assistant Agriculturist, Office of Sugar-Plant Investigations*, and E. L. Currier, *Professor of Farm Management, Montana Agricultural College.*

CONTENTS.

BASIS OF THE STUDY.

To obtain data on methods of management, labor requirements, and cost of growing sugar-beets, studies were conducted on a large number of farms during the summer of 1916 in the area which grows beets for the beet-sugar factory at Billings, Mont., including farms

[1] This bulletin was prepared jointly by the Montana Agricultural Experiment Station and the Bureau of Plant Industry and with the approval of the Office of Farm Management. The blanks used in collecting these data were prepared in the Office of Farm Management, hence the material incorporated in this bulletin is identical in form with that in the other bulletins of this series prepared jointly by the Office of Farm Management and the Bureau of Plant Industry. The members of the staff of the Office of Farm Management were engaged in taking records in other localities at the time this work was done, and for that reason they are not represented in connection with the preparation of this bulletin.

in the irrigated areas of Yellowstone, Stillwater, and Carbon Counties. Usable data were taken on 305 farms representing a sugar-beet crop of 8,849 acres, being about 36 per cent of the entire acreage grown for this factory during the year 1915. This acreage is generally distributed throughout the entire area and is believed to be typical of the region at the time the survey was made. The costs here given may not be accurate for present conditions. There have been, however, no changes in the methods of handling the crop tending to reduce the labor necessary to produce it; therefore, by readjustment to allow for prevailing labor prices these data can be applied to the present cost of production.

Records were taken on all types of farms of the area except such as seemed not typical of the region. A labor-income farm survey had been made of this region in 1915 by the same men who had charge of this survey. As the leases are for only one year and the owners often do not live in the region, data on many of the tenanted farms are hard to get, but records were obtained on 133 tenant farms, of which 77 were farms upon which the tenant had farmed but one year. After eliminating records of doubtful value, 305 records remain, on which the statements of this bulletin are based.

PROCEDURE.

The data presented in this bulletin, though not taken from systematic records kept on the farms, are based upon a large number of estimates given by beet growers. The results represent the best judgment and experience of men who have been actively engaged in the production of this crop. The schedules were filled out by well-trained enumerators and not only afforded complete information pertaining to farm practice and farm costs in the production of sugar beets but also furnished data showing the outcome of the entire business of the farm for the particular crop year to which they applied.

DESCRIPTION OF THE REGION STUDIED.

The portion of the Yellowstone Valley covered by this survey (fig. 1) consists of two parts, viz, the Huntley Irrigation Project and the irrigated area extending from Billings as far west as the town of Park City.

HUNTLEY IRRIGATION PROJECT.

The Huntley Irrigation Project occupies a strip of land along the south side of the Yellowstone River, from Huntley, Mont., eastward to Pompeys Pillar, a distance of about 22 miles. This strip of land has an average width of 3½ to 4 miles and comprises an area of 32,405 acres. This land was originally divided by the Government into tracts containing 40 to 80 acres, but at present many of the units have been combined so as to form larger farm areas. The soils of this area contain a rather high percentage of clay and are inclined to be heavy and somewhat difficult to till.

For several years the lower portion of the project has suffered rather badly from the effects of seepage water and a consequent accumulation of alkali salts on the surface of the soil. An extensive drainage system is being installed, which will probably do a great deal toward relieving this condition.

The growing of sugar beets forms the basis for the agriculture of this region. Other important crops are alfalfa, wheat, oats, and barley.

AREA FROM BILLINGS WESTWARD.

The area in the Yellowstone Valley west of Billings comprises a strip of land extending from about 1 mile east of Billings to 1 mile west of Park City, a distance of nearly 25 miles. At Billings this area is about 4 miles wide, and it gradually widens toward the west until at a distance of about 8 miles west of Billings a maximum width of 7 miles is reached. It then narrows abruptly to about 3 miles, which width it approximately maintains to Park City. The area comprises 68,416 acres, or about 107 square miles. The soils of this area for the most part are inclined to be a little heavy, although they seem well adapted to the growth of sugar beets and other crops that are found in this region.

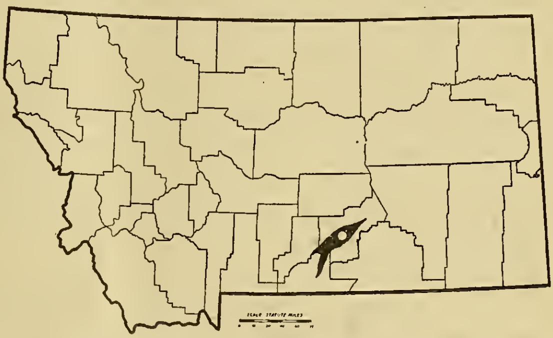

FIG. 1.—Outline map of the State of Montana, showing (in black) the approximate location of the sugar-beet region studied. The white dot in the black area indicates the location of the sugar-beet factory at Billings.

The considerable area of stock range adjoining the area has been an important factor in promoting the agriculture of this valley. On the whole, a well-balanced system of farming has developed, using beets as a cash crop and building around the beet crop a rotation of small grain and alfalfa.

This area as well as the Huntley project is irrigated by waters diverted from the Yellowstone Valley, the supply of which is more than ample for all purposes.

Clarks Fork Valley.—The Clarks Fork Valley occupies a strip of country along the Clarks Fork River about 50 miles long and varying from 4 to 10 miles in width. The greater part of this area is irrigated from waters diverted from the Clarks Fork River and numerous smaller streams that have their origin in the mountains near by.

Soil conditions in this valley are very similar to those in the adjacent Yellowstone Valley, with the exception that the soils are perhaps a little less heavy and more easy to till.

The altitude of this valley is somewhat higher than that of the Yellowstone, making a shorter growing season and increasing a little the liabilty to frosts. Sugar beets are grown toward the lower end of the valley.

DEVELOPMENT OF THE SUGAR-BEET INDUSTRY IN THE BILLINGS REGION.

The sugar-beet industry has developed rather rapidly in the Billings region of Montana. The factory at Billings has been in operation since 1906. Before that time sugar beets were grown in the region only experimentally, to determine the advisability of establishing a sugar factory. Previous to the introduction of the sugar-beet industry the region was mainly devoted to cattle raising and grain growing. The acreage of irrigated land and consequently the acreage of tillable crops has been increasing in this region for a number of years. Table I illustrates the increase in the acreage of sugar beets grown in this region and gives the average yields per acre for a period of 10 years.

Table I.—*Acreage and yields of sugar beets in the Billings region for the 10-year period from 1906 to 1915, inclusive.*

Year.	Total area.	Yield per acre.	Year.	Total area.	Yield per acre.
	Acres.	*Tons.*		*Acres.*	*Tons.*
1906	6,184	9.47	1912	19,017	10.11
1907	8,898	10.75	1913	22,887	10.21
1908	9,457	12.22	1914	18,707	10.91
1909	10,365	10.71	1915	22,233	9.76
1910	10,251	11.76			
1911	15,694	11.56	Average	14,369	10.75

IRRIGATED AREA IN BEETS IN 1915.

Many farms have tillable land that is not irrigated and therefore not suitable for the growing of sugar beets. The computations in Table II are based on the irrigated lands per farm, exclusive of irrigated permanent pastures, as such pastures are often seeped lands or otherwise not suitable for growing sugar beets. Irrigated pasture lands which are in the rotation are included in the tabulation.

The fact that the acreage of beets grown by owners is less than that grown by tenants is not due so much to the size of the farms or to the character of the lands as to the feeling of responsibility on the part of the owners for the future production from the farms. Landlords and tenants in this territory as a rule are not considering results beyond a 1-year period. Beets being a cash crop, the tenant can pay higher rents where the land is put to beets. Continuous cropping to sugar beets is practiced on tenant farms, and the fact that nearly 4 acres out of each 10 irrigated acres are in beets means that in some cases poor methods of rotation are in use and that ideal conditions exist for the introduction of beet diseases and beet insects. The solution of such problems is in the hands of the landlords and not the tenants, as the leases can be made so that the tenant will grow less beets and be able to practice a rotation of crops. Just what percentage of the irrigated tillable land should be planted to sugar beets is a matter to be decided for the individual farm.

Every farm should have a proper rotation of crops, but the type of soil and the other crops that can be grown have a great deal to do with the percentage of the total area that should be planted in beets. Previous to the introduction of sugar beets into this region there was no common cultivated crop that required summer tillage, the rotations being limited to alfalfa and small grains. Under these conditions many weeds that thrived with such a rotation became established in this region, and much land has been planted in beets in order to kill out these weeds. If continued growing of beets on the same lands is practiced no doubt insects and diseases of the beet will become established, which will necessitate rotation to do away with these pests.

The data collected would indicate that not over 25 per cent of the irrigated tillable area in this region should be planted to beets. This would permit the keeping of some live stock and provide a more substantial and well-balanced system of farming.

Grain and hay farming is not adapted to the needs of the man with a small farm who is trying to get sufficient returns from the farm to make a living for an ordinary-sized family. He must have crops that make a larger gross return per acre and give him a chance to use more labor. Many farms in this region have less than 40 acres of tillable land, and some of these farms have a large percentage of their tillable area planted to beets.

Table II also shows that a smaller percentage of the irrigated land on the larger farms is planted to beets than on the smaller farms. The acreage of beets per farm increases with the size of the irrigated area per farm, but not in proportion. This may be due to the desire on the part of each man to operate his farm with as little hired labor as possible; that is, there is a tendency toward the 1-man farm. On some of the smaller farms the operator has to grow intensive crops in order to occupy his entire time.

TABLE II.—*Classification of the 305 farms studied in the Billings region, according to ownership and size, showing the percentage relation between the total irrigated area and the area planted in sugar beets in 1915.*

Classification of farms.	Number of farms.	Irrigated crops (acres).				Percentage in beets.
		Total planted.		Average per farm.		
		Area.	In beets.	Area.	In beets.	
As to ownership:						
Owners	117	10,276	2,573	87.83	21.99	25.03
Owners renting additional acres	55	5,953	1,622	108.24	29.49	27.24
Tenants	133	12,132	4,654	91.21	34.98	38.36
All farms	305	28,363	8,849	92.99	29.01	31.20
As to size:						
25 acres and less	9	139	107	15.44	11.88	76.97
26 to 50 acres	77	2,844	1,273	36.94	16.53	44.76
51 to 75 acres	67	4,277	1,562	63.83	23.31	36.52
76 to 100 acres	45	3,845	1,357	85.44	30.15	35.29
101 to 125 acres	43	4,893	1,758	113.79	40.88	35.92
126 to 150 acres	28	3,919	1,121	139.96	40.04	28.60
151 to 175 acres	13	2,083	546	160.23	42.00	26.21
176 to 250 acres	14	3,001	653	214.35	46.64	21.75
251 acres and larger	9	3,362	472	373.55	52.44	14.04
All farms	305	28,363	8,849	92.99	29.01	31.20

PREVIOUS CROP.

Of the 8,849 acres of beets included in this survey, it was found that 6,129 acres were planted on land that had been in beets the previous year, 1,640 acres were on land that had been in alfalfa the previous year, 717 acres had been in grain the previous year, 86 acres had been in miscellaneous other crops, and data in regard to the previous crop, covering 277 acres, were wanting. This large acreage of beets planted on land that was in beets the previous year is an indication of a cropping system that should be modified by the growers as soon as possible if they do not wish to have decreasing yields of beets. Beets should not be planted on the same land continuously, even if the farmer has manure to put on the land each year. The figures given would indicate that nearly 70 per cent of the land was planted in beets at least two years in succession. Data for a longer period of time were not obtained, and it is not possible to state how long the average grower devotes land to beets without rotation.

On some farms certain fields are so located with respect to water supply and proximity to the loading dump, and have soil of so favorable a type that they are the most desirable parts of the farm for the growing of sugar beets. Naturally there is a tendency to plant beets on such fields for a number of years. This region having many tenants, no doubt much laxity exists in the planning of the crop rotation.

VALUE OF LABOR.

Throughout this bulletin the value of man labor is computed at 20 cents per hour, or $2 for a 10-hour day. Horse labor is valued at 10 cents per hour, or $1 per 10-hour day, whether the animal is worked single or in a 2-horse, 3-horse, or 4-horse team.

At certain times of the year labor may be rated higher than at other times, but the farmers were not able to give exact figures for different dates. Men were often hired by paying a definite sum per month for the entire year. Consideration was given to the variation in wages, and each grower was asked the highest and the lowest rate he paid for labor by the day or the month during the year. Data were also obtained as to the total time labor was hired and the total wages paid for each farm. Consideration was also given to the value of board furnished the laborers. Taking an average of all replies, it was found that the average wage was as stated above. The value of horse labor was ascertained by similar methods.

The cost of labor varied on different ranches, but in estimating the cost of production of beets for each farm the labor was rated at the average for the region. Family labor or labor done by the grower was figured at the same rate as hired labor.

MANURING PRACTICE.

As has been rather common in most western semiarid regions where the land was broken and planted to grain crops for several years, the farmers of this region have not placed a very high value upon barnyard manure. Manure has had a tendency to stimulate too heavy a growth of straw of the grain crops on these fertile lands. This attitude toward the use of manure soon disappears when the farmers begin to grow sugar beets. The feeding of stock has gradually increased on account of the manure produced, until now many of the sugar-beet growers state that without this by-product little profit would be found in the growing of sugar beets. The beet crop produces a great deal of stock feed in the form of tops, pulp, and waste molasses. Alfalfa hay grows well in this region, and this, with the grazing on range lands and the feed from the beets, furnishes the basis of an increasing feeding industry. It was reported that 36.7 per cent of the land planted to beets in the surveyed area had been manured at some time during the past three years. It was assumed that the manure would give beneficial results to crops for that length of time at least. The value of manures and the length of time over which the cost of application should be distributed were reported upon by all farmers, leaving little doubt as to the general sentiment in regard to the value of barnyard manures in the production of a crop. The rainfall in this region is not heavy, and manures do not rot and become available plant food as rapidly as they do in more humid regions. In averaging the result of the numerous answers upon this point it was decided that the nearest correct method of distributing the cost of manuring was to charge 40 per cent to the first crop, 40 per cent to the second crop, and 20 per cent to the crop grown the third year after the manure was applied. Some men favored a longer period of distribution. That the manure on land was worth as much to the second crop as it was to the first was the almost unanimous opinion. As many farmers stated that the second year was better than the first as the reverse, the usual answer being that the two crops were equally helped. Considering this, the distribution stated above as to cost of manure and manuring seems to be justified. That is, on the land where beets were grown but one year after manuring, the charge would be 40 per cent of the value of the manure in the yard and 40 per cent of the cost of the labor of spreading the same. If the land had been manured for two years in succession before planting the beets, the charge would be 80 per cent of the yard value plus 80 per cent of the cost of application. If land had been manured for the three years previous to the growing of the 1915 crop of beets the charge would be 100 per cent of the cost of the manure and all the labor charges. The cost of manure and manuring was charged to every farm in this manner. Commercial fertilizers were not used, and the growing of special green-manure crops is almost unknown; however, a form of green-crop manuring exists. It is common to plow under alfalfa that has some green growth when being plowed. Most men who practiced this considered a green crop of alfalfa as beneficial as a 15-ton per acre coat of barnyard manure. Of the 1,640 acres of alfalfa broken and planted to sugar beets in 1915, a large part of it had some green growth at the time of plowing.

The value placed upon manures and the fact that commercial fertilizers are not used is easily explained when the character of the soil is taken into consideration. This is a soil that runs rather low in humus but relatively high in mineral nutrients.

Sugar-beet growers almost without exception used their total available manure upon the land to be planted immediately to beets. This might in part be due to the fact that no other cultivated crop is grown to any great extent by most of these men, but their opinion was that the manure was most readily available and most beneficial when applied to beets.

The methods of applying the manure varied, but most of the growers used wagons and forks. Only 98 growers used manure spreaders, while 207 used farm wagons. The manure is mostly spread in the winter and early spring, and most men prefer to get manuring done when they have spare time. If the manure can be plowed under soon after it is spread, the spreader is the most successful method, but where manure is hauled to the field a long time before it is to be plowed under it is best to place it in small piles and spread it with a fork just before plowing. Spreading and disking under is often a better method than to pile the manure.

Either piling or disking the manure may cause a little more labor, but this method permits the work to be done at a time when teams are not busy, thus conserving the value of the manure by preventing its drying out and blowing away. To spread manure on the fields, leaving it exposed in this dry climate, entails a loss from the heavy winds that sometimes come in the early spring. That most farmers do their own work of spreading manure is indicated by the fact that on 62 per cent of the farms where manure was applied the spreading crew was one man and two horses and 69 per cent of the farmers used a 1-man crew.

It cost 27 cents per ton to distribute manure with one man to a wagon or spreader and a team of two or more horses; with two men to an outfit it cost 23 cents per ton, and with three men 20 cents. This variation in cost is due to at least two factors: (1) The larger crews were spreading a greater acreage, and (2) in most cases they used manure spreaders and did their work at a more rushed season. The man with little manure to spread does not usually use a spreader, and the man who uses a spreader prefers to spread the manure at a time when it can be plowed or disked under immediately.

One man with a 2-horse team did double the work per horse that was done by one man with a 4-horse team, the same being true of three men with 3-horse teams as compared with three men using 6-horse teams. This is perhaps due to the number of horses that stand idle while the manure is being loaded. A crew consisting of three men and six horses used two spreaders with a 3-horse team on each spreader. While two men and one 3-horse team were engaged in loading, the other man with his 3-horse team was spreading the manure. With three men, a 3-horse team, and two spreaders, two men loaded the spreaders and one man with the three horses spread the manure, switching the team from one spreader to the other. This appeared to be a very quick and efficient method, as one spreader was being loaded while the other was being unloaded.

A total of 49,570 tons of manure was spread on sugar-beet land in this region for the 1915 sugar-beet crop. At the estimated yard value of 85 cents per ton this would be worth $42,298, but according to the method of distributing the charge to the immediate crop after manure has been applied it was found that 79 per cent of this sum, or $33,510, should be charged to the 1915 crop of sugar beets. It thus appears that the total charge against future crops is greater than the amount that is accumulated in the soil from previous years. If the entire amount of manure used had been spread upon all the sugar-beet land devoted to the 1915 crop, the average per acre would have been 5.6 tons; but some growers spread as high as 25 tons per acre, and the average of 15.3 tons was spread on each acre manured, thus leaving 4,599 acres of land with no manure to benefit the 1915 crop of beets.

The growers on 72 farms did not manure any of the land they put in beets, 62 growers manured less than 25 per cent of their beet area, 116 used manure for approximately 50 per cent of their beet area, and 55 manured 75 per cent or more of all the land they put in beets. The lands that were manured as a whole produced a good increase in the yield, and, after deducting the value of the manure at 85 cents per ton and the cost of the labor of spreading it, a net profit of $1.41 per acre, due to manuring, is shown for the entire area. (Table III.)

TABLE III.—*Use of manure as affecting yields of sugar beets in the Billings region.*

[The valuation of beets is that given by the growers.]

Classification.	Not manured.	Percentage of area devoted to beets upon which manure was used.			All farms.
		1 to 24½.	25 to 74½.	75 to 100.	
Area devoted to beets........acres..	1,908	2,055	3,443	1,443	8,849
Beets produced........tons..	18,835	20,328	38,183	17,855	95,201
Production per acre........do....	9.87	9.89	11.09	12.37	10.76
Value of beets sold........	$110,742	$124,006	$228,022	$107,211	$569,981
Value of beets per acre........	58.04	60.37	66.24	74.29	64.45
Value of increase of crop per acre........	....	2.33	8.20	16.25	6.41

In considering the value of the increased yield per acre, the quality of the beets as well as the added tonnage should be considered.

In the comparison of those farms using no manure with those spreading manure on 75 per cent or more of their sugar-beet land, it was found that the estimate of 85 cents per ton for the value of manure in the yard was less than the actual value of the manure, for on this one crop the farmer received an average of $1 per ton for manure by increased crop production after deducting for all labor costs of spreading manure at the usual rates. (Table IV.) This shows that manure has a value, and the beet grower can not afford to let it waste.

TABLE IV.—*Returns to growers using no manure compared with returns to those manuring 75 per cent or more of their sugar-beet area in the Billings region.*

Crop treatment.	Number of farms.	Beet crop.			Returns for manure less the labor cost.
		Area.	Per acre.		
			Yield.	Value of the net increase.	
		Acres.	*Tons.*		
Manured	55	1,444	12.38	$16.10	$12.79
No manure	74	1,908	9.87		

Manure worth $3.79 was put on each acre manured. The cost of its application was $3.31, as it required 8.9 hours of man labor and 15.3 hours of horse labor.

Growers to the number of 233, or 75.7 per cent of the total, manured part of their beet land. They manured 3,250 acres, or 36.7 per cent of the total beet acreage, at some time in the 3-year period prior to the time of planting the 1915 beet crop. As already stated, the writers have assumed that manure is beneficial to the crop for at least three years succeeding its application.

The data showed that in this region the average established owner manured more land than the average tenant, because the tenants were unable to get long leases on the land. The difference in this respect was 17.2 per cent of the area planted to sugar beets. The data also showed that the owners made slightly heavier applications of manure to the land manured. In fact, most of the land manured on tenant holdings was on those farms where the landlord had encouraged the feeding of stock on the land by feeding all the hay which he received for rental. Some landlords were taking an interest in their farms and feeding their hay on the land, and some of the tenants were feeding with the landlord under agreements whereby the landlord advanced the money to finance the buying of feeding stock, and the tenant performed the labor of feeding, thus effecting an exchange of labor for the use of capital.

PLOWING PRACTICE.

The entire area planted to sugar beets was plowed during the preparation of the seed bed. This work was done at an average cost of $2.54 per acre, or an expenditure of 4.59 hours of man labor and 16.18 hours of horse labor. This does not include any labor of crowning alfalfa sod where such lands were crowned before they were plowed.

Almost all the plowing done in this region is done in the spring, as growers do not have time to harvest their beets and do much fall plowing other than that required for winter wheat. Some crowning of alfalfa is done in the fall and early winter, but little other than alfalfa land is plowed before early spring. Only 23 growers out of a total of 305 did any fall plowing, and only 3 plowed all of their beet land in the fall. Most growers were of the opinion that fall plowing of land for beets was advisable, but generally there was no time for this work because the beet harvest and work on other crops demanded all the available man and horse labor.

The data presented show that the average team of three or four horses and a man will plow a little less than 2 acres of land per 10-hour day.

All the growers plow rather deep in preparing land for sugar beets, and they so plan the operation that the land can be leveled off well for irrigation. The usual depth of plowing is from 8 to 10 inches, some plowing a little shallower or a little deeper, according to the type of soil they have. Two-way plows are used by some, and it was found that they leave the land in better shape for irrigation than plows of other types, as no dead furrows are left in the field. They are not difficult to operate. Definite data as to the number of 2-way plows were not obtained, because in many instances the enumerators did not differentiate between sulky plows and 2-way plows.

The variation in cost for different crews in plowing seems to be more in the cost for man labor than for horse labor. This is due to the fact that with more horses to handle less time is required by the man per horse, while the horse can do about the same amount of labor regardless of the method of hitching. As has been explained in regard to the kind of plows used, the classification of crews might be limited to 2-horse teams, 3 or 4 horse teams, and 5 or 6 horse teams. The 3-horse team seems to have an advantage over the 4-horse team. Part of this may be due to the method of hitching and the facility of turning. A 3-horse team is hitched abreast, while four horses are hitched in two teams tandem in most instances. Most of the advantage is due to the type of soils. In the sections where the soil is more sandy and loose the plowing is almost all done by three horses, and in sections where the soil is heavier all the growers plow with 4-horse teams. The depth of plowing also influences the number of horses required for plowing.

Of the 15 growers who plowed with a crew of one man and two horses, 13 used walking plows, 1 used a sulky, and 1 did not state the kind of plow used. Of the 87 growers who employed 3-horse teams, 8 used walking plows, 77 sulky plows, and 2 gang plows. Of the 110 teams of four horses, 99 were with sulky plows and 11 with gang plows. Of the 17 teams of five horses, 3 were with sulky plows and 14 were with gang plows. Five growers hitched 6-horse teams to gang plows. The remaining growers did not report the kind of plows used.

In considering the size of plows used, it was found that of the 310 plows reported 122 were 16-inch plows, 170 were 14-inch plows, and 18 were 12-inch plows. (Table V.)

TABLE V.—*Cost of plowing land for sugar beets with different plows in the Billings region in 1915.*

Kind of plow.	Area plowed.	Labor per acre.		
		Cost.	Man.	Horse.
	Acres.		*Hours.*	*Hours.*
Walking	272	$3.33	7.57	18.12
Sulky	6,396	3.10	5.61	19.74
Gang	1,319	1.94	2.85	13.67
Unknown	764	2.71	5.15	16.81
Hired	98	3.45		
All farms	8,849	2.90	5.15	18.32

CROWNING ALFALFA SOD IN PREPARING LAND FOR BEETS.

Alfalfa crowning is done in the fall or spring when there is some green growth on the alfalfa plants, which when plowed under adds to the humus content of the soil.

A total area of 1,394 acres of alfalfa land was crowned for beet growing by 69 farmers. This labor takes about as much time as to plow the land. It requires 4.35 hours of man labor and 16.14 hours of horse labor to crown 1 acre, and the cost is figured at $2.48 per acre. If the work can not be done in the fall it is done as soon as possible in the spring, if the land is for beets that year. The plowing is to a depth of 3 or 4 inches, which is sufficient to cut off and turn over most of the alfalfa plants. The ground is then harrowed. The exposed alfalfa roots and crowns soon dry out and die, while if plowed to a greater depth many of them would sprout up again. After allowing the roots to dry out for a few weeks the land is plowed again to a greater depth, with the result that few of the crowns then turned under grow again. This method of handling alfalfa sod is much better than plowing only once, as it makes a better seed bed and does away with much volunteer alfalfa, which would make beet cultivation very difficult; also not so many roots are left on top of the ground to clog the cultivating machinery. The cost of the extra work of crowning is easily saved in the later work of thinning and cultivating the beet crop. Most of the growers prefer to crown in the fall if other work permits, so as to let the crowns dry out over winter before turning them under; in actual practice, however, few of them were able to do much alfalfa crowning in the fall. Of the total of 1,640 acres of alfalfa broken and planted in beets, 1,394 acres were double plowed (or crowned and plowed) and 246 acres were plowed but once. Of the 1,394 acres crowned and plowed, 309 acres were crowned in the fall and 1,085 acres crowned in the spring. More of this crowning would have been done in the fall if the farmer could have found time to do it at that season of the year.

The crowning of the alfalfa sod is done with the same plows that are used to plow the land, and the time per acre for various crews runs similar to that required for plowing. The explanation of the variation in costs of plowing under varying conditions applies also to crowning alfalfa, the reasons being identical.

DISKING PRACTICE.

Disking was not a general practice in this region in 1915, as is shown by the fact that only 26.9 per cent of the farmers disked any land, and only about 21 per cent of the total area was disked. The plowing table shows that most of the land was plowed. Where disking was done, it was mostly by men who were preparing alfalfa land for beets. Some growers disked manured land before plowing.

Of the 82 growers who used the disk in preparing beet land, it was found that 7 used 12-disk implements, 40 used the 14-disk size, and 28 used 16-disk machines. The remaining 7 made no report as to the size of disk used.

Averaging all the farms, it is found that one man with the average number of horses (about four) can double disk 5.4 acres in a 10-hour day. A small number of farms use other than 4-horse teams for disking, so that a comparison of the cost by crews does not indicate much of practical value. The average acre disked required 1.84 hours of man labor and 7.19 hours of horse labor. This was applied at an average cost of $1.09 per acre for the 1,874 acres disked on 82 farms.

FLOATING PRACTICE.

The implement used in the operation of floating land is usually a homemade piece of machinery made from sawed timbers 2 or 3 inches thick and 12 inches wide; the length varies from 12 to 24 feet and the width from 6 to 14 feet. (Fig. 2.) Of the total number reporting, 50 per cent reported 16 feet as the length of the float, and most of those remaining were more than 16 feet in length. As to width, 20 used 6-foot floats, 12 used 7-foot widths, 89 used 8-foot widths, 33 used 10-foot widths, and 14 used floats wider than 10 feet. The pieces are bolted together so that the planks have only one edge touching the ground when in use. The three crosspieces usually provided serve to drag down the higher places in the field and deposit dirt in the depressions. This is an excellent implement for getting ground in level condition, so as to irrigate well. The longer floats do good work in leveling where depressions are wide. A narrow implement will have a tendency to scoop out these places. Four or more horses are needed to handle a large float properly, the average number for the region being a little more than four. The number of horses needed and the efficiency of operation depend upon the size and weight of the float. Some lighter material is commonly used on top of the implement in order that the driver may ride standing or move about, so as to make the leveling more nearly perfect.

Practically all the growers in the region used some such machine, a total of 8,580 acres (nearly 97 per cent of the area planted to beets) being thus prepared.

The growers who did not use a box level of this sort used a drag made of overlapping planks. These drags are usually from 3 to 5

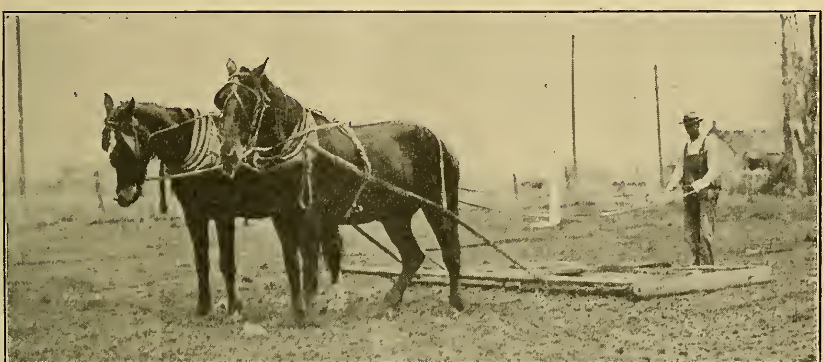

FIG. 2.—Floating sugar-beet land. The homemade implement here shown is used after disking to level the ground and put it into good condition for irrigation.

feet wide and 8 or 10 feet long. The drag is not considered so efficient an implement for leveling land as a level; the work it does is not so thorough. The drag is a somewhat less expensive implement to make and to operate and it requires less horsepower. The average cost for the 325 acres dragged was 66 cents per acre.

The average acre of land included under the survey was floated 1.82 times at an average cost of 89 cents per acre. This is the equivalent of 1.51 hours of man labor and 5.96 hours of horse labor. One man with a 4-horse team can float about 12 acres per day. The average cost is 49 cents per acre, or 0.83 hour of man labor and 3.27 hours of horse labor, to go over an acre once with a float.

Of the farmers who floated their land, 70 per cent went over it twice, 22 per cent floated only once, and the other 8 per cent floated more than twice. In floating twice it is the common custom to float both ways of the field.

Of the 302 growers who floated their land, 205 used 4-horse teams. The cost of floating with crews of different sizes can not be used for any practical application, for the men using the greater number of horses invariably have the heavier floats. These heavier floats usually accomplish more in the way of smoothing and firming the seed bed than the lighter floats for an equal number of operations.

HARROWING PRACTICE.

It required an average of 1.75 hours of man labor and 5.75 hours of horse labor to harrow an acre. All of the farmers harrowed their land in preparing the seed bed for beets; 246 growers used 2-section harrows, and 49 used 3-section harrows, while 13 used harrows of unclassified types. (Fig. 3.)

FIG. 3.—A 4-horse team harrowing a field of sugar beets. This crew economizes man labor.

Of the total number of growers, 31 harrowed their land but once, 158 harrowed twice, 70 harrowed 3 times, 34 harrowed 4 times, 4 harrowed 5 times, 4 harrowed 6 times, 2 harrowed 7 times, and 1 harrowed 10 times. The average field was harrowed 2.44 times, at an average cost of 38 cents per acre, or a total cost of 93 cents per acre.

Harrowing varied a great deal on the various farms, owing to two causes. The type of soil has a great deal to do with the number of harrowings that are necessary, and in this region the growers who use disks, drags, and levels do not use the harrow so much as those who have less machinery of this sort and who use the harrow as a sort of float or level by turning the teeth horizontal to the surface of the ground. The first harrowing of the land is usually done immediately after plowing. A man will harrow once what is plowed each day, so as to prevent rapid drying out and the formation of hard clods. As a rule, this is done by the same man who does the plowing by switching from the plow and using the harrow for a time each day. A few men attach small narrow harrows to their plows. The practice of harrowing the land as soon as it is plowed is an efficient one, as much good can be accomplished with the harrow at that time.

Spring-tooth harrows are not used to any great extent in this region, as is shown by the fact that only 103 acres of land were harrowed with these implements. Most men who use a spring-tooth harrow use it in place of a disk. One man with a 4-horse team was the crew mostly used in spring-tooth harrowing, and the cost per acre to do this work averages $1.05 per acre harrowed, or 5.7 acres per 10-hour day for a crew of one man and four horses.

ROLLING PRACTICE.

The practice of rolling land before planting the beet seed is not general in this region, as is shown by the fact that only 27.8 per cent of the 305 farmers visited reported rolling land before planting, and less than 21 per cent of the total area planted to beets was rolled before planting. This might vary somewhat with different seasons, as rolling to firm the land for a good seed bed would be necessary in some years and not in others; however, in this region there is seldom much trouble with lack of firmness in seed beds for beets. Rolling is usually done to break clods.

The average 10-hour day's work at rolling by one man with a 2-horse team covers almost 14 acres of land; hence to roll 1 acre of land requires an average of 0.71 hour of man labor and 1.49 hours of horse labor.

Of the 84 men reporting the use of rollers, 50 used 10-foot rollers, 25 used 8-foot rollers, 6 used 12-foot rollers, and 3 used rollers less than 8 feet long. Data were not obtained as to the number of smooth and of corrugated rollers.

Of the 84 men using rollers, 80 hitched two horses to the roller; and the average man rolled his land 1.13 times, at a cost of 29 cents per acre.

DITCHING PRACTICE.

The cost of maintaining the small laterals, including the work of cleaning them out and the making of such new small ditches as may be necessary for the distribution of the water in the field so that it can be run into the furrows between the rows of beets, is only 13 cents per acre. This required 0.32 hour of man labor and 0.61 hour of horse labor. The factors that affect the cost are the distance from the main lateral or ditch, the size of the fields, and the lay of the land. Some teamwork is used in plowing out ditches, but they must be cleaned out with shovels. A total of 8,666 acres was considered in the above as having a separate cost for ditch cleaning, six farms being so located that no extra work was required to get water to the beet field. This is a part of the cost of irrigation. Very few growers had any special tools for ditching, and they used common walking plows for plowing out ditches. A few had listers; others used homemade V drags.

In taking the records no separate accounting of the man labor and the horse labor was made, so no estimate can be given as to the hand labor done with shovels in cleaning out the ditches.

As already stated, the ditch cleaning is very variable, according to the type of ditches necessary to get water to each farm, and no comparison can be made as to the efficiency of the methods used by the individual farmers. Some seem to use more efficient tools than others, but as a general rule this work is governed by the lay of the land. More work is necessary in some years than in others, and a part of this work is sometimes more in the nature of a permanent improvement.

PLANTING BEET SEED.

Of the total of 305 growers in this region all but 3 used drills drawn by two horses each that planted four rows at a time. The other drills planted only two rows at a time. With a 4-row drill, the average area planted per 10-hour day was a little over 10 acres. Planting in this region begins as early as possible in the spring, sometimes the early part of April, and lasts until about the first of June. Early-planted beets seem to do better than those planted later, but the time necessary to prepare the land does not always permit early planting. Where the field is very large it is the custom to plant at different times, so that the thinning will be distributed over a longer period. It is not advisable to let the beets stand too long before thinning.

The most of the acreage in this area is planted in rows 20 inches apart. A few men planted rows 18 and 22 inches apart, so that it was possible to make a deeper irrigation ditch between the wide rows and irrigate only between alternate pairs of rows. This custom is not very common in this region, as the soil is heavy and water does not quickly soak across the rows where the furrows are very far apart. Also the land in most instances has a good slope for irrigation, and there is no need of a deep furrow or large head of water for irrigating between the rows of sugar beets.

It cost 40 cents per acre to plant beet seed, or one hour of man labor and two hours of horse labor.

ROLLING LAND AFTER BEETS ARE PLANTED.

After being planted, 4,935 acres, or 56 per cent of the total area in beets, was rolled. This rolling is usually done after the beets have come through the ground and before they have grown very much. It cost 31 cents to roll an acre of beets, or 0.77 of an hour of man labor and 1.55 hours of horse labor. Rolling is done for two purposes: (1) To break any crust that may have formed on the ground and enable many beets to come up that would not otherwise be able to get through, and (2) to break and crush clods that would be likely to be thrown on the beet row at the first cultivation. Most growers use corrugated rollers run crosswise of the beet rows. (Fig. 4.) Very few use smooth rollers, as they are not as efficient for breaking

FIG. 4.—A corrugated roller used on beet land. A good type of roller for firming the seed bed.

a crust on the land. Some growers rolled the beets after they were blocked and thinned, so as to firm down and level the soil and aid in cultivating.

By far the greater number of growers use only two horses in rolling beets. One man with two horses can roll an average of 13 acres of land per 10-hour day.

After the seed was planted. 178 of the men rolled a part of their beet land, and only 27 of these rolled the land more than once.

More rolling is done in some years than in others, because there is much variation in the seasons: for example, should a heavy rain occur between the time of planting the beet seeds and their germination, a heavy crust is likely to form on the ground and the small plants are unable to break through, which necessitates rolling to break the crust. If the ground is cloddy, the rolling should be done before the seed is planted, as beets never give the best results where there is lack of care in the preparation of the seed bed. Getting the young plants well started early in the spring is one of the essentials of a good tonnage of sugar beets. Rolling does not seem to damage the plants to any great extent, as they do not break off easily and the small leaves are not often crushed.

FIG. 5.—Cultivating sugar beets with a 4-row cultivator, which will do twice as much work as a 2-row machine, with practically the same amount of man labor and horse labor.

CULTIVATION OF BEETS.

Cultivation starts as soon as the beets are well through the ground and continues during the season at short intervals until the beets are so large that they shade most of the ground and one can not get through the rows without breaking the leaves. In early cultivations the work must be done slowly and carefully, as the beets are very small and there is danger of covering them with dirt. Knives or duck feet are used for the first cultivation, or both are used by attaching the duck feet behind the knives. (Fig. 5.) In later cultivations larger shovels are used, and the work can be done more rapidly than in the earlier cultivations. In the first cultivations the ground should be loosened to a good depth. If possible, shovels should be run in the middle between the rows, for if this strip of ground is allowed to get hard satisfactory cultivation will be difficult. Early deep cultivations, if not too close, do not disturb any of the beet roots, while late, deep cultivations are apt to injure the beet roots. As much care should be taken to avoid injury to the roots of the beet as to the tops, for both roots and tops are essential to the growth of the plants. The first root of a beet strikes down deep into the soil and the side roots spread out later.

The cultivation of beets is in most instances done by 2-horse cultivators, which till four rows at a time; 37 growers used 1-horse cultivators that worked only two rows at a time. These 2-row cultivators are not as efficient as the 4-row implements, as they take about twice the man labor per acre, and the horse labor is about the same as for the 4-row machine. It takes two hours for a man to cultivate 1 acre with a 2-row cultivator and only one hour with a 4-row implement. Cultivators of the 2-row type are not used on large areas, as is shown by the average acreage of beets of those using 1-horse cultivators being only 14.5 acres per farm, while the average for those using 2-horse cultivators is 31 acres per farm. (Table VI.)

TABLE VI.—*Relation of the number of cultivations of the sugar-beet crop to the cost of labor in the Billings region in 1915.*

Cultivated.	Number of farms.	Acres of beets.	Percentage of total area.	Average labor cost per acre.[1]	Cultivated.	Number of farms.	Acres of beets.	Percentage of total area.	Average labor cost per acre.[1]
2 times...	12	372	4.2	$0.79	6 times...	13	614	6.9	$2.23
3 times...	86	1,964	22.2	1.28	7 times...	9	288	3.3	2.81
4 times...	125	4,183	47.3	1.68					
5 times...	60	1,422	16.1	2.20	All farms.	305	8,843	100.0	1.74

[1] The cost of the labor for furrowing, which is usually done once each season and by some is considered a cultivation, is not here included.

There is no clear indication that the number of cultivations had any great effect on the yield of beets per acre, there being many factors that might tend to cause a variation in yield; for example, the ground in certain fields may be in poor condition or the beets may not be doing well, and such a field will receive extra cultivations, while a good field may not be cultivated so often. Weedy land will be cultivated more often than fields that are comparatively free from weeds. Beets that are growing rapidly and are healthy and vigorous have a shorter season for cultivation before they become too large, but such beets usually yield best.

It required 4.46 hours of man labor and 8.46 hours of horse labor to cultivate an acre of beets an average of 4.09 times. (Table VII.)

TABLE VII.—*Relation of crew labor to the cost of cultivating the sugar-beet crop in the Billings region in 1915.*

Crew.	Number of farms.	Acres of beets.	Average times cultivated.	Cost of cultivating per acre.	
				Once over.	Total.
1 man, 1 horse	37	537	3.63	$0.60	$2.19
1 man, 2 horses	265	8,206	4.19	.41	1.71
Hired	3	98	3.41	.50	1.70
All farms	305	8,841	4.41	.42	1.74

FURROWING FOR IRRIGATION.

To furrow the average acre requires one hour of man labor, and the team or horse labor is nearly two hours, being a little less than double the amount of man labor because some men use only one horse for furrowing. The average cost of labor for furrowing is 39 cents per acre. Only seven growers furrowed twice, and only one did not furrow, the others furrowing once.

The ordinary beet cultivator is used for furrowing, shovels that make small ditches about 3 or 4 inches deep being attached.

Implements covering two rows were used by 35 growers; 12 furrowed five rows at a time, one man did not furrow, and the remainder four rows at a time. The furrower makes one extra ditch each time across, but doubles back in it in cases where two or four rows are furrowed at a time. Those growers who used 2-row furrowers did not have very large acreages of beets, averaging only 6 acres per man. Their acreage being small, it probably would not pay them to buy more expensive machinery. They furrowed on an average 5.77 acres per 10-hour day at a cost of 52 cents per acre, this being 13 cents per acre more than the average cost for the entire area.

In furrowing four rows at a time the average day's work of a man and 2-horse team for a 10-hour day was 10.72 acres, at a cost of 37 cents per acre.

In furrowing five rows at a time the man and 2-horse team averaged 12.71 acres per 10-hour day, at a cost of 31 cents per acre. Although this is the least in cost per acre for furrowing, it is very doubtful whether it is the most economical method. It is necessary that more care be taken to cover all the rows in the same order, as they are planted by a 4-row drill. If the rows are a little wide or close between drill rounds, this method will plow up some beets; and 6 cents per acre is a small saving, as a few beets will more than amount to this sum. A dozen beets plowed out or covered per acre would eliminate any saving, regardless of other losses.

IRRIGATING THE SUGAR-BEET CROP.

Irrigation in the Billings region is by water supplied directly from the river to the farms and not stored in reservoirs, such as are found in many sections elsewhere. The supply is from the Yellowstone River and its tributaries, and much of the water is available in June and early July, as this is the time when the water in the river from the melting snows of the mountains at the headwaters of the Yellowstone River reaches its highest point. Large ditches are constructed to take the water from the river, and these ditches run at an altitude higher than the lands to be irrigated. By a gradual branching into smaller ditches the water is distributed to the beet fields, where it is run in small furrows between the beet rows.

In running the water through the furrows between the rows of beets it is necessary to have only a small head, as it is advisable that the water in the furrow should not overflow and submerge the crown of the beets. The furrows are usually about 3 or 4 inches deep. Different types of soil require different lengths of time for the application of the water in order to give the beets a thorough irrigation. Sandy lands require a quick run in order to be most efficient in the use of the water, while heavy soils which the water does not penetrate quickly require a long run of water. The farmer usually judges that the beets have sufficient water when the land is thoroughly saturated to the depth of an irrigating shovel in the middle of the strip between two water furrows. The length of time the water is run in the furrow depends greatly on the length of the row of beets. Many growers shut off the water as soon as it reaches the lower end of the furrow so as to avoid waste of the water from the ends of the rows.

Irrigating usually begins in the month of July, depending on the season, the amount of rains, and the size of the beets. The first irrigation water was applied to beets by 41 farmers of this group from July 5 to 15, 136 began irrigating from July 16 to July 25, 66 began irrigating from July 26 to August 5, and 5 did not apply the first irrigation until after August 6.

Six farmers applied the last irrigation to beets from August 1 to August 5, 14 finished irrigating from August 6 to 15, 83 finished from August 16 to 25, 75 applied the last irrigation from August 26 to September 5, 65 finished irrigating from September 5 to 15, and 5 irrigated beets as late as September 16.

The average length of time between the first and last irrigation of sugar beets was 37 days, while the extreme dates shown for individual irrigations range from July 5 to September 20, which gives a season of 77 days for irrigating.

Beets should not be irrigated until they are too large to cultivate and the leaves have spread out so that they will cover the ground and shade it (fig. 6), so that the heavy crusts will not form in the furrows where the water has run. The beets are usually ready for irrigation about July 15 to 25. There is a popular belief that early irrigation tends to shorten the root of the beet, but this is not true where the beet is suffering for want of water. If the season is dry the farmer should not wait too long to irrigate. A beet should be kept in the best growing condition possible at all times and should not be allowed to lie dormant or have its growth checked when an application of irrigation water would make it grow rapidly. The

FIG. 6.—A flourishing field of sugar beets. When the beets cover the ground as shown in this picture, cultivation ceases.

season in this region is not long enough to permit part of it to be wasted by allowing the bets to stand still for lack of water. If beets are suffering from want of water and a rain comes, none of the farmers would think of its doing any harm to the bets, yet some were of the opinion that an irrigation would harm the beets.

After irrigation is begun, it is usually necessary to continue to irrigate every 10 to 20 days from the time of the first irrigation until about the first of September. To know how to irrigate, the grower must know his soil well, and he must study the condition of his crop each year. The limit to the supply of available water must also be known, and the water must be so used that it will be properly distributed. The fact remains that the water must be used when it is delivered in the ditch. It may not always seem best for any given farm, but as there are many farms under the ditch each must take the water when it is available.

Irrigation usually proceeds day and night when the water is available, the average man putting in long hours in the operation. Some men turn the water on alfalfa fields at night, but most men set the water on long rows of beets and let it run all night. This sort of work demands that the water be set to running just before dark at night and changed as soon as day breaks in the morning. Many of the men stay in the field 14 or 15 hours a day when irrigating.

As already stated, irrigation is very distinctly an operation that is different for each farm. Some men can irrigate 5 or 10 acres per day and do it better, more efficiently, and easier than they could irrigate 2 acres on another farm. The head of water and the lay of the land cause part of this variation. It pays to irrigate carefully and not hastily. One should prepare his land so that there will be no low places where water will collect and stand.

The average labor cost of irrigation in the area studied is 61 cents per acre per irrigation; this means that the average man can irrigate about 4 acres in 12 hours. Four or five acres per day of about 12 to 15 hours can be covered when the water is running about all the time, day and night. The average man irrigated his beets 2.4 times; 26 men irrigated once, 168 irrigated twice, 89 irrigated three times, and 14 irrigated four times. The available data comparing the crop yields and the number of irrigations failed to show any manifest correlation. In order to form definite conclusions upon this subject, more detailed information as to time and number of water applications would be necessary, and types of soil and other considerations would have to be studied much more closely than was possible for the men gathering the data of this survey. Very little is known by the average farmer as to the quantity of water applied to each field or the quantity wasted, as he has no measuring devices for individual fields. The water is measured out of the main canal, but after that the farmer makes no accurate measurements.

These studies, made in 1915, show that detailed information was gathered from 301 farms upon which 8,745 acres of sugar beets were irrigated, the man labor expended upon each acre being 7.43 hours, at a cost of $1.49.

Four men did not irrigate their beets. These in all cases were beets on seeped or subirrigated lands. About 99 per cent of the total area planted to beets was irrigated. The nonirrigated lands of the region are not adapted to the production of profitable crops of sugar beets.

LIFTING PRACTICE.

Nearly 91 per cent of the growers used 3-horse teams to lift beets, as they all used crotch 1-row lifters. None used 2-row or side-row lifters. Lifting is an arduous operation when the season is such that the fields become very dry; and it would seem that the different types of soil would make corresponding differences in the amount of labor necessary to lift the beets, but in this region it seems that the same number of horses is used in most cases. There is, however, a variation in the acres pulled per day by the crews of different farms.

It is not customary to keep the lifter going the entire day, as a man lifting with three horses can lift during the average 10-hour day 2.29 acres of beets. The average man has not enough horses to haul so many beets per day in addition to the lifting work, so the custom is to lift and pile and top only as many beets per day as can be hauled in a day. If beets lie in the field after being lifted or topped there is considerable loss in weight unless they are exceptionally well covered. Covering them over with leaves when they are in small piles will stop the evaporation to some extent, but the leaves soon wilt and are of little protection. Farmers try to avoid having to cover beets in the field.

On account of the danger of freezing, the farmers are always anxious to get all the beets out of the ground as soon as possible after harvesting begins, and this season is perhaps the busiest of the year. Beet pulling usually begins about the first of October and lasts until November. As a rule, November 5 is considered the latest safe date to have beets still in the ground. The men who get through early are usually hired by those with larger acreages. Very little other work is done after beet harvesting begins until the harvest is finished.

It required 4.41 hours of man labor and 13.09 hours of horse labor to lift the average acre of beets harvested, the average cost of the same being $2.18 per acre.

HAULING BEETS.

The hauling of the beets is one of the hardest operations in the production of the sugar-beet crop. The beets are always hauled when there is a rush to get work done, as there is danger of loss of beets if they are not harvested before the ground freezes. Harvest begins about October 1 and should be completed by November 5 to be safe from loss by freezing. In some seasons it is possible to harvest after this date, but in other years the ground will be frozen so that it is very laborious or impossible to harvest the beets. Allowing for some wet or bad weather, it will be seen that beet harvesting is the rush season of the year.

Although labor at hauling beets is always paid a higher rate than other farm labor in this region, in estimating the cost of hauling the usual rate of 20 cents per hour for man labor and 10 cents per hour for horse labor is used as the basis in this bulletin. For hauling beets men get from $50 to $75 a month and board, according to the need the farmers have for labor.

Beets are hauled in special wagon boxes, which permit the beets to be dumped from the wagon directly into the cars that are to transport them to the factory. (Fig. 7.) The men do not have to shovel the beets when cars are available, but in many cases the number of

FIG. 7.—Loading and hauling sugar beets. Wagons are specially constructed to dump the load directly into a freight car or storage sheds.

beets harvested exceeds the quantity that can be stored at the factory, so the beets are piled at the dumps in large piles on the ground. Sometimes 5,000 tons are put into one pile. These piles are made about 8 feet high and of various widths and lengths. No extra compensation is provided for this piling of beets at the dumps.

Usually one man loads and unloads his beets at the dump, but in some cases the farmer has a man in the field who helps load the wagons, doing other work while the wagon goes to the dump.

These studies, made in 1915, show that detailed information with regard to hauling sugar beets was gathered from 305 farms, from which the product of 8,817 acres of beets was hauled, requiring an average of 10.36 hours of man labor and 29.66 hours of horse labor per acre. The cost of hauling was therefore $5.02 per acre, or 47 cents per ton.

The fact that hauling is done for less per ton with two horses than with other sorts of teams is perhaps not entirely due to the efficiency of this method of hauling, but is more likely to be due to the fact that the men with the uphill haul or harder haul used more horses to a wagon than the men with easier hauls. The cost of hauling varies with the season and the condition of the fields and roads. For 1915 the load hauled averaged 3.18 tons. Two horses hauled on an average 2.82 tons, three horses 2.92 tons, and four horses 3.37 tons, the average cost of hauling being 26 cents per ton per mile hauled, when man labor is figured at 20 cents per hour and horse labor at 10 cents per hour. If better methods of loading and unloading were devised, and especially if improvement could be made in loading beets on the wagons, this cost could be greatly lessened.

The hired hauling on an average cost 28.3 cents more per ton than hauling done by the farmer, where his labor was figured at $2 per day per man and $1 per horse for a 10-hour day, and the average distance for the hired hauling was 1.3 miles less. This gives some indication of the scarcity of labor which usually prevails during the harvest season. The man who has not the horses for hauling beets must hire the necessary men with teams and must have the labor done during a short period of time, so he has to pay for this work at a rate that is higher than is common for other seasons of the year. Usually he does not furnish wagons or any harness, which would mean some expense for wear and breakage. The average cost was $4.81 per acre for hauling the beets where the farmer did the work, counting labor only, and $7.85 for hired hauling, a difference of $3.04. In computing the cost of hauling 1 ton of beets 1 mile it was found that for farmers doing their own work in the first group, those averaging 0.76 of a mile, the average cost was 49 cents per ton-mile. For the second group, those averaging a 1.67-mile haul, the cost was 28 cents per ton-mile; in the third group, those averaging a 2.91-mile haul, the cost was 19 cents per ton-mile; in the fourth group, those averaging a 3.96-mile haul, the cost was 17 cents per ton-mile. The hired hauling cost 69 cents per ton-mile on an average haul of 0.88 mile, 51 cents per ton-mile for an average haul of 1.46 miles, and 36 cents per ton-mile for an average haul of 2.83 miles. The difference of 21 cents between groups 1 and 2 and 9 cents between groups 2 and 3 for farmers doing their own hauling might be taken as an indication that the average cost of loading beets was about 12 cents per ton; but this is not an accurate method of figuring, as the actual time taken to load the beets was not recorded. Table VIII, showing the cost of hauling according to distance, indicates that it costs the farmers in the group farthest from the dump an average of $3.11 more per acre to deliver their beets than those in the group closest to the dump.

In other words, the additional cost is about $1 per acre for each mile of distance from the dump. In the case of hired hauling this additional difference is more nearly $2 per acre for each mile from the dump.

TABLE VIII.—*Cost of hauling sugar beets in the Billings region of Montana in 1915.*

Classification.	Number of farms.	Beets hauled.	Average cost of hauling.	
			Per ton.	Per acre.
Hauled by grower:		*Tons.*		
Less than 1½ miles (average 0.76 mile)	112	39,220	$0.37	$3.98
1½ to 2½ miles (average 1.67 miles)	100	29,544	.463	4.98
2½ to 3½ miles (average 2.91 miles)	65	18,337	.544	5.85
3½ miles and farther (average 3.96 miles)	12	3,788	.659	7.09
All farms [1] (average 2.86 miles)	289	90,899	.447	4.81
According to the size of the crew:				
1 man, 2 horses	120	34,897	.402	....
1 man, 3 horses	30	8,521	.498	....
1 man, 4 horses	118	37,859	.46	....
3 men, 8 horses	11	5,021	.52	....
Mixed	10	4,591	.52	....
Total [1]	289	90,889	.447	....
Hired hauling:				
Less than 1½ miles (average 0.88 mile)	4	847	.61	6.56
1½ to 2$\frac{7}{16}$ miles (average 1.46 miles)	12	3,888	.75	8.07
2½ to 3$\frac{7}{16}$ miles (average 2.83 miles)	3	137	1.00	10.76
All hired (average 1.55 miles)	19	4,872	.73	7.85

[1] Excluding 19 farms from which the hauling was done under contract, as shown in the last part of the table under "Hired hauling."

HAND OR CONTRACT LABOR.

The labor on the sugar-beet crop that is done by hand without the use of machinery consists of blocking, thinning, two hoeings, and pulling, piling, and topping the beets. About three-fourths of this labor in the Billings region is done by contract. The labor contractors make an agreement with the farmer to do all the handwork on the crops, receiving therefor a definite sum under a system which makes it to the interest of the contractor to cover as large an acreage as possible per day. Some growers try to counteract the tendency toward careless work by paying a bonus to the workers if the beets yield more than a certain tonnage per acre. This bonus system is not in general use, not having reached any definite or satisfactory basis, but it has features which recommend it. The basis now varies according to the different ideas as to what it should be.

In cases where there is any disagreement, the factory agricultural force supervises and looks after the fulfillment of the contracts between the farmers and the laborers. Most of the contract laborers in this region are Russians or Belgians.

A great deal of this work is done by the children of the families of the men doing the hand labor. Women also are employed in the fields at this work. The work of thinning, which requires the worker to stoop or crawl along the beet row, is performed by boys or girls about 15 years of age, in many cases more efficiently than by men. In figuring the costs for this labor, children who are able to do full work have been allowed the same rate per hour for labor as men. All the labor is estimated on the basis of what a man can do per day. There is no indication that men who do their own beet thinning get better crops than those who have the thinning done under contract.

Of the 305 farms in the entire study, on 227 farms a whole or part of the hand labor was contracted for at a definite rate per acre for the work. The area worked in this manner was 6,399 acres, at a cost to the farmer of $18.53 per acre for all hand labor, which includes thinning, hoeing, topping, etc. On 91 acres the contract was for blocking and thinning only, at an average price of $6.89 per acre. On 123½ acres the contract was for piling and topping only, at an average cost of $9.14 per acre. There were no farms where hoeing was contracted for as a separate operation. (Table IX.)

TABLE IX.—*Average requirements and cost per acre of hand labor on the sugar-beet crop in the Billings region in 1915.*

[Hand labor is figured at 20 cents per hour.]

Kind of work.	Labor done by grower.		Labor contracted.		Average for each acre planted.	
	Hours.	Cost.	Hours.	Cost.	Hours.	Cost.
Blocking and thinning	36.9	$7.38	30.9	$6.18	32.25	$6.45
First hoeing	15.5	3.09	10.3	2.06	11.5	2.30
Second hoeing	7.9	1.59	5.15	1.03	5.8	1.16
Pulling and topping	36.5	7.30	46.30	9.26	43.65	8.73
Total	96.8	19.36	96.65	19.53	93.2	18.64

The general impression in the Billings region is that the contract laborers get a good price for the work of thinning, topping, etc., but the good daily wage is due largely to the fact that they work rapidly so as to complete the thinning before the beets are very large, and that they work very long days. The thinner averages from 12 to 14 hours per day; this is especially true of the contract laborers. Some of these workers become very expert, being able to block and thin an acre of beets in two days; some even exceed this rate.

Growers who do their own hand labor are in most cases men who have large families and who have had experience as contract beet workers. They are usually of foreign birth. It is very common for a man to come into the region and work a few years as a contract laborer and then rent or buy a farm and begin to work for himself. These men who are successful in saving enough money to begin farming for themselves are usually the most industrious of the contract laborers. Having had experience in handling the crop, they usually grow rather large acreages of beets.

COST OF SEED FOR SUGAR BEETS.

The seed for the sugar-beet crop is furnished to the farmer by the sugar company contracting for the beets. This seed has been sold to the farmers at 10 cents per pound for a number of years, and the quantity of seed per acre is often specified. Most farmers plant the amount per acre that the company specifies; therefore the cost per acre for seed runs very nearly the same for each farm. The cost of seed per ton of beets produced is very variable, as there is variation in the tonnage per acre. For individual farms the cost of seed per ton of beets produced varied from 10 cents to more than 60 cents. Detailed information gathered from 305 farms growing 8,849 acres of beets is as follows: Pounds of seed per acre, 17.2; cost of seed per pound, 10 cents; cost of seed per acre, $1.72; cost of seed per ton of beets produced, 16 cents.

COST OF MACHINERY.

The cost of machinery varies greatly in accordance with the amount of machinery the man owns and the area of beets that he cultivates. Some growers had high-priced machinery and a small area in beets, so the cost of machinery per acre ran very high; in some instances it was more than $15 per acre. To grow a crop of beets, a farmer should own the machinery or be able to rent certain machines when needed. To own all machinery is not always advisable where the area in beets is less than 10 acres.

The depreciation of machinery on various farms varied from 10 to 25 per cent of the original value, depending on the acreage of beets to be tended by one machine and the type of machinery owned. The grower should either own or have the use of the following machinery: Plow, harrow, level, beet drill, beet cultivator, beet wagon (with box of a special type for the automatic dumping of the beets), beet puller, hoes, shovels, topping knives, and beet forks. In some cases a roller and a manure spreader should be added to this equipment.

It is rather hard to get an exact figure for the cost of machinery for beets, as farmers use the same wagons, harrows, plows, etc., on other crops, and allowance for this has to be made; but it is possible to get a reasonably accurate estimate of the depreciation and repair cost of machinery that is chargeable to beets by comparing the acreage in other crops. These charges were figured separately for each farm, and Table X shows the results of the data furnished by 305 farmers as to the costs chargeable to the sugar-beet crop for the use of machinery.

Table X is necessarily more or less of an approximation, and there may be some items of cost not enumerated; however, the costs were obtained in a manner which should include the correct total cost of machinery for beets during the season of 1915.

TABLE X.—*Cost of machinery for growing sugar beets in the Billings region in 1915.*

Items of cost.	Total.	Per farm.	Per acre.	Per ton of beets.	Percentage charge.
Repairs	$5,671	$18.59	$0.64	$0.06	24.2
Depreciation	10,393	34.08	1.17	.11	44.3
Interest on investment at 8 per cent	6,678	21.89	.76	.07	28.8
Hired machinery	637	2.09	.07	.01	2.7
Total cost	23,379	76.65	2.64	.25	100.0

PRORATING INTEREST ON THE INVESTMENT.

Detailed information covering the cash investment in 305 farms on which 8,849 acres of sugar beets were grown showed an average of $3,656 per farm, and the prorated interest cost chargeable to the beet crop was $11.99, being an average of 41 cents per acre planted to beets and 4 cents for each ton of beets produced.

The average man pays about 41 cents per acre for interest on money invested in the beet crop. This is only for money spent for labor and miscellaneous items of cost, the greater part being for money paid to contract laborers or hired labor. Contract laborers receive about half of their contract price at a time soon after the blocking and thinning is done. For this region this averages about $9 per acre, and in most instances it is paid some time in June or July, although in some cases it is advanced to the laborer earlier in the season. No money is received from the beet crop until October or November, so the interest on money paid for hand labor runs for four to six months.

Interest on contract-labor money for four to six months at 8 per cent for $9 is 24 cents to 36 cents per acre, depending on the time the contractor receives the money. Interest on money paid to the farm laborers for one to eight months, depending on the number of laborers hired, varies on different farms from nothing to 60 cents per acre of beets grown.

COST OF LAND FOR SUGAR BEETS.

The owner's cost for land is divided between interest, irrigation water, and other items that are furnished by landlords on rented farms. These items aggregate $11.99 per acre, divided as follows: Interest on real estate, $9.86; land taxes, $1.15; cost of water for irrigation, 86 cents; miscellaneous charges, 12 cents. (Table XI.)

TABLE XI.—*Apportionment of interest, taxes, and charges for irrigation water for growing sugar beets on rented lands and owned farms in the Billings region.*

Classification of farms.	Number of farms.	Acres of beets.	Cost for land.		
			Total.	Per acre.	Per ton.
All farms	305	8,849	$104,931	$11.85	$1.10
Beet lands:					
Cash-rented		1,620	15,226	9.25	.85
Share-rented		3,801	49,071	12.91	1.28
Owned		3,428	41,098	11.99	1.04

The charges pertaining to owned lands are figured on the estimated value of the land planted to beets, with interest at the rate of 8 per cent. Lands under cash rentals are figured on a similar basis as to the value of the land in beets and the value of other lands on the farm, so as to charge the proper amount for beet lands. Lands under share rentals are figured on the basis of the value of the share of beets and beet tops that the landlord receives. This may be a little high when considered from the basis of the landlord's expectation that the beet-land rental will bring up the average rental of the farm which has a considerable acreage in grains and hay, on which a less rental per acre is paid to the landlord. The usual share of the beets paid for rental is one-fifth of the crop, and in many cases the landlord requires that a certain acreage of land be planted to beets. The tops are divided in various ways, there being no prevailing method as to the division.

Share renters on a few farms gave the landlord as much as one-half of the crop for rental; but in all of these cases the extra rental was for some special expense borne by the landlord, such as furnishing seed, part of the contract labor, a supply of manure, or the equipment and work stock. Under such conditions allowances were made for these extra items furnished, and this amount is properly deducted from the landlord's total charge, as the tenant in such cases is giving part of the crop for something else than the land on which to grow it, and the landlord is paying other expenses than those properly called land charges. These special rentals are not common, and in most cases the landlord, being responsible for the success of the crop, usually demands a good return for his investment. The tenants on such farms are often men who have very little capital, and they would be unable to handle farms of any size unless provided with some outside capital.

Cash rentals are much lower than the share rentals, owing to the small risk taken by the landlord, who is certain of a definite income from the farm; but the landlord who rents land for a share of the crop does not get much if the farm is badly handled or if the crops are poor from any cause. Most of the cash-rented farms are owned by absentee landlords, while many of the share-rented farms are owned by farmers who live in the region and can supervise their farms to some extent.

The average value of the owned beet lands is $123.60 per acre, and with interest at 8 per cent this item is by far the heaviest in the list of costs of land for beets. The valuation given for share-rented lands was $126.91 per acre and for lands that were rented for cash the value was given as $134.19. These values are based upon the sale value as estimated by the man operating the farm. The average value of all sugar-beet land studied in the Billings region was $126.95. Assuming that the cost of water for irrigation and the cost of taxes and miscellaneous items are the same for landlords as was found for owners of beet lands (a total of $2.13 for these items), the landlords of the region have an average of $7.36 per acre for interest on cash-rented lands and $11.98 for interest on share-rented lands. This amounts to interest at 5.5 per cent on the value as given per acre for cash-rented lands and interest at 9.4 per cent on the value of share-rented lands.

RELATION OF YIELDS TO COST AND PROFIT.

Seemingly there is the most profit in a crop of beets of about 14 tons or over per acre in the Billings region. The average profit per acre, as shown by this study, is the same for yields of more than 14 tons, but this should not be taken to indicate that to increase the yields on this land so as to produce more than 14 tons is to incur an expense that may not return a profit over and above the cost of the extra labor. High yields per acre seem to be associated with higher profits per acre. Most growers getting large yields are men who use much manure on their beet lands, and it is not correct to state that they do not get a profit on increasing the yields, as they find employment during a time they might otherwise be idle and have idle teams. In figuring the cost, allowance has been made for the yard value of the manure and regular prices paid for labor. The labor which is done in the winter and early spring is profitable, as no profit would otherwise be shown. Horse labor especially will show a profit, as the teams would cost about the same for keeping whether they were worked or not, and usually the work is not hard. To disregard these facts and figure on the actual cost might warrant the conclusion that increased yields are not profitable. It would be difficult to give any definite yield as the limit of profitable attainment, but it is reasonable to assume that it is higher than any of the yields produced, and perhaps many tons higher. The growers who showed a loss on beets yielding over 12 tons per acre were only three in number and grew only small areas, averaging less than 6 acres each. Each had used heavy applications of manure and had given it a value of $1 per ton in the yard; the investment in machinery was also high in each case. The average cost for their machinery was nearly $12 per acre, while the average for the region was $2.64 per acre. Unless land is capable of yielding better than an 8-ton crop of beets it is advisable not to plant beets on it, but to plant some crop that will not require so much labor for production. Cheap and poor lands are not adapted to beets or any crop that requires much labor per acre. The only case where a man can afford to grow beets on land that does not produce well is where he owns the land and is trying to eradicate weeds by careful cultivation. He must have some return other than that received from the beet crop. If the grower is willing to work for less than the price figured in this bulletin as the cost of growing beets or is an exceptional manager of labor he can make a return from a beet crop that is less than 8 tons an acre, but it is an uncertain speculation. It is admitted, however, that there are many exceptions and that some men can show a profit from a small yield, as they are growing the beets at a time when they would otherwise be unemployed. Beets afford a means whereby the farmers of this region are able almost to double the length of the season that they have field work to do, for there is no other common row-tilled crop, and hay and grain farming does not afford labor early in the summer at beet-cultivation time or late in the autumn when beets are to be harvested. A farmer's profits often depend on the length of the season of crop labor. There is no doubt that on a larger area the cost per acre for machinery would average less, as the investment total would need to be no larger. If these men were able to pay for labor and get a return for the manure used, there is no doubt that their loss is only a figurative one. If they had allowed only 50 cents per ton for the yard value of manure they would have shown a profit on their beets, as the average loss per acre was very small.

A few growers made a small profit per acre on beets that yielded about 8 tons per acre, and one that had a yield of 7 tons made a small profit. None of these men had any charge for manuring, and most of them were share renters. All reported rather rapid work and did not go over the ground a very great number of times. More than half of them did their own hand labor and reported doing it at a rapid rate, and the charge for hand labor in some of these cases was not over $12.50 per acre. These men show that in rare instances where the land is not hard to handle and the man works very rapidly it is possible to show a profit on beets that yield 8 tons per acre, but this is not possible in most cases and not possible on small areas where the fields are small and there is much turning to do. Few of these men had small areas, their average acreage being above 30.

The average yield per acre on the 305 farms covered by this study was 10.76 tons, and the information gathered indicates that a yield of 8.87 tons per acre is required in order to pay expenses. There was a loss on 2,019 acres (22.8 per cent of the total acreage) and a profit on 6,830 acres (77.2 per cent of the total acreage). (Table XII.)

TABLE XII.—*The cost and profit from sugar beets as related to yields per acre and to acreage per farm in the Billings region in 1915.*

Classification.	Percentage of total acreage.	Per acre. Cost.	Per acre. Profit.	Per ton. Cost.	Per ton. Profit.	Percentage of acreage showing a profit.
Yields per acre:						
4 tons and less	1.71	$13.13	−$19.66	$12.59	−$5.74	None.
4.1 to 5 tons	3.14	45.18	− 12.66	9.20	− 2.56	Do.
5.1 to 6 tons	3.76	46.91	− 7.20	7.87	− 1.21	Do.
6.1 to 7 tons	3.54	51.36	− 5.90	7.46	− .86	1
7.1 to 8 tons	8.53	51.52	− .56	6.50	− .07	57.7
8.1 to 9 tons	8.59	55.85	1.45	6.26	.16	66.1
9.1 to 10 tons	13.39	55.87	6.58	5.64	.66	77.3
10.1 to 11 tons	11.90	56.07	12.84	5.14	1.18	96.8
11.1 to 12 tons	17.30	59.93	16.34	5.00	1.36	99
12.1 to 13 tons	11.63	58.61	23.48	4.58	1.83	100
13.1 to 14 tons	6.35	60.47	28.15	4.32	2.02	97.7
14.1 to 15 tons	7.13	65.40	28.55	4.36	1.91	100
15.1 to 16 tons	2.40	64.64	33.95	4.06	2.13	100
16.1 tons or more	.63	77.10	30.91	4.55	1.83	92.6
Total	100	56.79	11.70	5.28	1.08	77.2

Classification.	Average area.	Number of farms.	Per acre. Yield.	Per acre. Value.	Per acre. Cost.	Per acre. Profit.
Area in beets per farm:	*Acres.*		*Tons.*			
5 acres or less	4.6	10	11.7	$74.80	$74.46	$0.34
6 to 10 acres	8.7	37	10.3	66.83	60.95	5.78
11 to 15 acres	13.2	26	10.8	69.08	62.21	6.87
16 to 20 acres	18.1	41	10.4	66.17	58.12	8.05
21 to 30 acres	26.0	79	10.7	68.82	55.63	13.19
31 to 40 acres	36.6	59	10.8	68.76	56.48	12.28
41 to 50 acres	46.2	27	11.0	70.10	56.18	13.92
51 to 60 acres	55.5	11	10.8	67.33	53.94	13.39
Over 60 acres	88.6	15	10.5	67.19	55.82	11.37
Total	29.1	305	10.76	68.49	56.79	11.70

Table XII indicates that the acreage of beets per farm had little to do with the yield per acre but had much influence as to the profits per acre within certain limits. It appears that each farmer should plant at least 20 acres of beets in order to have them grown most economically. Above 20 acres there seems to be but slight variation in the cost of production or profits per acre.

SUMMARY.

(1) The data gathered from 305 farms in the Billings region of Montana give the total hours of labor required to produce beets and the other costs of production for the season of 1915. (Table XIII.)

TABLE XIII.—*Summary of labor requirements for the production of sugar beets.*[1]

[Man labor is rated at 20 cents per hour and horse labor at 10 cents per hour.]

Kind of labor.	Average per acre worked.			Average per acre of all sugar beets studied.		
	Cost.	Man.	Horse.	Cost.	Man.	Horse.
Farm labor:		*Hours.*	*Hours.*		*Hours.*	*Hours.*
Manuring	$3.31	8.90	15.30	$1.21	3.27	5.59
Plowing	2.54	4.59	16.18	} 2.90	5.23	18.55
Crowning alfalfa	2.48	4.35	16.14			
Disking	1.09	1.84	7.19	.23	.39	1.52
Rolling land	.29	.71	1.49	.08	.20	.41
Floating	.89	1.31	5.96	.87	1.47	5.80
Harrowing	.93	1.75	5.75	.93	1.75	5.75
Cleaning ditches	.13	.32	.61	.12	.32	.60
Planting seed	.40	1.00	2.00	.40	1.00	2.00
Rolling	.31	.77	1.55	.17	.43	.86
Cultivating	1.74	4.46	8.46	1.74	4.46	8.46
Furrowing	.39	1.00	1.89	.39	1.00	1.89
Irrigating	1.49	7.43	....	1.47	7.34	....
Lifting	2.18	4.41	13.09	2.18	4.41	13.09
Hauling	5.12	10.36	29.66	5.02	10.36	29.66
Total	23.19	53.40	125.27	17.71	41.76	94.18
Hand labor:						
Blocking and thinning	....	....	....	6.45	32.25	....
Second hoeing	....	....	....	2.30	11.50	....
Third hoeing	....	....	....	1.16	5.80	....
Pulling and topping	....	....	....	8.73	43.65	....
Total	....	....	....	18.64	93.20	....

[1] In the columns headed "Average per acre worked" are given the average cost and labor expended on each acre for each operation, computed on the number of acres covered by each operation. In the columns under "Average per acre of all sugar beets studied" the total surveyed acreage (8,849) is the basis of computation.

The aggregate of overhead charges for the entire area was $20.44 per acre, divided as follows: Land charges, $11.85; manure, $3.79; machinery, $2.64; seed, $1.72; cash to run farm, 41 cents; miscellaneous, 3 cents.

The total cost of sugar-beet production as herein shown is $56.79 per acre, divided as follows: Farm labor, $17.71; hand labor, $18.64; overhead costs, $20.44.

The grower can apply these data to the present requirements by adjusting them to the present prices of labor, real estate, equipment, and the value of beets produced. There have been no changes of note in the labor requirements of production.

(2) The information obtained indicates that the growing of sugar beets can not be profitable in this region unless a yield of more than 8 tons of beets per acre is produced. It is also shown that each farmer should grow at least 20 acres for most economical production.

(3) Of the total area in sugar beets, 77.2 per cent of the acreage was grown at a profit.

(4) The average acre of the region devoted to sugar beets returned a profit of $11.70 after paying the cost of production.

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"IN THE FIELD OF AGRICULTURE we have agencies and instrumentalities, fortunately, such as no other government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed. The department has $2,500,000 available for this purpose now and has asked the Congress for $6,000,000 more."—*From President Wilson's Message to Farmers in Conference at Urbana, Ill., January 31, 1918.*

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 736

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ November 15, 1918

THE OPEN SHED COMPARED WITH THE CLOSED BARN FOR DAIRY COWS.

By T. E. Woodward, W. F. Turner, W. R. Hale, and J. B. McNulty, *of the Dairy Division.*

CONTENTS.

PRESENT DAIRY PRACTICE REGARDING OPEN AND CLOSED BARNS.

In order that milk and butterfat may be produced economically, it is necessary to provide shelter of some kind for dairy cattle during the cold, stormy seasons of the year. While the length of the stabling period varies in different sections of the United States, most dairy cows are now housed for at least five months, from November to March, inclusive.

An open-shed barn is usually partly or entirely closed on three sides, leaving one side, usually the south or east, open. The shed is large enough to allow each animal sufficient room for comfort and exercise, the space allowed varying from 35 to 150 square feet for each cow. The animals are allowed the freedom of the shed except at milking time. Usually there is a separate room into which the cows are driven for milking. This room may accommodate all or only a part of them. In the latter case they are milked in groups. In the milking room the cows are groomed, milked, and fed grain, after which they are driven out and another group takes their place. Roughage is fed in racks and troughs provided for that purpose in the open shed.

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The closed barn consists of a barn entirely inclosed with stall room enough to accommodate the entire herd. The animals are kept in the barn during most of the late fall and winter, and in some dairies the entire year.

It is almost the universal practice of dairymen to keep their cows in a closed barn of some type, although in recent years some have used the open shed. Advocates of the latter have maintained that the manure is handled more easily and is better preserved and that the cows yield more milk and butterfat and are healthier, cleaner and more comfortable than when confined in a closed barn. Dairymen who have had experience in stabling cows both in closed barns and in open sheds disagree as to the merits of the two. In order to obtain definite and reliable information on the problem the experimental work hereinafter described was carried on at the Dairy Division Experiment Farm, Beltsville, Md., near Washington, D. C. The results should be applicable to other parts of the country in a similar latitude.

REVIEW OF PREVIOUS WORK.

Fraser[1] of the University of Illinois Agricultural Experiment Station, investigated the open-shed system of housing dairy cattle by sending out a list of 21 questions to dairymen in Illinois who used the open shed. The answers of the 18 dairymen who replied indicated that the milking barn was kept cleaner when the open shed was used, and that the cows and the milk were cleaner. In almost every case more bedding was required, and the cows showed no tendency to injure one another. In the latter connection it must be remembered that in the opinion of the Illinois dairymen mentioned above dehorning was believed to be necessary to the success of the open shed. All who replied to Prof. Fraser's inquiry had either dehorned or polled cattle. In answer to the question "What do you consider the chief advantage of keeping cows in this way over ordinary stabling?" no one fact was so generally emphasized as the labor-saving feature of the open shed.

In an investigation at the Maryland Agricultural Experiment Station conducted by Buckley and Lamson[2] the open stable was compared with the closed stable. The following is a brief summary of the conclusions drawn from the experiment:

> The cost of construction for the open shed is smaller than for the closed barn. The cost of labor and the cost of milk, based on quality of feed consumed, is slightly less in the open shed than in the closed barn. In the open shed, manure is better preserved and cows are kept cleaner. The supply of fresh air and light is also better.

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[1] Fraser, W. J. "Should Dairy Cows be Confined to Stalls?" Illinois Circular 93, 1904.

[2] Buckley, S. S., and Lamson, R. W. Open Shed Versus Closed Stable for Dairy Cows. Maryland Agricultural Experiment Station, Bulletin 177.

The effects of extremely low temperatures are practically negative in reducing the flow of milk. No bad results were experienced from cows horning or butting one another when allowed the freedom of the open shed.

Davis,[1] at the Pennsylvania Agricultural Experiment Station, conducted an experiment in which the effect of open-shed housing for dairy cows was compared with the closed stable. He concludes as follows:

It appears that the cows kept under the open shed have keener appetites and consume more roughage than those kept in stables. Sufficient protein was consumed under both systems to meet the requirements of milk and maintenance. The milk yield of the outside group decreased more rapidly each winter than that of the inside group. Sudden drops in atmospheric temperature caused decreases in milk yield for both groups, the outside group having slightly greater decrease. More bedding was required outside, but less labor was necessary to keep the cows clean. Both groups finished each winter trial in good health.

THE EXPERIMENTAL WORK.

The following details of three years' experiments carried on at the Dairy Division Experiment Farm at Beltsville, Md., show the conditions under which the work was done.

DESCRIPTION OF THE OPEN SHED.

The shed used was of frame construction, 58 feet in length and 35 feet in width, inside measurements. On the north end a space of 18 feet was partitioned off and inclosed for a milking room with stalls for 8 cows. It had a concrete platform, gutter, and alleyway. The cows were allowed the freedom of the shed except at milking time. The north end of the shed and the east and west sides up to within 18 inches of the plate were kept closed, while the south end, except for a fence to keep the cows inside when desired, was entirely open. On the south was a small dry paddock where the cows were permitted to exercise. The space available for the cows within the open shed, excluding the space of the feeding troughs, was a little more than 1,200 square feet, which allowed each of the 16 cows housed in the shed approximately 75 square feet of floor space. Two doors opened into the milking room from the shed, one through which the cows were driven in to be milked and the other through which they were driven out after milking.

This was the type of shed used during the first year of the experiment. For the last two years a new shed, entirely open on the south side, replaced the old one. The north side and both ends had large doors which swung from the top. In summer the doors were raised to permit a better circulation of air, but in the winter months,

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[1] Davis, H. P. The Effect of Open-Shed Housing as Compared with Closed Stable for Milch Cows." Separate No. 14 (pp. 183–226), Annual Report, 1913–14, Pennsylvania State College. 1916.

while the experiment was in progress, the doors were lowered. For the purpose of the experiment there was no difference in the two structures. The new shed was built only a short distance from the main milking barn, so it was convenient to drive the cows from the open shed into the main barn to be milked; consequently both groups of cows were milked in the same structure during the last two years of the experiment.

THE CLOSED BARN.

The closed barn was of concrete construction, 36 feet by 59½ feet, with stall room for 26 cows, and was equipped with concrete floors, mangers, and gutters. The cows faced the outside walls, and the alleyway behind them was 8 feet wide. The feed alleys in front of the cows were 4 feet wide, and there was a 5-foot alleyway at each end of the barn. The 17 windows, 7 on each side, 1 on the north end, and 2 on the south end, provided 176 square feet of lighting space. A modification of the King system of ventilation was used.

The concrete floors on one side of the barn were covered with various kinds of insulators, such as cork brick, creosoted blocks, and planks. One-half of the cows used in the experiment stood on the floors and the other half on the concrete.

THE COWS.

The herd throughout the entire investigation consisted of 1 pure-bred Guernsey, 2 pure-bred Holsteins, 10 grade Jerseys, and 8 cows of miscellaneous breeding. The records of all the animals stabled under the two systems could not be used, on account of the irregularity of calving, etc.

PRODUCTION RECORDS.

The herd was divided into two groups. During the first year one group was kept in the open shed and the other in the closed barn. The second year the groups were reversed. The third year the groups were again reversed, which gave three years' records for comparison. Owing to the irregularity in calving, all the cows have not three years' records which are comparable. Four cows had two years' records in the open shed, an average of which was taken and compared with their one year in the closed barn. Seven cows had two years' records in the closed barn, an average of which was compared with their one year's record in the open shed.

Since the results of the housing are determined quite largely, if not entirely, upon the stabling period—November to March, inclusive—only the records obtained for the five months were studied. These records do not in any case cover the entire period of five months, owing to the irregularity of some of the cows in calving, though all records come within the five months mentioned. Only comparable records have been included. By way of illustration: Cow 201 calved October 26, 1914, while in the open shed. In 1915 she calved September 26, while in the closed barn. Therefore, in order that there should be no difference in the records due to time of freshening, records for December, 1914, and January, February, and March, 1915, in the open shed, were compared with the records for November and December, 1915, and January and February, 1916, in the closed barn. In a similar way other production records covering the same length of time in the two barns and taken the same time after calving have been compared.

The weight of each milking was recorded, and composite samples for two days were taken in the middle of the month and tested for butterfat. The butterfat test of the composite samples taken during the two days was used to calculate the total butterfat production for the month.

FEED RECORDS.

The grain mixture used throughout the experiment was the same for both groups of cows, and usually consisted of 2 parts corn meal, 2 parts wheat bran, and 1 part cottonseed meal. In some instances the mixture was varied slightly in the case of individual cows. The roughage consisted of silage and of such hay as was available on the farm—cowpea, crimson clover, and red clover.

All grain fed was accurately weighed out for each animal, and records were kept during the periods covered by the production record. The hay, silage, and other roughage fed to the cows in the open shed the first year were weighed out in quantities sufficient for the entire lot, and it was assumed that equal quantities were consumed by the various individuals. During the last two years of the experiment the roughage was weighed out to each animal. The quantity of grain fed was determined largely by the production of the individual cow, but consideration was given also to her physical condition. It was desired to keep all cows in good condition and to maintain each individual at a uniform weight. They were fed all the silage and hay they would consume without waste.

The cows in the open shed were bedded often enough to keep the inclosure clean, which was almost every day. In the closed barn the cows were bedded daily, and bedding enough was used to make them comfortable and to absorb the liquid manure. For the five months of the year during which data were taken wheat straw was used with both groups.

DISCUSSION OF RESULTS.

The milk and butterfat production records made under both the open-shed and closed-barn conditions are shown in Table 1

TABLE 1.—*Milk and butterfat records.*

Cow No.	Open shed.				Closed barn.			
	Date calved.	Milking period.	Milk.	Butter-fat.	Date calved.	Milking period.	Milk.	Butter-fat.
			Pounds.	*Pounds.*			*Pounds.*	*Pounds.*
1	Aug. 4, 1913 July 8, 1915	January, February, March, 1914 January, February, March, 1916	808.4	34.23	Aug. 19, 1914	January, February, March, 1915	745.5	34.12
2	Aug. 9, 1913	January, February, March, 1914	2,187.0	104.89	July 8, 1914	December, 1914, January, February, 1915	1,855.7	98.07
4	Dec. 6, 1913	....do	2,239.3	99.39	Dec. 1, 1914	January, February, March, 1915	1,994.2	89.33
7	Oct. 28, 1913	....do	2,368.8	93.99	Oct. 2, 1914	....do	2,029.5	86.67
8	Jan. 10, 1914	February, March, 1914	1,551.5	65.16	Dec. 2, 1914	January, February, 1915	1,386.6	59.62
9	Nov. 2, 1913	January, February, March, 1914	2,026.1	87.88	Nov. 25, 1914	January, February, March, 1915	1,568.5	66.49
12	Sept. 18, 1913	February, March, 1914	650.1	26.67	Aug. 25, 1914	January, February, 1915	999.4	42.88
14	Nov. 7, 1913 Sept. 16, 1915	January, February, 1914 November, December, 1915	1,121.0	51.37	Oct. 21, 1914	....do	1,338.3	67.72
17	Sept. 3, 1914	January, February, March, 1915	1,668.3	85.57	Aug. 21, 1913 Aug. 28, 1915	January, February, March, 1914 January, February, March, 1916	1,444.2	78.42
18	Sept. 6, 1913 Aug. 5, 1915	January, February, March, 1914 December, 1915, January, February, 1916	1,341.5	72.89	Sept. 18, 1914	January, February, March, 1915	1,369.2	76.44
19	Sept. 29, 1913	February, March, 1914	1,185.7	63.42	Sept. 3, 1914	January, February, 1915	1,004.3	51.60
20	Oct. 24, 1913 Oct. 17, 1915	January, February, March, 1914 January, February, March, 1916	1,135.4	49.47	Oct. 1, 1914	January, February, March, 1915	1,504.0	66.46
21	Sept. 18, 1914	December, 1914, January, February, 1915	2,717.2	141.60	Oct. 5, 1913 Aug. 7, 1915	January, February, March, 1914 November, December, 1915, January, 1916	1,596.0	90.81
22	Sept. 19, 1913	January, February, March, 1914	969.6	49.07	Oct. 4, 1914	January, February, March, 1915	1,368.8	69.92
23	Sept. 16, 1914	December, 1914, January, February, 1915	1,884.3	78.63	Oct. 5, 1913 Aug. 7, 1915	January, February, March, 1914 November, December, 1915, January, 1916	1,722.4	73.22
24	Oct. 14, 1914	February, March, 1915	1,469.7	64.68	Aug. 30, 1913	January, February, 1914	1,394.5	58.02
26	Sept. 12, 1914	January, February, 1915	878.3	53.71	Sept. 17, 1913 Oct. 27, 1915	....do February, March, 1916	649.2	40.79
27	Oct. 22, 1914	February, March, 1915	1,417.2	58.91	Sept. 13, 1913 Oct. 13, 1915	January, February, 1914 February, March, 1916	1,204.6	50.53
100	Nov. 7, 1914	January, February, March, 1915	974.8	40.79	Oct. 21, 1913 Oct. 6, 1915	January, February, March, 1914 December, 1915, January, February, 1916	1,417.9	67.47
201	Oct. 26, 1914	December, 1914, January, February, March, 1915	3,797.0	132.57	Sept. 26, 1915	November, December, 1915, January, February, 1916.	3,697.9	116.09
202	Sept. 26, 1914	January, February, March, 1915	2,239.7	80.25	Oct. 7, 1913 Sept. 1, 1915	January, February, March, 1914 December, 1915, January, February, 1916	1,607.1	52.74
	Total production.		34,630.9	1,535.15			31,898.7	1,437.41

NOTE.—Where 2 years are combined, the average of the 2 years' production is given.

TABLE 2.—*Feed consumed.*

OPEN SHED.

Cow No.	Corn meal.	Wheat bran.	Cotton-seed meal.	Red-clover hay.	Crimson-clover hay.	Cow-pea hay.	Corn silage.	Miscellaneous.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
1	196	158	79	72	....	405	2,970	Corn stover, 155.
2	443	296	148	144	....	445	3,210	
4	462	308	153	144	....	445	3,210	
7	460	306	153	144	....	445	3,210	
8	299	200	99	144	....	208	2,032	
9	446	297	148	144	....	445	3,210	
12	181	121	60	144	....	208	2,032	
14	206	166	82	....	....	363	2,114	Corn stover, 81.
17	276	276	138	134	295	....	3,150	
18	342	265	132	72	....	423	3,198	Corn stover, 115.
19	295	196	99	144	....	208	1,770	
20	263	263	132	72	....	405	2,948	Corn stover, 155.
21	487	361	148	112	225	75	3,090	Fish meal, 63.
22	448	300	149	144	....	445	3,210	
23	392	280	112	112	225	75	3,045	Fish meal, 56.
24	378	126	126	236	....	....	1,870	
26	188	188	94	....	267	....	1,910	
27	354	118	118	236	....	....	1,870	
100	276	276	138	134	295	....	2,995	
201	654	654	326	144	424	96	6,050	
202	432	432	215	144	354	....	4,325	
Total	7,478	5,587	2,849	2,620	2,085	4,691	61,419	

CLOSED BARN.

Cow No.	Corn meal.	Wheat bran.	Cotton-seed meal.	Red-clover hay.	Crimson-clover hay.	Cow-pea hay.	Corn silage.	Miscellaneous.
1	164	164	82	134	295	....	2,700	
2	360	360	180	....	337	75	3,010	
4	362	362	232	15	287	....	2,805	Cottonseed hulls, 138.
7	297	297	190	15	267	....	2,805	Cottonseed hulls, 138. Bone meal, 31.
8	206	206	103	....	236	....	1,770	
9	276	276	138	124	276	....	2,540	
12	213	213	106	....	267	....	1,770	
14	236	236	118	....	236	....	1,770	
17	343	267	145	72	[1] 212	259	2,013	Cottonseed hulls, 45. Stover, 115. Bone meal, 9.
18	264	264	132	134	292	....	1,715	Dried-beet pulp, 410.
19	214	214	107	....	295	....	2,065	
20	252	252	126	124	267	....	3,150	
21	276	223	171	73	....	197	3,108	Cottonseed hulls, 276. Bone meal, 26.
22	263	263	132	124	292	....	1,470	Beet pulp, 410.
23	317	262	205	26	[2] 57	417	1,455	Cottonseed hulls, 276. Bone meal, 15. Turnips, 2,655.
24	265	177	88	....	....	712	....	Turnips, 2,700.
26	174	137	69	....	[1] 228	192	885	Stover, 102.
27	204	163	82	....	....	478	900	Turnips, 1,325. Stover, 115.
100	358	297	149	73	182	240	2,917	
201	533	533	267	....	[1] 361	349	2,475	Stover, 474.
202	319	253	128	50	....	432	3,708	Stover, 115.
Total	5,896	5,419	2,950	964	3,520	3,351	45,031	

[1] Alfalfa hay. [2] Timothy hay.

In the data of Table 1 it will be noted that of the 21 cows kept under the two systems 15 produced more milk and butterfat when kept in the open shed, while 6 showed a higher production when kept in the closed barn. The total production while in the open shed was 34,630.9 pounds of milk, containing 1,535.15 pounds of butterfat, and that in the closed barn was 31,898.7 pounds of milk, containing 1,437.41 pounds of butterfat. Accordingly, under the open-shed system there was a total increase for the period considered, about 2.71 months, of 2,732.2 pounds of milk and 97.74 pounds of butterfat, or an average for each cow of 130.1 pounds of milk and 4.6 pounds of butterfat. The total number of months compared under each system was 57. Calculations from these figures indicate that there was an average monthly increase of 48 pounds of milk and 1.7 pounds of butterfat for each cow while stabled in the open shed.

Tables 2 and 3 show, respectively, the feed and digestible nutrients in the feed consumed by the two groups covering the same period of time as the production shown in Table 1. Where the figures in Table 1 are an average of two years the feeds in Tables 2 and 3 are also an average of two years.

TABLE 3.—*Digestible nutrients in feed consumed.*

Feeds.	Open-shed group.			Closed-barn group.		
	Protein.	Carbohydrates.	Fat.	Protein.	Carbohydrates.	Fat.
Concentrates:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn meal	515.98	5,159.82	261.73	406.82	4,068.24	206.36
Wheat bran	698.37	2,324.19	167.61	677.37	2,254.30	162.57
Cottonseed meal	951.57	692.31	225.07	985.30	716.85	233.05
Fish meal	44.98		13.80			
Dried-beet pulp				37.72	534.64	6.56
Total	2,210.90	8,176.32	668.21	2,107.21	7,574.03	608.54
Roughage:						
Alfalfa hay				84.91	312.39	7.21
Cowpea hay	614.52	1,580.87	46.91	438.98	1,129.29	33.51
Crimson-clover hay	202.24	767.28	20.85	345.61	1,295.36	35.20
Red-clover hay	199.12	1,029.66	47.16	73.26	378.85	17.35
Timothy hay				1.71	24.40	.68
Corn stover	10.63	214.54	3.54	19.34	390.50	6.45
Cottonseed hulls				2.62	290.71	13.09
Total	1,026.51	3,592.35	118.46	966.43	3,821.50	113.49
Silage and roots:						
Corn silage	675.61	9,212.85	429.93	495.34	6,754.65	315.22
Turnips				6.68	400.80	13.36
Total	675.61	9,212.85	429.93	502.02	7,155.45	328.58
Grand total	3,913.02	20,981.52	1,216.60	3,575.66	18,550.98	1,050.61
Pounds digestible nutrients required to produce 1 pound of fat	2.55	13.67	.79	2.49	12.91	.73

It may be noted in Table 3 that when the cows were kept in the open shed they required more digestible nutrients. However, the quantities of digestible nutrients required to produce one pound of fat in each of the two stables did not vary appreciably.

TABLE 4.—*Analyses used in calculating digestible nutrients.*[1]

Feed.	Crude protein (per 100 pounds).	Carbohydrates (per 100 pounds).	Fat (per 100 pounds).	Feed.	Crude protein (per 100 pounds).	Carbohydrates (per 100 pounds).	Fat (per 100 pounds).
Corn meal	6.9	69.0	3.5	Crimson clover	9.7	36.8	1.0
Wheat bran (all analyses)	12.5	41.6	3.0	Red clover (all analyses)	7.6	39.3	1.8
Cottonseed meal (prime)	33.4	24.3	7.9	Corn stover (medium in water)	2.1	42.4	.7
Beet pulp (dried)	4.6	65.2	.8	Cottonseed hulls	.3	33.3	1.5
Fish meal (high in fat)	37.8	....	11.6	Corn silage (well matured)	1.1	15.0	.7
Alfalfa (all analyses)	10.6	39.0	.9	Turnips	1.0	6.0	.2
Cowpea (all analyses)	13.1	33.7	1.0				

[1] From "Feeds and Feeding," by Henry and Morrison.

TABLE 5.—*Feed cost of milk and butterfat.*

Cow No.	Open-shed group.					Closed-barn group.				
	Cost of grain.	Cost of roughage.	Total cost of feed.	Feed cost of 100 pounds milk.	Feed cost of 1 pound butterfat.	Cost of grain.	Cost of roughage.	Total cost of feed.	Feed cost of 100 pounds milk.	Feed cost of 1 pound butterfat.
1	$6.58	$13.42	$20.00	$2.47	$0.58	$6.19	$11.67	$17.86	$2.40	$0.52
2	13.60	14.49	28.09	1.28	.27	13.59	12.33	25.92	1.39	.26
4	14.14	14.49	28.63	1.28	.29	14.51	11.39	25.90	1.30	.29
7	14.09	14.49	28.58	1.21	.30	11.89	11.23	23.12	1.14	.27
8	9.16	9.06	18.22	1.17	.28	7.78	7.20	14.98	1.08	.25
9	13.66	14.49	28.15	1.39	.32	10.42	10.88	21.30	1.36	.32
12	5.55	9.06	14.61	2.25	.55	8.03	7.45	15.48	1.55	.36
14	6.91	9.56	16.47	1.47	.32	8.91	7.20	16.11	1.20	.24
17	10.42	13.02	23.44	1.41	.27	11.52	11.94	23.46	1.62	.30
18	11.26	14.08	25.34	1.89	.35	16.12	8.69	24.81	1.81	.32
19	9.05	8.27	17.32	1.46	.27	8.08	8.55	16.63	1.66	.32
20	9.94	13.35	23.29	2.05	.47	9.52	12.71	22.23	1.48	.33
21	16.27	12.68	28.95	1.07	.20	10.27	12.66	22.93	1.44	.25
22	13.75	14.49	28.24	2.91	.58	16.09	7.87	23.96	1.75	.34
23	12.94	12.54	25.48	1.35	.32	12.02	17.56	29.58	1.72	.40
24	9.96	7.73	17.69	1.20	.27	8.12	13.80	21.92	1.57	.38
26	7.09	7.87	14.96	1.70	.28	5.79	7.34	13.13	2.02	.32
27	9.32	7.73	17.05	1.20	.29	6.84	10.95	17.79	1.48	.35
100	10.42	12.55	22.97	2.36	.56	12.23	12.79	25.02	1.76	.37
201	24.67	23.61	48.28	1.27	.36	20.13	16.44	36.57	.99	.32
202	16.30	17.10	33.40	1.49	.42	10.66	15.49	26.15	1.63	.50
Total	245.08	264.08	509.16	1.47	.33	228.71	236.14	464.85	1.46	.32

By comparing the data in Table 5 it may be noted that when the cows were kept in the open shed they consumed more feed and produced slightly more milk. The slight increase in production did not, however, entirely offset the extra cost of the larger quantity of feed consumed. On the average the cows when in the closed barn produced milk at a feed cost of 1 cent less per 100 pounds than when kept in the open shed; fat likewise was produced 1 cent per pound more cheaply.

It was observed, however, that one or two cows in each group were "boss cows" when kept in the open shed, and were inclined to intimidate the weaker and less aggressive animals, especially at feeding time. Cows Nos. 14 and 20 were timid individuals, and, unlike the large majority, produced decidedly less when in the open shed than when in the closed barn. No doubt this tendency of the stronger to boss and torment the weaker cows can be remedied, to a certain degree at least, by using some sort of tie on the cows when they are feeding. All cows used in the experiment were without horns; it is not practicable to attempt to keep horned cattle in an open shed.

The elimination of cows Nos. 14 and 20 from the data in Table 5 would change the results so that the feed cost of producing 100 pounds of milk in the open barn is reduced to $1.45 while that in the closed barn is increased to $1.47. As regards the butterfat, the cost of producing 1 pound becomes the same in both cases—32.73 cents.

The following prices of feeds have been used in calculating the foregoing tables. They represent a fair average of the market prices for this section during the time the investigation was in progress.

Prices of feeds.

	Per ton.
Corn meal	$33
Wheat bran	26
Cottonseed meal	33
Fish meal	35
Alfalfa hay	24
Cowpea hay	16
Red-clover hay	18
Crimson-clover hay	16
Corn stover	8
Corn silage	6
Beet pulp	30
Turnips	6
Cottonseed hulls	8

LABOR REQUIRED.

The labor required, aside from milking and feeding, is shown in Table 6. The figures in this table were compiled from accurate time records kept for each operation.

TABLE 6.—*Labor required (aside from milking and feeding).*

Labor operations (based on a herd of 16 cows).	Average per cow per day.	
	Closed barn.	Open shed.
	Min. Sec.	*Min. Sec.*
Preparing cows for milking	3 36	6 45
Removing manure and cleaning milking barn	4 25	3 11
Bedding	1 1	1 18
Total (aside from milking and feeding)	9 2	11 14

PREPARING COWS FOR MILKING.

In the open shed preparing the cows for milking included driving them into the milking room, putting them into the stanchions, brushing them, washing udders, flanks, and bellies, milking out the first few streams of milk to lower the bacterial count, and driving the cows out again. The time of milking was not taken into consideration, as the operation consumed practically the same time under each system. In the closed barn the time required to perform the same sanitary duties described above was considerably less because the cows were already stabled and the time of driving in and out was saved.

REMOVING MANURE AND FLUSHING OUT MILKING ROOM.

The second operation shown in Table 6 in the case of the open barn consisted in removing the small quantity of manure dropped by the cows while in the milking room and washing the floors, platform, and gutter of the milking room once daily. While the manure from the open shed was not removed daily, an allowance of time required to remove it has been included under this operation. It was assumed that the same quantity of manure was produced daily by the cows in the open shed as by the same number of cows in the closed barn. The time required to remove the manure from the open shed has been added to the time required to clean and flush out the milking room.

The operation in the closed barn included the time required to load the manure on a wagon and to remove it from the barn; also the time to wash up the floors, platforms, and gutters and to put the barn in the same sanitary condition as the milking room in the open shed.

With reference to the time required to keep both milking rooms clean, it may be noted (Table 6) that considerably less was needed for the small barn used in connection with the open-shed group. Doubtless the saving of time would have been even more marked had more cows been used. The figures were compiled for a herd of 16, handled in two shifts of 8 cows each. With a very little extra time for cleaning out, a much larger herd could have been milked in the small barn. It should be noted also that the figures are based on the assumption that the manure from the closed barn is to be hauled directly to the field. If it is necessary either on account of the small quantity or because of bad weather or soft fields to store the manure and haul it out later, about 1½ minutes should be added to the figures for the closed-barn cows, which would make the labor required, aside from milking and feeding, 10 minutes and 32 seconds, as against 11 minutes and 14 seconds for the open-shed cows.

BEDDING—TIME REQUIRED, POUNDS NEEDED, ETC.

By referring to Table 6 it may be noted that the time required to bed the cows did not vary widely in the two stables. A few seconds more for each cow were required in the open shed. It was observed throughout the trial, however, that the cows in the open shed kept themselves cleaner than those in the stalls.

The weights of the bedding used in each stable were recorded daily for 3 months during the trial, and the average was taken as the basis of comparison. The data thus obtained showed that the cows in the open shed required a daily average of 8.3 pounds, as compared with 4.94 pounds for the cows kept in the closed barn, or an increase of 68 per cent. Cornstalks, which at times were used for bedding the stock in the open shed, were so nearly decomposed when the manure was hauled to the field that they gave no trouble in loading on the spreader or in being evenly distributed on the land. No doubt other kinds of coarse bedding can be used with better results in open sheds than in closed barns, which is one advantage that tends to offset the extra cost of bedding in the open shed when only straw is used. On damp, rainy days more bedding was needed than in dry weather. Regardless of climatic conditions, however, the more space allowed each cow the less bedding will be required.

Good drainage is necessary for success with any open shed. Without it the quantity of bedding required is certain to be increased and the comfort of the cows seriously lessened. Water from the surrounding ground must flow away from, not toward, the shed. Eave spouts to carry the water from the roof of the shed to a place where it will readily flow away are provided for most sheds.

HEALTH AND CONTENTMENT OF THE COWS.

There seemed to be little, if any, difference in the amount of actual sickness observed under either open-shed or closed-barn conditions. In the closed barn the animals sometimes would get "big knees" from kneeling or falling on the concrete platform. This trouble was not observed when the open shed was used. Of the 21 cows used during the 3 years of the investigation two had their hips "knocked down" while in the open shed. Very probably the injuries were the result of being knocked against the side of the shed or the feed rack by stronger, more greedy, and aggressive cows.

In general, little difference could be noted in the contentment of the cows under either open-shed or closed-barn conditions. Some of the animals appeared to be more contented in the barn stalls; others appeared to be more at ease in the open shed, while still others seemed to have no preference. Under open-shed conditions the cows had more freedom. They could lie down and get up with ease, and could pick a clean place on which to lie whenever they chose. For them fresh air was abundant. Inasmuch as the closed barn used in the investigation was a modern, well-ventilated structure, no observations were needed on the subject of ventilation. In many of our poorly ventilated dairy barns, however, the impure air would doubtless be an important factor in determining the comparative merits of the two systems.

MANURE—PRESERVATION, HANDLING, ETC.

Under the open-shed system the manure was kept in an excellent state of preservation until it was hauled to the land, and it also was handled more economically. These are important considerations to the farmer who hauls manure direct from the barn to the field. Frequently the fields are too soft to be driven over and at certain seasons the growing of the crops prevents hauling the manure to the land. On this particular farm it was altogether impracticable, during most of the winter, to attempt to haul manure to the fields. Manure can be preserved until it is convenient to haul it to the fields by storing it in a manure pit. The walls and bottom of the pit are usually made of concrete and it is covered with a roof, so that it has the appearance of a small shed. When compared with the open-shed system of handling manure the manure pit has two disadvantages: First, it calls for an increased expenditure of money, and second, it necessitates handling the manure twice.

SUMMARY.

The cows consumed somewhat more feed and produced slightly more milk when kept in the open shed than when kept in the closed barn. The increase in production was not quite large enough to offset the extra feed cost.

When kept in the open shed there was a tendency for "boss cows" to deprive weaker individuals of their feed and of the normal advantages of the shed, which resulted in lower milk yields from the weaker and more timid cows.

All operations considered, milking and feeding excluded, slightly more labor was required to care for the cows when kept in the open shed.

The manure was apparently well preserved, until it could be hauled to the land, under the open-shed system. It was also handled more economically than in the closed barn. Cornstalks in the manure were sufficiently decomposed to be handled successfully with the manure spreader.

Under the open-shed system 68 per cent more bedding was required for each cow, but the cows were cleaner and more comfortable. There was little difference in the time required to bed them under the two systems. It is possible to use cornstalks or other coarse material for bedding in the open shed.

There appeared to be little if any difference in the frequency of injuries to cows under either open-shed or closed-barn conditions.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 737

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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THE TOBACCO BEETLE: AN IMPORTANT PEST IN TOBACCO PRODUCTS.

By G. A. Runner, *Entomological Assistant.*

(With technical descriptions of coleopterous larvæ by Adam G. Böving.)

CONTENTS.

A PEST IN CURED AND MANUFACTURED TOBACCO; ITS COMMON NAMES.

The tobacco beetle or "cigarette beetle," *Lasioderma serricorne* Fabricius, which feeds and lives mainly in dried vegetable products, is by far the most destructive pest with which manufacturers of or dealers in tobacco or tobacco products have to contend. It is present at times in practically all warehouses, cigar and tobacco factories, and retail or wholesale establishments where cured leaf tobacco or manufactured tobacco is handled or stored.

This beetle is now known under several names. "Tobacco beetle," "cigarette beetle," "tobacco bug," "tobacco flea," and "tobacco flea-beetle" are the terms most commonly used in referring to it. The

Note.—The author, Mr. G. A. Runner, was transferred from Southern Field Crop Insect Investigations to Deciduous Fruit Insect Investigations on May 21, 1917.

last two names may have originated from confusion of the species with a field insect, the tobacco flea-beetle, *Epitrix parvula*, which attacks growing tobacco, the holes eaten in the leaf showing in the cured leaf tobacco and somewhat resembling holes made by the true tobacco beetle, *Lasioderma serricorne.* The name "cigarette beetle" has been quite generally used in entomological literature but is not suitable as it conveys the impression that the insect confines its work to cigarettes whereas it is a general feeder upon all cured tobacco products. Throughout this bulletin the name "tobacco beetle," which was used by Mr. E. A. Schwarz in earlier accounts of the insect, is adopted, as the present consideration of the insect refers to its depredations upon all forms of cured and manufactured tobacco.

Fig. 1.—Cigars damaged by the tobacco beetle (*Lasioderma serricorne*) showing burrows of larvæ and exit holes of adults.

THE CHARACTER OF ITS INJURY.

The injury caused by the tobacco beetle is very great, owing to its habit of occupying its food substance during all stages of its life. The principal damage is done by the larva or "worm" stage, and with tobacco, as with other food substances, the actual amount consumed usually is of far less importance than is the presence of refuse, excrement, dust, and the dead beetles, which render the manufactured product unsalable.

The insect damages cigars (fig. 1) and pressed tobacco by burrowing small cylindrical tunnels which later become filled with dust and excrement. In cigars the holes may extend from one side to the other, and in some instances the holes or galleries may wind through the filler of the cigar, a large part of the interior being thus destroyed without external evidence of injury to the wrapper. The larvæ often will work between two closely packed cigars, slitting both wrappers lengthwise for some distance, and the pupal cells frequently are constructed between two closely pressed cigars or beneath the band. Injured cigars do not draw well, burn unevenly, and dust is drawn into the

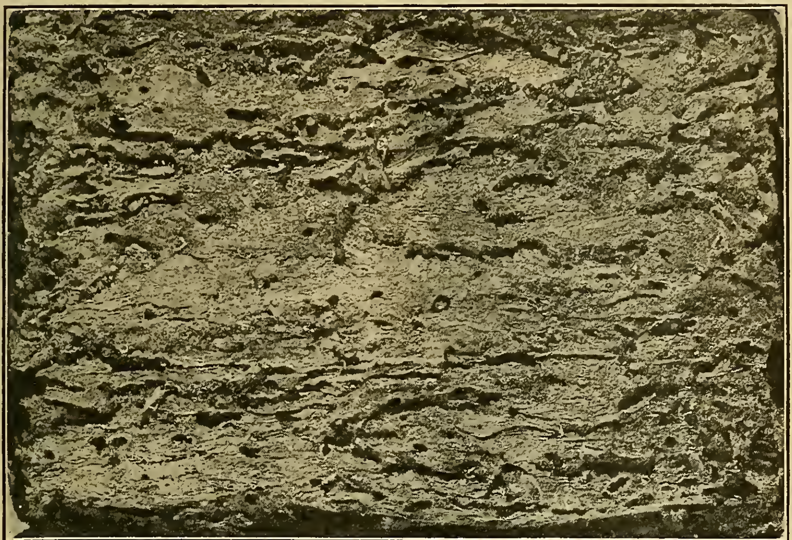

FIG. 2.—Pressed cut smoking tobacco showing burrows of larvæ and exit holes of adults of the tobacco beetle (*Lasioderma serricorne*).

mouth of the smoker. High-grade cigars, in which the more expensive leaf tobacco is used as wrapper or filler, are far more susceptible to injury than are cigars made from heavier, stronger,

FIG. 3.—Chewing tobacco injured by the tobacco beetle (*Lasioderma serricorne*).

and inferior grades. In cigarettes, also, injury is more apt to occur in those made from the sweeter, milder types of leaf, such as is used in the more expensive grades. Fine Turkish tobaccos are especially liable to infestation, holes being bored through the wrappers and frequently through the cork tips. The interior of the cigarette is filled with refuse, and the wrapper becomes soiled and discolored. Smoking (fig. 2) or chewing tobacco becomes badly worm eaten. In pressed kinds, such as plug tobacco and pressed and sliced smoking tobacco, galleries are formed. In pressed plug tobacco (fig. 3) the wrapper is cut and the edges furrowed. Granulated and fine-cut types become mixed with the dust and refuse from feeding and with the dead bodies of adult beetles. Pupal cells occur on the sides of the containers or in the tobacco. Leaf tobacco (fig. 4) is infested in much the same manner as cigars. The larvæ bore holes in every direction through the leaves. Fine wrapper tobacco is often so badly injured that it is worthless. In leaf tobacco used as filler, or in manufactured tobacco or snuff, the damage is confined more to the tobacco actually consumed by the larvæ than is the case with attacks of the insect on the manufactured product.

FIG. 4.—Damage to cigar tobacco by the tobacco beetle (*Lasioderma serricorne*).

CLASSIFICATION AND SYNONYMY.

The family Ptinidae, to which the tobacco beetle belongs, is composed of small insects which rarely exceed one-fourth of an inch in length. The head is usually retracted, the body more or less cylindrical and firm, and the wing covers firm. The species vary greatly in form, and several species belonging to the family have been widely distributed by commerce. Although the family is quite large, comparatively few species are economically important and injurious;

namely, those living in stored products and timber. Among these, besides the tobacco beetle (*Lasioderma serricorne*), may be mentioned the larger tobacco beetle (*Catorama tabaci*) and the drug-store beetle (*Sitodrepa panicea*). The genus Lasioderma of Stephens contains only five known species. The tobacco beetle was first described from America in 1792 by Fabricius (1)[1] under the name *Ptinus serricornis*.

SYNONYMY.

The following synonymy is given by Gemminger and Harold (16):

Lasioderma serricorne Fabricius, Ent. Syst. (1792), v. 1, p. 241; Mulsant, Ann. Soc. Linn. Lyon (1864), v. 12, p. 1, pl. 1, fig. 10; Le Conte, Proc. Acad. Nat. Sci. Phila. (1865), p. 236.

Lasioderma flavescens Dahlbom, Dej. Cat. 3 ed. (1837), p. 129.

Lasioderma testaceum Duftschmidt, Fauna Austr. (1859), Deutchl. Fauna Insecten (1837), v. 11, p. 89, pl. 237, fig. P.

FOOD SUBSTANCES OF THE TOBACCO BEETLE.

The tobacco beetle feeds upon a variety of dried vegetable substances as well as upon a few dried animal substances. Early records describe the insect as feeding upon or living in "dried plants." Its more common food is cured or manufactured tobacco. In drug and grocery stores it is often found infesting such substances as dried roots of various kinds, pressed yeast cakes, and seeds. The writer on one occasion found a collection of dried botanical specimens in a State museum badly injured by the pest. In the course of investigations of the insect it has been reared from and found infesting or feeding upon the following substances: Cured leaf tobacco, manufactured tobacco of various kinds, such as smoking and chewing tobacco, snuff, cigarettes, and cigars; tobacco seed, dried figs, cayenne pepper, ginger, dried dates, powdered orris root, curry powder, starch, pressed yeast cakes, and dried plants of different kinds in botanical collections. When large numbers of the beetles were required at times for experimental work it was found that they could be bred most conveniently in dried yeast cake (fig. 5).

In addition to the food substances already mentioned, the insect has been reported in entomological literature as injuring or infesting opium, red pepper, rice, paprika, stock foods, turmeric, spices, saffron, licorice, bran, belladonna, and pyrethrum powder. Dr. J. B. Smith (59) also mentions injury to cane and rattan work of all kinds, books, and gun wads. Jones (77) reported the insect breeding in raisins in the Philippines. Van Dine (55) states that in the Hawaiian Islands the tobacco beetle is the most common and destructive pest

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[1] Numbers in parenthesis refer to "Bibliography," p. 69.

in stored products, and that it infests groceries, drugs, and dried products indiscriminately, but possibly favors manufactured tobacco. He also reports having found the insect very injurious to wall paper and books in Honolulu.

Dried animal substances occasionally are attacked. Dried fish is mentioned as a food substance by Mackie (74), and Van Dine (55) reports the beetle as having been reared from fish guano used as fertilizer. There are also reports of leather goods having been injured. The late F. C. Pratt (53) noted injury by this species to an insect collection in western Texas, about 10 per cent of the specimens in a box of Orthoptera having been damaged.

There are numerous records of the tobacco beetle feeding upon and injuring upholstered furniture. Cook (25) has described injury to

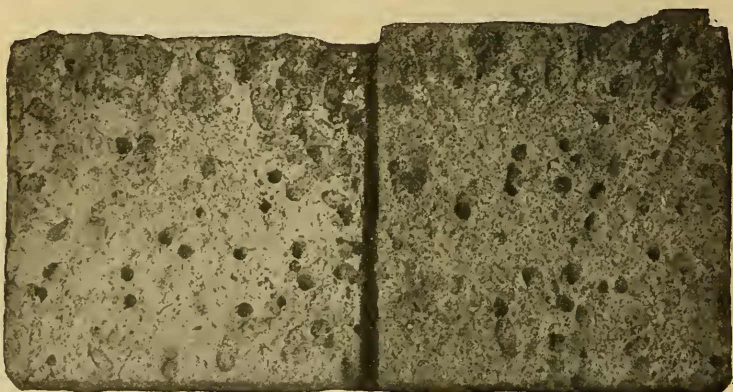


FIG. 5.—Work of the tobacco beetle (*Lasioderma serricorne*) in pressed yeast cake.

furniture, and stated that the work of the insect "made the plush covering look like a sieve." Chittenden (53, 58) has reported the insect as damaging upholstered furniture, rugs, and tapestry in dwelling houses in the District of Columbia, West Virginia, and New Jersey. Osborn (46, 49) has reported infestation of plush upholstered furniture at Columbus, Ohio. Silk as food is mentioned by Osborn (46). Injury to silk and plush hangings in France has been mentioned by Bordage (38).

The occurrence of the beetle in some of the substances given is undoubtedly more or less accidental. Attempts made by the writer to rear the beetle from the egg stage in many of these substances resulted in failure. In many instances the larvæ fed for a time but did not complete their transformation to the adult stage. In controls on these experiments adults were reared from eggs placed in yeast cakes, tobacco seed, or cured tobacco, at the same time and kept under the same conditions.

FOOD HABITS OF BEETLES RELATED TO THE TOBACCO BEETLE.

Beetles belonging to the same family as the tobacco beetle, the Ptinidae, in general usually feed on vegetable matter in an incipient stage of decay or in dried vegetable or animal substances. A few bore into solid wood and others attack living plants.

The larger tobacco beetle (*Catorama tabaci* Guérin) feeds on tobacco and tobacco seed (fig. 6).

The drug-store beetle (*Sitodrepa panicea* Linnaeus) feeds on drug-store supplies such as dried roots and seeds, and sometimes attacks tobacco. Its food habits are very similar to those of the tobacco beetle.

Mezium americanum Laporte occurs in dwellings and breeds in dried animal substances. It is known to infest tobacco seed.

A species of European origin, *Ptinus fur* Linnaeus, now widely distributed by commerce, is said to be often injurious to museum specimens, and has been reported as injuring tobacco.

FIG. 6.—Cigar tobacco injured by the larger tobacco beetle (*Catorama tabaci*).

The following records of food habits of several other species belonging to the same family have been given by Blatchley (71):

Trypopitys sericeus Say. Occurs beneath bark and on old branches of wild cherry and oak.

Caenocara oculata Say. On low vegetation and in puff balls (*Lycoperdon* spp.).

Ptilinus ruficornis Say. Larvæ bore into dead branches of oak and maple.

Some species of Ptinidae bore into decaying timbers of houses. The ticking sound made has given these insects the name of "death-watch" beetle.

LOSSES DUE TO THE TOBACCO BEETLE.

Losses occasioned by the tobacco beetle, either directly or indirectly, occur to some extent in every place where cured or manufactured tobacco is handled. Various statements have been received from manufacturers which show that loss at the factories is very large, but this probably represents only a small part of the loss due to damaged cigars, cigarettes, and manufactured tobacco in the hands of jobbers and retailers. In many factories the loss is estimated to be more than $5,000 a year. An agent of this bureau, on one occasion, in a single factory, was shown 14 barrels of damaged and worm-eaten cigars, part of these having been made from the finer and more expensive grades of Cuban tobacco. The loss from the beetle in this instance was estimated at not less than $7,000, and the damage occurred within a period of only 12 months. At the storerooms of a large jobbing concern in one of the Northern States the writer was shown a lot of smoking and chewing tobacco of various brands said to weigh over one-half ton which was infested and worthless. Part of this tobacco showed injury from mold, but a large part of the damage had been caused by the tobacco beetle. In 1913 a large tobacco firm reported to the Bureau of Entomology that its loss from the beetle amounted to fully $25,000 per annum. The average annual loss in the Philippines per factory for cigars actually destroyed in the factory is said to vary from 6,000 to 13,000 pesos ($3,000 to $6,500) (77). The total money loss in the Philippines from returned cigars which are infested with the beetle has been reported by Mackie (74) to exceed 500,000 pesos ($250,000 U. S. currency) per annum. The actual money loss to the manufacturers from tobacco products returned to the factory represents only a small part of the entire loss caused by the beetle. An enormous loss occurs through damage to hogshead tobacco of certain types, and, as in the case of manufactured or baled tobacco, it is impossible to make even an approximate estimate of the loss. In 1911 Mr. J. Matsumura, inspector of the bureau of monopolies for the Imperial Japanese Government, reported that in a shipment of 60 hogsheads of American tobacco to Japan 50 hogsheads had been so badly damaged by the beetle that the tobacco was almost worthless. In exported hogshead tobacco the lighter types, such as are used in the manufacture of cigarettes, are most susceptible to injury, and a comparatively slight infestation at first may result in a heavy infestation after a long sea voyage through warm or tropical waters. The specially favorable breeding conditions brought about by high temperatures and humidity incidental to long oversea shipments make the beetle unusually destructive to cigars shipped to the United States from the Philippines. A number of dealers have reported serious loss from this source, the infestation spreading to cigars and other classes of manufactured tobacco kept in stock.

Although the tobacco beetle is present and causes more or less loss in all parts of the United States, investigations of the Bureau of Entomology show that damage is greatest in the States bordering on the Gulf of Mexico. One large manufacturer reported that his loss due to infestation of goods, chiefly smoking and chewing tobacco, shipped to the Gulf States had been so great, fully 50 per cent of the manufactured tobacco becoming wormy, that his company had been forced to restrict its activities in that section. To replace this damaged stock made their business in that section unprofitable. The factory was said to be practically uninfested, and few complaints of damage came from other sections of the country where the same class of goods was shipped. In another instance a firm manufacturing high-grade cigars some years ago organized a separate department in which scrap tobacco was worked up into cheaper cigars. At first this department showed an annual profit of about $7,000. The beetle, however, finally became so destructive to this class of goods, and so many shipments were returned to the factory, that this branch of the business was discontinued.

The extent of injury to baled domestic tobacco can not be accurately determined until the tobacco is finally used, and, as with other classes of tobacco, it is difficult or impossible to obtain even an approximate estimate of the total loss.

In wholesale and retail drug stores the insect frequently becomes a serious pest and causes heavy loss by consuming or by making unsalable more expensive products.

DISTRIBUTION AND DISSEMINATION.

Commerce has served to distribute the tobacco beetle widely and it probably now occurs in all countries having a temperate, subtropical, or tropical climate. In warm tobacco-growing countries such as Cuba, Porto Rico, and the Philippines, where the beetles are numerous and breed continuously throughout the year, they are being constantly exported in shipments of cigars or bales of cigar tobacco. Examinations of warehouses in which bales of infested cigar tobacco are stored, at ports of entry in this country, have shown them at times to be heavily infested with the beetle.

There has been a very noticeable increase and spread of the tobacco beetle in tobacco factories in the United States within comparatively recent years. Experienced tobacco dealers and tobacco manufacturers attribute this to the general use of steam in heating factories. The higher and uniform temperatures which are thus maintained make breeding conditions more favorable.

In tobacco factories and buildings in which tobacco products or suitable food substances are stored the insect spreads by crawling or by flight. The adult beetle is capable of flying for a considerable distance. Beetles escaping from cars or ships in which bales or hogsheads of leaf tobacco are shipped find their way to suitable food substances which then in turn become new centers of infestation and dispersion. As the life cycle of the beetle is comparatively short in warm weather, hogsheads of export leaf tobacco, slightly infested when sent out, may become heavily infested *en route* and almost worthless after a long sea voyage, the high temperature and moisture in the hold of a vessel creating ideal conditions for reproduction.

The insect is now so generally disseminated throughout the country that it is a common occurrence to find it in show cases, storage rooms, or humidors in cigar stores. Records of returned shipments at cigar and tobacco factories show that the majority come from retailers in the Southern States and from localities where climatic conditions are especially favorable for the rapid increase of the beetle. In view of this fact it will be seen that the return of damaged goods to the manufacturers does not necessarily mean that the tobacco or cigars were infested when shipped from the factory, the actual source of infestation often being the retail store or distributing point. Even in summer few complaints come from dealers in certain of the Northern States and in Canada. Tobacco infested when shipped from the factory would certainly show damage in such localities if kept even for a short time in warm weather, as experiments made by the writer have shown repeatedly.

Tobacco may become infested also in the hands of the retailer, the beetles coming from other food substances such as yeast cakes in grocery stores, or from vegetable substances used as drugs.

In cigar or tobacco factories the beetles are being constantly introduced in bales or hogsheads of imported leaf tobacco. Cigar manufacturers frequently keep bulk tobacco in bonded warehouses at the port of entry until needed for fabrication. In many instances the bales of tobacco remain in bond for a considerable length of time. A large part of this tobacco comes from Cuba, where the beetle reproduces continuously throughout the year, and infested bales are brought into the warehouses with every shipment.

ORIGIN AND HISTORY.

The original habitat of the tobacco beetle is not definitely known, but probably the insect is native to warm or tropical parts of America. When it was first described from America by Fabricius (1) in 1792 tobacco was not mentioned specifically as food, but the insect was reported as infesting "American dried plants."

The earliest account of injury to tobacco seems to have been that by M. Planche (38), an inspector of tobacco factories, who reported in 1848 that the insect had been found at Paris for the first time in tobacco. It was thought to have been introduced from America. Since 1848 there have been many references to the species in entomological literature as destructive to tobacco and to various dried vegetable substances.

Chevrolat (13), in 1861, stated that the insect attacks cured tobacco, that it is acclimated in all parts of the world, and that in his collection were specimens from both Americas, Algeria, Syria, Germany, and Denmark. Le Conte (15), in 1865, mentioned the beetle as having been carried by commerce over the entire globe, and stated that it lives chiefly, although not exclusively, upon tobacco. Mr. E. A. Schwarz (20), of the Bureau of Entomology, in 1883 stated that it is a well-known pest in many cigar factories in the United States. It seems to have been only within comparatively recent years, however, that the insect has attracted attention as a serious pest in fabricated tobacco. Since the earliest days of the colonies tobacco has been an important crop and one of the main exports of several States. In Colonial times laws regulating the tobacco industry were very exacting and rigidly enforced, and for a long series of years tobacco for export which failed to come up to the legal requirements as to quality and soundness was destroyed. In view of these circumstances it seems strange, if damage to stored tobacco from insects had occurred to any great extent, that the fact was not recorded.

ECONOMIC HISTORY.

From an economic standpoint the history of the species begins with the paper by G. F. Atkinson (21), published in 1885–86. An account of the occurrence, habits, and life history of the insect is given and emergency remedies and means of control are discussed. In 1889 the same investigator published an account of the insect, its life history, remedies, etc., in a report (22) of the South Carolina Agricultural Experiment Station.

Prof. C. V. Riley (31), in 1892, reported the insect as injuring chewing tobacco in Baltimore. He discussed its habit of flight and recommended that windows be closed at night to prevent its entrance. Steaming is given as the best means of killing the larvæ and eggs.

In 1898, in a report upon insect enemies of tobacco, Dr. A. L. Quaintance (40), then State entomologist of Florida, described injury to stored tobacco caused by the beetle, giving an account of habits, food substances, and method of treatment of infested tobacco with carbon disulphid.

Dr. L. O. Howard (42), in 1899, in an article on tobacco insects, gave a general account of the tobacco beetle and other insects injuring stored tobacco, and suggested many practical means of control. Fumigation with carbon disulphid, steam sterilization, and other repressive measures applicable to factory and warehouse conditions were described.

In 1904 Prof. T. B. Symons (51) gave results of experiments in fumigation with hydrocyanic-acid gas and carbon disulphid. Dr. F. H. Chittenden (53), of the Bureau of Entomology, conducted experiments with hydrocyanic-acid gas against the beetle in furniture in 1905.

In 1909 Mr. J. S. Houser (65) reported the beetle extremely destructive in Cuba, and stated that infested tobacco may be fumigated with carbon disulphid or hydrocyanic-acid gas without injury.

The results of experiments with dry cold storage in treating infested tobacco in Brazil were given by Gustav Pook (69) in 1910.

It is stated that the method was in use throughout Brazil and that unusually good results had been obtained.

During the same year (1910) Mr. A. C. Morgan, of the Bureau of Entomology, in an article on insect enemies of tobacco in the United States (70), briefly described methods of treatment with fumigants. It was stated that no method entirely satisfactory had been found for the treatment of baled tobacco. The results of experiments with Röntgen or X rays in the treatment of infested tobacco, conducted by Mr. A. C. Morgan and the writer, were published in 1913 (76).

From Manila, P. I., in 1913, Mr. Charles R. Jones (77) published the most comprehensive article on the tobacco beetle which had yet appeared. The life history and seasonal history of the insect in the Philippines were determined and many practical methods of control tested under cigar-factory conditions. An exhaustive series of tests with hydrocyanic-acid gas showed this fumigant to be effective in treating infested cigars without affecting their quality.

Storage of infested tobacco at low temperatures is recommended by Mr. D. T. Fullaway (79) in a publication of the Hawaii Agricultural Experiment Station in 1914. In 1916 the results of experiments with Röntgen or X rays on different stages of the beetle were published by the writer (86). In 1917 the writer (89) published a general account of the species, its life and habits, and methods of control.

In the historical sketch given only the more important publications relating to the life history of the insect or to the measures employed in its control have been cited. In the bibliography (p. 69–77) reference will be found to most of the papers, relating to the insect, which have been published in permanent form. A synopsis is given of the contents of the more important publications.

DESCRIPTION OF STAGES.

THE EGG.

(Pl. I, fig. 8.)

Egg about 0.45 mm. (0.44–0.46 mm.) long and 0.2 (0.19–0.21 mm.) in diameter; ovoid elliptical, pearly white, becoming more opaque and dull in color just before hatching. Surface smooth, without reticulation or sculpture except a portion at the end from which the larva emerges, which is covered with numerous papillæ.

THE LARVA.[1]

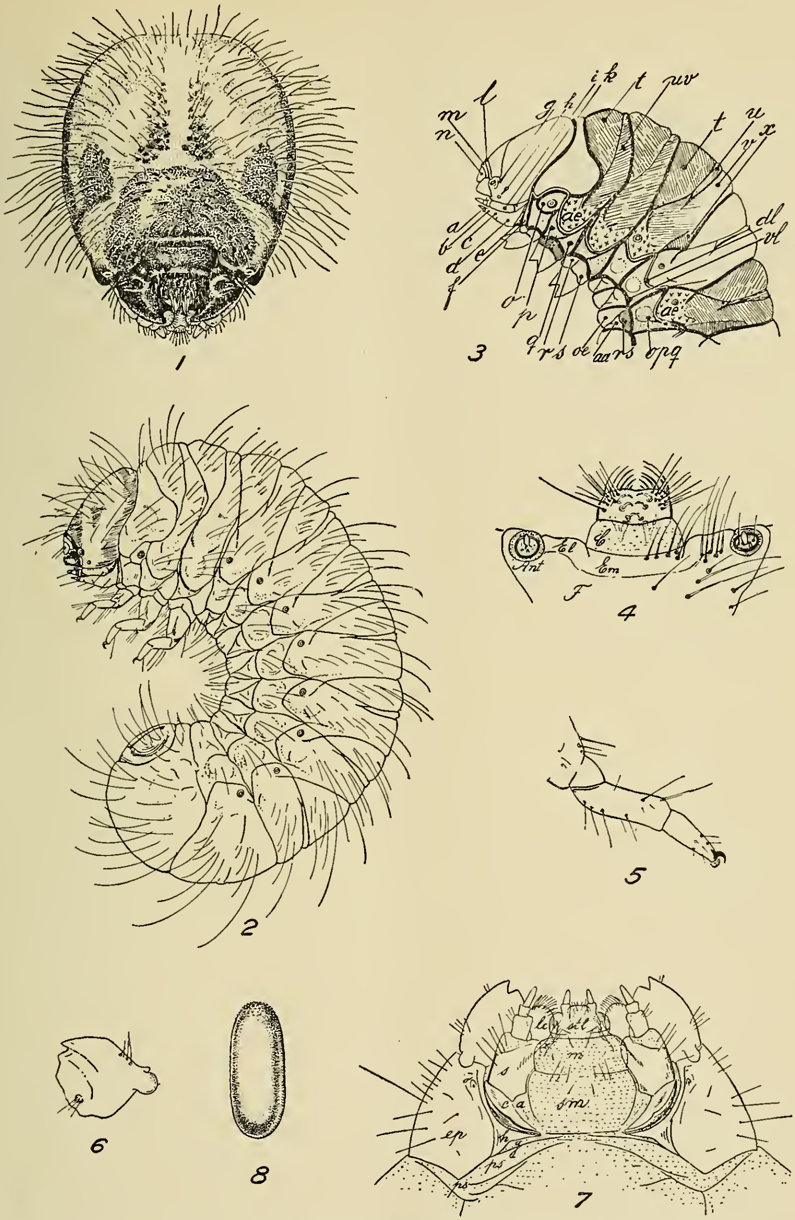
(Pl. I, figs. 1–7.)[2]

GENERAL CHARACTERS.

Ventral side of epicranium not continued behind the posterior end of hypostoma and its tentorial pits; gula transverse, laterally attached to the posterior

[1] In order that the identification in the field may be as accurate as possible it is necessary from time to time to incorporate in an economic bulletin technical descriptions. These descriptions are drawn up after extremely careful study of the anatomy of the larva by a specialist on the group. The following descriptions, kindly prepared by Dr. Adam G. Böving, will be of great assistance in future studies of ptinid larvæ. First is presented a description of the characters common to many ptinid larvæ, then the characteristics of the genus, and finally the specific characters of *Lasioderma serricorne*.

[2] Description of larva (with Pl. I, figs. 2–7) made by Dr. Adam G. Böving.



EGG AND LARVA OF THE TOBACCO BEETLE (LASIODERMA SERRICORNE).

FIG. 1.—Front view of face. FIG. 2.—Side view of larva. FIG. 3.—Thoracic and abdominal areas: *aa*, Parasternum; *a*, labial palp; *ae*, alar area; *b*, stipes labialis; *c*, mentum; *d*, submentum; *dl*, dorsolateral suture; *e*, gula; *f*, presternite; *g*, antenna; *h*, ocellus; *i*, stipes maxillaris; *k*, cardo; *l*, epistoma; *m*, clypeus; *n*, labrum; *o*, preepipleurum; *oe*, basisternum; *p*, epipleural lobe; *q*, postépipleurum; *r*, prehypopleurum; *s*, posthypopleurum; *t*, prescutum; *u*, scutum; *v*, scutellum; *vl*, ventro-lateral suture; *x*, postscutellum. FIG. 4.—Anterior portions of face (labrum, clypeus, epistoma, and frons): *Ant*, antenna; *c*, clypeus; *el*, epistoma, lateral part; *em*, epistoma, median part; *f*, frons. FIG. 5.—Prothoracic leg. FIG. 6.—Mandible, ventral side. FIG. 7.—Underside of head: *a*, Maxillary articulating skin; *c*, cardo; *ep*, epicranium; *g*, gula; *h*, hypostoma; *lc*, lacinia; *m*, mentum; *o*, ocellus; *ps*, presternum; *sm*, submentum; *stl*, stipes labialis; *x*, process between lacinia and hypopharynx. FIG. 8.—Egg. (Figs. 1 and 8 drawn by Joseph D. Smith; figs. 2–7 drawn by Adam G. Böving.)

margin of the hypostomal triangles, anteriorly adjoining submentum, posteriorly adjoining the presternites; occiput directed obliquely downwards and forwards. Mouthparts hypognathous; labrum and clypeus present; antenna small, situated at the anterior corner of frons, separated from basal skin of mandible by a narrow chitinous bridge; maxillary palp three-jointed, no definite palpiger; submentum and mentum the conspicuous parts of the ventral side of head; maxillary articulating area simple, neither chitinized nor subdivided into two or more separate lobes; stipes labialis with well developed ligula, labial palpigers, and palpi; hypopharyngeal chitinizations not developed. Tentorial bridge broad; hypopharyngeal bracon present. Body curved, wrinkled, fleshy, whitish. Legs developed; with several joints; last joint clawlike; no real claws; prehypopleurum and posthypopleurum indicated but not chitinized. Prothorax with small presternites fused into a narrow, transverse band; no separate prebasisternum; no sternellum; poststernellum well developed; mesothorax and metathorax with well developed epipleural median lobe closely connected with the alar area; spiracle-bearing preepipleurum not reaching the presternum; no definite sternellum; mesothorax with and metathorax without poststernellum. Abdominal segments ten; prescutal area large, protuberant; dorsal parts of scutum and scutellum not developed into ampullatory lobes; epipleurum bulged; parasternum anteriorly limited by a straight line; ninth abdominal segment without cerci or any chitinizations. Spiracles annuliform; mesothoracic spiracle apparently prothoracic, the preepipleurum of mesothorax being pushed forwards; metathoracic spiracle rudimentary; eight abdominal spiracles.

GENERIC CHARACTERS.

In the family Anobiidae (Ptinidae), the genus Lasioderma, belonging to the group Ptinini, is characterized as follows: Head rounded, not deeply sunk into prothorax; epistoma strong, rigid, with median region only slightly concave, and lateral regions subrectangular, projecting, not divided by any depressions; labrum subrectangular, with straight anterior margin and rounded corners; clypeus somewhat broader, subrectangular; one ocellus; antenna two-jointed, with large terminal sensory papilla; mandible with bidentate apex and convex, irregularly serrated cutting edge; no molar part or prostheca; maxillary lacinia single. broad, flat, semiovate, spinose, extending from distal end of stipes; at its base arising from the boundary region between hypopharynx and stipes maxillaris a freely projecting, somewhat shorter, four times narrower, lanceolate, spinose structure; stipes labialis broad and short; mentum somewhat large, transversely subrectangular, separated from the still broader, trapezoidal submentum by a straight, rather faint line; maxillary articulating lobe small; gula very narrow. Legs five-jointed; tarsal joint distinct, falciform, clawlike. Prothorax with tergum outlined like a dumbell, the alar areas being lobate, much larger than the upper tergal part; no chitinous linear impression between alar area and the upper tergal part. Mesothorax and metathorax both with sharply defined prescutum; scuto-scutellar parts fused. The first seven abdominal segments with a large prescutum, a narrow scutal fold, and a large scutellum; the tergal parts of the last three abdominal segments not divided; tergal folds dorsally and laterally granulated, but without transverse series of stout, backwardly curved spinules; teuth abdominal segment well developed, with two large, cushion-like pads on each side of a linear, vertical, anal fissure. Last spiracle no larger than the preceding abdominal spiracles.

SPECIFIC CHARACTERS.

Median region of epistoma with a row of five setæ on each side, lateral regions naked; labrum with about seven straight setæ on the upper surface at each anterior corner, several long, medianly curved setæ along the anterior margin and an oblique row of three, shorter, stouter, hook-shaped setæ on the under surface on either side of and posteriorly approaching the median line; clypeus naked; stipes labialis, mentum, and submentum with long soft setæ; maxillary articulating area not setiferous.

LARVAL INSTARS.

First-instar larva 0.55 to 1.4 mm. long; yellowish white; the digestive tract showing darker; body set sparsely with very long, pale hairs; head 0.12 to 0.16 mm. long. Second-instar larva about 3 mm. long; yellowish white; head 0.22 to 0.24 mm. long. Last-instar larva about 4 mm. long; yellowish white; set entirely with long, silky, yellowish brown hairs; chitinous parts brown; spiracles concolorous with body; head 0.5 to 0.7 mm. long.

THE PUPA.

Pupa (Pl. II, fig. 2) uniformly white when first transformed. Length (average) 3.5 mm. (2.5–3.75 mm.); width about 1.7 mm. (1.1–2 mm.); tips of elytra attaining fourth visible ventral segment of abdomen. Metathoracic legs beneath the elytra not attaining tips of inner wings. Head bent upon thorax and beneath pronotum. Ultimate and penultimate abdominal segments ventrally each with a pair of fleshy lateral protuberances.

THE ADULT.[1]

(Pl. III, fig. 1; text fig. 7.)

Elongate-oval, moderately convex. Uniform dull reddish yellow or brownish red. Head broad, eyes small. Antennæ rather narrow, second and third joints smaller than first, the third distinctly triangular; fourth to tenth about as wide as long; eleventh oval. Thorax strongly convex, front angles acute, hind angles wanting. Punctuation of entire upper surface fine, uniform, not dense. Length 2.2 to 3 mm.

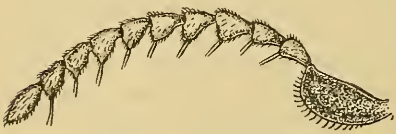


FIG. 7.—The tobacco beetle (*Lasioderma serricorne*): Antenna of adult. Greatly enlarged.

LIFE HISTORY AND HABITS.

SUMMARY OF LIFE HISTORY.

The life history of the tobacco beetle may be briefly summarized as follows:

In material kept constantly warm, breeding is continuous and there may be as many as five or six generations in a year. Under usual conditions in warehouses in the latitude of Virginia there are ordinarily three or four generations a year. The beetle lives in its food substances during all stages of its existence, and the time required to complete its life cycle depends mainly upon temperature and may be as short as 45 days. Normally, in summer, the time

[1] Description of adult by W. S. Blatchley (71).

varies from 45 to 70 days. Eggs are deposited in the food substance, and under usual conditions the incubation period is from 6 to 10 days, the larval period from 30 to 50 days, and the pupal period from 6 to 10 days. Adults live ordinarily from 3 to 6 weeks after emergence. In cold climates the species passes the winter mainly in the larva stage. It thrives best in localities where the temperature and humidity are high, and in substances in which the larvæ are protected from rapid evaporation.

THE EGG.

PERIOD OF INCUBATION.

The time required for hatching depends upon the prevailing temperature and probably upon moisture conditions, although considerable variation in the incubation period has been observed, even with eggs from the same female which were kept under identically the same conditions. The variation in the time required for hatching is least when the eggs are not subjected to extreme changes of temperature and humidity, and when the temperature is relatively high. At Key West, Fla., where the temperature is remarkably even, the incubation period varied from 5 to 10 days in numerous experiments conducted in April and May. During the experiments the maximum temperature ranged from 91° to 93° F., and the minimum from 81° to 83° F. The average period of incubation was found to be approximately 7 days.

The length of the egg stage at room temperature at Clarksville, Tenn., in May, ranged from 7 to 14 days. In 22 records obtained during July and August the average period of 7.6 days was recorded.

At Appomattox, Va., at room temperature in July, the average period of incubation was found to be 8.2 days. The shortest period observed was 6 days and the longest period 14 days.

Records obtained at Tampa, Fla., in July and August, show an average incubation period of approximately 8 days. The longest period observed was 10 days and the shortest period 6 days.

In determining the incubation period at a fixed temperature at Richmond, Va., eggs were kept in an electrically heated and automatically regulated incubator. The temperature was fairly constant at 30° C. (86° F.) and the relative humidity at about 80 per cent. During the period of incubation the variation in temperature was less than 1° C. All eggs used in the experiments were obtained from beetles kept in the incubator, the incubation period ranging from 6 to 8 days. In all of 20 different experiments hatching commenced during the sixth day.

THE LARVA.

Injury to tobacco by feeding is caused mainly by the larva or worm stage of the insect. It is this stage of the tobacco beetle that is often referred to by tobacconists as the "grub." Within the egg the embryonic larva lies with the head at the rough end. and when development is complete it eats its way through the shell in this position. Larvæ hatching in glass vials at the laboratory were observed to consume the eggshells almost completely when food was not provided. In rearing the insects for experimental work the young larvæ were often observed to live without food for periods of from 5 to 10 days. On emerging from the egg they are much more active than at other stages of growth and are capable of crawling a considerable distance in search of suitable food. Their activity at this stage accounts for the rather strange infestation of tobacco products, as the extremely minute worms readily enter very small openings in the boxes or containers. On hatching the larvæ are semitransparent, gradually assuming a whitish or creamy color as they become more fully grown. The food within the alimentary canal, seen through the skin, gives them a dark or dirty color, which varies with the amount of food present. When feeding on tobacco the fine particles of dust adhering to the minute hairs of the larvæ give them a brownish appearance, which is more noticeable in the last instar. The larvæ appear more robust, deeply wrinkled, and grublike as they become more fully grown. The young larva lies and crawls extended to full length; the older larvæ usually assume a curved position and are not so active as those newly hatched. At all stages of growth they are negatively phototropic, and when exposed to light disappear within the food substances as quickly as possible.

Larvæ of all ages are capable of crawling for a short distance and often migrate from infested to uninfested material. This habit often accounts for the quick appearance of injury in freshly made cigars. Partly grown larvæ have been found on the cigarmakers' tables and on the pickers' tables. They easily enter the open ends of the cigars that are being handled, and in a very short time their work can be noticed in the bundle or box of cigars. In a box of injured cigars examined, the work of a single larva was traced through four cigars. In another instance, in a box of sliced plug smoking tobacco, a single larva had cut a furrow in the tobacco for almost the entire distance across the top of the slices between the oiled paper covering and the tobacco.

It has been observed by leaf-tobacco dealers that a crop of Cuban tobacco which remains raw and does not cure quickly is apt to be damaged more by the beetle than the same type of tobacco which matures and cures properly. Under laboratory conditions a test was made at Richmond, Va., in 1914, with several types of leaf tobacco which confirms observations made in warehouses and factories. Similar quantities of different kinds of tobacco were closely packed in a tight container and several thousand eggs of the beetle scattered over the top, about the same number being placed on each "hand." The box, thickly wrapped with cloth and paper to avoid sudden changes in temperature, was kept in a warm place where proper breeding conditions could be maintained. At the end of three months the tobacco was examined. The degree of infestation found is given in Table I.

TABLE I.—*Preference shown by larvæ of the tobacco beetle* (*Lasioderma serricorne*) *for different types of leaf tobacco.*

Type of leaf tobacco.	Egg distributed.	Tobacco examined.	Degree of infestation.
Virginia heavy dark export, smoke-cured	July 10, 1914	Oct. 10, 1914	Slight.
Tennessee heavy dark export, smoke-cured	do	do	Do.
Burley, medium grade	do	do	Moderate.
Ohio cigar leaf, medium-grade filler	do	do	Do.
Cuban cigar leaf, Santa Clara, medium light	do	do	Heavy.
Florida shade-grown, light cigar wrapper	do	do	Do.
Carolina bright yellow, flue-cured (thin and poorly cured)	do	do	Do.

Strong, heavy types of leaf tobacco ordinarily are not injured to any great extent unless stored for a long time. Leaf tobacco which is "fire" or smoke cured, such as that grown in the "dark-tobacco" sections of Virginia or the "black-patch" sections of Kentucky and Tennessee, is seldom seriously injured. This, perhaps, is due in part to the flavor or quality given the leaf by the smoke, which acts as a repellent, whereas the same type of leaf flue cured is readily attacked, although not to so great an extent as are lighter-bodied types of tobacco. These types, as well as all others, however, are more apt to suffer injury after the leaf has aged. The changes brought about by long storage of any tobacco seem to make it more suitable as food for the beetles.

LENGTH OF LARVA STAGE.

At ordinary room temperatures in summer the larva or feeding stage extends over a period of from 30 to 70 days; the length of the period depends mainly on temperature and on the character and condition of the food substance. There is always considerable variation in the length of the larval period, even with larvæ from the same egg lot, kept in the same food substance, and under the same conditions. In cold weather the larvæ become dormant and may remain in this condition for several months. The insect passes the winter mainly in this stage in cool climates. When the larvæ have finished feeding and are encased within the pupal cells, they are able to stand considerable cold and are more resistant to the action of fumigants. Activity in the larva stage ceases at temperatures ranging from 60° to 67° F. At Clarksville, Tenn., larvæ which hatched about November 10, 1915, and when partly grown were placed in granulated smoking tobacco and kept in a cool room did not transform until April, 1916. The material was protected from severe freezing, but only a small proportion of the larvæ survived the winter. The most favorable conditions for the rapid development of larvæ are created by (1) suitable food substances in compact or concentrated form, (2) high and uniform temperature, (3) high humidity, (4) protection from strong light, and (5) protection from rapid evaporation. At Richmond, Va., during the period between August 1 and November 19, 1914, the shortest larval period observed in six lots of about 20 larvæ each was 39 days, and the longest period was 61 days. Pressed chewing tobacco was used as food. The maximum temperature during the period was 91° F. and the minimum temperature was 51° F. At Key West, Fla., during the period between April 16 and June 24, 1912, in cigars kept at room temperature, the shortest larval period observed was 42 days and the longest period 66 days. The temperature of the room varied from 80° to 94° F.

Numerous experiments have shown that with concentrated foods the larval period is shortened somewhat. In several experiments with different foods kept under the same conditions in an automatically regulated incubator at a constant temperature of 86° F. the larval periods were as follows: In tobacco seed, 2 experiments, 29 and 30 days; in pressed yeast cake, 2 experiments, 27 and 30 days; in pressed plug chewing tobacco, 29 days; in sliced plug smoking tobacco, 30 days; in loose granulated tobacco, 2 experiments, 35 and 38 days; in cigars, 2 experiments, 34 and 36 days; in cigarettes, 42 days.

At Clarksville, Tenn., the following records for the larva stage were obtained at room temperatures during summer:

TABLE II.—*Length of larva stage of the tobacco beetle* (*Lasioderma serricorne*), *Clarksville, Tenn., 1914.*

Record No.	Egg hatched—	Larva formed cell—	Larva pupated—	Days as larva.	Food.
1	June 7	July 18	July 22	45	Pressed plug tobacco.
2	do	Aug. 5	Aug. 17	71	Do.
3	do	Aug. 7	Aug. 11	65	Do.
4	do	Aug. 11	Aug. 16	70	Do.
5	June 19	July 16	Aug. 20	31	Tobacco seed.
6	June 25	July 30	Aug. 2	38	Do.
7	June 30	No record	July 25	25	Do.

THE PUPAL CELLS.

After the larva has become fully grown and is ready to transform into the pupa stage it forms, in any convenient place, the cell or cocoon in which transformation takes place. Apparently no special effort is made by the larvæ to reach the surface of the food substance although many of the cells are constructed on the outside. In leaf tobacco the cells usually are formed along the midrib or in the folds of the leaf. In boxes of cigars, cigarettes, and smoking tobacco cells may be found on the sides of the boxes, often within the paper lining; others may be found between closely packed cigars or cigarettes. The larva frequently cuts through the wrapper or binder of a cigar from the outside, forming a cell just within the wrapper, the cell filling the opening made in the cigar. The pupal cells usually are ovoid, but vary considerably in shape and completeness, this depending largely on the location of the larva and the character of the food substance. They average (inside measurement) about 4.5 millimeters long and 3 millimeters wide. They are often without definite shape, flimsy, and fragile, being constructed of small particles of the food substance and refuse cemented together by a secretion of the larvæ. On several occasions larvæ were observed to leave partly formed cells, crawl a short distance, and form other cells in which transformation to the pupa stage finally took place. In leaf tobacco the cells frequently are incomplete, the larvæ utilizing folds of the leaf for part of the cell, and on flat surfaces they simply form coverings over themselves. Within dense substances the surrounding material forms the necessary protection, the walls of the cell being thinly lined.

THE PREPUPA.

Before transformation there is ordinarily a period of from 4 to 12 days during which the larva within the cell undergoes structural changes preparatory to pupation. If exposed to low temperatures, as has been stated, the larva may remain in the cell for a considerable time before marked change in structure or appearance takes place. Before changing to the pupa stage the larva lies in a curved position within the cell, which is large enough to permit free movement. The body contracts and becomes somewhat more deeply wrinkled.

THE PUPA.

When newly formed the pupa is white (Pl. II, fig. 2), but gradually it assumes a brownish tinge before transformation to the adult stage, the eyes becoming reddish or reddish brown. It lies on its back within the pupal cell. Should the cell be broken open and the pupa removed, transformation takes place in an apparently normal manner if protected from rapid evaporation. In handling infested leaf tobacco many bare pupæ can be seen which have been dislodged from the fragile cells or cocoons between the leaves of the tobacco. After transformation has taken place a portion of the pupal skin frequently adheres for a short time to the tip of the abdomen.

The duration of the pupa stage of the tobacco beetle at room temperatures during the warmer months of the year in several localities was as follows: At Key West, Fla., between May 13 and June 4, the average time as shown by 10 records was 6 days and the shortest period 5 days. At Richmond, Va., the average of 11 records at room temperatures was 7.8 days, the shortest period 6 days, and the longest period 12 days. At Appomattox, Va., the average of 12 records obtained during July and August was 8.1 days. During September three records show pupal periods of 7, 8, and 9 days, respectively. At Clarksville, Tenn., 3 records secured during April and May show an average of 13.6 days, and 10 records during the period between July 29 and October 1 an average of 7.8 days. At Tampa, Fla., 21 records during July show an average of approximately 7 days, and 6 records during October show an average of 8.1 days.

THE ADULT.

When transformation to the adult stage has taken place the beetle lies inactive within the pupal cell for a period of three to seven days—usually about five days. After emergence it remains at rest for a day or more on the outside of the cell; the color of the beetle gradually becomes darker, and the normal shade of brown is reached about the time it has completed the resting period. The beetles are comparatively soft immediately after transforming and do not attain their final degree of hardness until they are ready to move away from the pupal cell.

The adults vary greatly in size. This undoubtedly is due to breeding conditions, the quality or abundance of food obtained by the insect while in the larva or feeding stage being the most important factor. The females will average larger in size than the males and they are also less active. In the vicinity of infested warehouses or factories beetles frequently are found in surrounding dwellings, and on several occasions were observed by the writer to fly from one tobacco warehouse to another located on the opposite side of the street. They avoid intense light, moving about most actively in subdued light or in darkness. When in the dark they are attracted toward subdued or artificial lights, and in tobacco warehouses often may be found in great numbers at the windows in late afternoon, the flight toward the windows being heaviest at sunset. Observations made at regular intervals throughout the night in a cigar factory showed that they were taken at a trap light at all hours of the night. During the day the greater number will be found in secluded places, such as crevices in the walls, or along the casings of windows. and within the leaf tobacco. When at rest the head and thorax are drawn downward (Pl. III, fig. 1). They have a habit of feigning death when disturbed, the head and thorax being bent downward and the legs drawn closely together.

MATING.

The adults generally begin to mate the second or third day after leaving the vicinity of the pupal cell. Mating in some cases occurred the first day, and was observed to take place several times during the egg-laying period.

PROPORTION OF SEXES.

The proportion of females seems to be somewhat greater than that of the males. Four lots which had emerged at different times from material kept at the laboratory gave a total of 36 males and 41 females. One hundred beetles collected at lights at a tobacco warehouse at Danville, Va., were dissected by Mr. S. E. Crumb, of the Bureau of Entomology, and of these 36 were males and 64 females.

LENGTH OF THE ADULT STAGE.

The length of life of the adults depends largely upon the temperature after emergence. In summer, or in rooms kept constantly warm, the beetles die much sooner than do those which emerge during cool weather. Normally the adults die in from 3 to 6 weeks after emergence. Although the mouth parts and digestive tract of the adult beetle apparently are complete and they are capable of gnawing through tobacco or other food substances to escape from the locality of the pupal cell, little if any evidence of feeding has been observed. Large numbers of adults, directly after emergence, were put in sealed tubes containing cigars, the open ends of the cigars being sealed to prevent entrance of the beetles. Several cigars prepared in this manner were kept until all adults had died, but no signs of feeding or injury to the cigars could be seen. Other beetles were kept in test tubes with small bits of leaf tobacco. In a few tubes the edges of the leaf had been slightly gnawed and fine particles of the leaf were found. Beetles confined in tubes closed with cork stoppers frequently gnaw into the cork for a short distance. No evidence has been secured to show that cigars or tobacco are directly injured by the adult or beetle except when burrowing out after transforming from the pupa stage. Eggs are deposited and the adults apparently live the normal length of time whether food is present or not. At Clarksville, Tenn., a number of experiments were made by Mr. K. B. McKinney and the writer to determine whether the presence of food has any bearing on egg deposition or length of life of the adults. A brief summary of the results obtained in one series of experiments follows: Number of pairs of beetles under observation, 44; average length of life of males kept without food, 23.4 days; average length of life of males kept with food, 21 days; average length of life of females kept without food, 31.2 days; average length of life of females kept with food, 30.5 days.

Another series of experiments was made to determine the length of life without food at ordinary room temperatures in summer. Twenty-three pairs of beetles were placed in separate tubes directly after emergence. The average length of life was 21 days for the males and 40.4 days for the females. Records from 24 pairs of beetles kept under observation at Clarksville, Tenn., during August and September, 1916, by Messrs. J. E. McMurtrey and E. H. Vance show an average length of life of 17.7 days for males and 21.4 days for females. An average of 30 eggs per female was obtained. The greater number of eggs was deposited between the third and the eighth day after egg-laying began. The period of oviposition ranged from the first until the seventeenth day after mating was observed. A similar experiment during the same period with 18 pairs of beetles kept without food gave the following: Average number of eggs deposited per female, 24; average number of days males lived, 21.2; average number of days females lived, 26.3.

OVIPOSITION.

Egg-laying usually begins in from 2 to 6 days after emergence. A large proportion of the females kept under observation commenced laying eggs the second and third day after mating. Indoors, where infested material is kept warm and is not subjected to much variation in temperature, the eggs may be found at any time. Humidors for storing cigars and tobacco usually are in steam-heated buildings, and the warmth and moisture conditions foster continuous reproduction throughout the year. Eggs usually are not deposited at temperatures below 70° F. The adults are more active at high temperatures, and eggs are most abundant in tobacco during the warmer period in summer. In the Middle and Northern States, when tobacco is subjected to approximately out-of-door conditions of temperature in unheated buildings, the eggs are laid only during the warmer months of the year. At Richmond, Va., the last eggs were obtained on October 28, 1914, from beetles kept in unheated buildings and the first eggs were obtained on May 2 of the following spring. Under ordinary conditions the eggs are deposited singly, usually in depressions or folds of the food substance. Owing to their small size and secluded location they do not ordinarily attract attention. Even to many who are thoroughly familiar with other stages of the beetle in tobacco the egg is an unfamiliar object.

There is a belief quite common that the eggs of the tobacco beetle are laid on the leaf tobacco in the fields or during the process of curing, and that these eggs do not develop until the tobacco is handled or made up into cigars or other products. This is not the case, as the eggs hatch within a few days after they are deposited and the beetles do not infest tobacco until it is cured. The eggs are laid during both day and night. In cigars, the greater number of eggs is deposited in the open end, the beetles frequently burrowing in the filler to a considerable distance.

At Key West, Fla., large numbers of adults were placed in test tubes containing fresh cigars of the panatela and perfecto shapes. After a few days the cigars were cut in sections, unwrapped, and the location of the eggs noted. Results from 10 cigars containing, in all, 372 eggs were as follows: Panatelas, 220 eggs; on outside, 6 eggs; inside, at end, first inch of cigars, 184 eggs; rest of cigars, 30 eggs. Perfectos, 152 eggs; on outside, 11 eggs; inside first inch of cigars, 129 eggs; rest of cigars, 12 eggs. In this experiment the number of eggs deposited on the outside of the cigars was probably more than normal owing to the large number of beetles in the tubes. In a similar experiment at Richmond, Va., with cigars of various shapes, only 5 per cent of a total of 320 eggs were found on the outside. This experiment was made with boxed cigars. All of the eggs recorded as deposited on the outside of the cigars were between two cigars closely packed, or on the edge of the filler exposed at the open end. In no instance were eggs laid on the wrapper where the surface was smooth. With cigarettes the eggs are deposited within the wrappers, the greater number being found near the end. In plug tobacco eggs were found mostly along the roughened edges of the slices, and between the slices when closely packed. The eggs do not adhere readily to leaf tobacco and are easily dislodged by handling.

NUMBER OF EGGS LAID, AND PERIOD OF OVIPOSITION.

The number of eggs laid by individual females varies greatly, depending on the vitality of the beetle, on the food obtained while in the larva stage, and on the temperature and moisture conditions during the egg-laying period. The largest number shown by any record obtained thus far is 103. This record, which also shows the rate of egg deposition, is as follows: On April 16, 1915, a pair in copula was placed with leaf tobacco in a tube and kept in an incubator at a constant temperature of 86° F. and a relative humidity of 80 per cent. The first eggs were laid April 17. The daily egg deposition from April 17 to April 25 is as follows: 24, 17, 18, 14, 11, 10, 2, 4, 3; total, 103. The male died April 21 and the female April 28.

In experiments made by the writer at Tampa, Fla., a total of 567 eggs was obtained from 21 females, or an average of 27 eggs each. The longest period of oviposition was 11 days. The largest number of eggs found in any one of 64 females dissected by Mr. S. E. Crumb on August 3, 1911, was 22.

At Clarksville, Tenn., the average number of eggs laid per female during July, August, and September was 32, as shown by 63 separate records. The longest period of oviposition was 21 days. Approximately 66 per cent of the eggs were laid during the first six days after mating was observed. Each pair of beetles was kept in a shell vial containing leaf tobacco.

INFERTILE EGGS.

Occasionally a female was found to lay infertile eggs, even after mating. No eggs were obtained from unmated females. In one series of experiments, of a total of 182 eggs obtained from 24 different females found in copula, 25 eggs, or 13.7 per cent, were infertile. The eggs were deposited on leaf tobacco and kept at a temperature of about 84° F., the daily variation being about 5°. This infertility probably is much above the average, as hatching in many other lots was almost perfect. The number of infertile eggs in 11 different lots, containing in all 773 eggs, was 30, or approximately 3.8 per cent.

LENGTH OF DIFFERENT STAGES IN DEVELOPMENT OF INDIVIDUAL BEETLES.

The following records from life-history studies made at Richmond, Va., show the time required for each period of development of different beetles from the egg to the adult.

TABLE III.—*Length of different stages in development of individual tobacco beetles (Lasioderma serricorne). Richmond, Va., 1914.*

Record No.	Egg laid—	Hatched—	Larva formed cell—	Larva pupated—	Adult appeared—	Adult left cell—
1	July 1	July 8	Aug. 17	Aug. 22	Aug. 29	Sept. 6
2	...do	...do	Aug. 19	Aug. 23	Sept. 1	Sept. 5
3	July 5	July 12	Aug. 22	Aug. 28	Sept. 4	Sept. 9
4	June 1	June 7	July 18	July 22	July 29	Aug. 2
5	June 18	June 25	July 30	Aug. 3	Aug. 9	Aug. 16

Record No.	Mated—	Eggs laid—	Food.	Egg to beetle.	Egg to egg.
				Days.	*Days.*
1	Sept. 9	Sept. 11	Tobacco	59	72
2	Sept. 7	Sept. 10	...do	62	71
3	Sept. 10	Sept. 17	...do	61	74
4	Aug. 6	Aug. 9	...do	58	69
5	Aug. 21	Aug. 24	...do	52	67

PHOTOTROPISM.

Adults of the tobacco beetle are accustomed to darkness or semi-darkness. Up to a certain degree of intensity they respond positively toward light, but they are negatively phototropic if the light is too intense. Observations made in tobacco warehouses and on beetles in specially constructed cages at the laboratory showed that they avoid intense sunlight, but toward sunset, or when the light intensity is lowered, they move toward the source of light.

REACTION TOWARD COLORED LIGHT.

Laboratory experiments made with apparatus which transmitted light through color screens or ray filters which made it practically monochromatic showed conclusively that the tobacco beetle, in common with other insects, reacts most strongly to colors of shortest wave length. The movement toward blue or blue-violet is most pronounced, and the movement toward red least of all. When a series of traps was operated with the light transmitted through color screens placed in regular order from red to violet the number of beetles attracted, in the majority of instances, increased in fairly regular order from red to violet. Experiments made with electric lights showed that the beetles were attracted toward a bulb of clear glass transmitting light rich in rays of short wave length, and scarcely at all toward a bulb of red glass, which transmitted rays of long wave length giving light at the lower or red end of the spectrum.

The adults, in common with other insects reacting negatively toward intense sunlight, are only slightly sensitive to light at the lower end of the spectrum, and rays of longer wave length, limited to red and orange, seem to act on them in much the same manner as darkness. Adults exposed to bright sunlight under color screens of red and blue were observed to collect under the red screen almost as readily as they did when an opaque screen was used in place of the red, although the apparent intensity of light under the two screens was the same. This shows a reaction directly opposite to that observed when the beetles, in darkness, are exposed to lights of low intensity.

EFFECT OF TEMPERATURE ON ACTIVITY OF ADULTS.

A series of laboratory experiments was conducted to ascertain the effect of ascending and descending temperatures on the activity of adults. Beetles were confined in the lower part of a long glass tube 20 millimeters in diameter. A thermometer was passed through an opening in the cork and the tube lowered into an inverted bell jar filled with water. A support was arranged in such a manner that the bell jar could be lowered into melting ice, or into a basin of water which could be heated gradually by an alcohol lamp underneath. By this means the temperature of the tube containing the beetles could be gradually raised or lowered as desired. In experiments with descending temperatures the beetles were taken from a lot reared in confinement and were kept at a constant temperature of 81° F. Those used in tests of rising temperatures were kept for a short time at 32° and were inactive when the experiment was commenced. Ten beetles were used in each test, a different lot being used each time. With increasing temperatures the beetles begin activity at temperatures between 48° and 75° F., one-half being active at 60° and 75 per cent at 64° F. With decreasing temperatures the beetles become inactive between 62° and 48° F., one-half being inactive at 56° and 75 per cent inactive at 55° F. In infested tobacco warehouses the adults are seldom found active at temperatures below 65° F. Activity increases as the temperature becomes higher. At temperatures between 117° and 120° F. all activity ceases, and temperatures above 117° F., if continued, result in death.

SEASONAL HISTORY.

SEASONAL ABUNDANCE AND NUMBER OF GENERATIONS.

Since the tobacco beetle is an indoor or stored-product insect, the terms "brood" and "generation" can hardly be applied in the sense that they are used in dealing with field insects, as the seasonal appearance and number of generations of such insects depend largely upon the variations in climatic conditions. In food substances maintained at constant warm temperatures adults may be found at any season of the year, and the wide variations in the time required for development under the same breeding conditions produce an overlapping of generations. Under ordinary conditions in warehouses there are, however, well-marked periods during which the adults are most abundant. At Key West and Tampa, Fla., most cigar manufacturers state that the adults are most abundant during the months of February and March, and again in August and September. At these places, however, the abundance of adults at any time may depend more upon the time the heaviest shipments of cigar tobacco from Cuba are received than upon local climatic conditions.

In the latitudes of Virginia and Tennessee there seems to be a period of greater abundance with the advent of the first warm weather in June, and again a marked increase occurs during September.

In tobacco warehouses at Clarksville, Tenn., adults usually begin to appear about May 1, and after November 1 comparatively few adults can be found. In unheated buildings three generations are possible between May 1 and November 1.

In the laboratory at Clarksville, Tenn., beetles were kept under observation continuously by Mr. S. E. Crumb during 1910–11. The rearing material was kept in a room heated only during the day during winter. Larvæ which constructed pupal cells in November, 1910, became adults May 18, 1911. These beetles deposited eggs about May 31, from which adults were obtained about July 29. These beetles deposited eggs August 13, from which adults were obtained on September 28. Eggs were obtained from these adults October 5. Larvæ from this lot of eggs constructed cells in which they passed the winter of 1911–12. This gives for the locality three distinct generations, emerging in the adult stage in May, July, and September. In localities farther south from three to six generations may occur, since under laboratory conditions at normal summer temperatures the entire life cycle was found to average 60 days.

At Richmond, Va., it was determined that three generations may occur under warehouse conditions. On October 14, 1913, eggs were placed in tobacco, and larvæ were found in cells in a dormant condition during December, which transformed the following spring. Adults collected from the lot May 5, 1914, deposited eggs on May 6–7. Adults reared from these eggs were obtained July 22, and eggs were laid about July 25. From these eggs adults were again obtained about October 2. Eggs deposited by beetles from this lot hatched October 18, the larvæ becoming dormant during the latter part of November. This shows that for this locality there are three complete life cycles, the adults appearing in May, July, and October, and that from the adults which emerge earliest there is a possibility of a fourth generation reaching the adult stage before winter.

In the Middle and Northern States, in warehouses and tobacco factories, a sudden appearance of large numbers of adults in spring or early summer is frequently observed. The greater number of larvæ which survive the winter complete their transformation and emerge in the adult stage with the advent of warm weather.

INSECTS LIKELY TO BE MISTAKEN FOR THE TOBACCO BEETLE.

Belief still prevails in many sections that the tobacco beetle is found on growing tobacco and that it continues to feed upon the tobacco after it has been cured. This impression is due perhaps to its slight resemblance to a smaller and very common insect, the tobacco flea-beetle (*Epitrix parvula* Fabricius) (fig. 8), which is abundant on growing tobacco in the field and in tobacco plant beds. Contrary to this belief the tobacco beetle (*Lasioderma serricorne*) does not attack growing tobacco and is not present in tobacco fields. It is not a field insect, but feeds and lives in dried substances, its more common food being cured tobacco. The habit of the tobacco flea-beetle of hopping when disturbed, its occurrence on growing tobacco, its smaller size, and its general appearance will serve readily to distinguish it from the tobacco beetle. Several species of insects which occasionally are found living or feeding in dried tobacco are likely to be mistaken for the tobacco beetle. These are enumerated below.

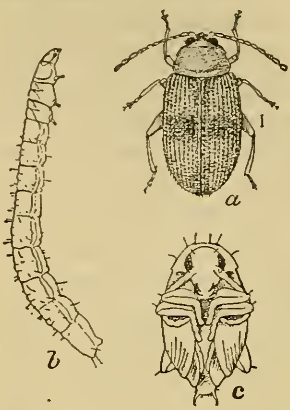
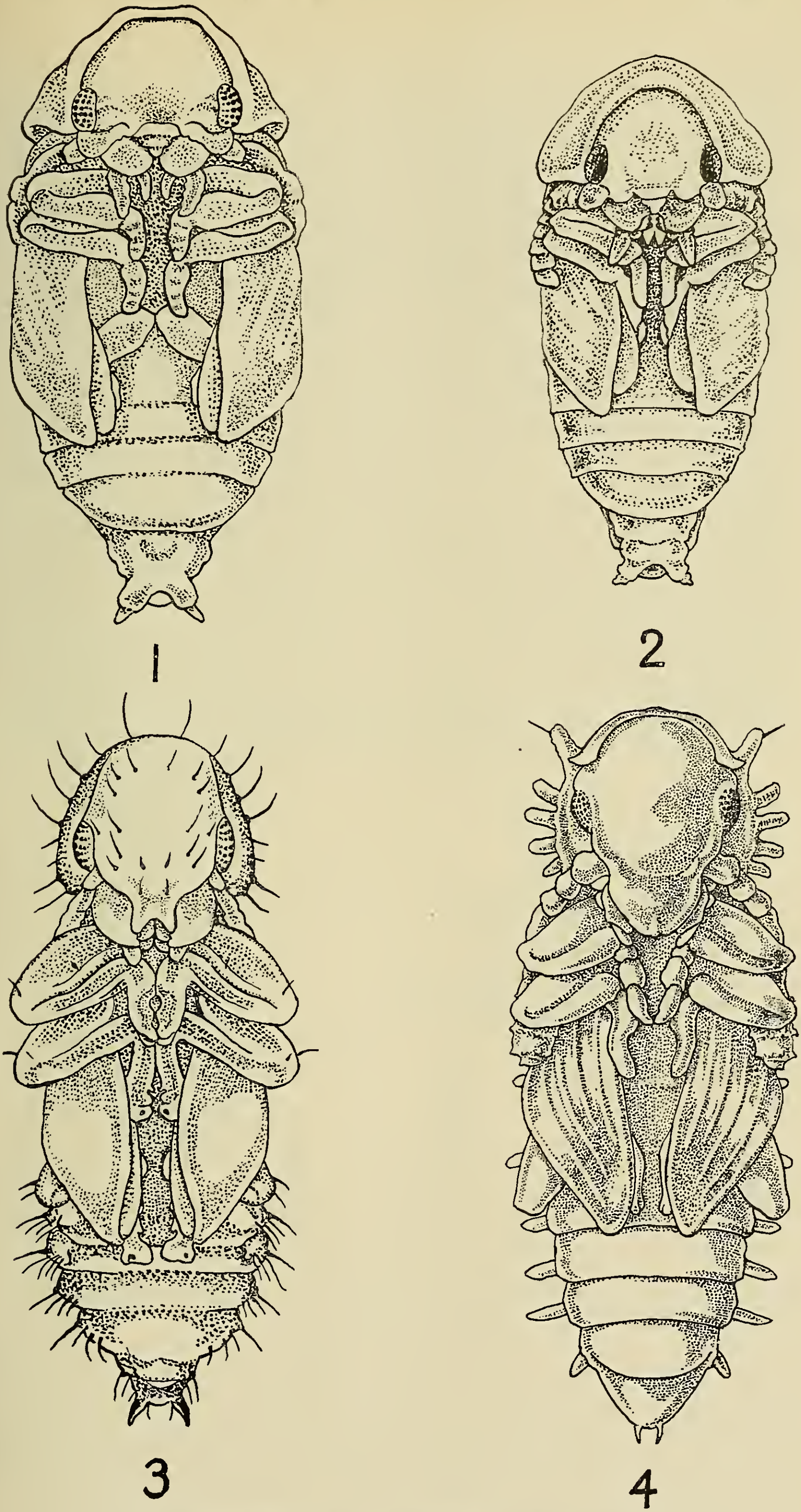


FIG. 8.—The tobacco flea-beetle (*Epitrix parvula*): *a*, Adult; *b*, larva, side view; *c*, pupa, from below. Enlarged. (Chittenden.)

A reddish-brown beetle (*Thaneroclerus girodi* Chevrolat), considerably larger than the tobacco beetle, often may be found in tobacco or in boxes of cigars. This species feeds on the different stages of the tobacco beetle. The adult, larva, and pupa stages are shown in Plate II, figure 3; Plate III, figure 5; and Plate IV. This insect is more fully discussed in the section dealing with the parasitic and predacious enemies of the tobacco beetle.

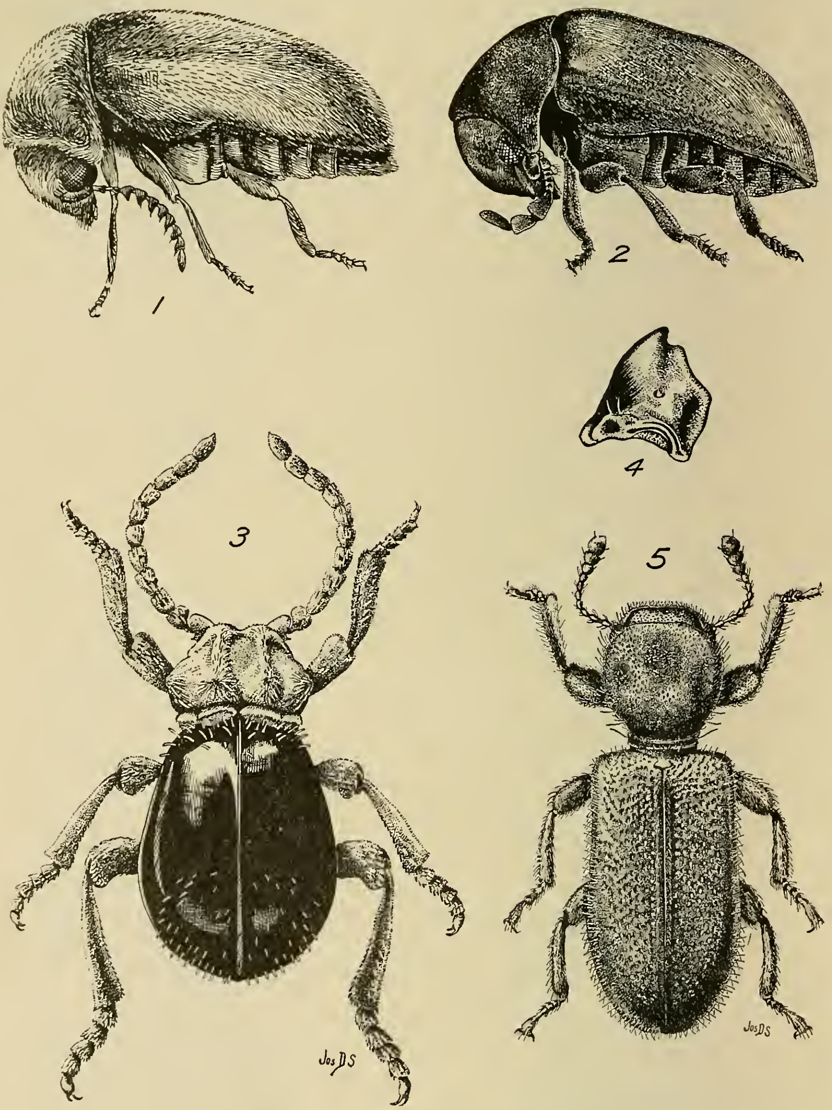
The larger tobacco beetle (*Catorama tabaci* Guérin) (Pl. II, fig. 1; Pl. III, figs. 2, 4; text figs. 9 and 10) attacks cured tobacco and tobacco seed in much the same manner as does the common tobacco or "cigarette" beetle (*Lasioderma serricorne*) and its larger size makes it still more destructive than is the common species. Cigar tobacco injured by *Catorama tabaci* is shown in figure 6. So far as known this species has been reported only from three localities in the United States. It was found in tobacco in this country for the first time in 1912. One of the leading cigar companies at Key West, Fla., reported the insect to the Bureau of Entomology and sent specimens collected in a shipment of cigar tobacco from Habana, Cuba. At about the same time a similar report accompanied by specimens was received from a cigar company located in Philadelphia, the beetles having been found also in a shipment of Habana tobacco. In the following year specimens of the Catorama were taken by Mr. A. C. Morgan of the Bureau of Entomology in bales of Habana tobacco which were being removed from a bonded warehouse at Key West, Fla., and also by the writer, in a bonded warehouse in Tampa, Fla. The records obtained indicate that the insect is native to Cuba. It was introduced into Paris, France, from Cuba and was first described by Guérin-Méneville (11) from the Paris importations in 1850, having been found in Habana cigars.

FIG. 9.—The larger tobacco beetle (*Catorama tabaci*): Antenna of adult. Greatly enlarged.



PUPÆ OF BEETLES THAT FREQUENT CURED TOBACCO.

FIG. 1.—The larger tobacco beetle (*Catorama tabaci*). FIG. 2.—The tobacco beetle (*Lasioderma serricorne*). FIG. 3.—*Thaneroclerus girodi*, a predatory enemy of the tobacco beetle. FIG. 4.—Saw-toothed grain beetle (*Silvanus surinamensis*). (Drawings by Joseph D. Smith.)



BEETLES THAT FREQUENT CURED TOBACCO.

FIG. 1.—The tobacco beetle (*Lasioderma serricorne*). FIG. 2.—The larger tobacco beetle (*Catorama tabaci*). FIG. 3.—*Mezium americanum*. FIG. 4.—*Catorama tabaci*: Left mandible of larva, dorsal view. FIG. 5.—*Thaneroclerus girodi*, a predacious enemy of the tobacco beetle (*Lasioderma serricorne*). (Drawings by Joseph D. Smith.)

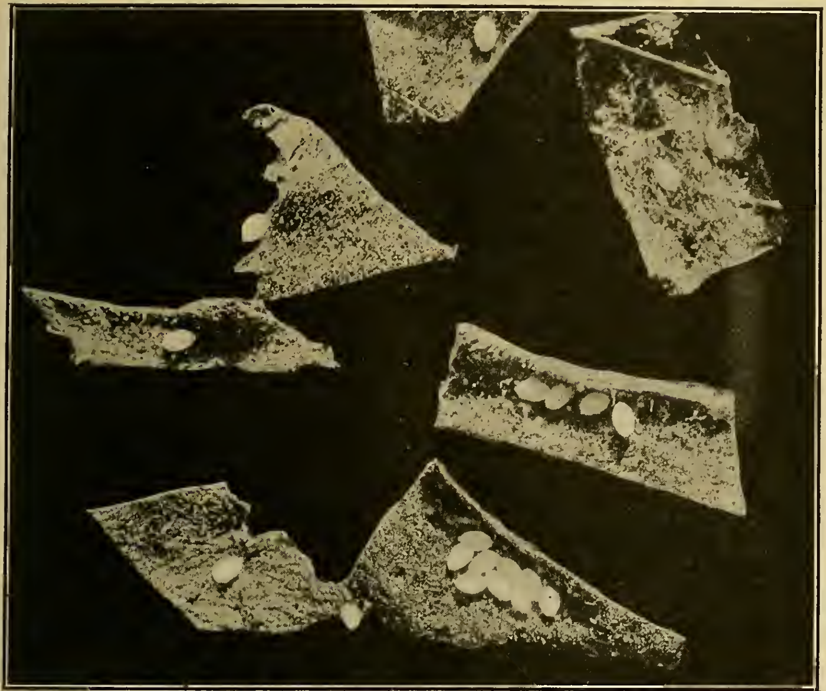


FIG. 10.—Eggs (enlarged) of the larger tobacco beetle (*Catorama tabaci*) on leaf tobacco.

Silvanus surinamensis Linnaeus and *Cathartus advena* Waltl are occasionally extremely abundant in tobacco warehouses, and the first-named species has been found to feed to a slight extent on tobacco and tobacco seed. The pupa of *S. surinamensis* is shown in Plate II, figure 4.

Jones (77) states that in the Philippines a species of Bostrychidae and the shot-hole borer of bamboo (*Dinoderus brevis* Horn) are abundant and often are mistaken for the tobacco beetle. Like other insects often found in tobacco, their occurrence, however, is purely accidental. Three other species of beetles have been recorded (43) as injuring cured and manufactured tobacco. These are the drugstore beetle (*Sitodrepa panicea* Linnaeus), the rice weevil (*Calandra oryza* Linnaeus), and the leather beetle (*Dermestes vulpinus* Fabricius). The first of these insects is similar in general appearance to the tobacco beetle and might be mistaken for it, but the form of antenna (fig. 11) serves to distinguish it from the tobacco beetle (fig. 7).

FIG. 11.—The drug-store beetle (*Sitodrepa panicea*): Antenna of adult. Greatly enlarged.

In addition to the insects already mentioned the following species have been found frequenting cured tobacco: *Trogoderma tarsale* Melsheimer, *Attagenus piceus* Olivier, *Tenebrioides mauritanica* Linnaeus, *Mezium americanum* Laporte. *Catorama impressifrons* Fall and *Attagenus piceus* Olivier have been recorded by Morgan (70) as infesting tobacco seed. *Mezium americanum* Laporte (Pl. III, fig. 3) has been found breeding in tobacco seed by Mr. S. E. Crumb of the Bureau of Entomology.

NATURAL CONTROL.

Numerous natural agencies are concerned in the control of the tobacco beetle. These forces, singly or combined, serve to keep the insect in check.

CLIMATIC CONTROL.

In the temperate zones, at least, the most important factor in holding the beetle in check is the cold of winter. Under ordinary conditions in cool climates their activities are confined to about one-half of the year. A comparatively small proportion of the insects survive the winter when exposed to even moderate cold if it is long continued, or to sudden abnormal changes of temperature. Severe freezing at temperatures lower than 10° F., if continued even for a short time, will result in extermination. At different times in order to determine the effect of exposure to variations of temperature in unheated buildings, heavily infested cans of smoking tobacco were wrapped in paper and kept over winter in various localities. The records obtained are as follows:

AT APPOMATOX, VA., WINTER OF 1910–11.

About 10 pounds of pressed plug and granulated smoking tobacco heavily infested were placed in original packages, in a large pasteboard box, wrapped with paper, and kept in an unheated room. A self-registering thermometer in the package showed that the lowest temperature reached was 11° F. Practically out-of-door conditions were experienced from December, 1910, until April, 1911. The beetles were exterminated. The tobacco was kept for several months but did not show signs of reinfestation.

AT RICHMOND, VA., WINTER OF 1913–14.

Two 5-pound packages of infested smoking tobacco were wrapped in paper. One package was placed in an unheated cellar, the other in a partly open building giving approximately out-of-door temperature variations. Both lots of tobacco were heavily infested. The exposure extended from November, 1913, until March, 1914. A self-registering thermometer in the open building showed the lowest temperature to be 12° F., and this temperature was reached several times during the winter. The lowest point reached in the cellar was not determined, but the protection afforded gave somewhat higher temperatures than obtained in the open building. On examination in March a very few live larvæ were found in the tobacco kept in the cellar. The tobacco in the open building was completely sterilized. The package was sealed and kept under observation until June, 1914, but no live stages of the beetles were found.

AT OAK HARBOR, OHIO, WINTER OF 1914–15.

A package prepared at Richmond, Va., contained about 5 pounds of heavily infested smoking tobacco, part pressed or sliced plug and the rest granulated, and a package of infested cigars and cigarettes. About 1,000 eggs of the tobacco beetle had been placed in the smoking tobacco November 1, 1914. This was mailed on November 14 to Oak Harbor, Ohio, where it was placed in an unheated building on November 17. It was examined June 10, 1915. No live stages of the beetle were found. The lowest temperature registered in the building was 10° F.

AT CLARKSVILLE, TENN., WINTER OF 1915–16.

About 10 pounds of smoking tobacco wrapped in paper were kept over winter in an unheated room in the laboratory. The tobacco contained all stages of the beetle. On November 1, 1915, about 1,000 eggs of the beetle were placed in the tobacco. These eggs hatched about November 10. No record was secured of the lowest temperature in the room. The lowest record out of doors was 5° F. The tobacco was examined during April, 1916. No live stages of the beetle were found. Although the tobacco was kept under observation for several months no signs of infestation were observed.

Evidence of the effect of freezing on the tobacco beetle has been observed on numerous occasions and it is not uncommon to find leaf tobacco or other food substances which have been exposed to low temperatures completely free from the beetle although its condition showed that it had been heavily infested previously. It has been the experience of those familiar with the tobacco industry that beetles always become more abundant and destructive after a mild winter.

DRYING OUT OF FOOD SUBSTANCES.

The tobacco beetle thrives best in tobacco that is protected from rapid evaporation and when the humidity is high. If the tobacco remains very dry for a considerable length of time the rate of multiplication is largely checked. In all cases observed in rearing experiments, the insects failed to develop properly if the food substance became too dry or if the larvæ or pupæ were not protected from excessive evaporation.

MOLD IN FOOD SUBSTANCES.

The growth of mold in the food substance usually results in the complete extermination of the beetle. This has been obse.. in many instances. It is often owing to this fact that infestation from damaged or worthless products does not extend to uninfested products near by.

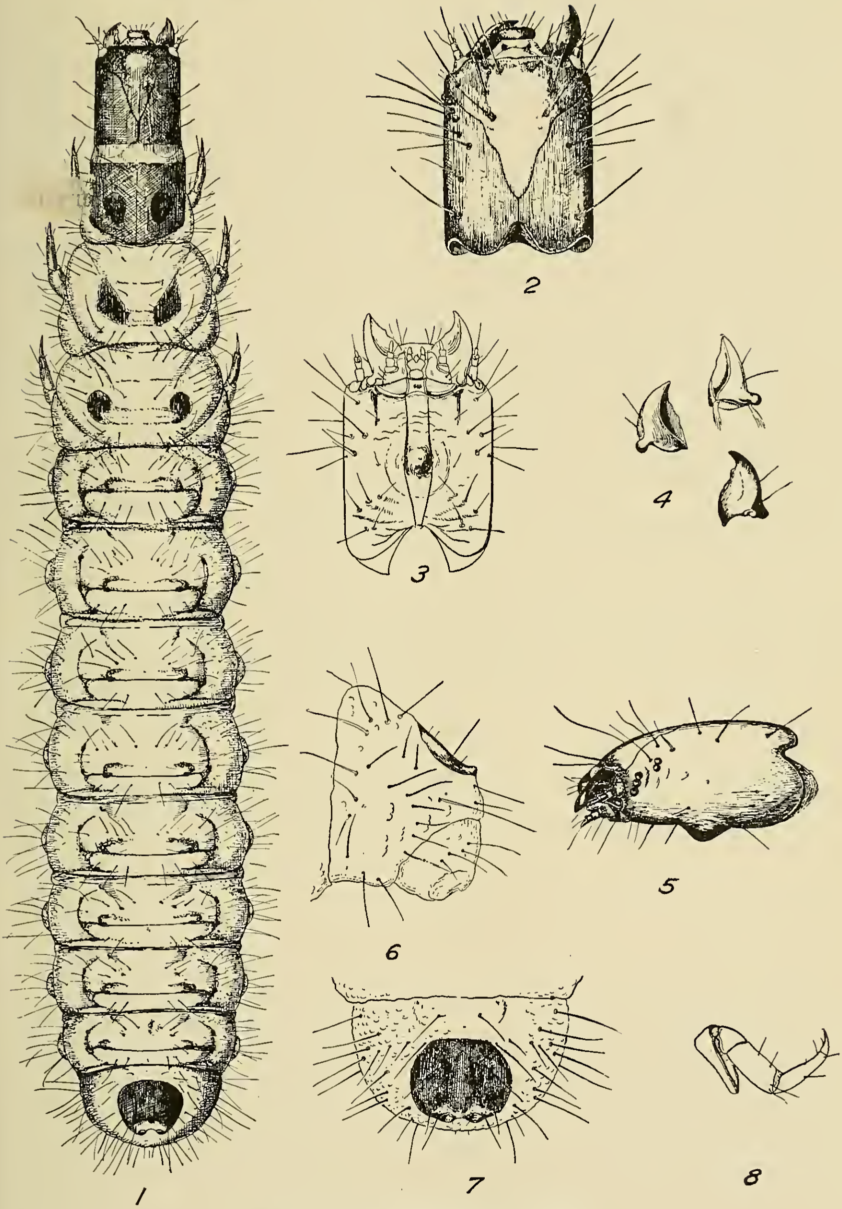
INSECT ENEMIES.

Several species of insects have been found to destroy the tobacco beetle and some of these appear to be widely distributed. While both predatory and parasitic insects are important factors in the repression of the tobacco beetle, the insect still is able to maintain itself successfully in all localities where it has become established.

Predacious Insects.

THANEROCLERUS GIRODI Chevrolat.

Among predatory enemies of the tobacco beetle the most important, so far as is known, is the clerid beetle *Thaneroclerus girodi* Chevrolat (Pl. II, fig. 3; Pl. III, fig. 5; Pl. IV). This beetle was found in unusually large numbers at Key West, Fla., and is a very important factor at that cigar-manufacturing center in keeping the tobacco beetle in check. It was first found in the United States by Dr. W. D. Hunter and Mr. A. C. Morgan, of the Bureau of Entomology, at Key West, Fla., in April, 1912 (78). Specimens of the beetle were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. The insect has since been found by the writer to be more or less common, but much less abundant, at Tampa, St. Petersburg, Jacksonville, and Quincy, Fla., and was found in tobacco stored in a tobacco barn at Tallahassee, Fla., in 1914 by Mr. J. R. Watson, State entomologist of Florida. Specimens were also located at Richmond, Va., in a package of smoking tobacco infested with the tobacco beetle, which had been returned to the manufacturers from Galveston, Tex. Mr. John Wardlow, of Key West, Fla., stated that he had observed the beetle frequently in the bales of cigar tobacco imported from Habana, Cuba. Among Cuban cigar makers the insect seems to be well known. They state that it is common in cigar factories in Habana, where it is called the "bicho grande" or "big bug" to distinguish it from the smaller species, the tobacco beetle (*Lasioderma serricorne*), upon which it



LARVA OF THANEROCLERUS GIRODI.

FIG. 1.—Dorsal view of body. FIG. 2.—Dorsal view of head. FIG. 3.—Ventral view of head. FIG 4.—Views of mandible. FIG. 5.—Side view of head. FIG. 6.—Lateral view of ninth and tenth abdominal segments. FIG. 7.—Dorsal view of ninth abdominal segment. FIG. 8.—Leg. (Drawings by Adam G. Böving.)

feeds. Jones (77) has described the habits of an undetermined clerid beetle which, he states, feeds in both the larva and adult stages upon the tobacco beetle in the Philippines. The drawings of the different stages of the clerid, given by Jones, show it to be either *Thaneroclerus girodi* or a very closely related species. Wolcott (72) records its presence in the United States.

The insect is new to the fauna of the United States and there is, in addition to the foregoing records, only a single reference to it in entomological literature, this being the original description by Chevrolate (18).

The Adult.

The adult (Pl. III, fig. 5) is a reddish-brown beetle about 6 mm. in length. The wing covers and thorax are pitted and somewhat pubescent. The indentations are smaller and somewhat more regular on the thorax than on the elytra. The original description by Chevrolat (18) is as follows:

Thaneroclerus Girodi.—Long. 6 mill.; lat. 2–1/3 mill. Elongatus, sanguineus, pilosus creberrime punctulatus; capite magno convexo, antice semicircuiter emarginato et crassiusculo; mandibulis nigris; antennis elongatis, art. 2 primis funiculi a equalibus modice elongatis, clava 3 articulata; prothorace minute et crebre punctulato, medio depresso et anguste sulcato; scutello rotunde transverso, longitudine sulcato; elytris in medio depressis; pedibus pallidioribus.

The following descriptions of the egg and pupa stages were prepared by Mr. S. E. Crumb from specimens collected at Quincy, Fla., in 1913. Dr. Adam G. Böving has drawn up the technical description of the larva.

The Egg.

Egg elliptical oval, faintly yellowish, 1.2 mm. long and 0.38 mm. broad at middle, membranous, without apparent sculpture, bearing on one side about one-third from the larger end two small, short, distant bristles.

The Larva.[1]

(Pl. IV.)

General characters.

Ventral side of epicranium continued horizontally behind posterior end of hypostoma and its tentorial pits; gula a rectangular plate between ventral margins of epicranium; occiput vertical. Mouthparts prognathous; labrum and clypeus present; antenna three-jointed; mandible without molar part, with simple apex and deep groove along cutting edge; ventral mouthparts not retracted; maxillary cardo as large as stipes, only posterior half chitinized; maxillary palpiger present, carrying a three-jointed palp; lacinia bilobed, extending from distal end of stipes; submentum well defined, in front of gular plate; no maxillary articulating area; mentum freely projecting; stipes labialis with well developed palpiger, two-jointed palp, and ligula; buccal cavity with a pair of small, widely separated, bidentate, hypopharyngeal chitinizations and a pair of flat, rounded, pharyngeal plates. Tentorium represented by a

[1] The descriptions of the larva, with figures (Pl. IV), are by Dr. Adam G. Böving.

pair of thin membranous rods, attached near antennal ring; no hypopharyngeal bracon. Body orthosomatic, elongate, fleshy. Legs five-jointed, with clawlike tarsal joints, no claws; thoracic prehypopleural and posthypopleural parts present and chitinized. Prothorax with large subsellate tergal shield; presternites rounded, paired; prebasisternum and basisternum covered by an unpaired, median, longitudinal, lanceolate chitinization; no sternellum; poststernellum well developed. Mesothorax and metathorax with large, poorly defined prescutum; on each side of scuto-scutellar region a small, rounded chitinization, larger on mesothorax than on metathorax; no median epipleural lobe; large triangular postepipleural arm; preepipleural arm united with the presternite into a fleshy, subtriangular spiracle-bearing region reaching ventrally the spina of the prothoracic poststernellum; no definite sternellum; poststernellum present on mesothorax, absent on metathorax. Abdomen with ten segments; prescutal area faintly indicated; dorsal parts of scutum and scutellum on several segments developed as feeble ampullatory lobes; postscutellum narrow, bandlike; epipleurum well developed with preëpipleural and postepipleural arms and a median epipleural lobe; ventral side with parasternum anteriorly limited by a straight line, in front of which there is no longitudinal muscle impression; ninth abdominal segment with a dorsal chitinous plate; tenth abdominal segment fleshy, wart-shaped, with five small lobes encircling the anus. Spiracles annuliform-bifore; the developed thoracic spiracles plainly mesothoracic; the rudimentary thoracic spiracle metathoracic; eighth abdominal spiracles present.

GENERIC AND SPECIFIC CHARACTERS.

Head elongate, with parallel sides, frons not reaching the occipital foramen; epicranial suture present; ocelli five, three in anterior, two in a posterior vertical line; gular plate with a large median, unpaired projection; cutting edge of mandible slightly sinuate; prothoracic shield as wide as head. Cerci rudimentary.

LARVAL INSTARS.

Last-instar larva 7 mm. long; body enlarging slightly posteriorly, pink, set with long, weak, pale yellowish-brown hairs; chitinous parts dark fuscous; head approximately 0.7 mm. broad and about twice as long; shield of ninth segment transversely oval.

The Pupa.

(Pl. II, fig. 3.)

Pupa pink to reddish, about 5 mm. long and 1.5 mm. broad; head beneath prothorax, prothorax broadly oval dorsally, eight tubercles on margin of anterior half, the most anterior pair forming a trapezoidal figure with two bristles posterior to them. Behind these two bristles and forming an arc with the adjacent marginal bristles are three equidistant transverse rows of bristles and on the posterior margin is a median group of four. Tubercles subconical and set with long, weak, yellowish-brown bristles. Antennal joints apically bearing large angular tubercles. Tip of abdomen bearing dorso-laterally a pair of curved divergent horns and apically a pair of conical fleshy appendages each apparently composed of three segments.

Notes on Habits and Life History.

To the description given by Chevrolat a brief note is added, of which the following is a translation:

This insect, peculiar to Cuba, has been found by Girod in cases of injured tobacco (injured presumably by the cigarette beetle) and was given tc me by M. Ant. Grouvelle. It is likely to be predacious upon the larvæ and perfect insects of the genus Catorama.

As the tobacco beetle, *Lasioderma serricorne*, was formerly included in the genus Catorama, the surmise made by Chevrolat concerning the food habits of the clerid has been found correct. Studies of the life history of the insect were made by the writer at Key West, Fla., in 1912. At temperatures varying from 80° to 90° F. the period of incubation was found to average about nine days. The eggs were laid singly as a rule, but sometimes were found in groups of two and three. Eggs usually were found in the burrows in cigars formed by the tobacco beetle. The largest number secured from a single female was 18 eggs. Pupation required from five to eight days, the average pupal period being about seven days. Pupation may take place in any secluded locality. The greater number of pupæ were found in holes in infested cigars. The larval periods as observed from three specimens were 42, 51, and 62 days respectively. From the development of a number of partly grown larvæ kept for about 30 days the larval period is thought to correspond closely to that of larvæ of its host. the tobacco beetle, the exact length of the period varying with temperature conditions and the abundance of food. Adults kept in tubes with cigars did not bore into the wrapper, but holes already made by the tobacco beetle were considerably enlarged. Adults of *Thanerocler us girodi* feed on the larva, pupa, and adult stages and on dead adults of *Lasioderma serricorne*, as well as on dead adults of their own species. The larvæ of the predacious beetle feed on eggs, larvæ, and pupæ of Lasioderma. Both larvæ and adults are cannibalistic when deprived of other food, this habit enabling the species to survive for a considerable length of time after all the Lasioderma obtainable have been devoured. When other food can not be obtained, these predacious larvæ feed upon the eggs, larvæ, and pupæ, and the predacious adults on the eggs, larvæ, and pupæ of their own species. The abundance of these beetles at times doubtless accounts for the complete disappearance of the tobacco beetle in boxes of damaged cigars, so often noticed in certain cigar factories.

Parasitic Insects.

Several species of hymenopterous parasites of the tobacco beetle have been recorded. Some of these are extremely abundant in infested leaf tobacco in warehouses and are without doubt important in natural control.

Aplestomorpha pratti Crawford is one of the more common species and has been found in various localities from Richmond, Va., southward to Key West, Fla.

Aplestomorpha vandinei Tucker was found abundant in a tobacco warehouse at Clarksville, Tenn. Specimens of this parasite were collected by Mr. J. U. Gilmore, of the Bureau of Entomology, and placed with larvæ of the tobacco beetle, from which specimens of the parasite were reared later. The egg and also the larval period was found to be six days, and the pupal period about 7 days. The larvæ were observed to feed externally on both larva and pupa stages of the tobacco beetle. Specimens were determined by Mr. A. A. Girault, of the Bureau of Entomology. Fullaway (79) records an undetermined species of Pteromalus reared from the tobacco beetle in Hawaii. Jones (77), in the Philippines, describes and figures *Norbanus* sp., which attacks larvæ and pupæ of the tobacco beetle while in the pupal cells.

Catolaccus anthonomi Ashmead has been recorded as a parasite of *Lasioderma serricorne* (43), but Mr. J. C. Crawford considers this an error. The original specimen can not be found.

OTHER ENEMIES.

Various species of mites are found frequently in tobacco, and some of these have been found to feed on eggs of the tobacco beetle. At

FIG. 12.—Cigars showing work of a jointed spider (Order Solpugida). Holes torn by the solpugid in order to reach larvæ or pupæ of the tobacco beetle (*Lasioderma serricorne*) within the cigar.

Tampa, Fla., considerable difficulty was experienced in keeping eggs used in experimental work from being destroyed by the mites. Specimens of these were examined by Mr. Nathan Banks, then of the Bureau of Entomology, and found to be a species of Cheyletus. The larva form of a mite belonging to this genus was observed to insert its beak into the eggs of the tobacco beetle, remaining in this position for some time, and leaving the eggs more or less collapsed. The adult females of this species were observed to stand guard over their own eggs, which were deposited in clusters and kept underneath the female. The clusters contained from 20 to 30 eggs. A mite belonging to the family Eupodidae, genus Rhagidia, has been recorded as attacking the tobacco beetle in all stages except the adult, in the Philippines (77). It is not uncommon to find mites of the genus Tyroglyphus feeding on dead larvæ and pupæ of the tobacco beetle. It is probable that live stages of the tobacco beetle are not attacked and that the mites present in these instances are merely acting as scavengers.

At Key West, Fla., a species of jointed spider of the order Solpugida and a small arachnid belonging to the order Pseudoscorpiones were found by the writer to destroy larvæ of the tobacco beetle. While these arachnids may destroy a considerable number of beetles and do no particular damage to the leaf tobacco, the work of the solpugid in cigars would hardly be considered beneficial, as the cigars are badly torn by the spider in its efforts to dig out the larvæ. The nature of this injury is shown in figure 12.

REMEDIAL MEASURES.

COLD STORAGE.

A readily available and effective means of treating infested tobacco is found in the modern cold-storage plant. This treatment has been used to a considerable extent, but usually the temperatures in operation have the effect of suspending insect activity rather than of causing death. The beetles become inactive at temperatures below 65° F., and the storage of infested materials at temperatures between 32° and 65° F. prevents further damage as long as the material is held in storage. When lower temperatures are available a more satisfactory and effective method, although somewhat more expensive, is to subject the tobacco for a week or more to the lowest temperature that can be obtained. Cigars or manufactured tobacco should either be removed from cold storage when the air is dry, to prevent "sweating," or the temperature should be raised gradually before removal. Air-tight receptacles for holding the cigars or tobacco and an atmosphere as dry as can possibly be secured are desirable when the cold-storage method is used. If the material is removed when the air is damp the condensation of moisture may cause the boxes to be discolored or develop mold in the tobacco or cigars.

A large number of cigars in boxes, placed in cold storage, were kept under observation by the writer. These cigars were not put in sealed containers but were merely placed in piles on the floor of the cold-storage room. They were removed when the air outside was dry and cool, put under presses in a dry room, and left for a time to prevent warping of the boxes. The treatment proved thoroughly effective in sterilizing the cigars, and the manufacturer reported that no injury was apparent. Different lots were kept at a temperature of about 12° F. for from one to four weeks.

Although there are certain objections to the method, such as loosening the wrappers of fine cigars by sudden changes in temperature, danger of injury from "sweating" on removal from cold storage, and injury to quality from too rapid aging, it has certain advantages and in some cases may be found more desirable than other methods of treatment. When care is taken to prevent "sweating," it is evident that the exposure of manufactured or leaf tobacco in cold storage is not more apt to produce injury than would be the exposure of the same material to low temperatures during the winter.

In determining the effect of cold-storage temperatures upon different stages of the tobacco beetle, experiments were conducted during 1913 and 1914 at Richmond, Va. The temperatures available for most of the experiments ranged from 12° to 16° F. At the laboratory an automatically regulated incubator heated by an electric current was used in rearing the beetles for experimental work and for holding the material used in the tests after it had been removed from the cold-storage room. By this means the proper temperature and degree of moisture favorable for the development of different stages of the beetle could be kept constant. A large quantity of infested manufactured tobacco of different kinds was secured from dealers and manufacturers. In many of the experiments the exposure to cold was made with the tobacco in original packages. Tobacco found slightly infested was kept in the incubator and eggs or other stages of the beetle placed in it until the degree of infestation desired for the experiments was obtained. Experiments were made with eggs on the tobacco or cigars on which they had been deposited, and also, for convenience in making examinations, with the eggs in glass-covered cells on microscope slides.

The results of some of the experiments made by the writer during 1913, and by Mr. S. E. Crumb and the writer during 1914, are given in Table IV.

TABLE IV.—*Effect of cold storage on the tobacco beetle (Lasioderma serricorne). Experiments at Richmond, Va., 1913–14.*

Temperature.		Humidity (relative).		Exposure.		Stages alive.			Stages dead.			Success of Experiment.	Material used.
Minimum.	Maximum.	Minimum.	Maximum.	Days.	Hours.	Adults.	Pupæ.	Larvæ.	Adults.	Pupæ.	Larvæ.		
° F.	° F.	Per cent	Per cent										
11	12	....	....	4	....	....	0	0	....	All.	All.	Completely effective........	Sliced plug smoking tobacco.
11	12	86	86	5	....	0	0	0	All.	All.	All.	.....do........	1 box smoking tobacco.
14	16	87	89	4	....	0	0	0	All.	All.	All.	.....do........	4 boxes granulated smoking tobacco.
14	16	84	86	5	....	0	0	0	All.	All.	All.	.....do........	Sliced plug smoking tobacco.
14	14	89	89	....	3.16	4	....	23	....	10	11	Partially effective........	Cut-plug smoking tobacco heavily infested. Exposure made in original boxes. Tobacco undisturbed. Examined two days after exposure.
14	14	86	86	....	10	....	×	×	....	×	×	.....do........	1-pound can badly infested smoking tobacco.
14	16	87	89	1	....	0	0	Few.	×	×	×	Partially effective; eggs shrunken.	1 box granulated smoking tobacco. 20 eggs in glass cell placed within the tobacco.
14	16	87	89	1	....	....	....	15	....	....	60	Partially effective........	1 box sliced plug smoking tobacco.
14	16	87	89	2	....	0	0	3	12	11	18	Partially effective; eggs shrunken.	1 box sliced plug smoking tobacco. Eggs on leaf tobacco placed in same box.
15	16	89	89	....	21	....	....	×	....	....	×	Partially effective........	Badly infested sliced plug smoking tobacco in original packages. Examined 5 days after exposure.
16	16	....	....	4	....	0	0	3	×	×	×	.....do........	5-pound lot granulated smoking tobacco wrapped in paper.
16	16	86	86	....	23	....	....	Few.	....	....	×	.....do........	Infested smoking tobacco (pressed) in sealed glass jars.
16	17	....	....	3	....	0	0	6	9	11	26	.....do........	2 packages infested sliced plug smoking tobacco.
16	17	87	87	....	3	0	....	×	×	....	×	.....do........	Larvæ and adults in cut plug tobacco placed in sealed glass jars. Examined 1 day after exposure.
16	42	35	35	1	....	0	3	31	100	97	69	.....do........	Granulated smoking tobacco. Examined 2 days after exposure.
17	17	87	87	....	1½	×	×	×	×	×	×	.....do........	Infested cut plug tobacco. Box not wrapped.

Most of the tests recorded in Table IV were made with the different stages of the beetle in smoking tobacco. In this series the time of exposure to cold varied from 1½ hours to 5 days. The treatment did not prove completely effective on all stages of the beetle at temperatures between 14° and 16° F. with exposures under 5 days. In all experiments under the same conditions exposures of over 5 days gave satisfactory results, all stages of the beetle in various classes of manufactured tobacco being killed. At temperatures below 20° F. the time of exposure in a long series of tests varied from 1½ hours to 56 days. Experiments with infested tobacco exposed for 56 days at temperatures between 33° and 40° F. were not entirely satisfactory, a few larvæ remaining alive. For short exposures it was found that results depended largely upon the insulation afforded by wrapping and upon the quantity of material used. Larvæ within the cells were found to be more resistant to cold than other stages of the insect. After treatment the material used in the experiments was placed in an incubator and kept for some time under observation at a constant temperature of 86° F.

Six additional experiments were made with cigars that were heavily infested. The boxes were wrapped with paper and kept in cold storage in sealed metal containers. The temperature varied from 12° to 20° F., but was fairly constant at 14° F. The time of exposure was 7 days for three experiments, 21 days for one experiment, and 31 days for two experiments. All stages of the beetle, including large numbers of eggs, were present in five lots of cigars. In the experiment in which the time for exposure was 21 days two boxes of 25 cigars each, in which large numbers of newly hatched larvæ had been placed, were used. In all the experiments the treatment proved completely effective. The boxes were kept under suitable rearing conditions at the Richmond laboratory for several months and no reinfestation developed.

At a temperature of approximately 14° F., three separate tests were made with cigarettes. Three boxes containing 100 cigarettes each, heavily infested with adults, larvæ, and pupæ, were utilized, the duration of the experiments being 14, 15, and 42 days respectively. In each lot all stages of the beetle were killed. In another series of experiments 30 separate tests were made with various quantities and classes of manufactured tobacco. The temperature of the cold-storage room was fairly constant, approximating 14°F., the variations during the entire period being from 12° to 18° F., and the relative humidity ranging from 84 to 90 per cent. In these as well as other experiments temperature and humidity records were obtained by means of a self-recording thermograph and hygrograph. Part of the material was exposed in air-tight containers and part exposed in the original containers, not sealed, or in paper-wrapped packages.

The amount of material varied from a few ounces of tobacco up to 20 pounds of loose tobacco or tobacco refuse, and the time of treatment varied from 1½ hours to 30 days. Exposures of over 5 days, in all experiments, gave satisfactory results, the tobacco being completely sterilized. A bale of infested cigar tobacco kept in cold storage for 28 days under the conditions mentioned above at a temperature of approximately 14° F. was found to have been completely freed from all stages of the beetle.

EFFECT OF COLD STORAGE ON EGGS OF THE TOBACCO BEETLE.

A large number of separate experiments were made with eggs of the tobacco beetle to determine the effect of low temperatures in cold storage. In these experiments eggs were placed in cigars and exposed at temperatures ranging from 12° to 20° F., the length of exposure varying from 24 hours to 16 days. All boxes of cigars were wrapped with paper. After removal from cold storage the material was placed in an incubator and kept at a constant temperature of 86° F. with humidity from 80 to 90 per cent. The checks were kept in the same incubator until the period of incubation had passed. In these experiments none of the eggs exposed to cold hatched, while hatching of the check lots was normal.

In another series eggs on leaf tobacco or in cells on microscope slides were exposed. Exposures to cold were made without special protection such as ordinarily is afforded by the food substance of the insect. Other conditions of the experiments were practically the same as described in the preceding series. The time of treatment ranged from 5 hours to 7 days, with temperatures varying from 14° to 18° F. In most experiments in which the time of exposures was shorter than 24 hours, the temperature was constant at 14° F. Exposures of less than 24 hours did not give satisfactory results, as all or part of the eggs hatched in most of the experiments. In experiments in which the duration of treatment was more than 24 hours all eggs were killed.

EFFECT OF REFRIGERATION ON QUALITY OF MANUFACTURED TOBACCO.

In order to determine whether or not cold storage seriously injures manufactured tobacco, cigars, cigarettes, and smoking and chewing tobacco were placed in cold storage for periods ranging from 30 to 50 days. The stock used for the experiment was fresh and in good condition. An exact duplicate of each brand was kept for the same period, in perfect condition, in the humidor or storage room at a cigar store. Part of the material put in cold storage was in sealed metal containers and part merely wrapped with paper in order to avoid sweating which ordinarily would occur upon removal from cold storage. When removed from cold storage it was placed in a dry room for several hours, then placed in the humidor or storage room at the cigar store with the control or check packages. At frequent intervals the treated tobacco was compared with check tobacco by Mr. J. M. Holt, a tobacco expert of Richmond, Va., and the writer. The tobacco put in cold storage seemed in perfect condition in every respect, and could not be distinguished from that which had been kept at the cigar store.

ALTERNATIONS OF HEAT AND COLD.

The alternation of a low temperature with a comparatively high temperature is apparently more effective on the tobacco beetle than is a single exposure to cold. During the course of cold-storage investigations at Richmond, Va., in 1914, two lots of badly infested smoking tobacco were put in cold storage for 2 days at temperatures ranging from 14° to 16° F. Lot A was not removed from the storage room, whereas at the end of 24 hours lot B was removed and kept in a warm room for 24 hours, then put back in cold storage for a further period of 24 hours. On March 22, 2 days after treatment, both lots were examined and no live stages of the beetle were found in lot B. In lot A about 90 per cent of the different stages were dead. The tobacco used in the experiments was kept until August 28, 1914, and upon examination lot A was found heavily infested whereas lot B was uninfested.

HIGH TEMPERATURES.

EXPERIMENTS WITH DRY HEAT AS A MEANS OF STERILIZING TOBACCO—TESTS IN TOBACCO FACTORIES.

Two series of tests were made, one at Richmond, Va., in a factory where smoking tobacco is manufactured, and the other at New Providence, Tenn., in a factory in which special processes are used in the preparation of leaf tobacco for export to Africa.

Excellent facilities were secured for determining the effect of high temperatures on different stages of the beetle, and for determining to what extent the tobacco is sterilized by the various processes of manufacture. It was found that in these factories the temperatures reached were sufficiently high to kill all stages of the beetle, reinfestation depending on methods of handling, packing, or storing the manufactured product.

At Richmond, Va. (May, 1915), large numbers of eggs of the tobacco beetle on leaf tobacco and in cells on microscope slides, pupæ, adults, and newly hatched and mature larvæ were placed in boxes of granulated smoking tobacco and passed during the regular course of manufacture through the drying processses in use in a large factory where smoking tobacco is manufactured. All stages of the beetle were destroyed. In one of the driers a temperature of 180°F. was reached, which is sufficiently high to sterilize the tobacco quickly and effectively.

In the New Providence factory the leaf tobacco, after treatment with vaseline, is compressed into packing cases, placed in drying rooms, and subjected to heat for some time. The maximum temperature reached was found to be about 150°F. This process is used for a certain grade of tobacco shipped to Africa and it is said that little or no damage has ever been reported from mold or insect injury. In the experiments made (Oct. 20–24, 1915) by Mr. A. C. Morgan and the writer to determine the effect of the heating process in destroying the different stages of the tobacco beetle, infested tobacco was placed in the heating room and a continuous record of the temperature obtained by means of a self-recording thermograph. Humidity records were taken at the beginning and close of each experiment. Part of the eggs used were on leaf tobacco on which they had been deposited, and part in cells on microscope slides, and control lots were kept for each of the different stages. In all of the controls development was normal, but it was found that the temperature reached in the heating room resulted in killing all stages of the beetle. The details of several of the experiments are given in Table V.

TABLE V.—*Effect of heat on different stages of the tobacco beetle (Lasioderma serricorne). Experiments at New Providence, Tenn., 1915.*

Stage of insect.				Relative humidity.	Temperature.		Time of exposure.	Results.	Remarks.
Eggs.	Larvæ.	Pupæ.	Adults.		Min.	Max.			
				Percent.	*°F.*	*°F.*	*Hours.*		
105	41	8	51	38–40	97	140	24	All stages killed.	Eggs 4 and 5 days old.
114	10	10	75	38–49	101	138	48	......do......	Eggs 1 day old.
32	42	10	28	38–49	93	140	72	......do......	Eggs 1 to 5 days old.

EFFECT OF HIGH TEMPERATURES ON DIFFERENT STAGES OF THE TOBACCO BEETLE—LABORATORY EXPERIMENTS.

At Clarksville, Tenn. (1916), numerous laboratory experiments were conducted to determine the effect of high temperatures. The incubators or ovens used in making the tests were fitted with water jackets which permitted exposures to be made without much variation in temperature. The different lots were kept with suitable food in sealed glass tubes for a considerable time after exposure. The eggs used were on leaf tobacco or in cells on microscope slides. Controls were kept corresponding to the different stages. It was found that adults and larvæ become inactive after a few minutes exposure to heat above 117° F., but recover if the temperature is not kept higher than 120° F. for a considerable length of time. An exposure of 1 hour at 140° F. killed all stages of the beetle in small quantities of tobacco but it was found that both larvæ and pupæ are more resistant to heat while in the cells formed before pupation, the cells serving as a protection. The results of several of the experiments are given in Table VI.

TABLE VI.—*Effect of high temperatures on the tobacco beetle.—Laboratory experiments at Clarksville, Tenn., 1916.*

Stage of insect.	Exposure.	Temperature.		Results.	Remarks.
		Min.	Max.		
	Hours.	*°F.*	*°F.*		
Larvæ	1	110	115	Not effective	In leaf tobacco.
Adults and larvæ	1	110	115	do	In cigar.
Adults	1	117	120	do	Became inactive, but recovered after treatment.
Adults and larvæ	1	128	130	do	Part of each stage killed; remainder recovered.
Eggs	1	128	131	Effective	None of eggs hatched. Check eggs hatched normally. Eggs 1 day old.
All stages	2	130	140	do	Eggs on leaf tobacco.
Eggs	½	138	140	do	In cigars.
Larvæ	½	138	140	do	Do.
Larvæ and pupæ	1	138	140	do	In yeast cake and tobacco.
All stages	1	144	145	do	In leaf tobacco.
Do	¾	146	150	do	Do.
Do	½	158	164	do	Eggs on leaf tobacco.
Do	1	158	165	do	Do.
Do	¼	180	181	do	Do.

In these tests only a small quantity of the food substance was used. The time required for treatment will therefore depend on the amount and character of the food substance and the insulation furnished by the container or wrapping material. The results of the numerous tests made show that comparatively mild heat, if long continued, is sufficient to kill all stages of the beetle. The temperatures found effective are in no way injurious to certain classes of tobacco, which in many cases are subjected to a much higher degree of heat in the process of manufacture.

STERILIZING TOBACCO WAREHOUSES BY MEANS OF STEAM.

At Quincy, Fla., in July, 1913, an experiment was conducted by Mr. D. C. Parman, of this bureau, and the writer in a large warehouse. It is the custom of the managers to clean up and sterilize the warehouses as far as possible, usually by fumigation, before the new crop is brought in. The warehouse used for the experiment was empty and the owners wished to ascertain to what extent steam could be employed.

Two tests were made, one in which the room was heated by turning the steam into radiators, and one in which the entire basement of the building was heated by admitting the live steam direct from the boiler. Evaporation during the experiment was about 75 gallons per hour.

The experiment in the room fitted with radiators was commenced on July 7, the temperature of the room being 85° F. Steam was turned on at 2 p. m.[1] All stages of the tobacco beetle were used in the experiment and were placed in cans of smoking and chewing tobacco in the middle of the room. Controls were kept for each lot. At 3.30 p. m. the temperature reached 100° F., and at 4.30 p. m. 117° F. This temperature was held until 6 p. m. and then gradually lessened until 7 a. m., July 8, when it registered 89° F. The steam was again turned on and the temperature gradually increased until, at 10 a. m., it registered 138° F. This temperature was held until noon, when the experiment was ended. At different times some of the material was taken out and the boxes labeled and kept for later examination. Tobacco exposed for 2½ hours at temperatures between 100° and 117° F. when examined on July 8 was found to contain live adults, pupæ, and larvæ. In all material kept in the room during the entire time, and which had been subjected to a temperature of 138° F. for 2 hours, all stages of the beetle were killed. In this experiment the air was dry. A hygrometer at 6 p. m. registered about 35° F.

In the second experiment the entire basement of the building was heated by live steam which was admitted directly through four half-inch nozzles. Three nozzles were fitted to the main steam pipe extending through the basement from end to end, and one nozzle fitted to the return pipe. Records of temperature were secured by means of self-recording thermometers placed in or near the packages of infested tobacco, which were divided into several lots and placed in different parts of the basement. The tobacco used in the experiment was badly infested with all stages of the beetle. The experiment was commenced at noon. The outside temperature in the shade was 92° F. A boiler pressure of 40 pounds was kept until noon of the following day, July 9, when the fire under the boiler was allowed to die out gradually to avoid too sudden cooling of the walls of the building. The tobacco used in the experiment was taken to Tampa, Fla., and kept under observation until July 15. The results were as follows: At temperatures under 114° F., with exposures of 6, 12, and 18 hours, results were practically negative. Exposure at temperatures between 118° and 130° F. for 24 hours killed part of the different stages, but was not entirely effective. Mate-

[1] All references to clock time refer to standard time.

rial was effectively sterilized when exposed for 24 hours in a part of the building where a temperature of 137° F. was reached, and all stages of the beetle were killed.

The tests made show that under certain conditions steam may be used to advantage in sterilizing empty warehouses, as much higher temperatures could easily be obtained than were reached in the experiments. Dry heat, secured by fitting the building or storage room with sufficient radiating surface, would, of course, be the most practical means of heating, as steam turned directly into a room for some time might cause injury to the building by expansion of beams from moisture and heat combined.

Other experiments have shown that temperatures of from 130° to 150° F. result in the death of all stages of the tobacco beetle, and it is probable that very little if any damage to most grades of tobacco would follow. In cleaning storage rooms, etc., live steam or hot water applied through a flexible pipe fitted with a nozzle can often be used to advantage in destroying the insects in refuse or dust in crevices in the floor or walls.

The expense of steaming in the foregoing experiment for 24 hours amounted to $15.20, as follows:

Engineer, 2 days @ $4 per day	$8.00
Fireman, 2 days @ $1 per day	2.00
Fuel	4.50
Water	.70

The expense of fumigating the same space (108,000 cubic feet) with hydrocyanic-acid gas would have amounted to about $75, or with carbon disulphid $60, these estimates being based on prices of chemicals used for fumigation at the time of the experiment.

USE OF STEAM AS A MEANS OF STERILIZING INFESTED TOBACCO.

Although steam furnishes, under some circumstances, an effective and convenient method of sterilizing storerooms or warehouses there are numerous difficulties which prevent its use in sterilizing infested tobacco. Leaf tobacco becomes more brittle if exposed to steam at high temperatures for any length of time, the texture and aroma are changed, and the color becomes darker. In spite of the general objection against steaming, however, there seems to be considerable evidence that mild steaming may be used to advantage in treating certain classes of cigar tobacco. In the application of steam the principal requisite is that the tobacco does not become too wet, and that unnecessarily high temperatures are avoided.

A method of treating cigar tobacco in revolving steam drums has been tested in the Philippines (77). Steam was applied for 20 minutes at a pressure of about 4 atmospheres, the temperature ranging from 140° to 194° F. The treatment was said to be thoroughly effective in killing all stages of the beetle, and cigars made from the steamed tobacco were pronounced indistinguishable from those made from unsteamed tobacco, the only apparent damage in any instance being that steaming the wrapper tobacco made it darker and somewhat more brittle.

EFFECT OF STEAM ON DIFFERENT STAGES OF THE BEETLE—LABORATORY EXPERIMENTS.

At Richmond, Va. (January, 1915), tests were made to ascertain the effect of steaming various classes of tobacco infested with the beetle. Steam under pressure was admitted directly into a tightly closed fumigating drum. Temperature records were obtained by inserting a chemical thermometer through a cork in the lid of the drum. The eggs used were on bits of leaf tobacco. Examinations of the treated eggs were made after the controls had hatched. All tobacco containing other stages of the beetle was put in seperate jars and sealed after treatment. Each lot was kept under observation for several months. The results of the experiments may be briefly summarized. Thirty-minute exposures at 115°F. gave practically negative results. All stages of the beetle were killed by the following exposures: 20 minutes at 160° and 165°F.; 30 minutes at 163°F.; 1 hour at 138° and 150°F.; 40 minutes at 140°F.

ULTRA-VIOLET RAYS.

At the request of a firm manufacturing apparatus for ultra-violet sterilization of water, a series of experiments were made to ascertain the effect of ultra-violet rays on different stages of the tobacco beetle and to determine whether or not the process could be successfully used in sterilizing tobacco. Apparatus for the work was installed at the laboratory at Clarksville, Tenn., the equipment consisting of a mercury arc rectifier for transformation of 110-volt, 60-cycle alternating current to 110-volt direct current, and 2 quartz mercury arc burners operated on direct current at 110 volts and consuming 3.5 amperes. The quartz mercury vapor burners, or lamps, were of different types: One was operated at a voltage of 66–67, consuming 3.3 amperes of current, and the other at a voltage of 70–75, consuming 3 amperes of current.[1] To avoid any effect of heat, all exposures were made with the material in a quartz glass container under distilled water kept at normal room temperatures (quartz glass and chemically pure water are transparent to the ultra-violet rays). In experiments with eggs of the tobacco beetle 3 lots were used in each test, arranged as follows: (*a*) Eggs on upper side of leaf tobacco, (*b*) eggs on under-

[1] The burners were operated under a hood to protect the eyes of the operator from injury, and glasses were worn as an additional precaution.

side of leaf tobacco, (*c*) eggs under glass cover. A check was kept for each experiment. It was found that with eggs exposed directly to the rays, without covering as under arrangement (*a*), at a distance of about 8 inches from the quartz mercury arc, an exposure even as short as 30 seconds was effective in sterilizing eggs under two days old. As has been found with Röntgen-ray radiation, the further embryonic development has advanced, the more resistant the eggs become, and longer exposures are required for their successful sterilization. Eggs exposed on the underside of the leaf, arrangement (*b*), and those under a cover of ordinary glass, arrangement (*c*), hatched normally. Ordinary glass has the property of transmitting ultra-violet rays only to a slight degree, its transmission being approximately only one one-thousandth that of quartz glass. It was found that a screen over the eggs, even of the thinnest glass such as is used for cover glasses on microscope slides, was sufficient to protect them completely from the effect of ultra-violet rays. These exposures served as an additional check on the results obtained from direct exposures to the rays. The experiments with the eggs on the underside of the leaf showed that the ultra-violet rays would not penetrate even the thinnest leaf of cured tobacco. This fact makes it impracticable to apply the method in treating infested tobacco.

Although eggs of the tobacco beetle when exposed directly to the ultra-violet rays can be quickly and effectively sterilized, experiments made so far do not indicate that other stages of the beetle are destroyed by the same exposure. Treated larvæ and pupæ completed transformations to the adult stage, and treated adults laid fertile eggs and died off at a normal rate. The effect of more intense radiation or of prolonged exposure of adults, pupæ, and larvæ has not been determined.

In order successfully to treat leaf tobacco containing eggs, it has been suggested that in preparing the leaf for use it might be possible to devise means for smoothing out the leaves and thus make more powerful exposures of ultra-violet rays from all sides while the tobacco passes through an exposure chamber containing the lamps. As it would be extremely difficult, or perhaps impossible, by any mechanical means, to smooth out completely all the creases or wrinkles in the leaf tobacco, and as the rays do not penetrate opaque substances like tobacco, the method, in the opinion of the writer, is not likely to prove entirely effective or practicable, as the eggs of the tobacco beetle ordinarily are deposited in wrinkles of the leaf. The results obtained from several of the experiments with ultra-violet rays are briefly summarized in Table VII.

TABLE VII.—*Effect of exposure of stages of the tobacco beetle (Lasioderma serricorne) to ultra-violet rays. Experiments at Clarksville, Tenn., 1916.*

Date.	Stage of insect.	Age of eggs.	Current.	Voltage.	Exposure.		Results.		
					Distance from mercury vapor arc.	Time.	Eggs on upper side of leaf; exposure direct.	Eggs on underside of leaf.	Eggs under glass cover.
1916.		*Days.*	*Amp.*		*Inches.*	*Min.*			
July 20	Eggs	1	3.3	66–67	8	½	None hatched	All hatched	All hatched.
Aug. 11	do	1–2	3.3	66–67	7.5	½	do	do	Do.
Do	do	4–5	3.3	66–67	8	½	Nearly all hatched.	Hatching normal.	Hatching normal.
July 20	do	3	3	70–75	7.5	5	None hatched	do	Do.
July 21	do	2	3.3	66–67	8	10	do	do	Do.
July 24	do	4	3	70–75	8	45	do	do	Do.
July 20	All stages	1–3	3.3	66–67	7.5	8	Exposed directly to rays. Eggs sterilized. No effect apparent on other stages.		
July 24	Adults and eggs.	2–3	3	70–75	8	5	Exposed directly to the rays. Eggs sterilized. No apparent effect on adults. Fertile eggs deposited after exposure.		

TRAPPING.

ATTRACTION TO LEAF TOBACCO.

In cigar factories it has often been noticed that the adult beetles collect on hands of leaf tobacco suspended for the purpose of ascertaining the humidity. Eggs in large numbers frequently can be found on the leaves, and in the rooms where cigars are made or handled young larvæ from these eggs may easily find their way to the cigars. Numerous experiments were made by liberating large numbers of the beetles in a closed room in which hands of leaf tobacco had been suspended about the walls. It was found that a large proportion of the beetles collected on the tobacco. This habit of the insect suggests the possibility, where conditions permit, of trapping the adults in this manner. The tobacco could be collected at frequent intervals and the eggs and beetles killed by heating or fumigating the leaves, and then replaced; thus, instead of being a source of infestation, this tobacco would to a large extent protect the cigars or other material in the room. The method is said to have been tested in a cigar factory in the Philippines and to have shown excellent results (78).

TRAP LIGHTS.

The movement of adults toward light has been discussed under "Phototropism" (p. 25). Specially constructed trap lights may often be used to advantage in factories or warehouses, and a large number of the beetles destroyed. A very efficient trap can be made quickly and easily by pinning together sheets of sticky fly paper in the form of a cylinder and suspending it around an electric light. The trap is more effective if the sheets of fly paper are pinned so that the surface on both the inside and outside of the cylinder is sticky. Traps of this type operated in a large tobacco warehouse were under observation for some time and were found to destroy large numbers of beetles (fig. 13). Another form of trap consists of a large globe, such as is used for street lights, placed over a funnel, the lower part of the spout of the funnel opening into a cyanid jar in which the beetles are killed. An electric-light bulb can be used in the globe, or a trap light of the same type can be operated with acetylene or other light. Another method of destroying the beetles consists of placing shallow pans of oil underneath the lights. A heavy odorless oil is best for this purpose in case leaf tobacco, which may take up odors of kerosene or other oils, is stored near by. The traps fitted with cylinders of fly paper will perhaps be found best adapted to most conditions. While adults fly more readily toward blue or blue-violet light than toward red or orange, colored light bulbs or colored screens cut down the intensity of a source of light. Ordinary electric-light bulbs of clear glass of the nitrogen-filled and other types which transmit lights rich in rays of short wave length have been found well adapted to trapping.

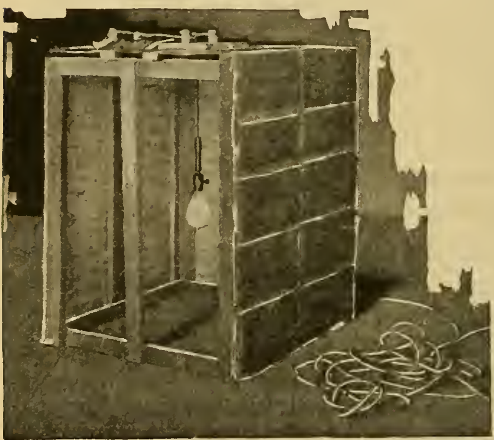


FIG. 13.—Arrangement for using sticky fly paper in collecting adults of the tobacco beetle in warehouses.

Sex of beetles collected at light.—A sheet of sticky fly paper which had been suspended around an electric light in a tobacco warehouse at Danville, Va., in July, 1911, was examined by Mr. S. E. Crumb. Of 100 beetles that were removed and dissected, 36 were males and 64 females. Four females contained, respectively, 2, 2, 17, and 22 mature eggs. Seventeen females contained immature eggs, half developed or more, as follows: 2, 2, 2, 2, 3, 3, 4, 5, 6, 7, 7, 8, 10, 10, 11, 12, and 36. Forty-three females were without eggs. Approximately 32 per cent of the females contained eggs and 68 per cent of the females did not.

COLLECTING AT WINDOWS.

As the light becomes dim in late afternoon in infested warehouses or factories the adult tobacco beetles fly to the windows, often collecting in large numbers on the glass and casings. The beetles may be easily destroyed at such times by brushing them down into pans of water or oil, or onto sheets of sticky fly paper. In a tobacco warehouse visited by the writer the owners make it part of the regular duties of the watchman to visit each window in the building where the beetles collect and sweep them down on sheets of fly paper spread out on the window sills. Immense numbers of the beetles are destroyed in this way at very little cost.

COLLECTING BEETLES BY SUCTION.

The use of suction fans operated at lights for collecting the beetles in warehouses has been reported. There has been no opportunity to

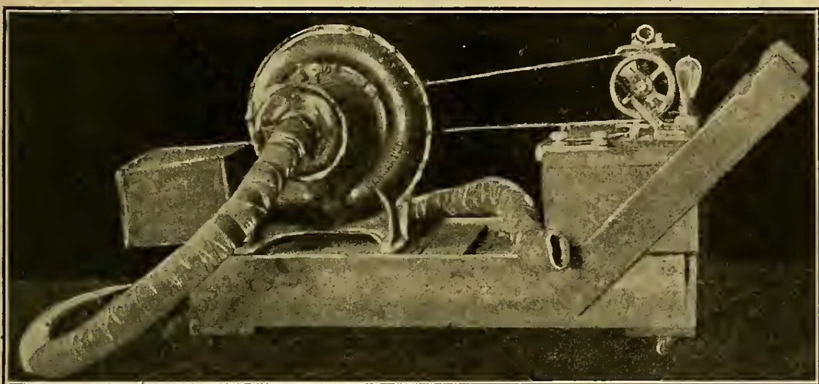


FIG. 14.—Suction fan used for collecting adults of the tobacco beetle in a tobacco warehouse.

test this method. The use of vacuum cleaners operated by electric current might possibly prove to be an effective method of collecting beetles at the windows of warehouses. At Lancaster, Pa., a suction fan was used in one of the large tobacco warehouses. Beetles could be readily drawn from cracks in the building and from about windows, and large numbers were said to have been collected in a short time on several occasions. A photograph of the apparatus used is shown in figure 14.

OTHER REMEDIES.

EXPOSURE TO VACUUM.

In 1912, a series of experiments were made at Clarksville, Tenn., by Mr. A. C. Morgan and the writer to ascertain the effect of treating infested tobacco in vacuum. With the apparatus used, a vacuum of about 28.5 inches could be readily obtained. When the air in the vacuum chamber was exhausted the beetles became inactive, but after exposures varying from 1 to 24 hours they again became active when normal air pressure was restored. In some of the experiments a few adults were killed. The eggs hatched normally after exposure. While the experiments with vacuum apparatus alone from a practical standpoint gave negative results it has been found that the process may be employed in connection with the fumigation of infested tobacco (fig. 15).

SEALED CONTAINERS FOR MANUFACTURED TOBACCO.

Investigations of factory conditions show that during the process of manufacture tobacco is, in many cases, thoroughly sterilized by heat. In one factory, in which experiments with different stages of the beetle were conducted, the tobacco was subjected to a temperature of 180° F. as it passed through the driers. This degree of heat has been found to destroy all stages of the beetle quickly, and is sufficiently high to sterilize tobacco thoroughly under any ordinary conditions. Tobacco may become infested before it leaves the factory, but it is evident from the usual condition of the tobacco which is returned with complaints of infestation, and from the time required for development of the beetle, that much of this tobacco becomes infested after it leaves the factory.

It is not unusual to find badly infested material in wholesale and retail establishments in the same room used for storing fresh stock. The grubs or larvæ of the tobacco beetle are very minute when hatched, and at this stage are most active and readily find their way through small openings in the boxes or containers. In containers sealed perfectly tight at the factory it is very unusual to find the tobacco injured.

In order to determine whether or not newly hatched larvæ could find their way into uninfested boxes used by different firms for packing smoking tobacco, experiments were made at Richmond, Va., and at Tampa, Fla. The boxes of tobacco were thoroughly sterilized by heat and then put in sealed jars in which eggs of the tobacco beetle were placed at frequent intervals. The boxes were sufficiently tight to exclude partly grown larvæ and the adult beetles, but all showed openings along the edge of the cover and at the hinge of the lid large enough to admit newly hatched larvæ. In the experiments 16 boxes were used and of these 12 boxes became infested after a time whereas none of the control boxes showed the least sign of infestation. In other experiments it was found that some of the larvæ hatching from eggs placed in empty boxes of the same kind escaped through even the smallest openings along the edges of the cover or at the hinges of the boxes.

CASING CIGAR TOBACCO IN A DECOCTION OF TOBACCO STEMS.

Soaking tobacco stems in water from 12 to 24 hours gives a solution which is said to hasten fermentation of leaf tobacco. Several cigar manufacturers, both in this country and in Cuba, have reported that when this solution was used in casing stripped tobacco there was in some cases a noticeable decrease in the number of infested cigars. It was suggested that the quicker and higher fermentation destroys some of the eggs or other stages of the beetle and that the solution may have a toxic effect when applied externally. No exact data have been secured as to the efficiency of the remedy.

USE OF COLD WATER IN CASING CIGAR TOBACCO.

Several cigar manufacturers have reported some success in preventing infestation of finished cigars by casing the leaf in cold water and thoroughly shaking out the tobacco before it is used.

BORIC ACID.

Boric acid has been used as a remedy for the tobacco beetle, but to what extent and with what success is not known. In a letter received by the Bureau of Entomology in 1909 from an importer of leaf tobacco in Boston, Mass., reference is made to the use of this remedy in Cuba, it being stated that a 5 per cent solution of boric acid [$B(OH_3)$] used in the water in which tobacco is cased before packing will prevent the tobacco from becoming wormy. The effect of boric acid on the quality of the tobacco has not been determined, but it is probable that no serious injury would occur if used in as dilute a solution as described. Both boric acid and borax are known to have some insecticidal value, and the treatment of manure piles with borax has proved effective against the larvæ of the house fly.[1]

While preliminary tests made with boric acid indicate that it has a toxic effect on larvæ of the tobacco beetle, there has been no opportunity to make tests of the substance on cigar tobacco in the manner mentioned above, nor to determine whether or not the remedy has any practical value in preventing or controlling infestation.

PREVENTIVE MEASURES.

In cigar stores and comparatively small establishments it is not a difficult matter to eradicate the tobacco beetle. By means of different remedies, infested stock may be treated and the building thoroughly cleaned. The humidors, or storage closets, should be perfectly tight and infested stocks promptly destroyed or treated as soon as signs of infestation are noticed.

In large factories and tobacco warehouses, however, complete eradication in many instances is extremely difficult, or perhaps impossible. The factories are in some cases old wooden buildings, roughly built, and containing innumerable cracks and crevices in

[1] U. S. Dept. Agr. Buls. 118, 245, and 408.

which tobacco dust and refuse have accumulated. These places make ideal hiding and breeding places for the beetles. Even in modern factories of brick or concrete construction it is difficult to eradicate the insect completely after it has once become established, but it is very much easier to keep such buildings clean and free from accumulations of refuse in which the beetles may breed. The measures to be employed in eradication work in sterilizing buildings will depend largely on local conditions.

For destroying the different stages of the beetle in crevices of floors or walls, live steam applied through a nozzle from movable pipes or hose, hot water, gasoline, carbon disulphid, dilute ammonia, paradichlorobenzene, or other suitable substances may be used. Suction cleaners may also be employed to advantage for such work. In cigar factories the stock of leaf tobacco should be kept in a tight or screened room, located as far as possible from the rooms in which the cigars are made or handled. Trays of unsorted cigars should be covered or preferably kept overnight in a screened compartment, as eggs deposited on the cigars at this time may be the cause of heavy loss afterwards.

In sections of the country where severe freezing occurs in winter the doors and windows of warehouses or other buildings in which tobacco is stored may be thrown open and the tobacco subjected to low temperatures. This control measure has been employed by tobacco men in different localities, and when severe freezing weather occurred excellent results were reported.

OPEN STORAGE OF LEAF TOBACCO.

The modern method of storing leaf tobacco in hogsheads in specially constructed buildings or sheds, giving practically out-of-door conditions and variations of temperature, furnishes an effective means in cool climates of reducing or preventing injury from the beetle to the classes of leaf tobacco which may be stored in this manner.

SOURCES OF INFESTATION IN FACTORIES.

In cigar and tobacco factories the greater number of beetles are brought in with the leaf tobacco. Factories are in some instances in close proximity to tobacco warehouses where beetles are present in large numbers. A comparatively small number of beetles in a room in which cigars are made, however, or in rooms where the cigars or other classes of manufactured tobacco are packed, are sufficient to infest the stock seriously. The protection of the finished product before it is packed is generally of more importance than the condition of the raw material, as the process of manufacture wholly or partly frees it from different stages of the beetle which were present in raw material.

FUMIGATION.

Fumigation is now generally employed as a means of destroying certain classes of insects, and is a standard remedy against insects which damage stored products and those infesting mills and factories.

The tobacco beetle has been found to be exceedingly resistant to fumigants. Numerous experiments have shown that it is necessary to use much stronger dosages of fumigants in treatment of this beetle than are employed usually against other insects. The insulation afforded by the pupal cells and by the compactness of food substances seems to protect the contained larvæ or pupæ from the action of the fumigant. In many instances only a small percentage of the tobacco-beetle larvæ survives treatment, but adults transforming from these small numbers serve to reinfest tobacco if it is kept for any length of time.

The properties and characteristics of the various chemicals used for fumigation should be thoroughly understood in every particular by the operator in order that necessary precautions may be taken and the work properly done. The treatment is simple, however, easily applied, and fairly effective.

Fumigation with Hydrocyanic-acid Gas.

In generating hydrocyanic-acid gas in fumigation sodium cyanid ($NaCN$), or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water are necessary. The hydrocyanic-acid gas, which is the killing agent, is produced by the action of the sulphuric acid (diluted with water) on the sodium or potassium cyanid. The cyanid is usually employed in the crystal form. It is now sold in molds weighing 1 ounce each. When small quantities are used, this form is best, as it avoids the trouble and danger of weighing. A high grade of cyanid should be used for fumigation, as the presence of adulterants greatly reduces the amount of hydrocyanic-acid gas evolved. Potassium cyanid should be guaranteed to be 98 or 99 per cent pure. A high grade of sodium cyanid should be used which is guaranteed to contain not less than 51 per cent cyanogen. Commercial sulphuric acid, sp. gr. 1.84 or 66° Baumé, which is approximately 93 per cent pure, is commonly used for fumigation.

DANGER ATTENDING USE.

Hydrocyanic-acid gas and the chemicals employed to produce it are extremely dangerous, and as hydrocyanic-acid gas is fatal to human beings if breathed in any quantity considerable care is necessary in its use. Sodium cyanid and potassium cyanid are violent and fatal poisons if taken internally, and sulphuric acid produces burns when coming in contact with the skin. When the chemicals are handled with care and all details of the method understood, however, there is no special danger and the method has been used in insect control for many years with few records of serious accidents.

EFFECT OF HYDROCYANIC-ACID GAS ON THE QUALITY OF TOBACCO.

Hydrocyanic-acid gas is slightly lighter than air and all traces of the gas are quickly removed from the tobacco by thorough airing. In order to determine whether or not any deposition of cyanogen in the cigars occurs as a result of the cyanid treatment different lots of freshly made cigars were fumigated at Key West, Fla., in 1912, and sent to the Bureau of Chemistry, United States Department of Agriculture, for examination. A list of the different lots of cigars sent is shown in Table VIII.

TABLE VIII.—*Effect of hydrocyanic-acid gas on quality of cigars. Fumigation tests at Key West, Fla.*

Date fumigated.	Cyanid of potash to 100 cubic feet of space.	Exposure.
1912.	*Ounces.*	*Hours.*
Apr. 20	8	24
May 4	8	24
May 10	4	48
May 29	4	24
June 8	8	36
June 14	8	24
June 18	8	24
Not fumigated. (Used as check on treated lots.)		

All lots of cigars were exposed to the air for a short time after fumigation, and then sealed. As the amount of potassium cyanid used was greater than is ordinarily employed in fumigation, the test was a severe one. The cigars were received by the Bureau of Chemistry on July 8. The following report was received on November 12, 1912, from Mr. R. E. Doolittle, acting chief of the Bureau of Chemistry: "We have made a careful examination of the eight samples of cigars submitted by you on July 8 last, and we are unable to detect the slightest trace of hydrocyanic acid in any of the samples."

Samples of cigars fumigated by the cyanid process and untreated cigars of the same brand were submitted to a number of expert cigar men at Key West, Fla., in order to ascertain if fumigation in any way affected the flavor or quality of the cigars. All reported that no difference between the treated and untreated cigars was apparent, the uniformity of burn, capacity for retaining a light, and color of ash appearing normal.

PREPARATIONS FOR FUMIGATION.

The fumigating closet or box should be perfectly tight to prevent escape of gas. In fumigating storage rooms or warehouses all openings should be closed and the windows and doors arranged so that they may be opened from the outside when the building is aired. *Do not enter the room until it is thoroughly aired.* The cubic contents of the closet, room, or box to be fumigated should be determined, so that the exact quantity of the different chemicals needed may be known. Food supplies that may be stored in the building should be removed, as moist foods, such as meats and vegetables or fruit, may absorb or retain the gas.

Care must be taken in fumigating large warehouses in close proximity to dwellings, as the liberation of a vast quantity of hydrocyanic-acid gas may endanger the persons within.

For generators use stoneware or crockery jars. They should be sufficiently deep that the liquid will not boil over when the gas is generated.

Hydrocyanic-acid gas is lighter than air. For this reason *place the generator underneath the material to be fumigated or on the floor of the room.* Whenever the room or building is of large size it is advisable to use two or more generators, limiting the amount of cyanid to 2 or 3 pounds in any one generating jar. The jars should be of small diameter in order that the cyanid may be completely covered by the acid and water.

PROCESS OF FUMIGATION.

The chemicals used in generating hydrocyanic-acid gas are placed in the generating jar in the following order: *First, water; then sulphuric acid; last, just before closing the fumigating closet or building, the cyanid.* Measure into the generating jar the proper amount of water, then add the acid slowly in the proper amount. Considerable heat will be developed by the addition of the acid, and for this reason it is best not to mix the water and acid until just before the cyanid is put in, as the heated liquid will act more quickly on the cyanid. The water and acid should be mixed as directed above. *Do not pour water into acid.* Severe burns may result from the ebullition or sputtering of the liquids if the order of mixing the water and acid is reversed. The acid should be kept in glass-stoppered bottles. Cyanid should be kept tightly sealed, as it deteriorates rapidly when exposed to the air. For convenience the cyanid may be put into thin paper sacks and these dropped into the generating jar. This method is applicable if large dosages are used; if only a small quantity of the cyanid is required, however, it is not best to use a paper wrapper, as the generation of the gas is somewhat retarded. An enameled dipper has been found convenient in placing the cyanid in the generators. *The reaction of the chemicals is extremely rapid, and the generation of the deadly gas begins at once.* In fumigating large buildings, where a considerable number of generators are required, the operator should have several assistants. In such cases it is best to have the proper amount of cyanid in paper sacks placed beside the jars holding the acid and water. Begin dropping the cyanid in the jars farthest from the door first, going from one jar to the next as rapidly as possible.

TEMPERATURES FAVORABLE FOR EFFECTIVE FUMIGATION.

In using fumigants for the control of the tobacco beetle, best results have been secured in warm weather and at temperatures above 70° F. Under 60° or 65° F. the beetles are more or less dormant and while in this condition are considerably more resistant to the action of the gas.

DOSAGES TO USE.

Sodium cyanid (*NaCn*).—This substance when pure liberates nearly one-third more hydrocyanic-acid gas per pound than does potassium cyanid and at present it is more generally used for fumigation.

Sodium cyanid should be combined with acid and water to generate the hydrocyanic-acid gas according to the following formula:

Sodium cyanid (grade guaranteed to contain not less than 51 per cent cyanogen)	avoirdupois ounce	1
Sulphuric acid (commercial)	fluid ounces	1½
Water	fluid ounces	3

Use multiples of the formula given above to secure the dosage desired. Fumigate for 24 hours. The dosage to use will depend upon the penetration required. For general use 4 ounces of the cyanid to 100 cubic feet will be found satisfactory. (This dosage requires 4 ounces of the cyanid, 6 fluid ounces of acid, and 12 fluid ounces of water.) For baled or closely packed tobaccos a somewhat heavier dosage may be used, or the time of exposure increased. An increase of the amount of cyanid above 4 ounces per 100 cubic feet, however, has not greatly increased the effectiveness of the treatment in many instances.

Potassium cyanid.—Should potassium cyanid be used in place of the sodium cyanid, it should be combined with the sulphuric acid and water according to the following formula:

Potassium cyanid (98–99 per cent)	avoirdupois ounce	1
Sulphuric acid (commercial)	fluid ounce	1
Water	fluid ounces	3

For every 100 cubic feet of space use multiples of this formula to secure the dosage desired. The dosage used may be the same as with sodium cyanid. It will be noted that the amount of acid required with potassium cyanid is less than with sodium cyanid.

In using either potassium cyanid or sodium cyanid for fumigating, a greater amount of water than that given in the formulas should not be used, as any quantity of water above 3 fluid ounces for each ounce of cyanid results in a smaller yield of hydrocyanic-acid gas.

In preparing chemicals for fumigation the cyanid is *weighed*, and the acid and water are *measured*. The time of exposure has been found to be an important factor in fumigation and it is not advisable to make the time less than 24 hours, unless the vacuum process of fumigating is employed. A comparatively small dosage with a long exposure appears to be as effective as is a heavier dosage with a shorter exposure.

SUMMARY OF RESULTS OF FUMIGATION EXPERIMENTS.

A brief summary of the average results obtained in a series of 34 fumigating experiments with material infested by the tobacco beetle follows. Different dosages of sodium cyanid varying from 1 to 8 ounces per 100 cubic feet of space were used. The time of treatment was 24 hours. The tests were made during July, August, and September, the maximum temperatures varying from 82° to 92° F. and the minimum temperatures from 42° to 72° F. All stages of the beetle in leaf tobacco, in different classes of manufactured tobacco, and in pressed yeast cake, were utilized. Part of the eggs, for convenience in making examinations, were placed in cells on microscope slides, and part were located on the original leaf tobacco on which they had been deposited. The eggs used were from 1 to 6 days old. Multiples of the 1–1½–3 formula were used with the sodium cyanid. The results obtained with different dosages were as follows:

Dosage 1 ounce per 100 cubic feet of space.—In three experiments only a few eggs hatched. In these embryonic development was nearly complete at the time of treatment. Newly hatched larvæ were nearly all killed, about 4 per cent in dense tobacco survived, and of the other stages, including adults, pupæ, and fully developed larvæ, about 22.3 per cent survived treatment.

Dosage 1.5 ounces per 100 cubic feet of space.—In four experiments eggs and newly hatched larvæ were killed. Approximately 21 per cent of other stages survived treatment. The adults remaining alive were mainly those which had not emerged from the pupal cells.

Dosage 2 ounces per 100 cubic feet.—This treatment destroyed eggs and newly hatched larvæ. In four experiments 18.6 per cent of the other stages survived.

Dosage 2.5 ounces per 100 cubic feet.—This gave somewhat better results. In one experiment all stages were killed. In three experiments all unprotected adults and newly hatched larvæ were killed. Of the other stages approximately 11.8 per cent survived.

Dosage 3 ounces per 100 cubic feet.—In four experiments this gave practically the same results as the 2½-ounce dosage.

Dosage 4 ounces per 100 cubic feet.—In six experiments this dosage killed eggs, newly hatched larvæ, and practically all unprotected stages. Approximately 9 per cent of the larvæ, pupæ, and adult stages within the pupal cells survived treatment. In one of the six experiments all stages were killed.

Dosage 6 ounces per 100 cubic feet.—Practically the same results were shown in five experiments with the 6-ounce dosage. Eggs, newly hatched larvæ, and unprotected adults were killed. About 9.4 per cent of the other stages, mainly mature larvæ protected by dense substances or by the pupal cells, survived. In two of the five experiments all stages were killed.

Dosage 8 ounces per 100 cubic feet.—In four experiments with an 8-ounce dosage about 10 per cent of the protected stages survived. All adults which had emerged from the pupal cells and all eggs, newly hatched larvæ, and unprotected larvæ and pupæ were killed. In one experiment all stages were killed.

The results obtained in other experiments made by Mr. Joseph Smith and the writer at Clarksville, Tenn., with both sodium cyanid and potassium cyanid in amounts from 1 ounce up to 8 ounces per 100 cubic feet did not differ materially from those obtained with sodium cyanid in the series described. With both substances, in many instances, an increased dosage above 4 ounces per 100 cubic feet did not show a very decided increase in effectiveness, possibly due to the inability of the gas to penetrate dense food substances or pupal cells.

DOUBLE FUMIGATION.

Fumigation under most circumstances has not been found entirely effective in sterilizing tobacco, as a few of the insects in either the larva, pupa, or adult stage, protected by the pupal cells or by dense food substances, are apt to survive. In comparatively few of the experiments were the beetles completely exterminated. While a single treatment may be fairly satisfactory, since the few live stages left will require considerable time to increase to sufficient numbers to reinfest the tobacco badly, it is desirable under some circumstances to give a second treatment later in order to destroy the beetles remaining after the first treatment. This can be accomplished easily after the beetles have emerged from the pupal cell. With tobacco kept at ordinary room or summer temperatures the second fumigation should be given about two or three weeks after the first treatment, as by this time most of the beetles will have emerged from the cells, and the adults, eggs, or newly hatched larvæ then present can be easily destroyed by fumigation. In two of the experiments already referred to, a second treatment was given 12 days later, resulting in the complete extermination of the beetles. Similar results were secured in several experiments not included in the series of tests described.

FUMIGATING IN A VACUUM.

In cooperation with the Federal Horticultural Board, a series of experiments was conducted at Washington, D. C., to determine the

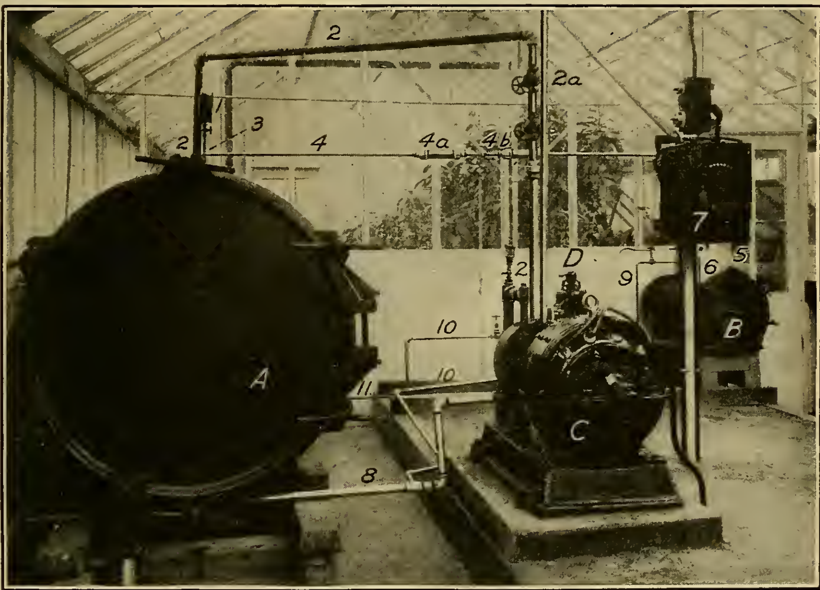


Fig. 15.—Apparatus used for fumigating in partial vacuum.

effects on the tobacco beetle of hydrocyanic-acid gas in the presence of a partial vacuum. The apparatus used for the work was designed by Mr. E. H. Sasscer, Chief Inspector of the Federal Horticultural Board.[1] (Fig. 15.)

By means of vacuum apparatus a very much greater penetration of the gas can be secured than is possible in fumigating at normal air pressure. It has been found in the tests made by the Federal Horticultural Board that hydrocyanic-acid gas when applied in vacuum readily penetrates to the interior of closely compressed bales

[1] A detailed description of the apparatus and process of fumigation in vacuum has been given by the designer, Mr. E. R. Sasscer, in Service and Regulatory Announcements, Federal Horticultural Board, for October, 1915.

of imported cotton. This shows a degree of penetration beyond anything likely to be found in the fumigation of hogsheads or bales of leaf tobacco, or of cigars, or other classes of manufactured tobacco. The exposures found effective with vacuum apparatus in destroying several other species of insects have not proved effective, however, in destroying all stages of the tobacco beetle. A series of 19 experiments with different amounts of sodium cyanid varying from 1 ounce to 6 ounces per 100 cubic feet of space, with an exposure of 1 hour and 45 minutes at a vacuum of about 25 inches; and a series of 14 experiments with 1, 3, and 6 ounces of sodium cyanid to 100 cubic feet of space, with an exposure of 2 hours and 30 minutes at a vacuum of approximately 25 inches, did not show the process, under the conditions specified above, to be more effective than fumigation with the same dosages for 24 hours at normal air pressure.[1] All stages of the tobacco beetle were used in the experiments. These were in baled cigar tobacco, in various classes of manufactured tobacco, and in pressed yeast cakes and tobacco refuse. The principal advantage shown was the gain in time, as large quantities of manufactured tobacco can be quickly treated by the vacuum process. It is thought that changes in the present method of vacuum fumigation will make the process better adapted to the treatment of tobacco. A repetition of treatment in the majority of instances will be found necessary for complete sterilization.

Fumigation with Carbon Disulphid.

Carbon disulphid (CS_2) is quite generally used for the destruction of the insect pests which infest grain, food products, etc., and has been used extensively in control of the tobacco beetle. It is a colorless liquid about one-fourth heavier than water, extremely volatile, evaporating with great rapidity when exposed to the air. If the temperature of the air is high and the evaporating surface large the rate of evaporation is increased. In the liquid state it is inflammable, but not explosive, and can be safely handled if the cans are kept perfectly tight and away from the fire. The vapor takes fire in the air at about 200° F. under certain conditions. It is a violent and dangerous explosive when mixed with air in the proportion of 1 volume of vapor to approximately 14.3 volumes of air, in the presence of fire of any kind, or at a temperature without flame of about 300° F. The vapor is considerably heavier than atmospheric air. For this reason carbon disulphid when used for fumigating should be placed at the *top* of the fumigating compartment, if possible *above* the material to be treated. *Care must be taken not to inhale the fumes, as the gas is*

[1] In the above experiments the writer was assisted by Mr. H. L. Sanford, of the Federal Horticultural Board, and by Mr. J. L. Webb, of the Bureau of Entomology.

poisonous. All traces of the fumigant quickly disappear from the substance treated when exposed to the air, and even foodstuffs have been treated without affecting their edibility in any way. Tobacco or cigars when properly aired do not retain the odor of the gas, and the quality and flavor are not perceptibly changed.

While carbon disulphid is not as effective as hydrocyanic-acid gas, the ease with which it may be employed makes it the more desirable fumigant, particularly when the material to be fumigated occupies a small space. The liquid carbon disulphid has merely to be poured into a shallow dish, placed near the ceiling of the compartment to be fumigated, and allowed to evaporate. The method is a favorite one with many cigar dealers, the main objection being the danger of fire. A dealer known to the writer, in fumigating small lots of infested stock, makes use of an old refrigerator so fitted that the door closes perfectly tight. This is placed in a building outside the cigar store, to avoid danger of fire and for convenience in airing after treatment. As soon as infested stock is detected it is fumigated promptly, and in this case there has been small loss from the tobacco beetle.

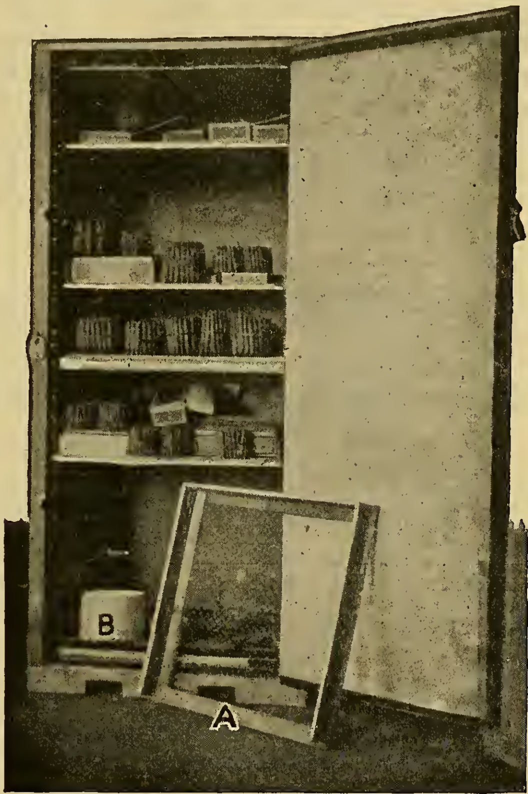


Fig. 16.—A closet for fumigating cigars or manufactured tobacco. *A*, Removable tray for holding cigars; *B*, generating jar.

The fumigating closet, shown in figure 16, was found to be a convenient size for cigar fumigation. Its dimensions are 2.5 by 2.5 by 6.5 feet. The sides are of matched boards. The inside is lined with sheet zinc. The door and fastenings are similar to those commonly used on refrigerators. Strips of heavy felt were attached where the edges of the door fitted. Boat clamps were used at top and bottom to insure perfect fitting of the door. The closet was fitted with removable trays to insure easy and rapid handling of the cigars. The trays have bottoms of one-half-inch wire screen.

Fumigation is more effective when the temperature is high, and it is not advisable to use carbon disulphid when the air temperature is much below 70° F. To be fairly effective against all stages of the beetle in tobacco, carbon disulphid should be used at a rate of not less than 4 pounds to 1,000 cubic feet of space. When only a small space is to be fumigated and the cost of the treatment is consequently slight, the exact amount of the carbon disulphid used is of no particular importance, even if the amount is very much in excess of the dosage advised above. The period of exposure should be from 24 to 48 hours. The results obtained in a number of experiments with carbon disulphid are given in Table IX. The time of exposure was 24 hours, except in experiments 5 and 11, in which the time of exposure was 48 hours.

TABLE IX.—*Experiments with carbon disulphid in control of the tobacco beetle (Lasioderma serricorne). Experiments at Clarksville, Tenn., 1915.*

Exp. No.	Date.	Dosage (rate per 1,000 cu. ft.).	Stage of insect.	Placement.	Results.
	1915.	*Pounds.*			
1	Aug. 3	1	Larvæ and adults	In smoking tobacco	Partially effective.
2	Aug. 4	1	Adults, larvæ, and pupæ	...do	Do.
3	Sept. 16	2	Larvæ (87)	In pressed yeast cake	3 days after treatment, 16 alive, 71 dead.
4	Sept. 4	2	Larvæ (73)	In wire cage, no protection.	All killed.
5	Sept. 3	3	Larvæ	In plug tobacco	2 days after treatment, 4 alive, 26 dead.
6	Aug. 20	3	Adults, larvæ, and pupæ	In glass tubes with cloth cover.	All killed.
7	Aug. 9	3	All stages	...do	Do.
8	Sept. 18	4	Larvæ (22)	In cigars	2 days after treatment, all dead.
9	Sept. 22	4	All stages	In smoking tobacco	No live stages found 2 days after treatment. Eggs did not hatch. Check eggs hatched normally.
10	Aug. 9	5	All stages	In cigars and refuse tobacco.	All stages killed.
11	Aug. 17	5	Eggs	About 50 on leaf tobacco.	Eggs did not hatch. Check eggs hatched normally.
12	Sept. 26	10	Eggs and larvæ	In cigars	Cigars kept for 6 months. No signs of infestation.

FUMIGATING WITH CARBON TETRACHLORID.

Carbon tetrachlorid (CCl_4) has been used to a considerable extent as a substitute for carbon disulphid in fumigation. It is not as efficient an insecticide as carbon disulphid, heavier dosages are required, and the cost of treatment is greater. The substance is noninflammable, however, and owing to this property is convenient for use when only a small space is to be fumigated where there might be danger of fire or explosion if carbon disulphid were used. When pure, carbon tetrachlorid is a thin, oily fluid, and in the open air quickly evaporates. It is heavy (sp. gr. 1.599), transparent, colorless, and has a pungent odor—not, however, as disagreeable as in the case of carbon disulphid.

For fumigating it is used in the same manner as carbon disulphid, being evaporated from shallow pans placed *over* the substance treated. The evaporating area of the pans holding the liquid should be large. As with carbon disulphid, an exposure of from 24 to 48 hours should be given. Tests made with carbon tetrachlorid in quantities up to 5 pounds per 100 cubic feet did not give satisfactory results in sterilizing tobacco. As carbon tetrachlorid is more likely to be employed in small compartments it is well to use very heavy dosages, as the increase in cost will be slight. The killing effect is greater when the air temperature is high.

Formaldehyde as a Fumigant.

Tests were made of 40 per cent formaldehyde at the rate of 2½ ounces to 100 cubic feet of space. All stages of the tobacco beetle were used and the formaldehyde was vaporized by means of heat. The substance at this strength was found to be only partially effective.

THE EFFECT OF RÖNTGEN OR X RAYS ON THE TOBACCO BEETLE.

The effect of the X rays on the higher animals, including human beings, is well known. Sensitiveness to the rays has been found by different investigators to vary with the species of animal. Newly formed, especially embryonic tissues, have been found to be more easily affected by exposure to the rays than are those more mature. Certain bodies of cells are remarkably susceptible, their functions being retarded, modified, or completely inhibited, although morphologically they are apparently normal. The rays are known to have a marked effect on the reproductive organs, prolonged exposure causing an animal to become temporarily or permanently sterile. In general it may be said that when living tissues of an animal are exposed to the action of the rays, the functions of the cells are retarded or depressed, and permanent injury, or even the eventual death of the animal, may result. The exact effect of the rays depends upon the intensity of the radiation, the duration of the exposure, and the distance of the organism exposed from the source of radiation. When the energy input through a Röntgen tube is great, the intense radiation resulting is correspondingly more active, and more injurious to living tissue, producing more marked physiological results. Exposure to rays of great intensity has been shown to retard or stop growth, differentiation and regeneration,

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and to interfere with the processes of cell division or multiplication, causing, in some cases, degenerative changes to take place or a decrease in the rate of cell division. On the other hand, an exposure of slight intensity or short duration may be without perceptible effect, or may even be accelerative, and perhaps increase the rate of cell division. It seems to be well established that the effects of repeated exposures to the rays are to a certain extent cumulative, an exposure of say 5 milliampere minutes having identically the same effect, whether the exposure is given in one treatment or in several treatments applied at different times so that the total exposure amounts to 5 milliampere minutes. The effect of the rays on the simpler forms of animal and plant life has been studied by numerous investigators and in general their action seems to be the same as on the higher animals.

The X-ray process of treating tobacco has been exploited commercially for sterilizing cigars infested with the tobacco beetle, and satisfactory results have been reported. Improvements in the method of treatment and in the apparatus have been made from time to time, and the modern forms of Röntgen tubes used make possible continuous and unchanging Röntgen-ray radiation of great power and intensity. Effects can now be obtained which were not possible or practicable in commercial work with the earlier forms of apparatus.

During 1912 experiments were made by Mr. A. C. Morgan and the writer (76) with apparatus designed to sterilize cigars on a commercial scale. The experiments, from a practical standpoint, gave negative results. Later experiments made with apparatus capable of producing and maintaining a much more powerful radiation have shown that the earlier tests failed to give satisfactory results owing to the comparatively light exposures obtainable with the apparatus then used.

A brief statement of the results obtained by the writer (86) in a series of experiments conducted under laboratory conditions at Schenectady, N. Y., in 1915, is presented.[1] These experiments were a continuation of investigations of a similar nature commenced at Tampa, Fla. In previous experimental work it had been found in sterilizing cigars or tobacco that light dosages are ineffective from a practical standpoint. To be effective the radiation must be intense, and it is evident that if the process can be applied successfully to commercial work the apparatus used must be capable of producing and maintaining such radiation during the entire period of exposure.

The results obtained in the experiments have been briefly summarized as follows:

[1] A detailed report of these experiments has been published (86).

Under laboratory conditions tests made with a Röntgen-ray tube permitting a high-energy input and giving an intense and powerful radiation produced results which promise that the X-ray process may be used successfully in treatment of cigars or tobacco infested with the tobacco or cigarette beetle.

Heavy dosages must be given, as is indicated by the results of exposures given in several series of experiments.

In treatment of the egg stage, heavier exposures are required to sterilize eggs which are near the hatching point than are required to sterilize eggs newly laid.

In experiments performed by the writer a dosage equivalent to 150 milliampere minutes exposure with a spark gap of 5.5 inches gave satisfactory results with eggs in tobacco placed 7.5 inches from the focal spot of the tube. With this exposure the eggs in which embryonic development was well advanced hatched, but in all cases where these larvæ were kept under observation they failed to reach the adult stage.

The minimum lethal dosage at a given distance from the focal spot of the Röntgen tube used was not determined.

In two separate experiments adults were given an exposure of 600 milliampere minutes (amperage × time), with a spark gap of 5.5 inches, giving an approximate voltage of 65,000. The distance from the focal spot of the Röntgen tube was 7.5 inches. The results were as follows:

(1) No effect on length of life was apparent, as the beetles died at about the same rate as the same number of beetles kept as check.

(2) Large numbers of eggs were deposited after exposure. These eggs were infertile. Eggs laid by the check beetles hatched normally.

Larvæ were given an exposure of 600 milliampere minutes, other conditions of the experiment being the same as in the experiments with adults given above. While no immediate effect was apparent the treatment had the effect of stopping activity and development, the larvæ remaining in a dormant condition for a prolonged period. All treated larvæ died before reaching the pupa stage.

Two methods of treating cigars in factories with the X-ray process are employed at the present time. In one method the finished cigars in closed boxes are conveyed by a belt very slowly through an exposure chamber containing the Röntgen tubes. The walls of the exposure chamber are constructed of thick sheets of lead (lead is not penetrated by the Röntgen rays) in order to protect the operator of the machine from injury.

In the other method of treatment a large room used as a humidor at the factory was completely lined with sheet lead. In a narrow compartment within the humidor, extending along one side, a series of 16 powerful Röntgen-ray tubes are arranged in two lines extending from end to end, and placed so that the rays penetrate the humidor from various angles. A rotary fan forces cold air through the tube compartment and over the tubes, keeping the temperature of the humidor normal. The finished cigars in closed boxes are placed on a long shelf extending along the partition of fibrous material (permeable to the rays) separating the tube compartment from the rest of the humidor. An exposure of 42 minutes is given by an automatic control of current. Cigars are left on the shelf until all space is taken up, then placed in other parts of the humidor, where they are kept until shipped out. This arrangement gives a minimum exposure, close to the Röntgen tubes, of 42 minutes. Ordinarily the method of handling gives many repeated exposures, on the shelf close to the tubes or at distances farther out in the humidor. A test of this process was made by the writer on November 7, 1916, to determine the effect on the egg stage of the tobacco beetle. About 200 eggs deposited on leaf tobacco were placed in a sealed cigar box and treated. An equal number of eggs were kept as a check. The eggs treated were placed in the humidor 7½ feet from the wall of the tube compartment and given three periods of 42 minutes' exposure; then placed on the shelf directly in front of the tubes and given one period of 42 minutes' exposure. This gave a total of three accumulative periods of 42 minutes each 7½ feet from the nearest tube and one period of 42 minutes on the shelf close to the tube compartment. By November 18 most of the check eggs had hatched, but all of the treated eggs were more or less shrunken and none had hatched.

SUMMARY AND RECOMMENDATIONS.

The tobacco beetle, a stored-product insect, is practically cosmopolitan and occurs wherever large quantities of leaf or manufactured tobacco are handled or stored. It attacks a variety of dried substances, its most common food being tobacco.

In tobacco factories, the principal sources of infestation of the finished products are:

(1) Infested leaf tobacco brought into the factory.

(2) Tobacco warehouses, where beetles are present in large numbers, close to the factory.

(3) Infested tobacco, refuse material, cigars, or manufactured tobacco which has accumulated. (Beetles breeding from this material quickly spread to all parts of the factory.)

A very few beetles present in storage or packing rooms in factories may be the cause of serious loss, by depositing their eggs on the finished product. The protection of the product at this time is usually of more importance than the condition of the raw material, since the leaf tobacco in most cases is partly or completely freed from different stages of the beetle by handling or by the process of manufacture. Whenever possible manufactured tobacco should be packed in insect-proof containers.

The more important means of controlling the tobacco beetle may be summarized briefly as follows:

(1) Scrupulous cleanliness in the factory, wholesale or retail establishment, including the prompt destruction or treatment of all refuse material, damaged stock, etc., in which the beetles may breed.

(2) In factories, screening or otherwise protecting the finished product from infestation.

(3) Constructing or refitting packing or storage rooms, especially in warm localities, so that they can be quickly and easily cleaned, and with a view to the exclusion of beetles which may be present in other parts of the factory.

Among destructive agencies which may be employed in control of the insect are:

(1) Freezing. (Treatment by cold storage or exposure to low temperatures in cold climates.)

(2) High temperatures or steam. (A temperature of from 125° to 140° F. continued for several hours, or 150° F. for a short time, kills all stages of the beetle.)

(3) Trapping or destruction by mechanical means.

(4) Fumigation with carbon disulphid, hydrocyanic-acid gas, or other fumigants.

(5) Sterilization of infested tobacco by means of exposure to Röntgen or X rays.

The modern method of storing leaf tobacco in hogsheads in specially constructed buildings or sheds, giving practically out-of-door conditions and variations of temperature, furnishes an effective means, in cool climates, of reducing or preventing injury from the beetle to the classes of leaf tobacco which may be stored in this manner.

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

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EFFECT OF GRAZING UPON WESTERN YELLOW PINE REPRODUCTION IN CENTRAL IDAHO.

By W. N. Sparhawk, *Forest Examiner.*

CONTENTS.

TIMBER AND LIVE STOCK.

The western yellow pine forest is the most important source of timber in the area drained by the Columbia River and its tributaries east of the Cascades and north of the Snake River Valley. There are estimated to be approximately 7 million acres of western yellow pine (*Pinus ponderosa*) in the National Forests of this region, and there is probably an equal area outside the Forests. A conservative estimate of the National Forest stand is 50 billion board feet. At a growth rate of 100 board feet per acre per year [1] the western yellow pine land within the National Forests alone is capable of producing a sustained yield of 700 million board feet of lumber every year. A considerable portion of the timberland now in private ownership

[1] See U. S. Department of Agriculture Bulletin 418, "Western Yellow Pine in Oregon," by T. T. Munger.

will probably be devoted eventually to other use, but much of it is more valuable for the continued production of timber than for any other purpose, so that it is reasonable to expect a total annual increment of at least a billion board feet on National Forest and privately owned land now occupied by western yellow pine. In this region growth is rapid, the quality of lumber produced is excellent, abundant natural reproduction follows logging, and the greater part of the area is accessible and fairly easy to log. The perpetuation of the western yellow pine stand therefore insures the continuation of an important part of the lumber industry in the Northwest.

Because of the small rainfall over most of the untimbered part of the region and the consequent dependence of the rapidly developing agricultural industry upon irrigation, the maintenance of a forest cover in the mountains is as desirable for regulation of stream flow as for the production of timber.

The live-stock industry is important throughout this region, and the greater part of the forest area is utilized as spring or summer range for sheep and cattle. Although the quality of forage in western yellow pine stands varies widely, there are no areas which do not contain at least a small amount of palatable feed. Allowing even the very liberal average of 7 acres per sheep or 35 acres per cow—a large part of it has at least double this capacity—the western yellow pine type in the region described will supply summer range for a million sheep or 200,000 cattle.

The utilization of this forage, particularly on areas suited to sheep rather than to cattle, has presented a somewhat difficult problem, owing to the serious damage done by sheep to forest reproduction under the methods of handling hitherto prevalent and to the resulting idea common among silviculturists that sheep grazing and forest production can not be carried on together. To determine just how much harm is done to forest reproduction by sheep and how far this damage can be reduced by more careful use of the range, an intensive study was made on the Payette National Forest in central Idaho during the years 1912 to 1914, inclusive. It is believed that the results of this study, which are presented in the following pages, are fairly applicable to the entire region described:

STUDIES MADE ON THREE GRAZING ALLOTMENTS.

The effect of sheep grazing upon conifer reproduction was studied on a number of small sample plots well distributed over three separate grazing allotments. The study was carried on for three years on two allotments, one on Deadwood River and the other on Silver Creek, a tributary of the Middle Fork of the Payette River. In the third year, 1914, a third allotment, on the South Fork of the Payette, was also studied.

These areas, which are near the western edge of the deeply dissected central Idaho plateau, are characterized by a very broken surface, steep slopes, and numerous streams with deeply cut canyons. The soft granite, which underlies most of this part of the Forest, interspersed with numerous veins of quartzite, outcrops frequently on the steeper slopes and along the ridges, and the soil which is derived from it is very porous and dries out quickly. Narrow flats along the streams and occasional broader basins—probably once the beds of small lakes—are covered with alluvial soil of considerable depth.

Annual precipitation in the areas occupied by western yellow pine averages between 20 and 25 inches, of which a large part falls as snow. Snow usually goes off between mid-April at the lower altitudes and early June at the upper limits of yellow pine, and growth starts immediately thereafter. Considerable rain falls in June; but after the first week of July there is generally very little rain, except occasional thunder showers, until the first part of September. In early September a fall rainy period, with snow at the higher altitudes, is usual. During the summer, days are usually hot and nights cool. Altitudes above 5,000 feet are apt to be visited by killing frosts at any time, while the lower altitudes are, as a rule, free from frost from June 10 to September 1.

The grazing season for sheep commences some time in May in the lower western yellow pine country and about the middle or end of June in the higher and more remote areas, such as the Deadwood allotment, and lasts until the feed dries and becomes comparatively unpalatable, about the middle of August. The sheep are then held on the higher ranges until driven down by snow or cold weather, after which they sometimes spend a short time on the western yellow pine range on their way out to the open country.

Western yellow pine and Douglas fir seeds germinate for the most part during May and the first half of June at the lower, and during June and early July at the higher elevations, and occasional seedlings appear all through the summer. Lodgepole pine germination continues in considerable quantity during most of the season. Western yellow pine seedlings to a very large extent, and lodgepole pine to a less extent, occur in small compact bunches, the result of the seeds being buried by chipmunks.

THE DEADWOOD ALLOTMENT.

On the Deadwood allotment, which represents the upper extension of the range of the western yellow pine type, and all of which is above 5,000 feet altitude, the timber is largely a mixture of varying proportions of western yellow pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga taxifolia*), and lodgepole pine (*Pinus contorta*), with some alpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanni*), whitebark pine (*Pinus albicaulis*), and a very few specimens of western larch (*Larix occidentalis*). Most of the western yellow pine stands are on ridges or southern exposures between 5,000 and 6,000 feet elevation; where western yellow pine occurs on other sites it is usually scattered as individuals or groups in stands of other species. Practically none is found above 6,500 feet. By volume, approximately 40 per cent of the timber on this area is western yellow pine, 30 per cent Douglas fir, 25 per cent lodgepole pine, and 5 per cent other species.

The virgin stand is more or less broken by old burns and insect-killed areas, on most of which reproduction, especially of Douglas fir and lodgepole pine, has become well established. Other openings which have been occupied by dense brush contain only scattered tree reproduction. Advance reproduction of all species is common over most of the timbered area, though it is very unevenly distributed and of slow growth. Except on rather limited areas, western yellow pine reproduction is unsatisfactory in amount. At the time the study was started (1912) there were very few seedlings of this species under 10 years old, which indicates that years of abundant reproduction are very infrequent at this altitude. There were practically no saplings over 30 years old, probably on account of extensive fires in the early 80's. On the sample plots (see p. 5), which were located for the most part only where some western yellow pine reproduction was present, only 38 per cent of the seedlings were western yellow pine, while 32 per cent were Douglas fir and 30 per cent lodgepole pine.

The undergrowth on the western yellow pine part of the allotment, a varying mixture of grasses, weeds, and browse, is unevenly distributed and averages rather low in forage value.[1]

THE SILVER CREEK ALLOTMENT.

The Silver Creek area, from 4,600 to 5,500 feet in elevation, is fairly representative of the middle range of the western yellow pine type. The timber is of much better quality than that on the Deadwood allotment, and a much larger proportion is western yellow pine. Except on the moist flats along the creek, there is no lodgepole pine in the stand. By volume, approximately 75 per cent is western yellow pine, 20 per cent Douglas fir, and 5 per cent lowland white fir (*Abies grandis*).

[1] Pine grass (*Calamagrostis rubescens*), arnica (*A. cordifolia*), geranium (*G. incisum*), lupine (*Lupinus spp.*), huckleberry (*Vaccinium membranaceum* and *V. scoparium*), spiraea (*S. lucida*), currant (*Ribes cereum*), willow (*Salix spp.*), and ceanothus (*C. velutinus*) are among the most widely distributed and characteristic plants. Other very common species include elk grass (*Carex geyeri*), blue grass (*Poa spp.*) blue bunch grass (*Festuca idahoensis*), silver dock (*Balsamorrhiza sagittata*), fireweed (*Chamaenerion angustifolium*), yarrow (*Achillea lanulosa*), hawkweed (*Hieracium scouleri*), paeony (*Paeonia brownii*), valerian (*Valeriana sitchensis*), bluebell (*Mertensia sp.*), meadow rue (*Thalictrum occidentalis*), Indian paintbrush (*Castilleja spp.*), foxglove (*Pentstemon spp.*), Indian tobacco (*Eriogonum spp.*), choke cherry (*Padus demissa*), fire cherry (*Prunus emarginata*) rose, (*Rosa spp.*), mountain ash (*Sorbus sambucifolia*), snowberry (*Symphoricarpos rotundifolius*), buck brush (*Kunzia tridentata*), and service berry (*Amelanchier alnifolia*).

Reproduction is abundant and well distributed and on account of the longer growing season growth is more rapid here than on the Deadwood area. On the sample plots 58 per cent of the seedlings were western yellow pine, 34 per cent Douglas fir, and 8 per cent lowland white fir.

The undergrowth on this allotment is dense and fairly evenly distributed; browse predominates. Its forage value is much higher than that on the Deadwood area because of its greater density and the larger proportion of palatable species.[1]

THE SOUTH FORK ALLOTMENT.

The South Fork allotment represents the best western yellow pine land in this region. Except for the main ridges, which reach 6,000 feet, most of the area is between 3,800 and 5,000 feet in elevation. Western yellow pine trees here occasionally reach a height of 190 feet. Western yellow pine makes up from 70 to 100 per cent of the volume of the stand, which probably averages for the entire area 85 per cent pine and 15 per cent Douglas fir.

The forage cover is denser and more palatable than that on either of the other two areas. Even on the south slopes there are few of the bare spots such as are common on the Deadwood allotment, but there are more brush areas so dense that they can not be utilized. Browse is the predominant type of forage, except on south slopes, on which grasses and weeds predominate.[2]

METHOD OF STUDY.

Small sample plots were chosen in such a way that they were well distributed over the three grazing allotments and were so located as to cover the greatest possible variety of conditions of topography, stand, forage cover, and use of the range. They are believed, therefore, to represent fairly the western yellow pine type of forest in the region described.

Thirty-nine plots were studied for the last year only, 40 more for two seasons, and 72 more for three years, a total of 151 plots with an aggregate area of approximately 75,000 square feet.

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[1] Characteristic plants are: Ceanothus (*C. velutinus* and *C. sanguineus*), ninebark (*Opulaster malvaceus*), huckleberry (*Vaccinium membranaceum*), choke cherry (*Padus demissa*), willows (*Salix spp.*), spiraea (*S. lucida*), snowberry (*Symphoricarpos rotundifolius*), rose (*Rosa spp.*), pine grass (*Calamagrostis rubescens*), silver dock (*Balsamorrhiza sagittata*), fireweed (*Chamaenerion angustifolium*), geranium (*G. incisum*), brome grass (*Bromus marginatus*), and meadow rue (*Thalictrum occidentale*).

[2] Characteristic plants are wheat-grass (*Agropyron spicatum*), June grass (*Koeleria cristata*), blue bunchgrass (*Festuca idahoensis*), brome (*Bromus marginatus*), blue grass (*Melica sp.* and *Poa sp.*), ceanothus (*C. sanguineus* and *C. velutinus*), ninebark (*Opulaster malvaceus*), snowberry (*Symphoricarpos rotundiolius*), spiraea (*S. lucida*), rose (*Rosa spp.*), willows (*Salix spp.*), service berry (*Amelanchier alnifolia*), mountain ash (*Sorbus sambucifolia*), maple (*Acer glabrum*), buck brush (*Kunzia tridentata*), syringa (*Philadelphus lewisii*), silver dock (*Balsamorrhiza sagittata*), asters (*Aster spp.*), geranium (*G. incisum*), sunflower (*Helianthella sp.*), pea-vine (*Lathyrus spp.*), lupine (*Lupinus spp.*), wild carrot (*Leptotaenia sp.*), fireweed (*Chamaenerion angustifolium*), hellebore (*Veratrum sp.*), brake (*Pteridium aquilinum pubescens*), nad meadow rue (*Thalictrum occidentale*).

The species and height of all seedlings on the plots were recorded at the beginning and end of each season, and in many instances at one or more other times during the summer. Injuries due to grazing or to other causes were noted at the same time. Record was also made of the approximate date when each plot was grazed, and of the intensity of grazing.

INJURIES TO REPRODUCTION CAUSED BY SHEEP GRAZING.

NATURE OF INJURIES.

Sheep injure forest reproduction directly both by browsing and by trampling. In the case of browsing the injury may be confined to a few needles or to the tips of side branches, the leader may be bitten off, or the bark may be gnawed. With conifers such injuries, except in extreme cases or when repeated, seldom result in permanent deformity or death. A careful study of comparative heights of uninjured seedlings and of those whose leaders had been removed several years before showed no perceptible difference in the rate of growth, except for the loss of the one year's increment. An uninjured side branch or a new bud takes the place of the leader, and the slight crook in the stem, which is evened out as its diameter increases, usually disappears within 10 years.

If the injury is repeated every year or two, of course the seedling will be permanently stunted and will never become a tree. This has happened along driveways which have been used for many years, and also on bed grounds which have been used several nights at a time year after year. It seldom happens except in such places. If an average of 1 per cent of the seedlings on an area are injured by grazing in one year, only 1 per cent of this 1 per cent will be likely to suffer a second injury the next year. In 20 years only 1.7 per cent of the seedlings will be likely to have been injured twice, and only 0.1 per cent three times.

Very severe browsing, such as frequently occurs on bed grounds which have been used too much, often kills the seedlings outright. In order to test the recovery from such injury, a number of seedlings between 6 inches and 3½ feet high were entirely defoliated in 1913. One year later 20 out of the 42 were dead, and the others, although they had put out new needles, appeared to be unhealthy and likely to die later. To test the effect of light browsing, only the foliage put out during the current year was removed from a number of other seedlings. This had no apparent lasting effect, since all were fully recovered within a year.

By trampling, sheep may bruise the seedling, bury it under loose soil or litter, uproot it, or break it. Such injuries, especially in case of the smaller seedlings, often cause death.

AMOUNT OF DAMAGE.

Table 1 shows the kind and amount of damage done by sheep on the different allotments during the course of the study.

The damage to seedlings more than a year old was negligible in quantity; a yearly average of 1.9 per cent of the number on grazed plots was killed on the Deadwood area, and 3.7 per cent on the Silver Creek area. The one year's record for the South Fork (4.7) indicates, when compared with the same year's record on the other allotments, that the yearly average for a three-year period would probably have been between the Deadwood and Silver Creek averages. Of seedlings less than one year old, on Deadwood an average of 15.4 per cent were killed, and on Silver Creek 24.9 per cent. The greater mortality of both classes of seedlings on the Silver Creek area was due partly to the greater intensity of grazing on that allotment and partly to differences in the relative distribution of ages; the Silver Creek area had a much larger proportion of reproduction less than 10 years old. These figures show the proportion of damage on grazed plots alone; that is, they indicate the maximum loss which would result if the sheep grazed over every square yard of their allotment. As a matter of fact an area is seldom grazed so closely unless it is very much overstocked; a great many spots are missed, and many of them are likely to be patches of reproduction, since there is usually little palatable forage in such places.

The last columns in Table 1 show the proportion of injury to the total number of seedlings on all of the plots on each allotment. On the Deadwood area, which was grazed rather lightly, averages of 1.1 per cent of the older seedlings and 8.8 per cent of those less than a year old were killed each year, while on the closely grazed Silver Creek area 2.5 per cent and 14.8 per cent, respectively, were killed.

Of the older seedlings on grazed plots on Deadwood but 0.7 per cent were browsed, and of those on Silver Creek 1.5 per cent. Considering all plots whether grazed or not, 0.4 per cent of the seedlings on Deadwood and 1.1 per cent of those on Silver Creek were browsed each year; and fully one-third of these "injuries" consisted of slight browsing of needles or tips of lateral branches only. The smaller proportion of one-year seedlings classed as "injured" is due to the fact that they are usually killed if injured at all.

Of the three important species present, western yellow pine appears to be most liable to browsing injury, lodgepole pine somewhat less so, and Douglas fir least. White fir is practically never browsed.

TABLE 1.—*Seedlings killed and injured by sheep.*

(A) SEEDLINGS MORE THAN ONE YEAR OLD.

Year and allotment.	Total number of seedlings on grazed plots.					Browsed.																
						Needles.		Side branches.			Leaders.			Bark.		Total.			Per cent of number on grazed plots.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
1912.																						
Deadwood	1,542	1,372	985	....	3,899	9	1	....	1	....	6	....	....	1	....	16	1	1	1.0	0.1	0 1	0.5
Silver Creek	976	746	....	199	1,921	2	....	....	....	....	1	....	....	....	....	3	....	....	.3	....	....	.2
	2,518	2,118	985	199	5,820	11	1	....	1	....	7	....	....	1	....	19	1	1	.8	.0	.1	.4
1913.																						
Deadwood	1,700	1,558	1,034	....	4,292	3	1	....	....	....	6	8	1	5	....	14	7	2	.8	.5	.2	.6
Silver Creek	1,366	753	....	115	2,243	13	....	2	4	....	35	8	....	1	....	51	12	....	3.8	1.6	....	2.8
	3,066	2,311	1,034	115	6,526	16	1	2	4	....	41	16	1	6	....	65	19	2	2.1	.8	.2	1.3
1914.																						
Deadwood	1,600	1,421	1,205	....	4,226	16	1	....	....	3	17	4	5	....	1	33	5	9	2.1	.4	.7	1.1
Silver Creek	775	667	....	102	1,544	3	....	1	....	....	16	1	....	....	....	20	1	....	2.6	.1	....	1.4
South Fork	1,104	42	....	....	1,146	2	....	9	....	....	12	....	....	1	....	24	....	....	2.2	....	....	2.1
	3,479	2,130	1,205	102	6,916	21	1	10	....	3	45	5	5	1	1	77	6	9	2.2	.3	.7	1.3

F-17385-A

BROWSE RANGE UNDER YELLOW PINE TIMBER.

F-17376-A

FIG. 1.—PINE-GRASS RANGE TYPICAL OF MUCH OF THE YELLOW PINE TIMBER RANGE.

F-12068-A

FIG. 2.—BROWSE, WEED, AND GRASS RANGE TYPICAL OF OPENINGS IN YELLOW PINE AND DOUGLAS FIR STANDS.

(B) SEEDLINGS LESS THAN ONE YEAR OLD.

1912.																						
Deadwood	29	117	143		289																	
Silver Creek	1,226	51		22	1,299	3					9								1.0			1.0
	1,255	168	143	22	1,588	3					9								1.0			1.0
1913.																						
Deadwood	1,392	334	990		2,716						7		1						.5		.1	.3
Silver Creek	1,797	327		14	2,138						7								.4			.3
	3,189	661	990	14	4,854						14		1						.4		.1	.3
1914.																						
Deadwood	22	12	51		85							1								8.3		1.2
Silver Creek	6	3			9																	
South Fork	5				5																	
	33	15	51		99							1								6.7		1.0

TABLE 1.—*Seedlings killed and injured by sheep*—Continued.

(A) SEEDLINGS MORE THAN ONE YEAR OLD—Continued.

Year and allotment.	Trampled.							Killed.										Total number of seedlings on all plots.					Per cent of number on all plots.								
	Number.			Per cent of number on grazed plots.				Number.				Per cent of number on grazed plots.									Injured.				Killed.				
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.
1912.																														
Deadwood	36	9	13	2.3	0.7	1.3	1.5	7	17	14	....	0.5	1.2	1.4	....	1.0	1,877	1,689	1,074	....	4,640	2.8	0.6	1.3	1.7	0.4	1.1	1.3	....	0.9
Silver Creek	3	3	....	.3	.4	....	.3	16	9	....	....	1.6	1.2	....	....	1.3	976	748	....	199	1,923	.6	.4	....	.5	1.6	1.2	....	....	1.3
	39	12	13	1.5	.6	1.3	1.1	23	26	14	....	.9	1.2	1.4	....	1.1	2,853	2,437	1,074	199	6,563	2.0	.6	1.3	1.3	.8	1.1	1.3	....	1.0
1913.																														
Deadwood	1	7	....	.1	.5	....	.2	7	16	24	....	.4	1.0	2.3	....	1.1	2,412	2,726	1,576	.....	6,714	.7	.6	.1	.5	.3	.6	1.6	....	.7
Silver Creek	2	....	....	.1	....	....	.1	31	18	....	8	2.3	2.4	....	7.0	2.6	1,545	888	....	229	2,662	3.6	1.4	....	2.6	2.1	2.1	....	3.5	2.2
	3	7	....	.1	.3	....	.1	38	34	24	8	1.2	1.5	2.3	7.0	1.6	3,957	3,614	1,576	229	9,376	1.8	.8	.1	1.1	1.0	1.0	1.6	3.5	1.1
1914.																														
Deadwood	4	4	4	.2	.3	.3	.3	29	33	92	....	1.8	2.3	7.6	....	3.7	3,387	2,916	2,582	.....	8,885	1.1	.3	.5	.7	.8	1.2	3.6	....	1.7
Silver Creek	1	....	....	.1	....	....	.1	87	25	....	1	11.2	3.6	....	1.0	7.3	1,666	999	....	233	2,898	1.3	.1	....	.7	5.2	2.5	....	.5	3.9
South Fork	4	....	....	.4	....	....	.4	47	7	....	....	4.2	16.7	....	....	4.7	2,383	973	....	.....	3,356	1.2	....	....	.8	2.0	.7	....	....	1.6
	9	4	4	.3	.2	.3	.2	163	65	92	1	4.7	3.1	7.6	1.0	4.6	7,436	4,888	2,582	233	15,139	1.1	.2	.5	.7	2.2	1.4	3.6	.5	2.1

(B) SEEDLINGS LESS THAN ONE YEAR OLD—Continued.

1912.																														
Deadwood	....	....	....	....	....	....	....	6	23	8	....	20.7	19.6	5.6	....	12.8	47	176	208	.....	431	....	....	....	....	12.8	13.1	3.8	....	8.6
Silver Creek	1	....	....	.1	....	....	.1	166	8	....	2	13.6	15.7	....	9.1	13.5	1,301	59	....	22	1,382	1.0	....	....	.9	12.8	13.6	....	9.1	12.7
	1	....	....	.1	....	....	.1	172	31	8	2	13.7	18.5	5.6	9.1	13.4	1,348	235	208	22	1,813	1.0	....	....	.7	12.8	13.2	3.8	9.1	11.7
1913.																														
Deadwood	4	1	1	.3	.3	.1	.2	295	58	110	....	21.2	17.4	11.1	....	16.9	2,059	463	1,905	.....	4,427	.5	.2	.1	.2	14.3	12.5	5.8	....	10.5
Silver Creek	1	1	....	.1	.3	....	.1	530	60	....	6	29.5	18.4	....	42.8	27.9	2,076	597	....	25	2,698	.4	.2	....	.3	25.5	10.0	....	24.0	22.1
	5	2	1	.2	.3	.1	.2	825	118	110	6	25.9	17.9	11.1	42.8	21.8	4,135	1,060	1,905	25	7,125	.5	.2	.1	.3	20.0	11.1	5.8	24.0	14.9
1914.																														
Deadwood	....	....	....	....	....	....	....	6	....	8	....	27.3	.....	15.7	....	16.5	32	22	139	.....	183	....	4.6	....	.5	18.7	....	5.7	....	7.2
Silver Creek	....	....	....	....	....	....	....	2	1	....	....	33.3	33.3	....	....	33.3	19	12	....	0	31	....	....	....	....	10.5	8.3	....	....	9.7
South Fork	....	....	....	....	....	....	....	5	....	....	....	100.0	....	....	....	100.0	42	13	....	.....	55	....	....	....	....	11.9	....	....	....	9.1
	....	....	....	....	....	....	....	13	1	8	....	39.4	6.7	15.7	....	22.2	93	47	139	0	269	....	2.1	....	.4	14.0	2.1	5.7	....	7.9

SIZES INJURED.

Table 2 shows the total amount of injury done by sheep on all the sample plots during the period of the study, classified according to the size of seedlings injured. Of the 1,782 seedlings killed, 1,294, or 73 per cent, were less than a year old, while only 11, or about one-half of 1 per cent, were over 6 inches in height. Only one seedling over 18 inches high was killed by sheep during the three years. Only one sapling over 3.5 feet high was browsed or trampled; most of the injuries from browsing or trampling were confined to seedlings less than 1.5 feet in height.

The relative mortality of seedlings of different sizes is shown in Table 3. During the first few years seedlings succumb very easily to slight injuries, because of their small size, shallow root system, and the lack of woody matter in their stems. The loss due to grazing decreased from about 20 per cent for seedlings in their first year to 11 per cent for those in their second and third years. By the end of the third year they are from 2 to 4 inches high (depending on species and site), their stems have become woody and fairly tough, and their roots penetrate the soil for a foot or more, so that they are not easily uprooted by trampling nor exposed to drying by the loosening of the soil. Injury from grazing is so slight after this that there is no need for closing reproduction areas to sheep after the third year, though it may be desirable to graze such areas lightly for a few years more, until the seedlings reach a height of 6 inches.

TABLE 2.—*Relation between size of seedlings and injury by grazing.*

(Total injuries for three years on sample plots on all allotments.)

Species and height class.	Injured.						
	Needles.	Side branches.	Leader.	Bark.	Trampled.	All.	Killed.
Western yellow pine:							
Under 1 year	3	....	23	....	6	32	1,010
1 year old to 6 inches high	10	....	46	....	13	69	216
6 inches to 1½ feet	31	1	38	5	36	111	7
1½ to 2½ feet	7	10	8	1	2	28	1
2½ to 3½ feet	....	1	1	2	....	4	....
Douglas fir:							
Under 1 year	....	....	1	....	2	3	150
1 year old to 6 inches high	....	....	8	....	10	18	124
6 inches to 1½ feet	....	1	9	....	12	22	1
1½ feet to 2½ feet	....	2	2	....	1	5	....
2½ to 3½ feet	....	2	1	1	....	4	....
Lodgepole pine:							
Under 1 year	....	....	1	....	1	2	126
1 year old to 6 inches high	1	....	1	....	6	8	128
6 inches to 1½ feet	1	1	5	....	6	13	2
1½ to 2½ feet	1	....	....	....	3	4	....
2½ to 3½ feet	....	1	....	....	2	3	....
3½ to 4½ feet	....	1	....	....	....	1	....
White fir:							
Under 1 year	....	....	....	....	....	....	8
1 year old to 6 inches high	....	....	....	....	....	....	9

TABLE 3.—*Seedlings killed by sheep, by sizes.*

(Percentages of total numbers on grazed plots.)

Year and size class.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
1912:				
Less than 1 year [1]	13.7	18.5	5.6	13.4
1 year old to 6 inches high	3.1	2.7	3.1	3.0
6 inches to 1½ feet	....	....	....	....
1913:				
Less than 1 year	25.9	17.9	11.1	21.8
1 to 2 years	4.4	7.1	7.2	5.5
2 years old to 6 inches high	.8	2.2	1.6	1.6
6 inches to 1½ feet	.4	....	.9	.3
1914:				
Less than 1 year	39.4	6.7	15.7	22.2
1 to 2 years	15.5	20.3	10.9	14.4
2 to 3 years	9.1	9.9	23.6	11.4
3 years old to 6 inches high	.4	1.6	1.4	1.1
6 inches to 1½ feet	.3	.2	....	.2
Average:				
Less than 1 year	22.4	17.8	10.8	19.8
1 to 2 years	10.8	13.9	9.9	11.0
2 to 3 years	9.1	9.9	23.6	11.4
3 years old to 6 inches high	1.5	2.1	2.2	1.9
6 inches to 1½ feet	.2	....	.6	.2

[1] Number killed by sheep in 1912 partly estimated.

Tables 4 and 5 show the rate of growth in height of the important species on the Deadwood allotment, which corresponds to sites of poorer quality than the average, and on the South Fork allotment, which corresponds to average or better western yellow pine sites. The figures given represent growth of advance reproduction, mostly under timber rather than in openings. For comparison, the growth of dominant western yellow pine seedlings in eastern Oregon [1] is also shown.

TABLE 4.—*Juvenile height growth on experimental area.*

Age in years.	Western yellow pine.			Douglas fir.		Lodgepole pine.
	Deadwood.	South Fork.	Blue Mountains.	Deadwood.	South Fork.	Deadwood.
	Height in feet.					
5	0.3	0.5	0.8	0.2	0.2	0.2
10	.6	.9	1.7	.4	.6	.6
15	1.2	2.1	2.7	.8	1.3	1.3
20	2.0	3.5	....	2.4	2.2	2.4
25	3.0	5.5	....	2.1	3.6	4.0
30	4.2	9.6	....	2.8	5.5	6.2
35	5.7	13.9	....	3.7	9.5	10.0
40	8.2	....	....	4.7	....	15.7
Number seedlings basis	586	738	1,182	914	521	206

TABLE 5.—*Years required to reach a given height.*

Height in feet.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.
	Years.	*Years.*	*Years.*	*Years.*	*Years.*
0.5	8	12	9	5	10
1.5	17	20	16	13	16
2.5	23	28	20	17	20
3.5	27	34	24	20	25
4.5	31	39	27	23	28
5.5	35	43	29	25	30

[1] From United States Department of Agriculture Bulletin 418, Western Yellow Pine in Oregon, by T. T. Munger.

After seedlings are 6 inches high the damage caused by moderately close grazing is negligible. According to Table 5, western yellow pine reaches this height in 5 years on the better sites or in 8 years on the poorer sites, Douglas fir in from 10 to 12 years, and lodgepole pine in 9 years. There is practically no damage at all after seedlings reach 1.5 feet in height, or after from 13 to 17 years for western yellow pine, from 16 to 20 years for Douglas fir, and 16 years for lodgepole pine.

From Table 3 and the height growth it is computed that on the Deadwood allotment 46.5 per cent of the western yellow pine which germinates will be killed if the area is grazed every year, or 8.7 per cent if grazing is eliminated until seedlings have passed their third year. On the South Fork the figures will be 43.4 per cent and 5.7 per cent. Of Douglas fir in Deadwood, 48.8 per cent will be killed by grazing every year, or 14.3 per cent if it is suspended for three years; on the South Fork 44.2 per cent, or 9.9 per cent after three years, will be lost. In Deadwood 39.7 per cent of the lodgepole pine seedlings will be killed, or 15.1 per cent if the area is grazed after the third year only.

According to Table 3 a much larger proportion of western yellow pine seedlings less than a year old are killed than of Douglas fir, while only half as many of lodgepole pine are killed. This is probably due partly to the taller and more succulent and brittle stems of western yellow pine seedlings and partly to the fact that lodgepole pine reproduction is more abundant where there is comparatively little palatable forage cover, so that grazing is apt to be lighter on spots where lodgepole pine seedlings predominate than where western yellow pine is the prevailing species. The characteristic distribution of western yellow pine seedlings in clumps planted by chipmunks and mice (Douglas fir and lodgepole pine usually occurring singly) may also result in a somewhat larger mortality, since the disturbance which affects one seedling in a clump affects the whole group.

Table 8 indicates that as a general thing western yellow pine is less likely to be killed after its third year than is Douglas fir or lodgepole pine. This may be due to the larger size of three-year old yellow pine seedlings.

SEASON OF INJURY.

To determine the relation between the amount of damage and the time of year when the grazing was done, the plots grazed on the Deadwood allotment in 1913 were grouped into three classes: (*a*) those grazed early in the season, or up to the latter part of July, which in 1913 was a fairly moist period; (*b*) those grazed in midseason, from late in July to the middle of August; and (*c*) those grazed late, or after the middle of August, the driest part of the season. Table 6 shows the relative amount of damage done during each period.

TABLE 6.—*Grazing injuries, by time of year, in percentages of number of seedlings on the plots at the time they were grazed.*

(Deadwood allotment, 1913.)

Time of grazing and species.	Injured (over 1 year old).		Killed.	
	Browsed.	Trampled.	Under 1 year old.	Over 1 year old and under 1½ feet high.
Early summer:				
Western yellow pine	(1)		24.2	0.5
Douglas fir	(1)		20.6	.8
Lodgepole pine	(1)		18.5	4.8
All	.1		23.4	1.4
Middle summer:				
Western yellow pine	(1)		14.3	.5
Douglas fir	(1)	(1)	24.7	1.4
Lodgepole pine	(1)	(1)	6.8	1.5
All	.6	.2	11.6	1.1
Late summer:				
Western yellow pine	(1)		6.7	
Douglas fir	(1)	(1)	8.9	
Lodgepole pine	(1)	(1)	9.3	2.0
All	.5	.1	8.0	.5

[1] Very small.

Injuries which did not result in death, particularly those due to browsing, though insignificant at any season, were greater late in the season than during the earlier period. This is probably due to the drying of the succulent forage of the early part of the season and to the greater liking of sheep for browse types of forage as the season advances.

The proportion of seedlings killed by grazing, particularly of those less than a year old, was very much greater early in the season than it was later. The reasons for this are that early in summer the seedlings are rather brittle, with little wood in their stems; their roots do not go down very deep; the soil is moist and easily shoved out of place by the sheep; and seedlings injured early are either killed outright or have small chance to recover because of the dry period which follows the injury. By the middle of August the season's growth is nearly completed, the stems are tougher, the roots deeper and more widely spread, the soil is more firmly packed, and an injury is soon followed by the fall rainy period and the long winter period of rest, so that there is a fair chance for recovery from slight disturbance.

RELATION BETWEEN AMOUNT OF DAMAGE AND INTENSITY OF GRAZING.

The relation between intensity of grazing and amount of damage is shown in Table 7. Where the surface of the ground was not appreciably disturbed by trampling and very little of the forage cover was eaten the plot was classed as "lightly grazed"; where most of the palatable forage was eaten, but the ground was not seriously trampled, the plot was classed as "moderately grazed"; and where practically all forage was eaten and the surface considerably worn by trampling, it was called "closely grazed." Bed grounds, where the sheep bunched up for the night or during the middle of the day and where grazing was most intense, were grouped separately.

TABLE 7.—*Grazing injuries according to intensity of grazing.*

(All years and allotments.)

(A) SEEDLINGS MORE THAN ONE YEAR OLD (1912 TO 1914).

Intensity of grazing.	Seedlings on plots.				Numbers. Killed.				Numbers. Browsed.			Numbers. Trampled.		
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.
Light	2,503	2,446	1,392	168	35	37	25	1	13	4	.....	6	5	1
Moderate	2,174	1,761	714	193	59	33	52	8	25	3	.....	9	1	2
Close	2,388	1,351	398	76	80	23	11	.....	40	6	2	18	4	5
Beds	1,188	993	685	.....	50	32	42	.....	83	13	10	18	13	9
(B) SEEDLINGS LESS THAN ONE YEAR OLD (1913 AND 1914).														
Light	252	85	496	1	16	12	26	.....	1	.....	.....	.....	.....	.....
Moderate	947	138	385	11	230	29	58	6	.....	.....	.....	.....	.....	.....
Close	1,200	240	106	2	344	35	18	.....	12	.....	.....	1	.....	.....
Beds	823	213	54	.....	244	45	16	.....	2	.....	1	3	.....	1

(A) SEEDLINGS MORE THAN ONE YEAR OLD (1912 TO 1914)—Continued.

Intensity of grazing.	Per cent. Killed.					Per cent. Browsed.				Per cent. Trampled.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
Light	1.4	1.5	1.8	0.6	1.5	0.5	0.2	.....	0.3	0.2	0.2	0.1	0.2
Moderate	2.7	1.9	7.4	4.1	3.2	1.1	.1	.....	.6	.4	.1	.3	.3
Close	3.3	1.7	2.8	.....	2.7	1.7	.5	.5	1.1	.8	.3	1.3	.7
Beds	3.8	3.2	6.1	.....	4.2	7	1.3	1.5	3.7	1.5	1.3	1.3	1.4
(B) SEEDLINGS LESS THAN ONE YEAR OLD (1913 AND 1914)—Continued.													
Light	6.3	14.1	5.2	.....	6.5	.4	.....	.....	.1	.....	.....	.....	.....
Moderate	21.3	21.0	15.1	54.5	21.8	.....	.....	.....	.....	.....	.....	.....	.....
Close	28.7	14.6	19	.....	25.7	1	.....	.....	.8	.....	.....	.....	.1
Beds	29.6	21.1	29.6	.....	29	.2	.....	1.9	.3	.4	.....	1.9	.4

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FIG. 1.—AREA USED FOR BED GROUND FOR ONE NIGHT.

Injury to reproduction and to forage cover is not serious.

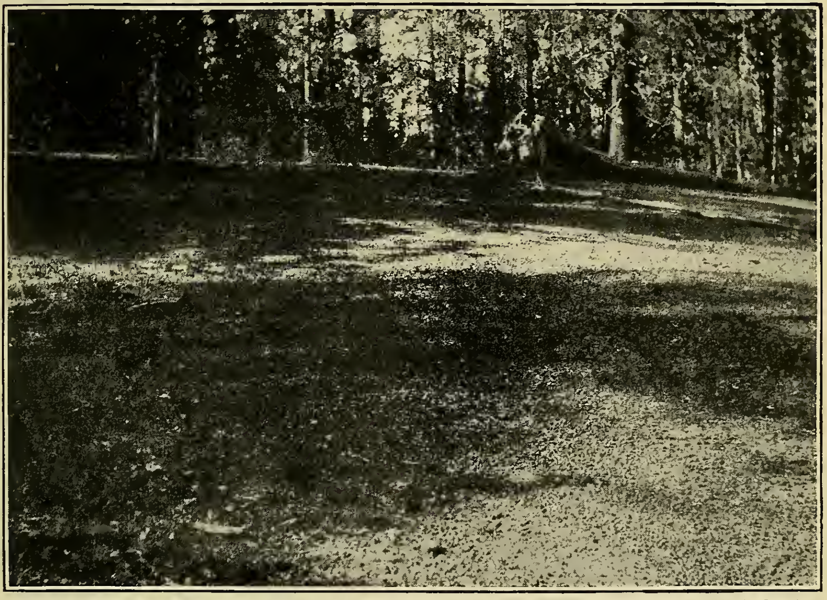

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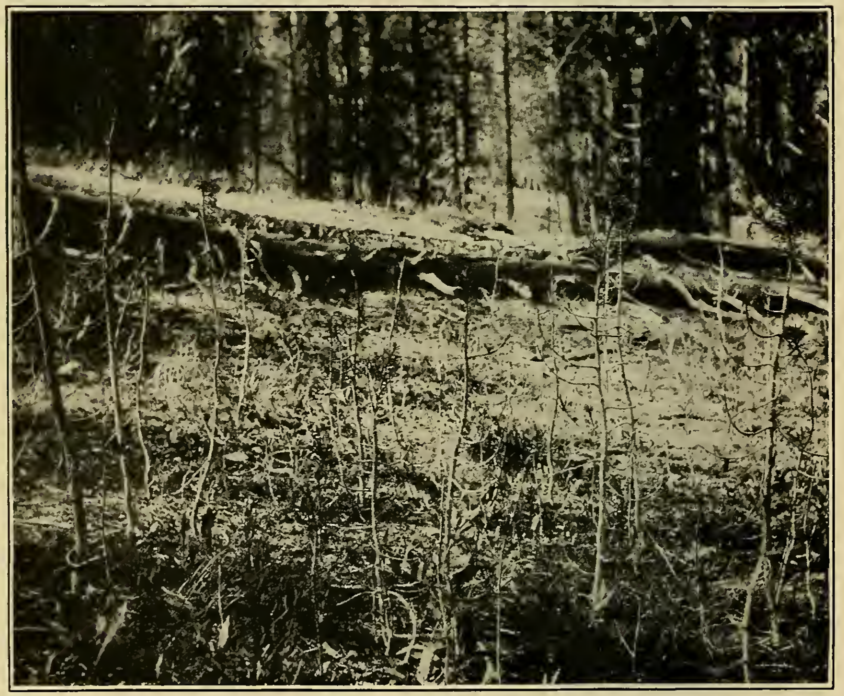
FIG. 2.—BED GROUND USED SEVERAL NIGHTS IN SUCCESSION.

Note entire absence of vegetation and thick layer of mulch.



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INJURY TO LODGEPOLE PINE REPRODUCTION ON BED GROUND USED FOR SEVERAL NIGHTS.

Few of these saplings recovered from the injury.

As would be expected, the amount of injury and death increased fairly constantly with increased intensity of grazing. Except on bed grounds and areas grazed with similar intensity, the damage was not very serious for seedlings more than a year old, and even in such places only 4 per cent of the seedlings were killed. A considerable proportion, from 20 to 30 per cent, of those less than a year old were killed on all except the lightly grazed plots, where only 6.5 per cent were lost.

Table 8 shows that after their third year a very small proportion of seedlings, less than 1 per cent per year, is killed by grazing of moderate intensity; that is, by grazing close enough to utilize practically all of the palatable forage.

TABLE 8.—*Seedlings from 3 years old to 1½ feet high killed by sheep on moderately grazed plots.*

Allotment and species.	Per cent of seedlings on grazed plots killed.			
	1912	1913	1914	Average for period.
Deadwood:				
Yellow pine			0.7	0.26
Douglas fir		.5	.8	.47
Lodgepole pine		.5	2.5	1.08
All		.3	1.1	.51
Silver Creek:				
Yellow pine	6.5			1.11
Douglas fir	4.6	1.6		1.07
White fir				
All	5.5	.8		.95
South Fork:				
Yellow pine			.8	
Douglas fir			33.3	
All			3	
All areas:				
Yellow pine				.52
Douglas fir				.98
Lodgepole pine				1.08
White fir				
All				.76

Although the plots did not happen to be located so as to show the effect of repeated use of the same bed ground, it was established by observation that the damage on the second and succeeding nights was very much greater in proportion than that on the first night. The first time a bed ground is used the sheep spend the time just before dark and in the morning before they are driven off the area in browsing, first, such forage plants as are present, and then, if they are left too long or forage is scanty, the conifer reproduction. Very few seedlings were browsed on the experimental areas on bed grounds used for one night only. On one plot which was part of a bed ground in 1913, only 37 out of 160 seedlings less than a year old were killed by the sheep. If sheep are driven back to the same bed the next night, or at any time before a full new crop of foliage has sprung up, the damage by browsing is almost always very serious, as there remain only the least palatable forage plants and the conifers. On bed grounds used for several times in succession every green leaf is removed, and even the bark of saplings up to several inches in diameter is gnawed off. For like reason similar conditions prevail along driveways used for several bands of sheep.

CUMULATIVE EFFECT OF GRAZING.

The cumulative effect of three years' grazing is indicated in Table 9, which shows in percentages of the numbers originally on the plots in the spring of 1912, the numbers gained by germination, those lost by death, and the net result. The figures, which are grouped according to the average intensity of grazing during the three years, show plainly that in spite of greater germination on the more closely grazed plots the net loss increased rapidly with increased intensity of grazing. While there was an increase in the number of seedlings on plots grazed lightly or not at all, there was a slight decrease on moderately grazed plots, and a considerable loss on closely grazed areas.

TABLE 9.—*Changes in numbers of seedlings from spring 1912 to fall, 1914, on 71 plots on Deadwood and Silver Creek, in percentages of the numbers originally on the plots in the spring of 1912.*

Average intensity of grazing.	Western yellow pine.			Douglas fir.			Lodgepole pine.		
	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.
Not grazed	96.3	61.5	65.2	104.6	54.4	49.8	143.8	59.7	15.9
Grazed lightly	94.4	42.7	48.3	100.6	30.2	29.6	172.3	184.7	112.4
Grazed moderately	78.4	76.0	97.6	102.4	25.2	22.8	133.1	87.3	54.2
Grazed closely	73.2	101.7	128.5	96.1	61.2	65.1	99.4	38.2	38.8
Beds	65.3	133.7	168.4	100.0	316.7	316.7			
All	83.4	71.8	88.4	101.3	36.7	35.4	146.1	108.9	62.8

Average intensity of grazing.	White fir.			All species.		
	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.
Not grazed	100.0	12.9	12.9	110.3	54.3	44.0
Grazed lightly	105.3	21.1	15.8	110.6	64.3	53.7
Grazed moderately	100.0	28.5	28.5	93.6	56.6	63.0
Grazed closely				81.2	86.5	105.3
Beds			100.0	67.9	150.9	183.0
All	100.5	20.7	20.2	98.5	64.9	66.4

RELATION BETWEEN AMOUNT OF DAMAGE AND AMOUNT AND CHARACTER OF THE FORAGE.

The quantity of palatable forage on a given area may affect the amount of damage done in two ways. If the total quantity of feed is too small for the number of stock allotted to the area, there will probably be considerable browsing injury and more injury from trampling than if there is abundant feed so that the sheep need not wander around looking for it. On the other hand, whether the allotment as a whole has ample forage for the allotted stock or not, the injury due to trampling, which causes most of the deaths of small seedlings, is likely to be greatest on those parts of the allotment where the amount of palatable forage is greatest. The reason for this is that the sheep will spend more time where forage is abundant than where it is scanty.

Trampling is more serious on steep slopes than on more level places, except around beds, watering places, or along driveways, because of the tendency of sheep on hillsides to follow each other's footsteps and thus wear trails, and because of the greater likelihood that seedlings will be uprooted or buried by trampling in such places.

Where the forage is composed largely of tender herbaceous vegetation reproduction is more subject to damage than where there are shrubs or dense tufts of perennial grasses or weeds to protect the seedlings.

COMPARISON OF THE DAMAGE CAUSED BY SHEEP AND BY OTHER AGENCIES.

To account for deaths due directly or indirectly to grazing, but whose cause could not be definitely traced, a comparison was made between the total deaths during the summer on grazed and ungrazed plots.

With very few exceptions, the mortality on grazed plots was the greater for all species and size classes. Excepting the 2 to 3 year old white fir, for which there were too few figures for a good average, this difference in favor of ungrazed plots was very marked for all seedlings less than 6 inches high.

Table 10 indicates that a large number of the smaller seedlings died even where no grazing was done. The total amount of injury and death during the period of the study due to causes other than grazing is summarized in Table 11. Tables 12 and 13 compare grazing injuries with those due to other causes for the different species and allotments.

The increase in the number of deaths in 1913 and 1914 was due to the greater number of plots and the larger number of seedlings examined, and to the greater proportion of seedlings less than 1 year old which resulted from the abundant germination, especially in 1913.

TABLE 10.—*Deaths during summer, from all causes, on grazed and ungrazed plots.*

(All years and allotments.)

Height class.	Western yellow pine.		Douglas fir.		Lodgepole pine.		White fir.		All.	
	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.
	Deaths in per cent of the numbers of seedlings on the plots.									
Under 1 year	36.5	59.2	35.2	50.0	24.2	34.7	27.3	36.1	31.3	53.4
1 to 2 years	19.0	25.2	23.6	29.9	17.1	21.1	43.7	44.8	19.8	24.9
2 to 3 years	12.5	17.8	11.8	17.8	7.9	25.2	40.0	25.0	11.8	19.0
3 years old to 6 inches high	4.9	6.1	2.1	3.9	2.8	5.6	......	1.0	2.9	4.8
6 inches to 1½ feet	1.1	.7	.3	.4	......	.5	......	......	.6	.6
1½ to 2½ feet	.3	.6	......	.1	......	......	......	......	.2	.3
2½ to 3½ feet	.4	.2	......	......	......	......	......	......	.2	.1
3½ to 4½ feet	......	.7	......	......	......	......	......	......	......	.2
4½ to 5½ feet	......	......	......	......	......	......	......	......	......	......

Taking the combined areas as a whole, more than three times as many seedlings were killed by other causes as were killed by sheep grazing, and five times as many were injured. The injury to leaders and side branches of Douglas fir and lowland white fir was principally due to late frosts, which in 1913 and 1914 killed back much of the new growth on these species. This injury was less serious on the Deadwood than on the other areas, probably because growth commences several weeks later at the higher altitudes. The pines, especially western yellow pine, are attacked by a tip moth whose larva develops in the leader and finally cuts it off. Other injuries were due to rodents (rabbits and porcupines especially), birds (particularly grouse), and fungous diseases of needles and bark.

TABLE 11.—*Deaths and injuries on all plots, due to causes other than sheep grazing.*

Year and species.	Deadwood.						Silver Creek.				
	Needles.	Side branch.	Leader.	Bark.	Trampled.	Killed.	Needles.	Side branch.	Leader.	Bark.	Killed.
1912:											
Western yellow pine	1	......	58	4	1	19	......	......	18	1	525
Douglas fir	......	1	20	......	2	57	......	......	3	......	19
Lodgepole pine	......	......	11	2	1	13	......	......	......	......	......
White fir	......	......	......	......	......	......	......	......	......	......	1
All	1	1	89	6	4	89	......	......	21	1	545
1913:											
Western yellow pine	1	2	76	6	......	709	......	......	65	2	1,222
Douglas fir	......	......	61	......	......	273	......	......	20	......	244
Lodgepole pine	......	......	19	1	......	593	......	......	......	......	......
White fir	......	......	......	......	......	......	......	......	2	......	11
All	1	2	156	7	......	1,575	......	......	87	2	1,477
1914:											
Western yellow pine	3	2	55	......	......	518	1	4	23	2	487
Douglas fir	......	26	262	......	......	220	......	46	468	......	269
Lodgepole pine	......	1	15	......	......	620	......	......	......	......	......
White fir	......	......	......	......	......	......	......	21	116	......	19
All	3	29	332	......	......	1,358	1	71	607	2	775
All years total	5	32	577	13	4	3,022	1	71	715	5	2,797

TABLE 11.—*Deaths and injuries on all plots, due to causes other than sheep grazing*—Con.

Year and species.	South Fork.						All areas.					
	Needles.	Side branch.	Leader.	Bark.	Trampled.	Killed.	Needles.	Side branch.	Leader.	Bark.	Trampled.	Killed.
1912:												
Western yellow pine							1		76	5	1	544
Douglas fir								1	23		2	76
Lodgepole pine									11	2	1	13
White fir												1
All							1	1	110	7	4	634
1913:												
Western yellow pine							1	2	141	8		1,931
Douglas fir									81			517
Lodgepole pine									19			593
White fir									2			11
All							1	2	243	8		3,052
1914:												
Western yellow pine	2	1	43	5	2	142	6	7	121	7	2	1,147
Douglas fir		19	218			62		91	948			551
Lodgepole pine								1	15			620
White fir								21	116			19
All	2	20	261	5	2	204	6	120	1,200	7	2	2,337
All years total	2	20	261	5	2	204	8	123	1,553	23	6	6,023

TABLE 12.—*Comparative damage from sheep grazing and from other causes.*

(All allotments and years.)

Species and cause of injury.	Nature of injury.						
	Needles.	Side branch.	Leader.	Bark.	Trampled.	All not killed.	Killed.
Western yellow pine:							
Sheep	51	12	116	8	57	244	1,234
Other	8	9	338	20	3	378	3,622
Douglas fir:							
Sheep		5	21	1	25	52	275
Other		92	1,052		2	1,146	1,144
Lodgepole pine:							
Sheep	3	3	7		18	31	256
Other		1	45	3	1	50	1,226
White fir:							
Sheep							17
Other		21	118			139	31
All species:							
Sheep	54	20	145	9	99	327	1,782
Other	8	123	1,553	23	6	1,713	6,023

Table 14 shows the causes of death in 1913 and 1914, as far as could be ascertained with a fair degree of certainty. Of the several hundred deaths whose cause could not be determined, most were probably due to drought or a combination of drought and excessive heating of the surface soil. This is the most serious obstacle to successful reproduction in the western yellow pine type. "Winter-killed" in the first column of the table really embraces a number of causes, including drought, frost, fungus, and others.

TABLE 13.—*Comparative damage from sheep grazing and from other causes.*

(All years and species.)

Allotment and cause of injury.	Nature of injury.						
	Needles.	Side branch.	Leader.	Bark.	Trampled.	All not killed.	Killed.
Deadwood:							
Sheep	34	4	65	7	84	194	753
Other	5	32	577	13	4	631	3,022
Silver Creek:							
Sheep	18	7	68	1	11	105	970
Other	1	71	715	5		792	2,797
South Fork:							
Sheep	2	9	12	1	4	28	59
Other	2	20	261	5	2	290	204

TABLE 14.—*Causes of deaths of seedlings between the end of the summer of 1912 and the end of the summer of 1914.*

Cause of death.	Less than 1 year old.			More than 1 year old.		
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.
Sheep:						
Known	520	72	118	201	91	114
Probable	838	119	118	201	99	116
Drought	917	264	523	615	298	267
Winter-killed	523	215	282	216	161	125
Frost			4		2	1
Erosion					1	
Damped off	166	7	2			
Fungus	2	2		110	18	2
Bitten off by rodents or birds	240	5				
Dug up by rodent			1			
Chipmunk				3		
Mole				2		
Rabbits	7			4		
Deer				3		
Bear	6					
Cattle	2			3		1
Horses	2			1		1
Men	12	2	3	20		
Insects				5		
Porcupine				4		
Shade	3		2	4		
Rolling log						1
Crowded	1					
Total	2,719	614	935	1,191	579	514

VALUATION OF DAMAGE.

Using the table of height growth and the average proportions of seedlings of different sizes killed by all agencies on the grazed plots on all areas, curves were constructed to show the per cent of mortality at different ages. Table 15 was read off from these curves, and from it was computed Table 16, which shows the number of seedlings of any age up to 20 years necessary to insure a stand of 100 trees per acre of any of the three species at an assumed maturity of 150 years. These figures allow for deaths from all ordinary causes, including grazing every year, but, of course, do not allow for extraordinary deaths due to such causes as fires or epidemics of insects or of fungous diseases.

TABLE 15.—*Average mortality from all causes on grazed areas of seedlings of different ages.*

Year of age.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodge pole pine.	Western yellow pine.	Douglas fir.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	82	80	50	82	80
2	42	47	35	41	47
3	27	28	24	22	28
4	20	20	16	14	18
5	15	16	11	9	13
6	11	12	7	7	10
7	8	10	5	5	8
8	6	8	4	4	6
9	5	6	3	3	4
10	4	5	2.5	2.5	3
11	3	4	2	2.5	2.5
12	2.5	3	1.5	2	2
13	2	2.5	1.5	2	1.5
14	2	2	1.5	2	1
15	2	1.5	1	1.5	1
16	1.5	1.5	1	1.5	.5
17	1.5	1	1	1.5	.5
18	1.5	1	1	1.5	.5
19	1.5	1	1	1	.5
20	1.5	1	1	1	.5
21 to 25	1	.5	.5	1	.5
26 to 30	1	.5	.5	.5	.5
Over 30	.5	.5	.5	.5	.5

TABLE 16.—*Average number of seedlings per acre at different ages necessary to insure a stand of 100 trees per acre of any of the three species at 150 years, if ordinary grazing every year is permitted.*

At beginning of year.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.
1	6,700	6,850	1,475	4,350	5,170
2	1,200	1,370	735	790	1,085
3	700	725	480	470	575
4	510	525	365	365	415
5	410	420	305	315	340
6	345	350	270	290	295
7	310	310	255	270	265
8	285	280	240	255	245
9	265	255	230	245	230
10	255	240	225	240	220
11	245	230	220	230	215
12	235	220	215	225	210
13	230	215	210	220	205
14	225	210	205	215	200
15	220	205	205	210	195
16	215	205	200	205	195
17	210	200	200	200	195
18	210	200	195	200	190
19	205	195	195	195	190
20	205	195	195	195	190
21	200	190	190	190	190

On the basis of the material in United States Department of Agriculture Bulletin 418, "Western Yellow Pine in Oregon," a full stand of western yellow pine of 16 inches diameter, approximately 150 years old, should have about 40 trees per acre. This would mean a volume of about 10,000 board feet. A small, even-aged stand on the Payette Forest, approximately 150 years old, had 230 trees per acre, practically all western yellow pine, between 10 and 22 inches diameter, besides 160 trees below 10 inches; and its volume (trees 10 inches and over) was approximately 23,000 board feet per acre. This is very exceptional for a stand in virgin forest, but may be possible with managed forests.

If 40 trees per acre are assumed to constitute a full stand, but 0.4 as many seedlings as are indicated in Table 16 will be needed; but if 200 trees per acre are assumed, the figures in the table should be doubled. If a full stand of Douglas fir is taken as 167 trees,[1] the figures should be increased by two-thirds for Douglas fir stands. Assuming 250 trees per acre [2] as normal for lodgepole pine at maturity (140 years) the figures in Table 16 should be multiplied by 2.5—that is, there should be approximately 3,700 seedlings the first year.

TABLE 17.—*Amount of reproduction on all plots, spring of 1914, reduced to a per acre basis.*

(All sizes up to 5½ feet high.)

Allotment.	Number per acre.					Per cent of total.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Total.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.
Deadwood	3,450	2,870	2,750	....	9,070	38	32	30	....
Silver Creek	6,580	3,940	....	910	11,430	58	34	....	8
South Fork	5,050	2,070	....	....	7,120	71	29	....	....

Table 17, which shows the number of seedlings per acre actually present on the plots on all three allotments in the spring of 1914, indicates plainly that there was sufficient reproduction present to make a full stand in spite of grazing injuries. On areas as well stocked with reproduction as those covered by the study the comparatively small amount of scattered injury which results when the stock is carefully managed can hardly be said to represent a tangible loss of value. Where the number of seedlings present is already insufficient to make a full stand at maturity, or where injuries are concentrated, as on trails, bed grounds, or very seriously overgrazed areas, so as practically to eliminate all reproduction over a continuous area of any considerable size, there is a loss.

If seed trees are present in sufficient quantity to reseed the area, the loss will equal the value of the growth already made by the seed-

[1] See Bulletin 418.

[2] See United States Department of Agriculture Bulletin 154, "Life History of Lodgepole Pine in the Rocky Mountains," by D. T. Mason, p. 31.

lings, which at 10 years of age will be approximately 30 cents per acre or $0.001 per tree if there are less than 300 seedlings per acre, and at 20 years 75 cents per acre or one-third of a cent per seedling where there are less than 250 per acre. These values, which are based on an average annual increment (for a 150-year rotation) of 100 board feet per acre and a stumpage price of $5 per 1,000 feet, are liberal.[1] With an average annual increment of 200 board feet, which may be possible on the best sites, the loss would be 60 cents and $1.50 per acre at 10 and 20 years.

In case of restocking open burns, clear-cut areas, or plantations, where the reproduction must be replaced artificially, the loss will be the above cost plus the cost of restoration, which has been estimated at $9 per acre for eastern Oregon; $10 per acre, or 4 to 5 cents per tree, will cover the whole loss. Such areas of total destruction need not occur with regulated grazing, except possibly in the case of a few driveways which for topographic or other reasons can not be so located as to avoid injury; and unless the range is overstocked these can in any case be kept very small.

BENEFITS OF SHEEP GRAZING TO THE FOREST.

Benefits to the forest resulting from the use of the range may often offset the slight damage done by regulated grazing. These benefits may consist in direct aid to forest reproduction or in lessening the danger of serious fires.

AID TO REPRODUCTION.

The value of sheep grazing in helping tree reproduction to start is frequently overestimated. It does result in more abundant germination under certain conditions, viz, in case of heavy grazing on poor sites. A pair of plots on a very poor lodgepole pine site, similar in all respects except in the intensity of grazing on them, showed this result:

	Bed ground, 1912.	Lightly grazed, 1912.
Area (square feet)	800	800
Seedlings over 1 year old	None.	None.
Germinated, 1913	75	17

In this case the soil was so dry and lacking in organic matter as to be very unfavorable to reproduction, but the sheep, bedding in the same place for several successive nights, left a thick layer of mulch, so that seedlings not only germinated in greater numbers, but grew much more vigorously than those on the lightly grazed plot. As is usually the case where an area is excessively overgrazed, all of the

[1] See Bulletin 418.

reproduction already on this bed ground was severely browsed and much of it killed.

Table 9 also shows an increase in germination on the most closely grazed areas, but indicates that light or moderate grazing did not have this result; while a series of plots on sites naturally favorable to reproduction showed that on such sites even close grazing may not result in greater germination. These plots showed this result:

	Bed ground, 1912.	Lightly grazed, 1912.
Area (square feet)	1,380	1,380
Seedlings over 1 year old	41	40
Germinated, 1913	128	235

The theory is often advanced that sheep grazing aids the seeds to germinate by "harrowing" them into the soil. This might be an important factor if the grazing were done after the seeds fall; but since the cones usually do not begin to open to any great extent until September, near the end of the grazing season, and since most of the germination takes place before the sheep go on the timbered range in the spring, the benefit is slight. As lodgepole pine seed begins to fall somewhat earlier than the other species and germinates during most of the summer and fall, its germination may be considerably helped by the "harrowing-in" process.

It it probably not true that sheep by loosening the soil and eating competing foliage help seedlings to survive. Table 18, in which the total deaths between the fall count in 1913 and the first count in 1914 are grouped according to the intensity of grazing during 1913, shows that the proportion of survival through the winter was slightly greater on grazed areas than on those which were not grazed. Table 10, however, shows plainly that the sheep did not help seedlings to live through the summer season and Table 9 shows that the greater mortality on grazed areas during the summer more than balanced the slight gain in survival over winter plus the increased germination on grazed areas.

TABLE 18.—*Deaths from all causes between last count, 1913, and first count, 1914, according to intensity of grazing in 1913. Per cent of number on plots, fall 1913.*

(Deadwood and Silver Creek.)

	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.
Number of seedlings	5,392	4,083	2,892	237	12,604
Per cent died on:					
All ungrazed plots	12.0	8.5	14.5	3.0	11.4
All grazed plots	10.7	6.6	9.3	2.2	9.0
Per cent in favor of grazed plots	1.3	1.9	5.2	.8	2.4
Died on "moderately" grazed plots	9.7	5.2	12.4	2.6	8.6
Per cent in favor of "moderate" grazing	2.3	3.3	2.1	.4	2.8

PROTECTION AGAINST FIRE.

The most important benefit to the forest which can be attributed to grazing is the reduction in quantity of inflammable ground cover and the consequent decrease in fire hazard. It is not probable that the number of fires can be reduced in this way, but their intensity and consequently their size and the amount of damage done, is bound to decrease with a decrease in the quantity of fuel on the ground. This is particularly apt to be true in a forest of the western yellow pine type, where fire seldom runs in the crowns but nearly always on the ground. If the ground cover is scanty, the older timber is to a certain extent immune from serious damage by surface fires and there is more likelihood that occasional patches of reproduction will escape destruction. Entire denudation of the soil, such as occurs on much-used bed grounds and along driveways, absolutely prevents fires from spreading in such places, but of course destroys any reproduction which may be present. Light or moderate grazing does not remove enough of the cover to stop fires, but may considerably reduce their heat and rapidity of spread and make them easier to combat.

MANAGEMENT OF GRAZING.

The points brought out in the study suggest a number of principles for the management of grazing in western yellow pine and, with slight modifications, in the other timber types of the region. These principles are based on (1) the utilization of the forage in the way most advantageous to the stockman, (2) the welfare of the forest reproduction, (3) the reduction of the fire hazard.

TIME TO GRAZE.

In general, the range should be grazed before the forage becomes dry and unpalatable. Grazing should start in the lower parts of the western yellow pine country (3,000 to 4,000 feet altitude) early in May and practically close by the middle or end of July. The higher altitudes can be grazed from about June 1 to the end of July, or, in wet seasons, to the middle of August. Areas consisting largely of grass or weed range should be used first, since they contribute largely to the inflammable ground cover of August. Besides, if they are fed off early, they will often produce another crop of foliage or seeds before the end of the season. Areas where there is great likelihood of fires starting should be grazed before the dry season begins. Areas upon which most of the reproduction is under 3 years old should be grazed as late in the season as is possible with proper utilization of the feed, since they are the least liable to injury. Such areas should not be grazed when the ground is saturated, especially early in the season.

INTENSITY OF GRAZING.

As a general rule the range should be grazed just enough to remove the greater part of the palatable forage. Extensive browsing of the less palatable species or of conifer reproduction is the best evidence that an area is being grazed too closely not only for the good of the range but also for the best interest of the stock.

Steep slopes with loose soil, particularly where the seedlings are less than a foot and a half high, and reproducing burns, clear-cut areas, or plantations with seedlings up to 5 or 10 years old, depending on the site, should be grazed rather lightly, especially in the first part of the season or during a wet period. In many instances it will be desirable to eliminate grazing entirely from plantations or other areas of seedlings less than three years old. During a dry season spots where danger of fire is greatest may be grazed as closely as possible. Very close grazing is also permissible on areas poorly stocked with reproduction where a heavy crop of seed is expected in the fall, or where artificial reseeding is planned. If a good catch of seedlings takes place such areas should be grazed very lightly or not at all for at least three years succeeding the seed year.

The carrying capacity of western yellow pine range varies so widely with the locality and the season that no definite figures can be laid down which will have a general application. Much of the poorer range, such as that on the Deadwood allotment, will require up to 10 acres per grown sheep for a 60-day season; while the best range will sometimes, with favorable weather conditions, average two acres per sheep over limited areas. An average for most of the better class western yellow pine areas is approximately from three to four acres per sheep.

METHODS OF HANDLING.

HERDING.

The sheep should be allowed to scatter out and graze with as little disturbance as possible. No attempt should be made to keep them in a compact bunch, except for convenience and safety when they bed down at night, and at such times they should be gathered together with a minimum of driving or excitement. The use of dogs should be avoided as far as possible.

Driving the sheep to and from water, bed grounds, or different parts of the allotment is seldom necessary and should be avoided. When it is necessary to drive them, they should be taken where damage from trampling is least apt to occur, such as areas with no reproduction or with plenty of seedlings over 1.5 feet high, or places where complete removal of foliage and denudation of the soil is desirable to reduce the fire hazard.

DRIVEWAYS.

The driving of the sheep in fairly compact bands to and from their allotments in spring and fall can hardly be avoided, but in many cases great damage to the forest can be prevented by careful location of driveways in places least subject to damage. Areas without small reproduction, untimbered areas where danger of erosion is not serious, sites which are too poor to produce merchantable timber in a reasonable rotation, such as dry, rocky ridges with little soil, are examples of such places. Although usually impracticable from the administrative standpoint, it may sometimes be possible to reduce considerably the amount of injury by changing the location of such driveways from year to year, by limiting the number of bands of sheep which may use the same one, by limiting the time each band may spend on the trail, and by making the trail wide enough to supply feed for all the stock which use it.

It will very often be possible to locate the driveways so that they will be an advantage to the forest. Such areas make excellent fire breaks for stopping light surface fires and for use in back-firing and fighting severer fires. When it is possible, they should be located near places of great fire danger. For instance, closely grazed strips along roads, trails, railroads, or around camping places, sawmills, and the like, will be of considerable value in preventing the spread of incipient fires from such places. In such cases due regard should of course be had for the rights of other users; for instance, sheep should not be allowed to graze on camp grounds or so close to them as to make conditions unpleasant for campers, nor should feed necessary for pack and saddle animals be eaten off near camping places, nor should areas much frequented by travelers and tourists be grazed in such a way as to impair their scenic beauty. Similar trails along the edges of burns, reproduction areas, or slashings will be of much value in fire control. Such strips should, of course, be fed clean every year, and the more closely they are grazed the better.

SALTING.

Sheep should be supplied with all the salt they want, at least every five or six days, so that they will not trail around hunting for it. They should be salted in a different place each time, and the salt should be so well distributed that they will not bunch up closely and cause serious injury to the forage cover and forest reproduction by trampling. Bed grounds are good places to supply the salt; for if the stock spend part of their time there eating salt, they will have less time to graze or browse conifers.

WATERING.

In the particular locality studied water is so well distributed that driving to water was not necessary. In places less plentifully supplied much of such driving can be eliminated by the development of watering places. It is also important to remember that sheep do not ordinarily require water every day, but, especially during rainy periods, can do without it for several days.

BEDDING.

The most serious damage to reproduction under the old unrestricted methods of herding was due to repeated use of the same camp and bed ground, which not only resulted in the entire denudation of the area so used, but necessitated much driving back and forth at morning and night. This damage can be very largely eliminated by the so-called "bedding-out" method of herding in which the herder moves around with the sheep and camps near wherever they stop at night. As they bed in a different place each night no driving is necessary.

By locating bed grounds where liability to damage is least—either because of lack of small reproduction, presence of plenty of palatable forage not previously eaten off, or of sod cover—the injury which is inevitable in such places can be reduced to a negligible amount. It is also advisable in places which are liable to considerable damage, such as areas with only a limited stock of seedlings, areas of reproduction mostly less than 1.5 feet high, and areas with loose and easily disturbed soil, not to use the same bed ground in two successive years.

If the sheep are not gathered on the bedding area until nearly dark and are herded off soon after daylight, the injury from browsing will be much less than if they are allowed to feed on the one spot for several hours.

On bare dry ridges where natural soil conditions have not allowed reproduction to become established, severe and repeated use of bed grounds may often be desirable to fertilize the soil so that seedlings can grow on it. As with driveways, bed grounds may often be so located and used as to be of considerable assistance in reducing fire hazard. In places where danger is great repeated use of the same area will be desirable.

None of the foregoing suggestions is impracticable or contrary to the best interests of the stock owner. To carry them out will require in many cases a somewhat higher grade of camp tenders and herders and better supervision, consequently the cost of the business may be slightly greater than with the old unrestricted and usually rather careless methods of herding. This additional cost will be much more than repaid by the increased returns from meat and wool, for it is a well-known fact that sheep do best when they are disturbed as little as possible and bunched or driven around no more than is absolutely necessary. It is obvious that they will keep in better condition if held on palatable feed than if kept on an area after the feed is gone so that they have to eat unpalatable species such as conifers. With careful application of these principles injury to forest interests will be reduced to practically nothing, the forest will in many cases benefit largely by reduction of the fire hazard, and, whether or not there is an actual increase in the number of head grazed on a given area, there will be considerable increase in the quantity and improvement in the quality of the meat and wool produced.

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JOHN R. MOHLER, Chief

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THE SIGNIFICANCE OF THE COLON COUNT IN RAW MILK.

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CONTENTS.

PRESENT STATUS OF THE QUESTION.

For many years the organisms of the colon-aerogenes group have occupied a position of very great importance in the eyes of sanitarians. From the public-health standpoint the quality of water supplies has been determined by means of the number of these organisms present; not because they are considered pathogenic but rather because they are present in fecal material in large numbers, and therefore their presence in any considerable number in water may indicate the presence of pathogenic organisms of fecal origin.

Investigations have shown, however, that the colon bacillus is by no means confined to the human intestines, but is often the prevailing form in the intestines of many animals, including cows. It would seem at first thought, therefore, that the presence of colon organisms in milk might afford a valuable means for determining pollution by cow feces. In fact, the determination of colon bacilli in milk as a means of indicating manurial pollution has become quite general on account of the value of the colon test as an index of the purity of water and the apparent analogy between the contamination of water by fecal material and the contamination of milk by cow feces.

In this connection Savage (18) [1] states:

Lactose fermenters of the colon type are absent from pure milk drawn without contamination, and as far as it is known at present, all such organisms indicate outside pollution of the milk and in general (directly or indirectly) manurial pollution.

Kinyoun and Dieter (10) stated that their experience led them to conclude that the colon and streptococcus content of milk could be taken with reasonable certainty to indicate the amount of filth and dirt in milk. These authors also realized that temperature had an effect upon the colon content of milk, and in this connection they state:

It is evident from this fact alone that it will account for a considerable proportion of the number, but it must be understood that we do not believe that this factor alone is responsible for the enormous numbers found.

Again, Kinyoun (9) writes as follows:

What is the significance of the colon group in milk? The colon group comes from the intestinal canal of man and animals, indirectly may be found in soil, water, and food. This is such a well-established fact that it does not need discussion. When it gains access to food and drink it must be from one of these sources. Water frequently contains colon bacilli, and sanitarians agree that in determining the wholesomeness of water for drinking purposes the colon bacillus is the best index for purity.

Kinyoun while admitting that temperature played a part in the colon count believed that most of them gained entrance to the milk during milking, for in the same article he states:

When milk is contaminated by the colon group it indicates that it owes its presence there to uncleanly methods at the time of milking, or to the collection of the milk in dirty utensils, or to the contamination from air. The greater proportion of the colon bacilli gains entrance to the milk at the time of milking, and they owe their presence directly to fecal matter which has gained access to the pail by dirty, filthy cows, equally so the hands of the milker.

Other investigators are inclined to credit more importance to the growth of colon organisms in milk which has been held at high temperatures. Thus Harrison, Savage, and Sadler (4) made colon counts on a large number of samples in a study of the milk supply of Montreal, and, in speaking of the colon and aerogenes groups, state:

We regard any member of these groups as indicating manurial impurities in milk. A large number of this group present in the sample shows either carelessness and uncleanliness in milking, subsequent keeping at a high temperature, or, as most frequently happens, a combination of both.

In view of the fact that milk is an ideal medium for the growth of bacteria it seems that a determination of the colon bacilli as a means of indicating original contamination must be greatly complicated by the ability of these organisms to grow in the milk unless it is kept cold. Kendall, Day, and Walker (8) realized this difficulty and state:

The numbers of colon bacilli which may be present in a sample of milk do not necessarily furnish any evidence of the nature or extent of fecal contamination, for there is no way of distinguishing between the initial number of these organisms in a given sample of milk and their descendants.

[1] Figures in parentheses refer to "Literature cited" at end of paper.

If the colon count were a direct measure of original contamination during milking, it would be a most valuable aid in determining the purity of a milk supply. Can the colon count, however, be considered a direct measure of such contamination? This is a question which seems to be unsettled. As has been shown there are opinions on both sides of the question. While the test was formerly considered of considerable importance, more recently it has lost some of its significance because of the recognized ability of organisms of the colon and aerogenes group to grow rapidly in milk when not properly cooled and kept cold.

A test which gives promise of indicating original contamination, particularly fecal contamination, is worthy of attention, and it has seemed desirable to study this subject under controlled conditions with a view of determining the true value of the colon count in milk.

Throughout this paper the expressions "colon-aerogenes group" and "colon count" are used. The "colon count" means the number of organisms belonging to the colon-aerogenes group, and the term "colon-aerogenes group" as used includes both the *Bacillus coli* and *B. aerogenes* types of organisms. When any differentiation is made between the *B. coli* and *B. aerogenes* types it will be indicated in the text.

DO ORGANISMS OF THE COLON-AEROGENES GROUP INDICATE THE PRESENCE OF MANURE IN FRESH MILK?

If the organisms of the colon-aerogenes group are to be considered evidence of external contamination it must first be known whether or not they are present in the udders of cows. Both Savage (17) and Race (13) believe that organisms of this group are derived from sources outside the udder. Our results confirm this opinion, for in an examination of four cows no organisms of the colon-aerogenes group were ever found in milk drawn directly from the teats into sterile tubes. While only a few cows were examined, the results obtained, together with those of other investigators, seem to indicate that in general organisms of the colon-aerogenes group are not derived from the udder of the cow and therefore represent external contamination.

Raw market milk contains both the *Bacillus coli* and *B. aerogenes* types of organisms, as has been shown by the work of Rogers, Clark, and Evans (14), who found the colon-aerogenes group in such milk to be made up of nearly equal proportions of *B. coli* and *B. aerogenes* types. This being the case, it becomes necessary to know the source or sources of the *B. coli* and *B. aerogenes* types before they can be accepted as an indication of manurial contamination. It has been known for a long time that cow manure contains large numbers of organisms of the colon-aerogenes group, and the authors last men tioned have shown that practically all the organisms found in this group are of the *B. coli* type. Among 150 cultures isolated from 16 samples of bovine feces they found only one culture of *B. aerogenes*. Even special methods used to demonstrate the presence of the *B. aerogenes* type in bovine feces failed to reveal their presence.

Our results in a general way confirm those of Rogers and his associates, for among 1,160 cultures isolated from 20 samples of fresh cow feces only 4 cultures of the *B. aerogenes* type were found. By means of special enrichment methods, however, it was often possible to isolate *B. aerogenes* types from 1/100 gram of fresh feces. The most satisfactory method of enrichment was to inoculate varying small amounts of cow feces into sterile skim milk. It seems evident, therefore, that the colon-aerogenes group found in cow feces consists mainly of the *B. coli* type. The *B. aerogenes* type is probably always present, but in very small numbers.

In view of the facts just presented, the contamination of milk by the colon-aerogenes group through cow feces would introduce principally organisms of the *B. coli* type. Occasionally the examination of fresh milk produced under clean conditions with sterilized utensils shows the presence of the colon-aerogenes group in small numbers which are mostly of the *B. aerogenes* type. Milk produced under these conditions would probably have an exceedingly small amount of fecal contamination, and taking into account the very small number of the *B. aerogenes* type in fresh cow feces compared to the number of the *B. coli* type, it is evident that the *B. aerogenes* found in the milk did not represent fecal contamination.

The *B. aerogenes* type being found at times in small numbers in low-count fresh milk led to the suspicion that the proportion of the *B. coli* and *B. aerogenes* types in cow feces might change as the feces aged and dried. Should this change occur it might explain the preponderance of the *B. aerogenes* type sometimes found in such milk. This seemed a very logical possibility because fecal material entering milk is probably not fresh but more or less dry, and gains entrance to the milk largely by dropping from the body of the cow. In order to determine whether the proportion of *B. coli* to *B. aerogenes* types changed in feces as it dried, a composite sample consisting of equal amounts of fresh feces from 4 cows was placed in a sterilized dish and allowed to dry at 86° F. (30° C.) to a practically constant moisture content, which after 14 days was 5 per cent. At regular intervals 1/100 of a gram of the material was inoculated into sterile milk. Two flasks of milk were inoculated with equal amounts of feces, one was incubated for 24 hours at 70° F. (21.1° C.) and the other for the same length of time at 86° F. (30° C.). After incubation, samples of milk were plated on litmus-lactose-asparagin agar of the following composition:

	Per cent.
Agar	1. 5
Asparagin	0. 3
Lactose	1. 0
Sodium dibasic phosphate	0. 1
Saturated neutral solution of litmus	2. 0

From these plates typical colonies of the colon-aerogenes group were then picked and inoculated into the dextrose-peptone broth of Clark and Lubs [3], and the methyl-red test made after five days as proposed by the same authors. By means of this test organisms are divided into *B. coli* and *B. aerogenes* types. If the proportion of the types changed as the feces dried, then enrichment in milk should show the presence of the *B. aerogenes* type. It is evident from Table 1, where the percentage of the two types after enrichment is shown, that the general proportion of *B. coli* to *B. aerogenes* which exists in fresh feces is not changed to any great extent as the feces dries. It is interesting to note, however, that when the feces was seven days old the enrichment method showed the presence of as high as 11 per cent of the *B. aerogenes* type. They were still present on the tenth day but not on the fourteenth, in milk held both at 70° F. (21.1° C.) and at 86° F. (30° C.). This indicates that as feces dries the proportion of *B. aerogenes* to *B. coli* in it may increase slightly, but, generally speaking, it is not believed that this is the main source of the *B. aerogenes* type.

TABLE 1.—*Effect of drying cow feces on the proportion of Bacillus coli and B. aerogenes types.*

Number of days dried at 70° F. (21.1° C.).	Held 24 hours at 70° F. (21.1° C.).			Held 24 hours at 86° F. (30° C.).		
	Colon count.	*B. coli.*	*B. aerogenes.*	Colon count.	*B. coli.*	*B. aerogenes.*
	Per c. c.	*Per cent.*	*Per cent.*	*Per c. c.*	*Per cent.*	*Per cent.*
0 (fresh)	320, 000	100	0	26, 000, 000	100	0
1	2, 500, 000	100	0	23, 000, 000	100	0
2	420, 000	100	0	103, 000, 000	100	0
3	760, 000	100	0	210, 000, 000	100	0
6	490, 000	100	0	280, 000, 000	100	0
7	680, 000	89	11	132, 000, 000	99	1
10	6, 500, 000	99	1	270, 000, 000	96	4
14	6, 500, 000	100	0	37, 000, 000	100	0

The colon-aerogenes group of organisms is introduced into milk not only through feces but also from unsterilized utensils. In fact this is a very important source of contamination. Both *B. coli* and *B. aerogenes* types can be introduced into milk from unsterilized milk utensils, as may be seen in Table 2. The results given in the table represent a very extreme condition of production, such as would rarely be met with under commercial conditions. The milk was produced in a dirty barn and placed in utensils handled in the following manner: The milk was poured out of the utensils promptly after milking, but the drippings were not removed till 24 hours later, when the utensils were washed in lukewarm water without the use of either brush or washing powder. During the time that the utensils were allowed to remain unwashed they were exposed to an atmospheric temperature averaging 85° F. (29.5° C.) Reference to Table 2 shows that in the six samples examined both the total and colon counts were very high in the fresh milk, and that most of the organisms of the colon-aerogenes group were of the *B. aerogenes* type, although a considerable percentage consisted of the *B. coli* type. These figures merely show that both types of organisms may be introduced through unsterilized utensils, but it must be clearly understood that the high total and the high colon counts obtained under this abnormal condition are very extreme, as will be subsequently seen. Milk may become heavily contaminated in this manner with both the *B. coli* and *B. aerogenes* types.

TABLE 2.—*Bacillus coli and B. aerogenes contamination due to filthy utensils.*

Sample No.	Total count.	Colon count.	*B. Coli.*	*B. aerogenes.*
	Per c. c.	*Per c. c.*	*Per cent.*	*Per cent.*
1	18,900,000	5,200,000	31	69
2	25,300,000	3,600,000	35	65
3	16,500,000	1,190,000	38	62
4	28,200,000	6,700,000	8	92
5	33,000,000	1,620,000	2	98
6	17,200,000	340,000	14	86

Organisms of the colon-aerogenes group may also be introduced into milk through the air. In this connection it is necessary to make some distinction between contamination by relatively large particles of feces which drop directly into milk from the body of the cow and very fine particles of dry feces and feed carried by the air in the form of dust. Under average conditions it is practically impossible to eliminate this kind of dust. An examination made of the air at various places as shown in Table 3 shows the nature of such dust infection. Twenty liters of air from each location was drawn through 20 cubic centimeters of sterile milk. A determination of the colon-aerogenes group was then made immediately by plating the milk on litmus-lactose-asparagin agar, 1/100 of a cubic centimeter being the lowest dilution made. It may be seen that in the fresh milk only two samples showed the presence of the colon-aerogenes group, and both were of the *B. aerogenes* type. The milk was examined again after 24 hours at 70° F. (21.1° C.), when all but 5 out of 22 samples showed the presence of organisms of the colon-aerogenes group.

TABLE 3.—*Nature of colon-aerogenes contamination from the atmosphere (20 liters of air drawn through 20 cubic centimeters of sterile milk).*

Location of air.	Examination of milk.					
	Fresh.			After 24 hours at 70° F. (21.1° C.).		
	Colon count.[1]	*B. coli.*	*B. aerogenes.*	Colon count.[1]	*B. coli.*	*B. aerogenes.*
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Barn air during feeding	0	0	0	36,000	91	9
Do	0	0	0	140,000	93	7
Barn air during currying	0	0	0	18,000,000	98	2
Barn air during feeding	0			0		
Do	0			0		
Barn air during currying	0			5,000	0	100
Barn air during milking	0	0	0	4,000,000	92	8
Barn air during currying	0			1,700,000	100	0
Barn air during milking	0			27,000	0	100
Do	0			0		
Do	0			230.000,000	0	100
Do	0			205,000,000	0	100
Do	0			680,000	0	100
Barn air during currying	0			230,000	83	17
Do	0			12,800,000	0	100
Feed-room air	0			12,700,000	8	92
Do	0			0		
Do	2,100	0	100	14,000,000	0	100
Outside air near barn	0			0		
Do	0			6,700,000	0	100
Do	200	0	100	7,500,000	0	100
Do	0			60,000	0	100

[1] 0 means none in 1/100 of a cubic centimeter of milk.

It is of further interest to note that after enrichment in sterile milk the majority of samples contained organisms mostly of the *B. aerogenes* type, although in a few there was a large proportion of the *B. coli* type. It is not surprising that organisms of the *B. coli* type can be found in barn air, for they are present in large numbers in fresh cow feces, and probably actually multiply as the feces become dry. Evidence of this is furnished in Table 4, in which a composite sample of feces from 4 cows was examined when fresh, and again after 2, 10, and 14 days. The colon count is given per gram on both the dry and the wet basis. The calculations of the count on a dry basis show that there was an increase of from approximately 600,000 per gram when fresh to approximately 93,000,000 per gram when air-dried for 14 days. At the end of that time the organisms were still sufficiently active to grow readily on litmus-lactose-asparagin agar. It is easy to understand, therefore, how milk produced under clean conditions may become contaminated with organisms of the *B. coli* type. Contamination by this means, however, is not serious from the standpoint of numbers introduced, because the small numbers that enter from the air are greatly diluted in the milk.

TABLE 4.—*Direct increase of colon count in dried cow feces.*

Number of days dried at 70° F. (21.1° C.).	Moisture.	Colon count, wet.	Colon count, dry.
	Per cent.	*Per gram.*	*Per gram.*
0 (fresh)	84.5	320,000	590,000
2	79.0	1,500,000	2,685,000
10	6.3	49,000,000	51,940,000
14	5.0	89,000,000	93,450.000

It is not difficult to explain the presence of bacteria of the *aerogenes* type in air either inside or outside the barn, for they appear to be widely distributed on grains and other feeds, and in the soil. Rogers, Clark, and Evans (15) in their study of 166 organisms of the colon-aerogenes group occurring on grains, found that 151 were of the *B. aerogenes* type, while 8 resembled but were not identical with the *B. coli* type. An examination of many samples of alfalfa, cane, corn, and kafir-corn forage by Hunter (5) at the time of filling the silo showed *coli*-like cultures ranging in number from 1,000 to 1,000,000 per gram. A study of 95 of the organisms isolated from different kinds of silage, and of 15 strains obtained from growing fields of alfalfa and kafir corn showed about 21 per cent to be of the *B. coli* type and 79 per cent of the *B. aerogenes* type, as differentiated by the methyl-red test.

That *coli*-like organisms are present in soil has been shown by Johnson and Levine (7), who found them more prevalent in soils upon which crops were growing than in absolutely fallow areas receiving soil treatment. Aerogenes-cloacæ types were found to be the predominant *coli*-like forms in the soil.

It is apparent that the *B. aerogenes* type found in air may be derived from various sources, and it is not inconceivable that the organisms of this type found in market milk produced under clean conditions are the descendants of those introduced into the fresh milk in extremely small numbers by means of air contamination. It is also possible to contaminate milk with organisms of the *B. aerogenes* type by using unsterilized utensils.

Having surveyed the various means by which fresh milk is infected with organisms of the colon-aerogenes group it is now possible to answer the question "Do organisms of the colon-aerogenes group indicate the presence of manure in fresh milk?" The presence of the *B. coli* type indicates manurial contamination either directly from fecal material which drops into the milk principally from the body of the cow or indirectly through unsterilized utensils. It must be pointed out that the contamination by cow feces represents a much more serious form than that from unsterilized utensils. This statement may be explained by the fact that the introduction of cow feces into milk may carry organisms of bovine tuberculosis. Schroeder (19) has shown that cattle having tuberculosis swallow their sputum, and the tubercle bacilli in it pass through their bodies and out into the feces. The contamination of milk through unsterilized utensils represents a condition of careless handling in which there has been growth of the *B. coli* type in the utensils. While this kind of contamination may add as large a number of the *B. coli* type to milk as the fecal, it would not represent the same possibilities for infection with the bovine tubercle bacillus as does the latter. So far as the

B. coli type is concerned except for infection from manure and utensils, all other avenues of infection are probably of a negligible nature.

The *B. aerogenes* type does not indicate direct fecal contamination, because it is found only occasionally in manure and then only in an extremely small proportion in comparison with the *B. coli* type. On the other hand, the presence of the *B. aerogenes* type may indicate indirect fecal contamination through unsterilized utensils. As has been previously shown, this type of organism may be introduced through unsterilized utensils which have been held for 24 hours before washing in lukewarm water without a brush. Under this condition large numbers of the colon-aerogenes group were introduced which were principally of the *B. aerogenes* type. This can be explained only by the growth of organisms of the colon-aerogenes group in the utensils during storage following the original infection with the *B. aerogenes* type, which in all probability was due to either fecal or air contamination. If due to air contamination, the *B. aerogenes* type was very likely of nonfecal origin. The abnormality of this condition of production and the lack of sufficient results under normal conditions prevent a statement as to the probability of the contamination of milk by the *B. aerogenes* type through unsterile utensils. Air-borne infection probably plays a very important part in the introduction of this type in small numbers into milk, such contamination originating mainly in various feeds and in the soil. It seems evident, therefore, that the *B. coli* type in fresh milk indicates fecal contamination either directly or indirectly, while the *B. aerogenes* type occasionally may indicate indirect fecal contamination, but is usually an index of nonfecal contamination.

Although the *B. coli* type of organism may be considered an index of fecal contamination in fresh milk, it must be remembered that the colon count as usually made and as considered in this paper includes both types and does not differentiate between them. Our results confirm the opinion of Rogers, Clark, and Evans (16), who state:

> It is difficult to avoid the conclusion that while the presence of fecal bacteria in milk may be determined with great certainty, the ordinary presumptive tests and even the usual confirmatory tests do not necessarily prove the contamination of the milk with fecal matter. In order, therefore, to prove definitely the presence of the fecal colon type special confirmatory tests must be used to determine their presence.

CAN MILK BE PRODUCED COMMERCIALLY WITHOUT CONTAMINATION BY ORGANISMS OF THE COLON-AEROGENES GROUP?

This is a very important question, for if milk can be produced and handled under clean conditions without contamination by organisms of the colon-aerogenes group the presence of these organisms at any time in the milk would prove that it had not been so produced and handled.

Investigators who have studied the question do not believe that milk can be produced even under the best conditions without contamination by organisms of the colon-aerogenes group. Prescott (12) states:

> We may take certified milk to be a milk product which is as free from filth as it can be obtained under practical conditions, and when I say practical conditions I mean by using extreme care. Even milk which is obtained with ultra refinement and which may have a very low bacterial count is almost certain to contain some colon bacilli.

According to the author two-thirds of 200 samples of certified milk examined showed colon bacilli in 1 cubic centimeter, and of the remaining one-third fully one-half showed them to be present in 5 cubic centimeters or less. Race (13) has the same opinion on the subject, for he says:

> Milk even when produced under the best conditions is never quite free from *B. coli*, but if reasonable precautions are taken this group should not be present in 25 cubic centimeter quantities of byre milk.

The results obtained in our work lead us to the same opinion, namely, that milk can not be produced commercially, even under the best of conditions, without contamination by organisms of the colon-aerogenes group. Throughout the work, unless otherwise stated, the colon count has been determined by plating methods, using either litmus-lactose-asparagin agar, the composition of which has been previously given, or Endo's medium prepared according to the method of Kinyoun and Dieter (11). The value of litmus-lactose-asparagin agar as a selective medium for use in the determination of organisms of the colon-aerogenes group in milk can not be too highly emphasized. Sometimes the count on this medium is higher than on Endo's and sometimes lower, but it is believed that in general it gives a more accurate colon count than the Endo medium. Ayers and Johnson (2) called attention to the value of the asparagin medium, and the results obtained from its use in the present investigations again confirm its value. As mentioned, however, both media have been used and the highest counts recorded so as to give the highest colon count.

In order to determine whether milk could be produced without contamination by organisms of the colon-aerogenes group, 16 samples of milk were examined which was produced in a clean barn, from clean cows, and handled in sterilized utensils. The milk had a low total count, ranging from 1,130 to 8,900 per cubic centimeter. As may be seen in Table 5, none of the samples contained any organisms of the colon-aerogenes group in 1/10 cubic centimeter amounts. However, when these samples were held for 24 hours at 70° F. (21.1° C.) the colon count ranged from 900 to 303,000 per cubic centimeter. Since these organisms were present after 24 hours' incubation, some must have been in the fresh milk.

TABLE 5.—*Colon count from milk produced under clean conditions.*

Sample No.	Total count.	Colon count.	
		Fresh.	After 24 hours at 70° F. (21.1° C.).
	Per c. c.	*Per 1/10 c. c.*	*Per c. c.*
1	6,200	0	12,000
2	6,200	0	5,000
3	8,900	0	16,000
4	5,100	0	9,000
5	3,900	0	125,000
6	5,400	0	51,000
7	3,600	0	24,000
8	2,200	0	900
9	6,500	0	3,300
10	4,600	0	88,000
11	6,300	0	6,000
12	3,300	0	54,000
13	4,700	0	35,000
14	1,130	0	303,000
15	2,270	0	291,000
16	5,300	0	83,000

Further examination was made of 14 samples of certified milk as shown in Table 6. According to this table only 7 of the 14 samples showed the presence of colon organisms in 1 cubic centimeter of fresh milk, as determined in lactose-broth tubes; but after 24 hours they were found in every sample. These results, together with those of other investigators, clearly indicate that milk as commercially produced under the most careful conditions is never entirely free from organisms of the colon-aerogenes group.

TABLE 6.—*Colon count from certified milk.*

Sample No.	Total count in milk as delivered.	Colon count.				
		Fresh.	Held 24 hours at—		Held 48 hours at—	
			60° F. (15.6° C.).	70° F. (21.1° C.).	60° F. (15.6° C.).	70° F. (21.1° C.).
	Per c. c.	*Per c. c.*	*Per c. c.*	*Per c. c.*	*Per c. c.*	*Per c. c.*
1	7,400	10	10	4,600	23,700	4,400,000
2	10,400	[1] 1	110	38,000	49,000	15,000.000
3	5,200	[1] 1	10	2,900	46.000	2,890,000
4	10,100	20	280	79,000	55,000	16,400,000
5	8,200	0	100	400	1 900	1,130,000
6	4,200	[1] 1	170	16,600	120,000	6,100.000
7	12,600	10	320	13,500	169,000	12,500,000
8	5,900	[1] 1	20	1,800	21,600	560,000
9	14,800	0	0	3,100	2,700	610,000
10	11,400	0	0	400	4,600	5,300,000
11	10,100	0	460	38,000	186.000	13,100,000
12	22,800	0	10	1,100	6,400	3,700.000
13	7,800	0	20	6,500	10.800	8,700,000
14	15,700	0	150	5,800	36,000	1,510,000
Average	10,471	....	119	15,121	52,336	6,564,286

[1] 1 means at least 1 per cubic centimeter.

HOW MANY ORGANISMS OF THE COLON-AEROGENES GROUP CAN BE INTRODUCED INTO MILK DURING MILKING?

In order to interpret the significance of the colon count it is necessary to know not only that organisms of the colon-aerogenes group are always introduced into milk, but also in what numbers under both normal and abnormal conditions. In determining the numbers, the colon count has been made on a great many samples produced under different conditions. The results of these examinations have been summarized and are presented in Table 7. They are discussed briefly at this point in order to emphasize the fact that under normal conditions small numbers of organisms of the colon-aerogenes group are found in fresh milk. The averages given for the colon-aerogenes group are based on those samples showing the presence of colon bacilli in 1/100 of a cubic centimeter. Included in the table are the results of the examination of 14 samples of certified milk, which were examined at the time of delivery to the consumer. Except for the certified milk all the data presented in the table are based on the examination of milk produced under controlled conditions from 4 cows kept in a small experimental barn. The condition of the barn and the cows was changed at times from clean to extremely dirty in order to suit the purpose of the experiments. The handling of the utensils was also varied for similar reasons.

TABLE 7.—*Summary of colon-aerogenes contamination under different conditions of milk production.*

Conditions of milk production.	Samples examined.	Colon-aerogenes organisms in 1/100 c. c.		Range of colon counts.	Average colon count.	Average total bacteria.
	Number.	*Number.*	*Per cent.*	*Per c. c.*	*Per c. c.*	*Per c. c.*
Certified milk as delivered	14	[1] 0	0	1–20	0	10,471
Clean barn, clean cows, sterilized utensils (A)	86	6	6.9	100–200	116	6,091
Dirty barn, dirty cows, utensils sterilized (B)	56	6	10.7	100–400	183	36,541
Dirty barn, dirty cows, utensils washed at once after milking, but not sterilized (C)	84	24	28.6	(2)	(3)	465,086
Dirty barn, dirty cows, utensils held for 8 hours before washing, and not sterilized (D)	28	20	71.4	100–1,800	750	1,299,000

[1] 7+ in 1 cubic centimeter.
[2] 23 samples, 100–2,000. 1 sample, 28,400.
[3] Average of 23 samples, 557. Average of 24 samples, 1,717.

The examination of 86 samples of milk produced in a clean barn, from clean cows, and with sterilized utensils, is shown in Table 7. The term "sterilized" signifies steamed for 20 to 30 minutes. That the milk produced under these conditions was of high quality from a bacterial standpoint is shown by the average total count of 6,091 per cubic centimeter. Only 6 samples of the 86, or 6.9 per cent, contained organisms of the colon-aerogenes group in 1/100 of a cubic centimeter. The number of these organisms in the 6 samples ranged from 100 to 200 and averaged 116 per cubic centimeter.

A study was also made of 56 samples produced under conditions in which the cows were very dirty and the barn was cleaned only once or twice a week. The utensils were sterilized so that they would play no part in the contamination, thus demonstrating the extent of contamination by the colon-aerogenes group which might take place in a filthy barn. Of the 56 samples of milk produced under these conditions only 6, or 10.7 per cent, showed organisms of the colon-aerogenes group in 1/100 of a cubic centimeter. The range of these organisms was from 100 to 400 and averaged 183 per cubic centimeter. The average total count of the 56 samples was 36,541 per cubic centimeter. This at first thought might seem low in view of the filthy conditions of production described. The work of Ayers, Cook, and Clemmer (1), however, has shown that large numbers of bacteria are not generally introduced through manurial filth even under extreme conditions, but come largely from unsterilized utensils.

An analysis of 84 samples of milk produced under the same dirty conditions as previously described but with utensils which were not sterilized showed that 24 samples, or 28.6 per cent, contained organisms of the colon-aerogenes group in 1/100 cubic centimeter. The utensils in this case were washed in hot water containing washing powder within one hour after milking, rinsed in clean, cold water, and allowed to stand inverted until the next milking. The colon count of the 24 samples which showed positive results in 1/100 of a cubic centimeter ranged from 100 to 28,400 per cubic centimeter. Only one sample ran over 2,000, that one being 28,400. Including this high count the average would be 1,717, while leaving out this one high count the average for the remaining 23 samples would be 557 per cubic centimeter. These figures indicate clearly that unsterilized utensils play a prominent part in contamination of milk by the colon-aerogenes group. It will be noted in Table 7 that in the milk produced in unsterilized utensils the colon count was almost three times higher and the total count also higher than in the milk produced in sterilized utensils. In both cases the barn was equally dirty.

The manner in which the utensils are cleaned plays a very important part in the contamination of milk by organisms of the colon-aerogenes group, which is clearly shown in the last line of Table 7. The milk was produced in the same dirty barn as just mentioned, but the drainings were allowed to remain in the utensils for 8 hours, after which they were washed in hot water containing washing powder. Of the 28 samples produced under this condition 20, or 71.4 per cent, showed colon bacilli in 1/100 of a cubic centimeter. They ranged from 100 to 1,800, averaging 750 per cubic centimeter, and were no higher than in the milk produced in the previous experiment, in which the utensils were washed immediately, but a much greater percentage showed organisms of the colon-aerogenes group than in the previous case.

It is believed that the results shown in Table 7 cover the analyses of fresh milk produced under the widest range of conditions generally met with in the commercial production of milk. The conditions of production ranged from clean barn and cows and sterilized utensils to extremely dirty conditions and unsterilized utensils not washed till 8 hours after milking. The colon counts produced under such circumstances should represent the maximum number of these organisms usually introduced into milk.

The results on this point are considered so important that they have been plotted in figure 1. The graph shows the percentage of samples in which the colon count was 100 per cubic centimeter or more, as well as the percentage with lower counts. The letters correspond to those in Table 7; therefore the conditions of production are not repeated. Within each column is shown the colon count of every sample having 100 or more per cubic centimeter. Column A represents milk of high quality from a bacterial standpoint, only a small percentage of the samples showing the presence of organisms of the colon-aerogenes group in 1/100 of a cubic centimeter. A number of these samples were examined for the presence of the colon-aerogenes group in $\frac{1}{10}$ of a cubic centimeter, but none were found. Much larger amounts of milk of this quality would probably have to be examined in order to obtain positive tests.

Column B represents milk produced under extremely dirty barn conditions with sterilized utensils. This is a condition which would rarely be encountered because a dairyman who kept his barn and cattle in as dirty a condition as they were in this experiment probably would not be the kind who would take the trouble to sterilize utensils. This condition is, nevertheless, one of interest because only about 10 per cent of the samples produced under it showed the presence of the colon-aerogenes group in 1/100 of a cubic centimeter.

Column C represents results obtained from milk produced under the same dirty conditions as previously described, but the utensils were not sterilized. Milk produced under this condition represents, in a bacterial sense, more nearly the average milk of poor quality, but even then the condition of the barn and cattle was worse than is usually found. The term "dirty conditions" merely presents to the reader a degree of filth, and therefore depends upon his own opinion. It is believed, however, that the reader will be convinced of the degree of filth under which the milk was produced by referring to Plates I and II, where sediment disks from 1 pint of milk handled in unsterilized small-top and open pails under the filthy conditions mentioned are shown. One must admit that the quantity of manure shown on most of the sediment disks is greater than that usually found in milk. The illustrations show, besides the total bacterial count, the colon count per cubic centimeter in samples where they

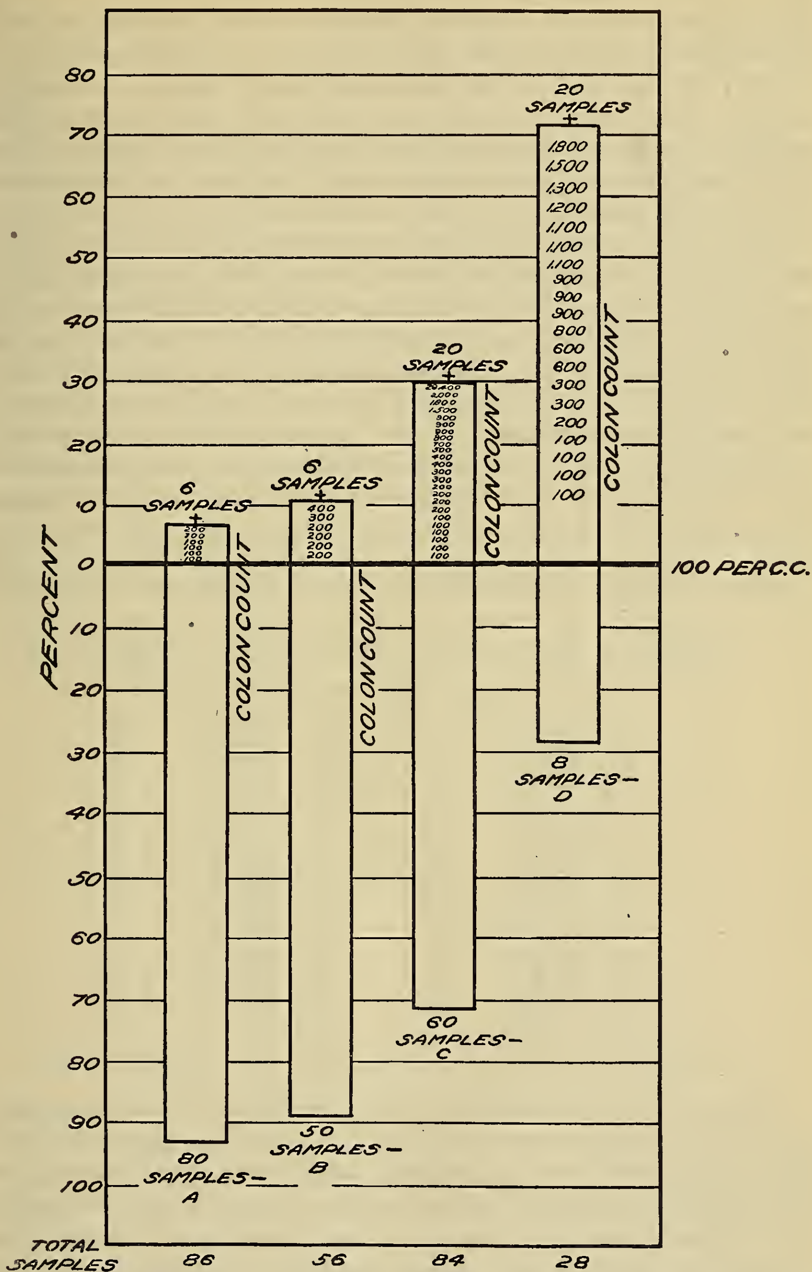


FIG. 1.—Colon-aerogenes group in fresh milk under different conditions of production (See Table 7 for conditions *A*, *B*, *C*, and *D*).

were present in $\frac{1}{100}$ of a cubic centimeter. Only 9 samples showed organisms of the colon-aerogenes group, and 8 of these ranged from 100 to 2,000, while the other had a count of 28,000 per cubic centimeter. Further study of the disks shows that there is no correlation between the quantity of manure and the colon count; some samples having a considerable amount of sediment showed no organism of the colon-aerogenes group, while others with a considerably less amount showed several hundred per cubic centimeter.

Reference to column C of figure 1 shows that about 72 per cent of the samples of milk produced under the conditions described did not contain any organisms of the colon-aerogenes group in $\frac{1}{100}$ of a cubic centimeter. Table 8 gives the results of a series of samples in which larger quantities of milk were examined. It is evident that milk, when fresh, even though produced under extremely dirty conditions and handled in unsterilized utensils, contains only a few organisms of the colon group. Of the 38 samples, 11 showed no colon organisms in $\frac{4}{10}$ of a cubic centimeter of milk, while in the remaining 27 samples the minimum colon count ranged from 3 to 75 per cubic centimeter.

TABLE 8.—*Small colon-aerogenes infection in fresh milk produced under dirty conditions.*

Sample No.	Total count.	Colon count.[1]	Sample No.	Total count.	Colon count.[1]
	Per c. c.	*Per c. c.*		*Per c. c.*	*Per. c. c.*
1	179,000	0	20	580,000	5
2	180,000	0	21	620,000	50
3	182,000	10	22	630,000	0
4	190,000	5	23	680,000	50
5	225,000	10	24	750,000	0
6	260,000	10	25	790,000	75
7	270,000	10	26	820,000	8
8	295,000	8	27	840,000	0
9	304,000	10	28	1,080,000	10
10	318,000	10	29	1,120,000	10
11	320,000	0	30	1,170,000	8
12	340,000	0	31	1,310,000	3
13	366,000	0	32	1,320,000	3
14	450,000	5	33	1,440,000	5
15	460,000	0	34	1,450,000	0
16	490,000	3	35	1,600,000	0
17	490,000	10	36	1,940,000	10
18	497,000	8	37	1,950,000	10
19	560,000	75	38	2,400,000	10

[1] Cipher indicates no organisms of the colon-aerogenes group in $\frac{4}{10}$ cubic centimeter of milk.

Additional sediment disks are shown in Plate III, the corresponding samples of which are also included in column D of figure 1. In this case the utensils were not washed till 8 hours after milking, but otherwise the conditions were the same as in the previous experiment. Here, again, even with very large quantities of manure found in the milk, together with the increased possibilities of colon contamination from the unsterilized utensils, the colon count never ran over 2,000 per cubic centimeter when the milk was fresh. Plates I, II, and III show that under these conditions there is no definite relation between the quantity of manure and the colon count. This is undoubtedly due to the variable number of such organisms found in cow feces, and to the different degrees of such contamination introduced through unsterilized utensils.

The results thus far presented show very clearly that unsterilized utensils play a prominent part in the contamination of milk with organisms of the colon-aerogenes group. To emphasize this point an experiment was conducted in which the milk from three cows went into sterile utensils while that from three others went into unsterilized utensils which had been allowed to stand for 24 hours before washing. All six cows were clean and were kept in a clean barn, and the only chance for difference in the contamination of the milk was due to the unsterilized utensils. The results in Table 9 show that in the milk handled in sterilized utensils there were no organisms of the colon-aerogenes group present in 1/100 of a cubic centimeter, while all the samples of milk handled in unsterilized utensils showed the presence of these organisms, ranging from 1,100 to 350,000, and averaging 80,650 per cubic centimeter in the fresh milk. This, of course, represents contamination from unsterilized utensils which were handled in an unusual manner, but it serves to emphasize the importance of sterilized utensils in connection with the colon count.

TABLE 9.—*Effect of sterilized utensils on colon count.*

Sample No.	Sterilized utensils.		Utensils not sterilized and not washed for 24 hours.	
	Total count.	Colon count.[1]	Total count.	Colon count.
1	17,100	0	2,050,000	91,000
2	4,600	0	2,800,000	72,000
3	7,300	0	2,320,000	120,000
4	5,700	0	2,210,000	350,000
5	3,900	0	254,000	1,100
6	4,300	0	680,000	1,400
7	10,200	0	450,000	5,200
8	6,300	0	365,000	4,500
Average...	7,425	....	1,391,125	80,650

[1] 0 indicates none in 1/100 of a cubic centimeter.

At this point it is possible to answer the question "How many organisms of the colon-aerogenes group can be introduced during milking?" The answer is, not over 2,000 per cubic centimeter, and is based on the examination of 254 samples produced under both clean and unusually filthy conditions, only one sample of which showed a colon count of over 2,000 per cubic centimeter in fresh milk. A summary of these counts is shown in Table 7 and also in figure 1. If this is the maximum number of organisms of the colon-aerogenes group which can be introduced into milk under normal conditions of production, it will be of great importance in connection with the significance of the colon count. If correct, it means that any colon count over 2,000 per cubic centimeter could at once be attributed to growth.

The results obtained in our experiments indicate that, generally speaking, 2,000 per cubic centimeter is the maximum number of organisms of the colon-aerogenes group introduced into fresh milk. It is realized, however, that occasionally abnormal conditions may be encountered where the colon count in fresh milk runs higher than the maximum limit mentioned. The only time such a condition was met in the experiments occurred during the period from August 21 to September 12, 1917, when milk was produced under the dirty conditions as previously described. The utensils were held for 24 hours before washing, and then simply washed in lukewarm water without brush or washing powder. During this 24-hour period the air temperature ranged from 70° F. (21.1° C.) to 98° F. (36.7° C.), a very favorable condition for growth of organisms of the colon-aerogenes group in the unwashed utensils. Table 10 shows that the colon count of 12 samples of fresh milk produced under these conditions ranged from 80,000 to 6,700,000 per cubic centimeter. The experiment was stopped on September 12 and was repeated about October 1 under the same conditions with the exception that the air temperature averaged much lower, ranging between 40° F. (4.4° C.) and 70° F. (21.1° C.). It was found that at this time the colon counts were all within the maximum of 2,000 per cubic centimeter. This led to the belief that the holding of utensils containing milk drainings at the high temperatures which prevailed during the period from August 21 to September 12 was responsible for the extremely heavy contamination by organisms of the colon-aerogenes group.

In order to confirm this opinion further experiments were conducted during October under the same dirty-barn conditions except that the utensils, which were not washed for 24 hours, were held in artificially heated rooms. From the results in the lower part of Table 10 it is evident that even under these conditions it was impossible to obtain the high colon counts that had previously been obtained. While it was impossible to maintain as high temperatures artificially as occurred normally in our earlier experiment, temperatures as high as 86° F. (30° C.) were obtained, and it is believed that in many cases the utensils were held at as high temperature as in the previous experiment. In the last experiment where the utensils were held in artificially heated rooms the colon count ranged from 100 to 350,000 per cubic centimeter. Only 9 of the 25 samples showed more than 2,000 organisms of the colon-aerogenes group per cubic centimeter.

TABLE 10.—*Number of organisms of colon-aerogenes group introduced into fresh milk under abnormal conditions.*

Conditions.	Sample No.	Total count.	Colon count.
		Per c. c.	*Per c. c.*
Utensils held 24 hours before washing; not sterilized. August 21 to 30, and September 8 to 17; air temperature 70° F. to 98° F. (21.1° C. to 37.5° C.)	1	18,900,000	5,200,000
	2	25,300,000	3,600,000
	3	16,500,000	1,190,000
	4	22,700,000	5,100,000
	5	28,200,000	6,700,000
	6	33,000,000	1,620,000
	7	17,200,000	340,000
	8	33,500,000	690,000
	9	54,000,000	1,780,000
	10	65,000,000	2,350,000
	11	25,000,000	1,190,000
	12	2,040,000	80,000
Utensils held 24 hours before washing; not sterilized. October 3 to 12, 75° F. (23.9° C.)	1	2,050,000	91,000
	2	2,800,000	72,000
	3	2,320,000	120,000
	4	2,210,000	350,000
	5	680,000	1,400
	6	450,000	5,200
	7	365,000	4,500
Utensils held 24 hours before washing; not sterilized. October 22 to 25, 60° F. (21.1° C.)	1	1,010,000	(1)
	2	340,000	200
	3	690,000	100
	4	580,000	300
Utensils held 24 hours before washing; not sterilized. October 22 to 25, 75° F. (23.9° C.)	1	270,000	1,400
	2	560,000	500
	3	370,000	300
	4	490,000	400
Utensils held 24 hours before washing; not sterilized. October 29 to November 5, 60° F. (21.1° C.)	1	163,000	1,200
	2	490,000	2,200
	3	410,000	800
	4	288,000	700
	5	310,000	100
Utensils held 24 hours before washing; not sterilized. October 29 to November 5, 86° F. (30° C.)	1	1,100,000	37,000
	2	225,000	13,000
	3	98,000	400
	4	161,000	300
	5	42,000	200

[1] 0 in 1/100 c. c.

These results indicate that under abnormal conditions the colon count may be over 2,000 per cubic centimeter in fresh milk, but it is believed, in view of our experiments, that such exceptional conditions are seldom encountered. These high counts therefore do not detract from the value of the 2,000 maximum colon count per cubic centimeter, which has been set as the maximum contamination by organisms of the colon-aerogenes group in fresh milk.

WHY ARE HIGH COLON COUNTS OFTEN FOUND IN RAW MILK?

Assuming the correctness of the fact just established that fresh milk produced under normal conditions very rarely contains over 2,000 organisms of the colon-aerogenes group per cubic centimeter, the question "Why are high colon counts often found in raw milk?" can be answered by the statement that high colon counts in raw milk are due to growth which takes place between the time of production and that of consumption.

If organisms of the colon-aerogenes group were not able to grow in milk the colon count would be of far greater value as an index of contamination during production. Jackson (6) evidently believed that these organisms did not grow in milk, for he states:

> Contrary to expectation it has been found that under ordinary conditions, considerable numbers of other bacteria being present, *B. coli* does not increase in milk, or if so only to a very slight extent, then gradually dies out. On this account the amount of original contamination may be determined.

Most investigators, however, have recognized the fact that organisms of the colon-aerogenes group were able to multiply in milk and that this fact complicated the significance of the colon count. Kinyoun (9), while recognizing that the age of the milk and the temperature at which it has been held are important, believed that original contamination was responsible for the most part in causing high colon counts. According to Prescott (12), organisms of the colon group will grow in milk which is held at 50° F. (10° C.), and he found that even when milk was packed in ice for several days the rate of increase was much greater than had been expected. This author believes that the question of growth must be taken into consideration in interpreting the colon count, for he says:

> The mere question of the numbers of colon bacilli found in milk or cream may be settled or explained in two ways. It may have been due to initial infection or due to growth. Here discrimination must be employed as to the relative number of organisms and the types which are present in order to determine which of these explanations is the satisfactory one.

The opinion of Race (13) on this subject is expressed in the following statement:

> When milk is kept at a temperature not exceeding 45° F. (7.2° C.) the *B. coli* do not increase and this temperature may therefore be regarded as the critical anabolic temperature. Above this point they rapidly multiply and in summer the *B. coli* content of milk must be regarded as due more to reproduction than original contamination.

In the several pages following are shown the results of a large number of samples of milk produced under different barn conditions and the growth of organisms of the colon-aerogenes group at various temperatures. Of these, 20 samples were produced under clean conditions and handled in sterilized utensils, 34 samples were produced under dirty conditions with sterilized utensils, and 23 samples were produced under similar dirty conditions but handled in unsterilized utensils, and in each case the samples were held at 50° F. (10° C.) and duplicate samples were held at 60° F. (15.6° C.), and the colon count determined in the milk when fresh and after each succeeding 24 hours up to 96 hours. The results obtained when the milk was held at 50° F. (10° C.) are shown in Table 11. The results have been summarized and the per cent of samples showing the presence of organisms of the colon-aerogenes group in 1/100 of a cubic centimeter of milk and their average counts are given, together with the per cent of samples which did not show the colon-aerogenes group in this quantity of milk. Where more than one sample of a group showed colon organisms the range is also given. The colon counts represent the highest number determined on either litmus-lactose-asparagin agar or on Endo medium.

TABLE 11.—*Growth and frequency of organisms of colon-aerogenes group at 50° F. (10° C.)*

Number of samples.	Conditions.	Average total count.	Colon count.	
			Fresh.	24 hours.
		Per c. c.	*Per c. c.*	*Per c. c.*
20	Barn clean, cows clean, utensils sterilized (A).	4,245	100 per cent— in 1/100 c. c.	94.4 per cent—. 5.6 per cent+. Average colon count, 300.[1]
34	Barn dirty, cleaned once a week; cows dirty; utensils sterilized (B).	38,262	94.1 per cent—. 5.9 per cent+. Range, 100 to 300. Average colon count, 200.	100 per cent—.
23	Same as B, but utensils not sterilized.	161,083	95.6 per cent—. 4.4 per cent+. Average colon count, 400.	100 per cent—.

Number of samples.	Conditions.	Average total count.	Colon count.		
			48 hours.	72 hours.	96 hours.
		Per c. c.	*Per c. c.*	*Per c. c.*	*Per c. c.*
20	Barn clean, cows clean, utensils sterilized (A).	4,245	94.4 per cent—. 5.6 per cent+. Average colon count, 3,200.	83.3 per cent—. 16.7 per cent+. Range, 1,600 to 28,000. Average colon count, 10,533.	83.3 per cent—. 16.7 per cent+. Range, 1,600 to 79,000. Average colon count, 27,533.
34	Barn dirty, cleaned once a week; cows dirty; utensils sterilized (B).	38,262	95.6 per cent—. 4.4 per cent+. Average colon count, 1,900.	95.6 per cent—. 4.4 per cent+. Average colon count, 3,200.	54.2 per cent—. 45.8 per cent+. Range, 2,000 to 186,000. Average colon count, 24,172.
23	Same as B, but utensils not sterilized.	161,083	94.7 per cent—. 5.3 per cent+. Average colon count, 11,600.	83.3 per cent—. 16.7 per cent+. Range, 4,500 to 12,500. Average colon count, 8,100.	55.5 per cent—. 44.5 per cent+. Range, 3,300 to 22,000. Average colon count, 13,300.

[1] Average colon count per cubic centimeter in samples showing them in $\frac{1}{100}$ of a cubic centimeter and over.

The average total count of 20 samples of milk produced under clean conditions was 4,245, indicating a high quality of milk, from a bacterial standpoint. No organisms of the colon-aerogenes group were found in 1/100 of a cubic centimeter in any of these samples when fresh. After 24 hours 94.4 per cent of the samples were still negative, while 5.6 per cent were positive. The same results were obtained at the end of 48 hours, only one sample showing organisms of colon-aerogenes group, and this one contained 3,200. After the milk had been held 72 hours, 83.3 per cent were still negative in 1/100 cubic centimeters while 16.7 per cent were positive. The colon count ranged from 1,600 to 28,000, the average being 10,533 per cubic centimeter. After 96 hours at 50° F. (10° C.) the same percentage of the samples showed growth as after 72 hours, but the average colon count was higher.

Among the 34 samples of milk produced under dirty conditions and handled in sterilized utensils 5.9 per cent showed organisms of the colon-aerogenes group in 1/100 of a cubic centimeter of milk. The range in colon count was from 100 to 300 and the average 200 per cubic centimeter. After 24 hours at 50° F. (10° C.) none of the samples showed the organisms in 1/100 of a cubic centimeter. This is explained by the fact that the colon count in the samples which showed positive results in the fresh milk ranged from 100 to 300. Since 1/100 of a cubic centimeter of milk was plated this meant from one to three colonies per plate, and as there was probably no growth during the 24-hour holding period at 50° F. (10° C.), these organisms were missed in a hundredth dilution on the second day's plating. At the end of 72 hours only 4.4 per cent of the samples showed colon-aerogenes organisms, which averaged 3,200 per cubic centimeter. There was a slight growth among these samples between 72 and 96 hours, for, as may be noted in the table, 45.8 per cent showed positive results at the end of 96 hours. The colon counts ranged from 2,000 to 186,000 and averaged 24,172 per cubic centimeter. The results obtained in the examination of 23 samples produced under dirty conditions and handled in unsterilized utensils agreed very closely with those just discussed.

From these results it seems evident that there is practically no growth of organisms of the colon-aerogenes group in milk produced under normal conditions when it is held for a period of 48 hours at 50° F. (10° C.). After 72 hours at this temperature there was evidence of multiplication, which was still further increased by holding for 96 hours.

Duplicate samples of the milk produced under the conditions presented in Table 11 were held at 60° F. (15.6° C.) and the summarized results are given in Table 12. It will be noted that there is a marked difference in the growth of the organisms of the colon-aerogenes group in milk held at the higher temperature. Quite high colon counts were obtained in the majority of samples held at 60° F. (15.6° C.) even in 24 hours. No further discussion of the results is necessary, as the effect of temperature on the colon count is plainly shown by the results presented.

Table 12.—*Growth and frequency of organisms of colon-aerogenes group at 60° F. (15.6° C.).*

Number of samples.	Conditions.	Average total count.	Average colon count. Fresh.	Average colon count. 24 hours.
		Per c. c.	*Per c. c.*	*Per c. c.*
20	Barn clean, cows clean, utensils sterilized (A).	4,245	100 per cent — in 1/100 c. c.	66.6 per cent —. 33.4 per cent +. Range, 400 to 76,000. Average colon count, 14,083.[1]
34	Barn dirty, cleaned once a week, cows dirty, utensils sterilized (B).	38,262	94.1 per cent —. 5.9 per cent +. Range, 100 to 300. Average colon count, 200.	31 per cent —. 69 per cent +. Range, 1,000 to 510,000. Average colon count, 79,175.
23	Same as B, but utensils not sterilized.	161,083	95.6 per cent —. 4.4 per cent +. Average colon count, 400.	33.3 per cent —. 66.7 per cent +. Range, 6,100 to 710,000. Average colon count, 156,450.

Number of samples.	Conditions.	Average total count.	Average colon count. 48 hours.	Average colon count. 72 hours.	Average colon count. 96 hours.
		Per c. c.	*Per c. c.*	*Per c. c.*	*Per c. c.*
20	Barn clean, cows clean, utensils sterilized (A).	4,245	50 per cent —. 50 per cent +. Range, 1,000 to 840,000. Average colon count, 318,333.	35.3 per cent —. 64.7 per cent +. Range, 1,700 to 25,500,000. Average colon count, 5,506,518.	37.5 per cent —. 62.5 per cent +. Range, 4,000 to 152,000,000. Average colon count, 27,288,900.
34	Barn dirty, cleaned once a week, cows dirty, utensils sterilized (B).	38,262	4.0 per cent —. 96.0 per cent +. Range, 98,000 to 21,600,000. Average colon count, 3,285,750.	8.3 per cent —. 91.7 per cent +. Range, 900,000 to 68,000,000. Average colon count, 18,786,364.	100 per cent +. Range, 1,000,000, to 66,000,000. Average colon count, 23,008,333.
23	Same as B, but utensils not sterilized.	161,083	26.3 per cent —. 73.7 per cent +. Range, 84,000 to 4,300,000. Average colon count, 882,929.	5.5 per cent —. 94.5 per cent +. Range, 64,000 to 42,000,000. Average colon count, 4,579,117.	100 per cent +. Range, 115,000 to 168,000,000. Average colon count, 15,600,611.

[1] Average colon count per cubic centimeter in samples showing them in 1/100 of a cubic centimeter and over.

When milk is held at higher temperatures the growth of organisms of the colon-aerogenes group increases in rapidity, which is shown by the results given in Table 13. Twenty samples of milk produced under dirty conditions with unsterilized utensils were held at 50° F. (10° C.) and 70° F. (21° C.) and the colon count determined in the fresh milk and after holding for 24 hours. Although this milk was produced under extremely filthy conditions, only 3 of the samples when fresh showed organisms of the colon-aerogenes group in 1/100 of a cubic centimeter. This series contained the only sample of fresh milk produced under normal conditions which showed a colon count of over 2,000 per cubic centimeter. The results in this table show the remarkable difference in growth of organisms of the colon-aerogenes group in milk held at 50° F. (10° C.), compared with 70° F. (21° C.). While there is some indication of slight growth in a few of the samples held at 50° F. (10° C.), there was the rapid multiplication of the organisms in milk held at 70° F. (21° C.), the average colon count in 20 samples held for 24 hours at this temperature being 7,385,500 per cubic centimeter.

TABLE 13.—*Growth of organisms of colon-aerogenes group at 50° F. (10° C.) and 70° F. (21.1° C.).*

Sample No.	Total count.	Colon count.[1]		
	Fresh.	Fresh.	Held for 24 hours at 50° F. (10° C.).	Held for 24 hours at 70° F. (21.1° C.).
1	225,000	0	100	180,000
2	1,140,000	28,400	83,000	55,500,000
3	270,000	0	200	2,600,000
4	680,000	0	0	2,350,000
5	1,080,000	0	0	3,400,000
6	490,000	0	800	5,100,000
7	850,000	900	1,300	8,300,000
8	840,000	0	200	2,700,000
9	1,450,000	0	600	2,520,000
10	2,400,000	0	0	12,800,000
11	1,950,000	0	0	22,000,000
12	260,000	0	0	1,250,000
13	610,000	2,000	600	15,300,000
14	340,000	0	0	830,000
15	630,000	0	0	1,170,000
16	179,000	0	0	1,180,000
17	366,000	0	0	6,400,000
18	304,000	0	0	120,000
19	460,000	0	0	1,810,000
20	620,000	0	400	2,200,000

[1] 0 indicates none in $\frac{1}{100}$ of a cubic centimeter.

Further studies on the growth of organisms of the colon-aerogenes group at different temperatures are shown in Table 14. Three different sets of conditions were used so as to determine the subsequent growth in three distinct grades of fresh milk. Special attention is called to the colon counts after the milk had been held for 6 hours at 86° F. (30° C.). Among the 22 samples of milk produced in the dirty barn and handled in sterilized utensils there was practically no increase in the colon count after 6 hours at 86° F. (30° C.), but after 24 hours at the same temperature the colon count had reached the high figure of 63,279,545 per cubic centimeter. Twenty-six samples produced in the dirty barn and handled in unsterilized utensils showed after 6 hours a distinct increase in the colon count in most of the samples, and after 24 hours the colon count averaged about 24,000,000 per cubic centimeter.

Similar increases occurred among the 20 samples produced in a dirty barn and handled in unsterilized utensils which had not been washed until 8 hours after milking. The average colon count of the fresh milk was 595 per cubic centimeter. After 6 hours, at 86° F. (30° C.) the average count had increased to 37,525, while after 24 hours at the same temperature the average count was about 205,000,000. The difference in the rate of growth of organisms of the colon-aerogenes group at this temperature seems to vary somewhat with the amount of initial contamination, as is shown by the colon counts of the fresh milk and after 6 and 24 hours. Further observation of Table 14 shows that when the milk was held at 50° F. (10° C.) there was little or no increase over the count in the fresh milk. There are, however, a few samples which show a distinct growth.

TABLE 14.—*Influence of conditions of production on the subsequent increase of organisms of the colon-aerogenes group.*

Sample No.	Conditions.	Total count in fresh milk.	Colon count.[1]			
			Fresh.	Held 6 hours at 86° F. (30° C.).	Held 24 hours at— 50° F. (10° C.).	Held 24 hours at— 86° F. (30° C.).
1	Barn dirty, cleaned twice a week; utensils sterilized.	27,000	0	200	0	290,000,000
2		58,000	100	400	0	294,000,000
3		54,000	100	0	100	126,000,000
4		83,000	0	100	0	11,900,000
5		28,000	0	0	0	550,000
6		96,000	0	0	0	14,200,000
7		11,800	0	0	0	38,000,000
8		39,000	0	100	0	2,400,000
9		21,600	0	0	0	1,700,000
10		12,400	0	0	0	5,300,000
11		10,200	0	100	0	139,000,000
12		22,000	0	0	0	11,500,000
13		12,500	0	0	0	1,100,000
14		42,000	100	0	0	250,000,000
15		16,400	0	(2)	0	6,300,000
16		22,800	0	(2)	0	42,000,000
17		24,000	0	(2)	0	12,400,000
18		37,000	0	(2)	0	17,600,000
19		13,500	0	(2)	300	8,600,000
20		57,000	0	(2)	0	54,000,000
21		14,200	400	(2)	100	37,000,000
22		15,500	0	(2)	0	28,600,000
Average		32,477				63,279,545
1	Barn dirty, cleaned twice a week; utensils washed immediately but not sterilized.	1,320,000	0	0	0	60,000,000
2		790,000	0	400	100	450,000,000
3		1,600,000	0	0	0	1,900,000
4		295,000	0	500	0	330,000,000
5		1,940,000	0	200	0	2,800,000
6		690,000	100	300	0	7,500,000
7		1,310,000	0	1,400	0	650,000
8		520,000	100	4,500	0	248,000,000
9		750,000	0	0	0	11,400,000
10		460,000	100	2,600	0	510,000,000
11		320,000	0	(2)	0	9,400,000
12		440,000	400	(2)	800	260,000,000
13		180,000	0	0	0	46,000,000
14		490,000	0	900	1,100	285,000,000
15		318,000	0	1,000	0	210,000,000
16		497,000	0	1,200	100	480,000,000
17		580,000	0	(2)	0	174,000,000
18		440,000	200	(2)	100	216,000,000
19		780,000	100	2,400	100	420,000,000
20		710,000	800	46,000	600	525,000,000
21		590,000	100	8,600	(2)	580,000,000
22		310,000	900	41,000	(2)	430,000,000
23		190,000	0	800	100	55,000,000
24		230,000	300	74,000	15,100	400,000,000
25		182,000	0	1,100	100	152,000,000
26		340,000	900	48,000	900	244,000,000
Average		625,846		10,677		234,948,077

[1] 0 indicates no organisms of the colon-aerogenes group in 1/100 of a cubic centimeter of milk.
[2] No determinations made.

TABLE 14.—*Influence of conditions of production on the subsequent increase of organisms of the colon-aerogenes group*—Continued.

Sample No.	Conditions.	Total count in fresh milk.	Colon count.			
			Fresh.	Held 6 hours at 86° F. (30° C.).	Held 24 hours at— 50° F. (10° C.).	Held 24 hours at— 86° F. (30° C.).
1	Barn dirty, cleaned twice a week; utensils washed after 8 hours but not sterilized.	670,000	100	200	0	260,000,000
2		820,000	0	2,100	100	117,000,000
3		3,300,000	1,200	35,200	1,400	342,000,000
4		1,800,000	100	3,100	200	240,000,000
5		1,170,000	0	400	0	181,000,000
6		1,440,000	0	700	200	159,000,000
7		620,000	100	(1)	300	1,850,000
8		860,000	300	(1)	500	194,000,000
9		570,000	800	1,500	(1)	120,000,000
10		630,000	300	9,700	(1)	162,000,000
11		1,300,000	600	1,400	800	72,000,000
12		2,720,000	1,800	510,000	3,300	285,000,000
13		1,120,000	0	600	0	96,000,000
14		1,840,000	900	14,200	1,200	330,000,000
15		1,080,000	1,100	4,500	1,500	460,000,000
16		1,920,000	1,300	4,300	2,700	370,000,000
17		1,160,000	100	100	1,300	160,000,000
18		3,820,000	1,100	12,400	21,000	196,000,000
19		2,200,000	600	(1)	(1)	115,000,000
20		4,300,000	1,500	(1)	(1)	220,000,000
Average		1,667,000	595	37,525	2,156	204,875,000

[1] No determinations made.

The results of these experiments in general confirm the opinion of Race (13) that organisms of the colon-aerogenes group do not grow at 45° F. (7.2° C.), for as a rule little or no growth was found to take place when milk was held at 50° F. (10° C.) for lengths of time comparable with commercial practice.

In studying the growth of organisms of the colon-aerogenes group in milk held at different temperatures, $\frac{1}{100}$ of a cubic centimeter was the largest quantity of milk examined, so that any growth occurring in quantities less than 100 per cubic centimeter would not have been detected. The results obtained therefore do not conflict with those of Prescott (12), who found that milk which showed no colon bacilli in a single cubic centimeter when fresh, after 24 hours at 50° F. (10° C.) contained from 10 to 50 per cubic centimeter.

When milk is kept at temperatures above 50° F. (10° C.) there is a rapid growth of organisms in the colon-aerogenes group in direct proportion to the temperature and time to which milk might be subjected under commercial conditions.

ARE BOTH THE B. COLI AND B. AEROGENES TYPES PRESENT IN MILK; AND IF SO, IS THEIR RELATIVE PROPORTION OF ANY VALUE?

Since Rogers and his associates (14, 15) have shown that organisms of the colon-aerogenes group found in bovine feces are principally of the *Bacillus coli* type while those occurring on grains correspond to the *B. aerogenes* type, it seems as if a differentiation of these types in milk might be of value in determining the source of contamination. Raw milk ordinarily contains both the *B. coli* and the *B. aerogenes* type. Rogers and his associates found that nearly 50 per cent of the cultures isolated from milk were of the *B. aerogenes* type.

In our experiments an effort has been made to determine the presence of the two types and their proportion to each other in milk produced under different conditions of cleanliness and held for 24 and 48 hours at 60° F. (15.6° C.), 70° F. (21.1° C.), and 86° F. (30° C). The *B. coli* and *B. aerogenes* types were divided on the basis of the methyl-red test proposed by Clark and Lubs (3). The results of the work as shown in Table 15 give the total and colon counts, the number of *B. coli* and *B. aerogenes* types in fresh milk, and the colon count and the percentage of the two types in the same milk held at different temperatures.

Table 15 shows that, as a rule, the colon count of fresh milk comprised only organisms of the *B. coli* type. This statement is based on the results obtained when 1/10 and 1/100 of a cubic centimeter of milk were plated. In a few cases the colonies from the fresh milk were of the *B. aerogenes* type. After the milk was held for a time and further examined both types of organisms were found in most cases. It must be remembered that even when the figures indicate that all the organisms of the colon-aerogenes group were of one type it does not mean that none of the other type were present. This is true because the method of differentiation was the picking off as near as possible of all the colonies of the group which appeared on the plates, inoculating them in a dextrose-peptone broth as described by Clark and Lubs (3), and determining their reaction by methyl red. It is evident, therefore, that the dilution in plating might have been so high as to exclude entirely the type that was in the minority.

From the results obtained it seems safe to conclude that both types are usually present in raw milk. Since milk usually contains both types, it might be assumed that the proportion of *B. coli* to *B. aerogenes* would be of value in tracing the conditions under which the milk was produced.

Table 15.—*Proportion of B. coli and B. aerogenes types in different grades of milk.*

Sample No.	Conditions.	Fresh.		24 hours.									48 hours.					
				60° F. (15.6° C.).			70° F. (21.1° C.).			86° F. (30° C.).			60° F. (15.6° C.).			70° F. (21.1° C.).		
		Total count.	Colon count.	Colon count.	Per cent.		Colon count.	Per cent.		Colon count.	Per cent.		Colon count.	Per cent.		Colon count.	Per cent.	
					B. coli.	*B. aerogenes.*		*B. coli.*	*B. aerogenes.*		*B. coli.*	*B. aerogenes.*		*B. coli.*	*B. aerogenes.*		*B. coli.*	*B. aerogenes.*
1		10,400	[1] 0	110	100	0	27,900	99	1				37,000			12,600,000		
2		10,100	[2] 20	280	44	56	79,000	75	25									
3		8,200	[1] 0	0			400	100	0				1,900			1,130,000	100	0
4		4,200	[1] 0	140			3,700						62,000	91	9	1,120,000	100	0
5	Certified milk	11,400	[1] 0	0			400						4,600	100	0	5,300,000	100	0
6		10,100	[1] 0	220			9,300						169,000	80	20	11,800,000	98	2
7		22,800	[1] 0	0			700						6,400	84	16	3,700,000		
8		7,800	[1] 0	0			6,500	100	0				7,100			7,600,000		
9		15,700	[1] 0	150	100	0	5,800	96	4				36,000	46	54	1,510,000	39	61
	Average							94	6					80	20		88	12
1		5,800	100	86,000	98	2	5,400,000	91	9				14,600,000	95	5	91,000,000	100	0
2		10,200	0	58,000	52	48	1,720,000	59	41				3,700,000	67	33	31,000,000	94	6
3		13,400	0	124,000	25	75	5,900,000	56	44				1,750,000	6	94	8,800,000	38	62
4		3,400	100	3,900	17	83	1,480,000	7	93				990,000	7	93	52,000,000	0	100
5		6,800	[2] 100	139,000	5	95	610,000	27	73				2,900,000	10	90			
6		3,300	10	3,600	54	46	109,000	77	23				2,900,000	74	26			
7	Barn cleaned daily, utensils sterilized	2,800	[2] 10	900	50	50	78,000	87	13				1,180,000	72	28			
8		2,100	0	2,400	5	95	14,000	30	70				600,000	2	98			
9		3,500	110	69,000	100	0	500,000	99	1				14,700,000	83	17			
10		10,300	20	1,100	62	38	123,000	74	26									
11		11,200	0	3,200	0	100	5,000	100	0				250,000	50	50			
12		18,200	0	400	100	0	28,000	100	0				180,000	60	40			
13		15,400	10	1,200	83	17	23,000	96	4				1,030,000	3	97			
14		69,000	120	9,200	94	6	1,050,000	96	4									
	Average				52	48		72	28					44	56		58	42

1	Barn and cows dirty, utensils not sterilized.	207,000	1,800	720,000	100	0	28,200,000	100	0				22,900,000	100	0	470,000,000	97	3
2		640,000	1,500	190,000	61	39	14,200,000	79	21				19,300,000	33	67	49,000,000	88	12
3		510,000	200	199,000	97	3	33,000,000	92	8				26,500,000	94	6	144,000,000	98	2
4		54,000	100	10,400	97	3	850,000	89	11				2,780,000	92	8	113,000,000	95	5
5		344,000	200	87,000	98	2	2,600,000	100	0				18,100,000	97	3	26,900,000	98	2
6		237,000	700	2,800,000	95	5	13,800,000	97	3				36,000,000	93	7	118,000,000		
	Average				91	9		93	7					85	15		95	5
1	Barn cleaned daily, utensils sterilized	5,100	0				206,000	74	26	108,000,000	32	68						
2		8,000	[2] 200				273,000	75	25	37,000,000	100	0						
3		1,100	0				39,000	83	17	20,300,000	96	4						
4		2,400	0				3,400	37	63	1,300,000	8	92				600,000	0	100
5		7,700	0				680,000	90	10	2,600,000	87	13				1,680,000	13	87
	Average							72	28		66	34					7	93
1	Barn and cows dirty, utensils not sterilized	23,900	0				35,000	70	30	8,400,000	100	0						
2		39,400	0				33,000	80	20	3,450,000	100	0						
3		46,000	0				9,600	91	9	6,300,000	100	0				39,000,000	0	100
4		155,000	300				208,000	100	0	290,000,000	100	0				38,000,000	65	35
5		38,000	200				930,000	100	0	203,000,000	100	0						
6		46,000	0				23,000	79	21	1,200,000	99	1				850,000	66	34
7		97,000	0				76,000	51	49	870,000	69	31						
8		189,000	0				670,000	97	3	63,000,000	0	100				96,000,000	98	2
9		1,320,000	100				10,800,000	93	7	238,000,000	0	100				162,000,000	100	0
	Average							84	16		74	26					66	34

[1] None in $\frac{1}{10}$ of a cubic centimeter; other "0" in colon count indicates none in $\frac{1}{100}$ of a cubic centimeter.
[2] All *aerogenes* types. When not marked they were all of the *B. coli* type.

The results of the first experiments carried on in connection with this point are shown in sections 2 and 3 of Table 15, where it will be noted that the average percentage of the *B. aerogenes* type was considerably higher in milk produced under clean conditions and handled in sterilized utensils than the percentage found in milk produced under dirty conditions and handled in unsterilized utensils, for any given temperature and time. The average percentage of the *B. aerogenes* type was consistently higher in milk produced under clean conditions when stored at 60° F. (15.6° C.) and 70° F. (21.1° C.) up to a period of 48 hours. Further experiments with milk produced under the same two sets of conditions, but held at 86° F. (30° C.) showed a similar high proportion of *B. aerogenes* in the milk produced under clean conditions, although the actual percentage of the *B. aerogenes* in the milk produced under dirty conditions was also somewhat higher than when held at the lower temperatures. These results are shown in sections 4 and 5 of Table 15.

Further analysis of the results shows that among the samples produced under a given condition there was a wide variation in the proportion of the *B. coli* to the *B. aerogenes* types. Further than this, the proportion of the two types after 24 hours' incubation was often entirely reversed after 48 hours at the same temperature. Considering the higher average percentage for the *B. aerogenes* type in milk produced under clean conditions than under dirty conditions, it seemed that this might be a significant fact in tracing the conditions of production.

The results obtained, however, from a few samples of certified milk as shown in section 1 of Table 15, seemed to indicate that no hard and fast rule can be attached to the proportion of the two types. In view of the earlier findings with milk produced under clean conditions it was thought that certified milk would, upon holding at temperatures above 50° F. (10° C.), show a high percentage of the *B. aerogenes* type, but the result shows that this was not the case.

Based on these results it seems evident that both types of organisms of the colon-aerogenes group are always present in raw milk, but the differentiation into the *B. coli* and the *B. aerogenes* types is of little or no value in indicating the conditions under which the milk was produced or the age and temperature at which it has been held.

The conclusions reached in regard to the value of differentiating the *B. coli* and the *B. aerogenes* types are based on a study of relatively few samples. While the results obtained indicate that the proportion of *B. coli* to *B. aerogenes* types is of little value in determining the history of the milk, it is believed that this point deserves much further study before any more definite conclusion can be reached.

HAS THE COLON COUNT ANY SIGNIFICANCE IN RAW MILK?

Before discussing the question of whether the colon count in raw milk has any significance it must be pointed out that the colon count as made at present includes both *B. coli* and *B. aerogenes* types, of which the *B. coli* type is principally of fecal origin and the *B. aerogenes* type mainly of nonfecal origin. If, therefore, it could be assumed that the number of organisms of the *B. coli* type was a direct measure of the amount of manure in milk (an impossible assumption), the colon count would not even then be a direct measure of such contamination, since it may include the *B. aerogenes* type. Since, however, it is impossible at present to differentiate between the two types by plating methods alone, the significance of the colon count must be considered as it stands, irrespective of the fact that it measures the number of both types of organisms.

The significance of the colon count must be considered in two distinct relations; first, in its connection with fresh milk and, second, in its connection with milk which has been held.

SIGNIFICANCE IN FRESH MILK.

The colon count is, generally speaking, a measure of contamination during production only when fresh milk (less than two hours old) is examined. In fresh milk the colon count measures the degree of contamination from several sources. The organisms gain entrance directly from manure, from unsterilized utensils, and in small numbers from the air and from other minor sources.

Milk produced under clean conditions and handled in sterilized utensils usually does not show the presence of organisms of the colon-aerogenes group in $\frac{1}{10}$ of a cubic centimeter, and probably they are not present in even larger quantities. In milk produced under dirty-barn conditions and handled in unsterilized utensils these organisms can usually be found in $\frac{1}{10}$ of a cubic centimeter and may run as high as 2,000 per cubic centimeter. The colon count of fresh milk therefore bears a somewhat direct relation to the conditions under which the milk was produced. A similar relation, however, does not exist between the colon count and the amount of manurial contamination, first, because different samples of feces vary widely in their colon content, and, secondly, because these organisms may be introduced into milk through other channels, particularly from unsterilized utensils.

SIGNIFICANCE IN MILK THAT HAS BEEN HELD.

When milk is not fresh, no significance can be attached to the colon count in relation to contamination during milking unless it is known that the milk is comparatively fresh and that it has been kept at temperatures not exceeding 50° F. (10° C.). Perhaps a safer limit would be 45° F. (7.2° C.). In other words, if the history of the milk is not known it is impossible to interpret the colon count in terms of the condition under which it was produced. This situation arises because of the fact that organisms of the colon-aerogenes group grow rapidly in milk when it is held above 50° F. (10° C.).

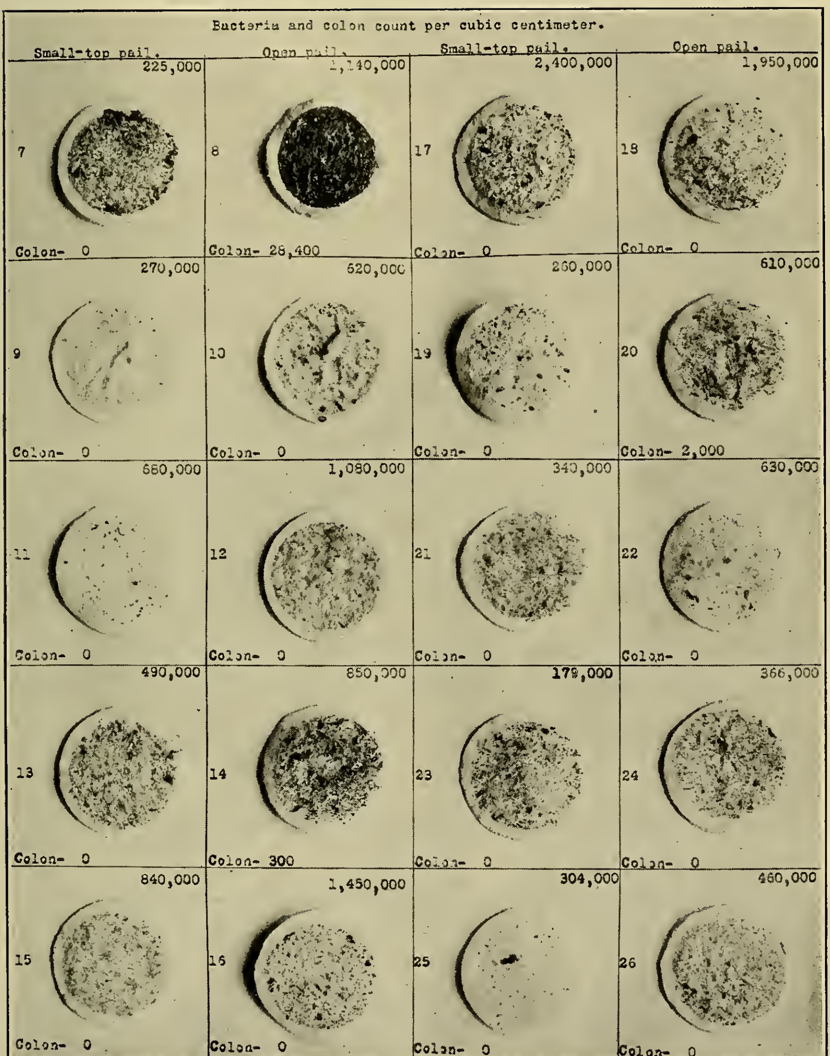
When the history of the milk is not known, it is believed that colon counts above 2,000 per cubic centimeter indicate growth. This belief is based on the fact that only one sample of fresh milk out of the 254 samples which were produced under conditions ranging from clean to extremely filthy contained more than 2,000 colon per cubic centimeter. If, therefore, a sample of milk of unknown history is examined and found to have a colon count between 100 and 2,000 per cubic centimeter, it is impossible to decide whether the colon count indicates original contamination or whether this small number of organisms was due to the growth of the few originally introduced into a very clean milk. Colon counts above 2,000, however, under normal conditions can be attributed to growth. In this connection the colon count is significant so far as it indicates that the milk has at some period in its history been held above 50° F. (10° C.).

There is one abnormal condition of production under which fresh milk may have a high colon count. As previously pointed out, in one series of experiments where utensils were allowed to contain milk drainings for 24 hours during extremely hot weather, and then washed carelessly in lukewarm water without the use of brush or washing powder, the colon count of the fresh milk averaged about 1,000,000 per cubic centimeter. An attempt was made to duplicate these counts under similar conditions, but without success. It is believed that this extreme condition of production would rarely be encountered in the commercial production of milk. High colon counts due to this condition can probably be readily distinguished from similarly high colon counts which are due to growth, because the ratio of total count to colon count would probably be less than 1 to 50 in the fresh milk, while in that due to growth the ratio would be much higher.

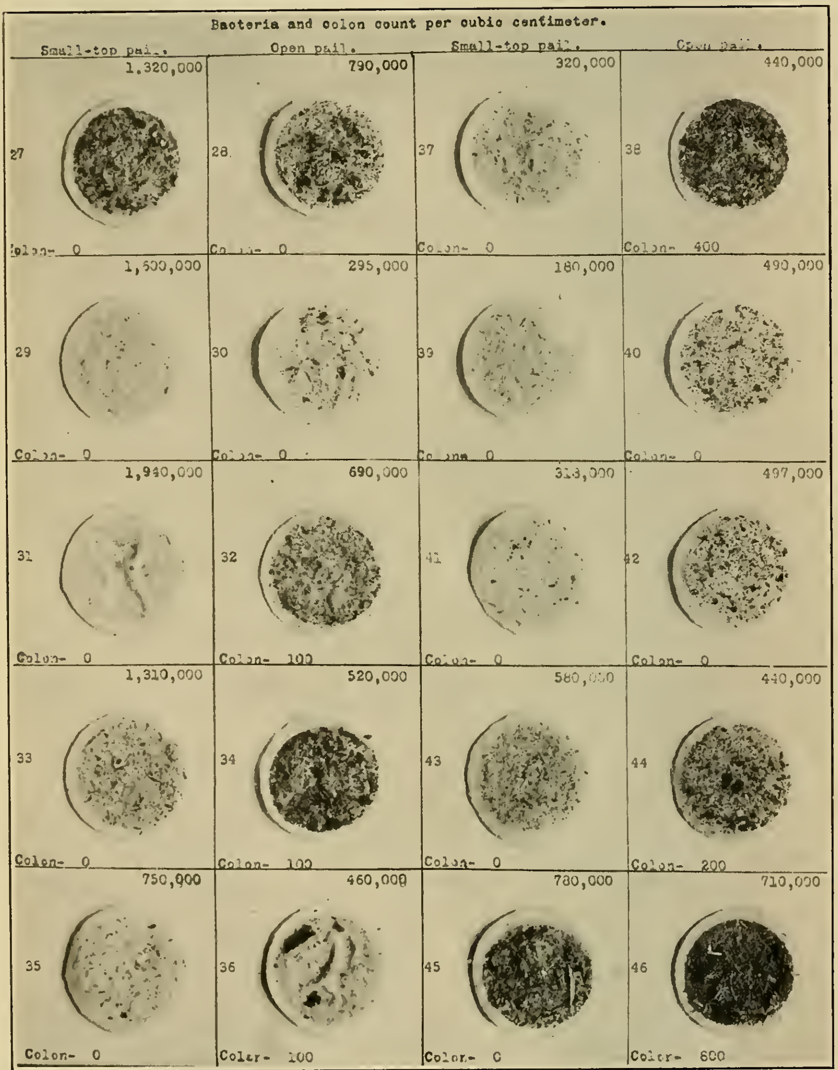
SUMMARY.

1. The colon count as determined at the present time includes both the *B. coli* and *B. aerogenes* types of organisms. Since the *B. coli* type is principally of fecal and the *B. aerogenes* type of nonfecal origin, the colon count at best can not be a direct measure of manurial contamination.

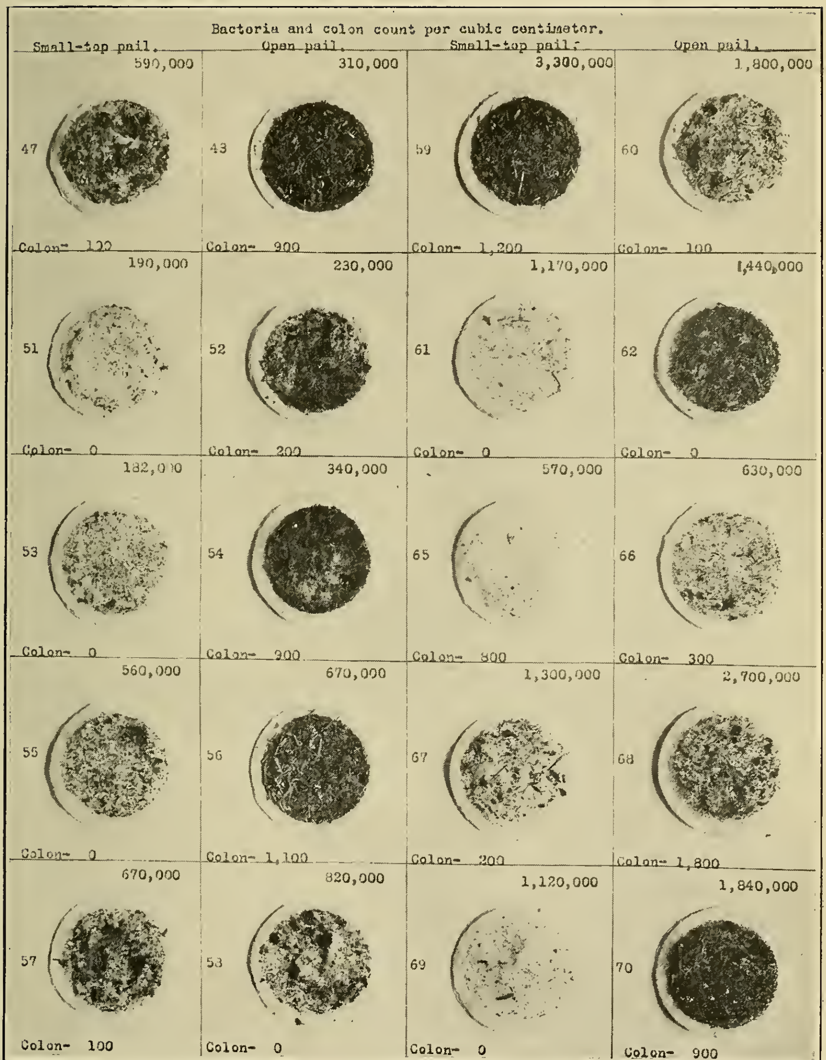
2. Fresh milk produced under the best conditions always contains some organisms of the colon-aerogenes group, but rarely contains over 2,000 per cubic centimeter even when produced under the worst conditions normally encountered.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED IN DIRTY BARN WITH UTENSILS NOT STERILIZED BUT WASHED AT ONCE AFTER PREVIOUS MILKING.



Sediment Disks from Pints of Milk Produced in Dirty Barn with Utensils not Sterilized but Washed at Once After Previous Milking.



SEDIMENT DISKS FROM PINTS OF MILK PRODUCED IN A DIRTY BARN WITH UTENSILS NOT STERILIZED AND NOT WASHED UNTIL 8 HOURS AFTER PREVIOUS MILKING.

3. High colon counts can nearly always be attributed to the growth of organisms originally introduced into milk. Little or no growth of the organisms of the colon-aerogenes group occurs below 50° F. (10° C.), but rapid growth takes place at higher temperatures.

4. The differentiation of the *B. coli* and *B. aerogenes* types does not assist materially in tracing the conditions under which milk is produced, but future results from a greater number of samples may show that it is of some value.

5. In fresh milk the colon count does not indicate the extent of direct manurial contamination, but does indicate the general conditions of cleanliness under which the milk was produced.

6. In milk of unknown history no significance can be attached to the colon count other than that high counts usually indicate that it has been held above 50° F. (10° C.), or rarely, that it was produced under very abnormal conditions, as previously described.

7. A careful study of the limitations of the colon count as an index of cleanliness in milk production, taking into account especially the effect of temperature on the growth of the organisms, will materially assist the laboratory man in makin the colon count serve to the best advantage.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 740

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. | January 13, 1919

A STUDY OF SOME OF THE CHEMICAL CHANGES WHICH OCCUR IN OYSTERS DURING THEIR PREPARATION FOR THE MARKET.

By Edward E. Smith, *Junior Chemist.*[1]

CONTENTS.

SCOPE OF INVESTIGATION.

This bulletin gives the results of an investigation to determine the amounts of ammoniacal nitrogen, amino-acid nitrogen, moisture, total solids, ash, and sodium chlorid present in oysters under the various conditions through which they pass in ordinary commercial practice in the oysterhouse, and to ascertain the effect of washing and soaking on both the chemical composition and physical condition of the oysters. The investigation was conducted during the fall and winter of 1914–15, in certain oysterhouses in Connecticut, selected as being representative of the oyster industry throughout the North Atlantic States. The oysters used were grown in various beds, ranging from New Haven, Conn., on the east, to Raritan Bay, N. J., on the west. As work was done in several houses, each using a different method of treatment of the stock, the methods given represent commercial practice at that time and in that locality, but may not be representative of later practice or other localities. The experiments which were made to show the results of various special treatments do not represent commercial practice.

[1] The writer wishes to express his indebtedness to Dr. E. D. Clark and Mr. L. H. Almy, who instructed him in the methods of determination of ammoniacal nitrogen and amino-acid nitrogen; to Mr. Carleton Bates and Dr. Lester Round, who assisted materially in planning the work and under whose direction it was carried out; and especially to Mr. R. W. Lamson, without whose help Series V would have been impossible.

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COMMERCIAL TREATMENT OF OYSTERS.

As a slight knowledge of the methods of handling oysters is necessary for a clear understanding of the various subjects touched upon in this bulletin, a brief outline of the essential features involved in the preparation of oysters for the market, beginning with the dredging of the mature oysters, that is, those which are three or four years of age, will be given first.

Oysters are grown in water of a salinity ranging from 1.5 to 3.5 per cent, calculated as sodium chlorid, the average being about 2.5 per cent, and are covered to a depth of from 5 to 50 feet at mean low tide. In many cases the beds are so far from the oysterhouse that upon arrival the oysters may have been out of water for several days. For the beds near the house the period is shortened to a few hours. "Shucking" oysters, the process of opening the shells and removing the meats therefrom, is always done by hand, and those engaged in the work are called "shuckers." The shucker puts the oyster meats into a perforated dipper holding 1 gallon. From the shuckers' dippers the oysters are emptied upon the "riffles," inclined, corrugated metal boards, down which a thin stream of water runs. The slight bumping caused by the corrugations tends to remove the bits of shell which may cling to the body of the oyster, and the water both hastens its progress and washes off most of the dirt which it has acquired during the process of opening. From the riffles the oysters slide through metal chutes to the sorting table, where they are graded and those not fit for food are culled out. In Connecticut the following grades of oysters are recognized: (1) "Straights," the name given to the entire output of the plant, not graded, with only those unfit for food removed; (2) "counts," very large oysters, not mutilated in opening, perfect in shape and color; (3) "selects," smaller than "counts," but larger than the ordinary run of stock, unmutilated and perfect in shape and color; (4) "standards," the ordinary run of stock from which the "counts," "selects," and "culls" have been removed.

From the sorting table the oysters slide down metal chutes to the washing and chilling tanks, where they are thoroughly washed in running water, and chilled by means of ice, if the weather is warm enough to require it. The method of washing and chilling oysters had changed materially in the years immediately preceding the time of this investigation, and, instead of only one method, several methods were in use. The old method of preparing shucked oysters for the market consisted in washing the stock as received from the shucker upon a perforated "skimmer board," by means of running water from a hose, the oysters being moved about with a paddle during the process. The oysters were then placed in tanks of ice water with chunks of ice, and chilled for a period of time not exceeding 20 or 30 minutes. Mechanical devices, however, had been invented for the washing and chilling of the shucked oysters, and in 1914–15 the air-agitation system of washing was in general use in the larger plants. In this system, from 20 to 30 gallons of oysters are placed in a tank of water, ice is added if necessary, and the whole is agitated by means of a blast of air blown in through the perforated bottoms of the tanks. A constant flow of fresh water is maintained. In this way a very thorough washing is secured. With the change in the method of handling, however, the oysterman did not modify the length of time for washing and chilling, which resulted in a great gain in the bulk of the oysters, due to osmotic action. For in the old method of washing, the oysters remained stationary in the bottom of the tank, their mass was slowly pervious to water, and osmosis could not take place to any extent, whereas in the latter method each individual oyster was constantly exposed to the action of fresh water for a period of from 20 to 30 minutes. As a result, the oysters lost a marked proportion of their soluble constituents, and due to the process of osmosis became greatly distended.

From the washing and chilling tanks, the oysters were run out upon "skimmers," which are perforated metal tables, to drain. They were stirred about upon the skimmers with metal paddles until they were thoroughly drained, then were run off into cans, which were immediately sealed and stored in a refrigeration room at a temperature of about 33° F. Stock was not usually kept in the refrigerator more than one or two days; in fact, it was usually shipped the morning after packing.

EXPERIMENTAL WORK.

METHODS OF ANALYSIS.

1. *Preparation of sample.*—The sample of oysters is drained in a colander for two minutes, with gentle shaking or stirring to facilitate drainage, the liquor being discarded. After draining, one pint of the drained meats is ground in a meat chopper, No. 2, using the next-to-finest blade, and thoroughly mixed. The required amount of sample is weighed out immediately, as evaporation causes serious errors in a short time.

2. *Amino-acid nitrogen.*—Weigh out 100 grams of the finely-ground oyster meat upon the rough balance, wash into a 500 cc volumetric flask, make up to the mark with distilled water, and shake thoroughly every 10 minutes for 1 hour. Allow to settle, and pour off the supernatant liquid. Upon this liquid the determination for amino-acid nitrogen is run according to Sörensen's method.[1]

3. *Ammoniacal nitrogen.*—This determination was made by Folin's method,[2] aerating for exactly 2 hours, and using 20 grams of the

[1] Allen's Commercial Organic Analysis, 4th ed., 7:262. [2] Am. J. Physiol., 1903, 8:343.

finely-ground oyster meats, weighed to within 0.1 gram. Tenth normal solutions of acid and alkali were used.

4. *Total solids.*—Place a thin layer of dried shredded asbestos on the bottom of a thin lead dish, add a short glass rod, and weigh the whole. Add about 5 grams of the ground sample, and weigh as quickly as possible. Evaporate to dryness on the steam bath, and dry for exactly 4 hours in a water-jacketed oven at the temperature of boiling water. Weigh, and calculate the percentage of total solids. During evaporation, the meat is stirred occasionally with the glass rod. This stirring with the asbestos prevents the formation of a crust which would hinder evaporation.

5. *Moisture.*—Determined by difference from the total solids results.

6. *Ash.*—Weigh about 5 grams of the finely-ground sample as quickly as possible into a previously ignited and weighed platinum dish or crucible, drive off moisture at a moderate heat, and ignite at the dullest red heat until the ash is gray in color. Extraction with water, followed by a second evaporation and ignition, may be necessary to secure a clean gray ash. Weigh, and report as percentage of original sample.

7. *Salinity.*[1]—Extract the ash obtained in the preceding determination with hot water, cool, and titrate against silver nitrate solution containing 29.0575 grams of silver nitrate per liter of solution at room temperature. As indicator, use one or two drops of a 10 per cent solution of potassium chromate. One cc of this silver nitrate solution is equivalent to 10 mg of sodium chlorid. Calculate all chlorin as sodium chlorid, and report as percentage present in original sample.

SERIES I.

In this series, determinations for amino-acid nitrogen and ammoniacal nitrogen only were run. A summary of results is given in Table 1.

The column headed "Shucker" represents oysters as taken from the shuckers' dippers; "Riffle," oysters taken from the chute below the riffle-boards; "Commercial package," oysters after washing and chilling, packed into cans ready to go into the refrigerator; "Refrigerator," oysters from the same day's run as those upon the same line in the preceding columns, but sampled from the cans remaining in the refrigerator one or two days later.

[1] These results are not exactly accurate, due to the fact that all the chlorin is not in the form of sodium chlorid. As no analysis for oyster ash could be found in the literature, and there was no time to make such analyses, the plan of calculating all the chlorin as sodium chlorid and reporting it as salinity was adopted. Since all the data have been prepared on this basis, the results are comparable, and the error probably is negligible, as the amount present is small in any case, and it is certain that a large proportion of the chlorin is present in the form of sodium chlorid.

TABLE 1.—*Percentages of nitrogen obtained at various stages of handling.*

Date.	Amino-acid nitrogen.				Ammoniacal nitrogen.			
	Shucker.	Riffle.	Commercial package.	Refrigerator.	Shucker.	Riffle.	Commercial package.	Refrigerator.
1914.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oct. 5	0.183	0.166	0.128	0.120	0.00200	0.0018	0.0012	0.0025
6	.173	.159	.1267	.085	.00189	.0015	.0015	.0004
8	.171	.1495	.115	.146	.00042	.0004	.0000	.0010
10	.148	.149	.106	.116	.00074	.0011	.0000	.0022
12	.155	.152	.106	.089	.00154	.0011	.0004	.0000
13	.1658	.1534	.1183	.1237	.0007	.0006	.0007	.00077
14	.1439	.1433	.1142	....	.0007	.0007	.00042	....
15	.1551	.1512	.1232	.1378	.00077	.0003	.00024	.00087
16	.1580	.1542	.1198	....	.00038	.0005	.0000	....
Nov. 9	.1522	.1582	.1249	.1272	.0000	.0000	.0000	....
10	.1484	.1400	.1215	[2].0946	.00032	.0002	.00115	[2].00024
	....	....	....	.1210	....	....	....	.00017
11	.1703	.1670	.1064	.1232	.00021	.00007	.0000	.00073
12	.1813	.1692	.1305	....	.00098	.00021	.00073	....
	....	....	.1311	....	....	....	.00073	....
16	....	....	....	.1540	....	....	....	.00035
	....	....	....	.1540	....	....	....	.00035
17	.1932	.1727	.1318	[2].1084	.00084	.0002	.00098	[2].00031
	....	....	.1429	....	....	....	.00056	....
18	.1635	.1585	.1204	....	.00049	.00011	.0000	....
21	.1652	.1630	.1142	....	.00014	.0000	.00024	....
	[1].1658	[1].1429	....	....	[1].00053	[1].00025	....	....
	....	[2].1170	....	....	....	[2].00025	....	....
Dec. 10	.1739	.1558	.1188	.1177	.00014	.0000	.00032	.0000
11	.1456	.1479	.1367	.1177	.00035	.00007	.00007	.00011
12	.1702	.1685	.1317	.1250	.00014	.0000	.00008	.00011

[1] Selects. [2] Counts.

From this table it is apparent that a considerable amount of amino-acid nitrogen is present in the oyster as it comes from the shell. It is probable that a certain percentage of amino-acid nitrogen exists in the tissues of the oyster body, being either absorbed or formed in the process of metabolism. Some of this may be due to bacterial activity within the oyster itself.

The comparatively slight washing of the oyster upon the riffle board removes approximately 10 per cent of the amino acids present, which shows that a certain proportion of them are present in the mucus surrounding the oyster. An additional amount of approximately 25 per cent is removed in the washing and chilling process proper, which may be explained partly by solution in the wash water, partly by the fact that most of the remaining mucus is washed from the outside of the oyster, and partly by the increase in volume of the oyster due to osmosis.

From the figures in the "Refrigerator" column it is seen that the relative figures vary widely. In some cases the percentage of amino-acid nitrogen apparently increased, in others remained constant, and in still others decreased. This variation is due largely to difference in stock used, as it was found impossible, in a large plant, to be sure that the oysters stored were from exactly the same stock as those analyzed in the preceding columns. However, if the amino-acid content be taken as indicative of decomposition, it is evident that no appreciable amount takes place while the oysters are stored in the refrigerating room of the oysterhouse for a short time. It is interesting to note that the figure for the larger oysters, selects and counts, is uniformly smaller than that for the standards of the same stock.

From the results obtained in this series, there appears to be no relation between the amino-acid nitrogen and the ammoniacal nitrogen present. In general, the figures for ammoniacal nitrogen change in the same way as do those for amino-acid nitrogen; but the former are so inconsistent, even in duplicates run on the same sample, that the whole table is practically meaningless in this connection. Similar determinations were run in all the following series of experiments, but as they are in all cases as conflicting as those in Tables 1 and 2, they have been omitted from all subsequent tables.

SERIES II.

In order to prove that the amount of amino-acid nitrogen and ammonia present would not indicate decomposition in oysters if the water over them was changed occasionally, the following series of experiments was run.

A 5-gallon can of oysters was divided into two lots, and the oysters in each were covered with water. One lot was stored at room temperature, the other in a small ice box at a temperature of about 45° F., and the water over each lot was changed every day. Determinations were run upon each lot every day for one week. A summary of results obtained is given in Table 2.

TABLE 2.—*Amino-acid and ammoniacal nitrogen as index of decomposition.*

Date of analysis.	Amino-acid nitrogen in portion stored at—		Ammoniacal nitrogen in portion stored at—	
	Room temp.	45° F.	Room temp.	45° F.
1914.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oct. 5	0.1290	0.1290	0.00123	0.00123
	.1280	.1280	.00116	.00116
Oct. 6	.1244	.1272	.00329	.00259
Oct. 8	.1075	.1120	.00165	....
Oct. 9	.1250	.0687	.00392	.000105
	.1250	.0676	.00185	.000098
Oct. 10	.1215	.0638	.00473	.000840

At the end of this time the oysters soaking at room temperature were badly decomposed. In spite of this condition, the amino-acid nitrogen content decreased, and the figure for ammoniacal nitrogen, though larger than in the same oysters at the beginning of the experiment, was smaller than that found in several samples of fresh oysters. The oysters stored in the refrigerator kept much better than those stored at room temperature, though they also were slightly decomposed at the end of the week. In this lot, the values for both amino-acid and ammoniacal nitrogen were smaller at the end than they were at the beginning of the experiment.

Of the two determinations intended to show the amount of decomposition which has occurred in oysters, it appears that determination of ammoniacal nitrogen by the Folin method is worthless in commercial oyster work for the following reasons:

(*a*) The free ammonia and ammonium salts are washed out of the oysters nearly as fast as they form.

(*b*) The very small amount of standard acid neutralized by the ammonia makes the probable error relatively large.

(*c*) With alizarin red as an indicator, the color change obtained is not sharp, under such conditions.

For the last two reasons, duplicate determinations often varied widely, and no great reliance is to be placed upon the accuracy of the determinations; hence, very little weight should be attached to the meaning of the results obtained. Often higher ammoniacal nitrogen figures were obtained from fresh oysters than from others which had undergone decomposition.

It is believed that the amino-acid nitrogen determination is much more consistent and reliable. It is more consistent in that a larger amount of solution is taken for titration, which lessens the probable error, and in that the end point is easier to locate. The principal objection to this determination is that the amino-acid nitrogen content is not a true indication of the amount of decomposition which has taken place in the oysters, for the following reasons:

(*a*) Amino acids, being soluble, are washed out of the oysters by each change of water in the same way as are the ammonia and its compounds.

(*b*) Amino acids present a very suitable medium for bacteriological growth, and are, therefore, being continuously broken down into some of the simpler compounds already mentioned. Therefore, the amount of amino acids present is never a measure of the total amount of decomposition, and in many cases is a measure of only a very small percentage of it. However, the results obtained on oysters undergoing washing treatments are comparable, and are of great value in indicating the amount of soluble matter removed.

In the study of washing oysters, the greatest reliance is to be placed upon the determinations for amino-acid nitrogen, total solids, and ash. The figures for moisture are very useful in showing the amount of water added to the oysters in the washing processes. The determinations for salinity were of little assistance, as the salt was removed quite completely in a comparatively brief period of washing.

SERIES III.

Since the amino acids present in oysters had been regarded as decomposition products, it was assumed that their amounts would be at a minimum in oysters fresh from the beds, and would increase with the length of time the oysters were out of the water. As some of the experiments indicated that this was not the case, the following series of experiments was carried out.

By means of a portable apparatus carried aboard an oyster boat, amino-acid determinations were run upon liquors and meats of oysters as they came from the water at Princess Bay, New York. Two bushels of the same stock were transported to the laboratory at South Norwalk the same night. Determinations were run upon representative samples of this lot every day for six days, the oysters being shucked in the laboratory immediately before analysis. On the last day, analyses were also run upon a lot of shell oysters from the same locality, which had been stored in the laboratory in baskets for four weeks. The results of this series are given in Table 3.

TABLE 3.—*Percentage of amino-acid nitrogen present in meats and liquors of shell oysters, and its variation with age.*

Date.	Meats.	Liquors.	Remarks.
1914.	*Per cent.*	*Per cent.*	
Nov. 30	0.1938	0.0588	Perfectly fresh.
	.1970	.0625	Oysters immediately after dredging.
	.1976	.0598	
Dec. 1	.1640	.0336	
	.1626	.0353	
2	.1709	.0280	
	.1709	.0263	
3	.1737	.0224	
	.1647	.0258	
4	.1645	.0380	
	.1594	.0342	
5	.1651	.0302	
	.1651	.0300	
5	.1720	.0370	Oysters from same locality stored in laboratory 4 weeks.
	.1728	.0377	

This series leaves no doubt that the percentage of amino acids in perfectly fresh oysters is much greater than has been supposed. This value decreases to a minimum in the first day or two that the oysters are out of water, and remains practically constant as long as the oysters remain in the shell but do not lose shell liquor. Shortly after losing the shell liquor from any cause death ensues with attendant decomposition.

As no further work was done on this very interesting point, no conclusions can be drawn at this time. This series seems to indicate, however, that some reason other than decomposition must be sought to explain the presence of amino acids in fresh oysters.

SERIES IV.

In this and the following series, determinations for total solids, ash, moisture, and salinity were made, in addition to those for ammoniacal and amino-acid nitrogen, as those were found to be the most satisfactory determinations for showing the effects of commercial washing processes. These determinations were run upon oysters in all the various stages of preparation in several oysterhouses. The results are shown in Table 4.

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TABLE 4.—*Effect of washing.*

WASHING BY TANK METHOD, WITH AIR AGITATION.

Date.	Experiment No.	Amino-acid nitrogen.			Total solids.			Moisture.			Ash.			Salinity.		
		Shell.	Shucker.	Commercial package.	Shell.	Shucker.	Commercial package.	Shell.	Shucker.	Commercial package.	Shell.	Shucker.	Commercial package.	Shell.	Shucker.	Commercial package.
1915.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Jan. 15	1	0.1650	0.1660	0.1232	22.3	24.7	16.4	77.7	75.3	83.6	1.67	1.88	1.17	0.36	0.37	0.02
					21.7	23.0	15.8	78.3	77.0	84.2						
22	3	.1600	.1615	.1025	21.0	23.6	13.9	79.0	76.4	86.1	1.79	1.82	.71	.52	.54	None.
					20.9	22.0	14.0	79.1	78.0	86.0						
26	4	.1630	.1740	.1280	21.4	21.4	15.3	78.6	78.6	84.7	1.80	1.74	.74	.65	.61	None.
					20.8	21.8	15.8	79.2	78.2	84.2						
Feb. 5	6	.1336	.1606	.1290	16.7	19.2	15.3	83.3	80.8	84.7	1.75	1.75	.87	.56	.63	Trace.
					17.1	18.9	15.2	82.9	81.1	84.8						
12	8	.1370	.1520	.1185	19.2	20.9	16.2	80.8	79.1	83.8	1.55	....	1.15	.55	.95	0.17
					19.6	20.7	16.4	80.4	79.3	83.6						
16	9	.1476	.1684	.0873	20.5	21.5	13.6	79.5	78.5	86.4	1.95	1.85	.62	.58	.50	None.
					20.1	21.3	13.7	79.9	78.7	86.3						
23	11	.1723	.1748	.1242	19.1	20.4	15.6	80.9	79.6	84.4	1.89	1.95	.94	.62	.60	0.03
					19.6	20.5	15.9	80.4	79.5	84.1						
26	12	.1535	.1571	.1087	20.2	21.4	14.8	79.8	78.6	85.2	1.89	2.10	1.81	.63	.63	.05
					20.2	21.0	15.1	79.8	79.0	84.9						
Mar. 2	13	.1542	.1675	.0826	19.0	21.3	12.6	81.0	78.7	87.4	2.00	2.03	.71	.74	.63	None.
					19.5	21.1	13.1	80.5	78.9	86.9						
5	14	.1723	.1748	.1242	20.0	20.9	15.4	80.0	79.1	84.6	1.64	1.63	.77	.52	.52	None.
					19.5	20.3	15.3	80.5	79.7	84.7						
9	15	.1605	.1747	.1100	18.7	21.8	15.3	81.3	78.2	84.7	1.84	1.88	.82	.65	.52	None.
					19.2	22.6	15.5	80.8	77.4	84.5						
12	16	.1597	.1635	.1176	19.4	19.7	15.0	80.6	80.3	85.0	1.64	1.98	.96	.41	.64	0.04
					19.2	19.8	15.1	80.8	80.2	84.9						
	....	.1566	.1662	.1130	19.79	21.25	15.06	80.21	78.75	84.94	....	....	....	....	....	....

WASHING BY HOSE AND PADDLE, ON SKIMMER-BOARD.

1915. Jan. 19	2	0.1512	0.1522	0.1475	20.2 20.5	22.4 22.7	19.5 19.3	79.8 79.5	77.6 77.3	80.5 80.7	1.70	2.05	1.29	0.10	0.26	0.02
29	5	.1605	.1580	.1605	21.3 21.1	21.3 21.6	20.6 20.8	78.7 78.9	78.7 78.4	79.4 79.2	1.77	1.77	1.28	.48	.47	.17
Feb. 9	7	.1298	....	.9770	17.2 17.3	....	14.9 14.8	82.8 82.8	....	85.1 85.2	.94	....	.92	.12	....	.08
19	10	.1630	.1652	.1680	20.1 19.8	20.5 20.7	19.4	79.9 80.2	79.5 79.3	80.6	1.86	2.21	1.67	.57	.62	.34
	....	.1511	.1585	.1434	19.69	21.53	18.47	80.31	78.47	81.53	....	....	....	....	....	....

It had been assumed previously that the composition of oysters in the shell would be identical with that of oysters taken from the shuckers' dippers. Table 4 shows that this is not the case, that there is a slight but well-defined difference in composition. The percentage of total solids and other constituents except water is greater in the samples from the shuckers than in the sample of the same stock shucked in the laboratory immediately before analysis, while the percentage of water is correspondingly less. This difference probably is due to the fact that the oysters drain for half an hour or more while in the shuckers' dippers, and tend to lose a certain amount of their body fluids, shell liquor, and adhering mucus. The shell stock, being opened in the laboratory, had had less time in which to lose water, and, therefore, was always poorer in solids. This marked difference in composition between oysters which it would seem at first glance should be of identical composition, shows very plainly that the stock for each determination must be handled in exactly the same way every day if the results are to be comparable.

Table 4 is of great interest in showing the composition of oysters during the various stages of progress through the oysterhouse, and it shows also in a very striking manner the difference between the old and the new methods of washing oysters, to the discredit of the new methods, if amount of total nutrients is a proper criterion. With the purpose of plainly showing this difference, the table has been arranged in two parts, the analyses of oysters washed by the modern method of air agitation in tanks and the analyses of stock washed by the old method upon a perforated skimmer.

Of the substances determined, amino-acid nitrogen and total solids are taken for comparative purposes, as they are the most consistent determinations made and most clearly represent the condition of the oysters examined. The amino-acid nitrogen represents a truly soluble constituent which would be dissolved out of the oysters by the wash water. The total solids, though including most or all of the amino-acid nitrogen, are in the main insoluble substances whose apparent diminution in quantity is due largely to the distention of the bodies of the oysters because of osmosis and loss of particles of solid meat in handling or washing. A glance at the average values of amino-acid nitrogen and total solids for the two classes of washing shows that the content of both is much higher in oysters washed by the old method than in those washed by the modern one. A brief analysis of the results will show exactly how the two sets of figures compare. Taking the amount of each of these substances present in the shell stock as a basis upon which to calculate the losses, this figure may be called 100 per cent. Thus, the amounts of each of the constituents are expressed in percentages of the amount present in the same stock while in the shell. For the shucked stock and the commercial package, then, the figures in Table 5 are obtained.

TABLE 5.—*Average values of amino-acid nitrogen and total solids of oysters washed by both methods.*

(Shell stock, 100 per cent.)

Determination.	Old method.	New method.
Shucker:	*Per cent.*	*Per cent.*
Amino-acid nitrogen	104.8	106.2
Total solids	109.4	107.3
Commercial package:		
Amino-acid nitrogen	95.0	72.2
Total solids	94.0	76.0

Considering the comparatively small number of determinations made, and the multiplication of error involved in expressing the various fractions as percentages, the figures in Table 5 are very satisfactory checks. They show that in the old method of washing the finished product contains, in a given volume, about 94 per cent of the food value possessed by the same oysters in the shell, whereas in the modern method of washing this figure falls to a percentage of about 74 per cent.

This series, however, does not indicate in any way the cause of the loss, as the amino acids disappear at the same rate as do the total solids. This loss may be due almost entirely to osmosis, or it may be due in part to solution in the wash water of soluble parts of the oyster, or to both. That there is a loss of soluble matter in the wash water there is no doubt. This is proved by the complete disappearance of sodium chlorid after a comparatively short period of washing. Sodium chlorid and other crystalloids would wash out much faster than the soluble protein compounds, which are colloids, but if the sodium chlorid disappears it is certain that other soluble constituents tend to disappear also.

SERIES V.

In order to determine, if possible, just what proportion of the apparent loss of the various constituents is due to osmotic distention and what proportion is due to solution in the wash water, and also the general chemical effect of all kinds of oyster washing, a series of experiments was run in which measured volumes of oysters were subjected to various washing processes and were both measured and analyzed at various stages of washing. The results of this series are given in Table 6, and a mathematical analysis of the results obtained is given in Table 7.

Experiment 1.—Five gallons of standards were taken from the chute immediately before they entered the agitation tank, carefully measured, put into an equal volume of water, stirred thoroughly, and allowed to stand. Measurements were made of both water and oysters every 6 hours for the first day, and every 12 hours thereafter for 3 days. The water was renewed after each measurement. Chemical determinations were made once a day upon samples taken in the morning. In all these tables allowance has been made for all samples removed. Due to the fact that the oysters settled to the bottom of the tank and formed a compact mass which was almost impervious to water, very little opportunity was offered for osmotic action to take place, and the volume of the oysters remained practically constant throughout the experiment. In the periods of disturbance, however, which occurred while the oysters were being measured and the water was being removed fresh water came into contact with the oysters, and some of it remained with them in the bottom. Thus, a little osmotic action other than that at the top of the mass took place, and solution progressed continuously, though somewhat slowly. Since the volume remained practically constant throughout this experiment, it is evident that all the loss observed in this case must be due to solution or mechanical loss. In this case mechanical loss was small. In commercial pratice oysters never are subjected to such long continued action of water, but this experiment proves that a large percentage of the substance of the oyster is soluble in fresh water, and that osmotic distention is negligible in oysters washed in a tank without agitation. As is to be expected, the purely soluble constituents show a much more marked decrease than do the total solids, which include both soluble and insoluble substances.

Experiment 2.—This experiment was carried out in the same way as was Experiment 1, with the same purpose in view. On the third day, however, the samples were taken from the bottom of the tank instead of from a representative sample of the whole, as was usually done, in order to determine whether or not the bottom oysters were being affected by the water. The results show very clearly that they were not being so affected, as the percentages of total solids, etc., did not change during 24 hours of soaking. The percentages show the same relative decrease as in Experiment 1.

Experiment 3.—Having established the fact that a marked proportion of the solid substance of the oyster is soluble in fresh water, it becomes desirable to discover what proportion of the apparent loss of the various substances is due to actual loss in the wash water, and what is due to the increase in volume of the oyster. In this experiment, 20 gallons of oysters were taken from the chute immediately before entering the agitation tank, carefully measured into one of the tanks, and washed in the regular way, except that the washing was continued for one hour. Samples were taken before the process was started and at 15-minute intervals during washing. Detailed discussion of this and following experiments will be taken up later in connection with Table 7.

Experiment 4.—This experiment was conducted in an oysterhouse in which the old system of washing was used. Five gallons of shucked oysters were measured out and placed upon the skimmer.

They were then washed for about 5 minutes by means of water from a 1¼-inch hose, the oysters being constantly stirred about with a wooden paddle. They were then drained and packed for shipment. This represents regular commercial practice in this particular oyster-house.

Experiment 5.—This experiment was conducted in a plant which uses the old method of washing, but in which the oysters are subjected to the action of water in a tank, with occasional agitation by means of a paddle, for 20 or 30 minutes, then drained upon a skimmer. Seven gallons of oysters were placed in the tank and treated as already described.

Experiment 7.—This experiment was run in a tank, but, instead of air agitation, the oysters were stirred constantly by means of a large metal paddle. They were drained, measured, and replaced in the tank at such intervals that the period of washing between measurements was 10 minutes. Samples were taken before washing was begun, and each time the oysters were measured. Washing was continued until the oysters began to lose markedly in volume, which was observed after 50 minutes of washing.

Experiment 8.—This experiment was conducted in the same manner as Experiment 7, except that it was done in a different oyster-house and that the regular air-agitation method was used.

Experiment 9.—The object of this experiment was to determine whether or not oysters lose appreciably in volume on account of repeated handling and measurement as done in the preceding experiments. Six gallons of drained oysters were placed in one tank and washed for 30 minutes by the regular method, with air agitation. Seven gallons of the same stock were washed in the adjoining tank with air agitation, but were drained and measured at 10-minute intervals, as in the foregoing experiment.

Experiment 10.—Having shown that handling oysters during washing has a marked effect in decreasing the osmotic distention and increasing the actual loss of substance, it was decided to run an experiment to compare the volumes and chemical composition of oysters washed and handled under conditions identical except for the time of washing. This experiment was also designed to find out what the maximum of osmotic distention would be. Five gallons of drained oysters were placed in each of three adjoining tanks and washed with the regular water current and air agitation, Tank A for 30 minutes, Tank B for 60 minutes, and Tank C for 90 minutes. A representative sample of the whole lot was taken before the washing was begun, and from each tank at the expiration of its period of washing.

Experiment 11.—This experiment was made under regular shipping conditions, and was simply a measurement and analysis of oysters before and after washing with the regular water current and air agitation for 30 minutes.

Experiment 12.—This experiment is of the same nature as the preceding one, simply measurement and analysis of a commercial shipment before and after washing with regular water current and air agitation.

Experiment 13.—This experiment was carried out in the same manner as was Experiment 12, except that enough dairy salt was added to the wash water to make the salinity of the solution 2.53 per cent. The water over the beds where the oysters were grown varied from 2.48 to 2.70 per cent salinity, so no osmosis should take place. The object of this experiment was to test the correctness of the belief commonly held that all the salt must be washed out of oysters to have them "keep." It has been observed since the beginning of the industry that oysters tended to spoil if the salt was not washed out to below the point where it could be tasted in the water; hence the spoiling was connected with the salinity. This phenomenon appears to be merely a coincidence, due to the fact that the putrefactive bacteria are washed out at about the same rate as is the salt.

Experiment 14.—The oysters in this experiment were washed upon a skimmer with a hose for 10 minutes, and were stirred constantly with a paddle.

Experiment 15.—In this experiment the oysters were washed in a regular agitation tank by the regular method, except that instead of being constantly agitated by a current of air they were stirred every 5 minutes with a large metal paddle. Thus, the oysters were affected by a constant stream of cold water from the bottom of the tank, and were thoroughly agitated six times during the experiment.

TABLE 6.—*Washing experiments* (*Series 5*).

Date.	Method of washing.	Experiment No.	Interval of examination.	Volume.	Increase in volume.	Amino-acid nitrogen.	Total solids.	Moisture.	Ash.	Salinity.
1915.				*Liters.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Jan. 15	Stationary, in tank with equal volumes of water and oysters. Laboratory conditions. Fresh water added (waters renewed) after each measurement. No agitation except that caused by measurement.	1	At start	19.15		0.1232	16.41	83.50	1.17	0.02
							15.80	84.20		
			After 6 hours	18.30						
			After 12 hours	19.50						
			After 24 hours	19.10		.0948	14.49	85.51	.87	None.
						.0967	14.23	85.77		
			After 36 hours	19.08						
			After 48 hours	19.20		.0519	10.93	89.07	.50	None.
							11.45	88.55		
19	Same method as No. 1, except that on third day samples were taken from bottom of tank, showing impermeability of mass of oysters.	2	At start	19.10		.1475	19.45	80.55	1.29	0.02
						.1475	19.30	80.70		
			After 12 hours	20.00	4.72	.1018	15.20	84.80	.83	Traces.
			After 24 hours	20.16	5.55	.1009	15.40	84.60		
			After 36 hours	20.44	7.01					
			After 48 hours	20.36	6.60	.1064	15.60	84.40	.90	Traces.
						.1040	15.50	84.50	.93	
			After 60 hours	20.40	6.80					
26	Mechanical washer, with air agitation and constant flow of water. Commercial conditions.	3	At start	90.86		.1647	18.50	81.50	1.07	0.14
							18.10	81.90		
			After 15 minutes			.1270	15.20	84.80	.66	.03
							15.50	84.50		
			After 30 minutes			.1238	14.90	85.10	.67	None.
							15.10	84.90		
			After 45 minutes			.1015	13.10	86.90	.65	None.
							13.40	86.60		
			After 60 minutes	116.06	27.73	.0940	13.20	86.80	.56	None.
							13.50	86.50		
				Gallons.						
29	Washed on skimmer with hose and paddle. Commercial conditions.	4	At start	5		.1605	21.30	78.70	1.77	0.47
							21.10	78.90		
			From commercial package	5	None.	.1605	20.60	79.40	1.28	.17
							20.80	79.20		
Feb. 9	Hand agitation in tank. Commercial condition	5	At start	7		.1298	17.20	82.80	.94	.12
							17.30	82.70		
			After 30 minutes	8.75	25.00	.0977	14.90	85.10	.92	.08
							14.80	85.20		

TABLE 6.—*Washing experiments (Series 5)*—Continued.

Date.	Method of washing.	Experiment No.	Interval of examination.	Volume.	Increase in volume.	Amino-acid nitrogen.	Total solids.	Moisture.	Ash.	Salinity.
1915.				*Liters.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
12	Washed with flowing water; agitated with paddle	7	At start	10.53	....	0.1520	20.90 20.70	79.10 79.30	1.55	0.95
			After 10 minutes	11.55	9.68	.1355	17.10 17.10	82.90 2.90	1.47	.36
			After 20 minutes	12.03	14.24	.1185	16.20 16.40	83.80 83.60	1.15	.17
			After 30 minutes	12.86	22.12	.0973	14.60 14.40	85.40 85.60	.91	.00
			After 40 minutes	12.73	20.89	.0836	13.60 13.30	86.40 86.70	.66	Trace.
			After 50 minutes	12.36	17.40	.0765	13.30 13.50	86.70 86.50	.66	None
16	Regular commercial practice, with air agitation, except in measuring every 10 minutes.	8	At start	6.00	....	.1677	21.50 21.30	78.50 16.70	1.85	0.50
			After 10 minutes	7.10	16.66	.1344	16.40 16.40	83.60 83.60	.97	.06
			After 20 minutes	7.41	23.33	.1062	15.20 14.90	84.80 85.10	.79	None.
			After 30 minutes	7.37	22.83	.0992	14.30 14.40	85.70 85.60	.67	None.
			After 40 minutes	7.26	21.07	.0874	13.60 13.70	86.40 86.30	.62	None.
23	Mechanical washer, with air agitation: Tank A, 30 minutes continuous	9	At start	6.00	....	.1534	20.40 20.50	79.60 79.50	1.95	0.60
			After 30 minutes	7.37	22.80	.1068	15.60 15.90	84.40 84.10	.94	.026
	Tank B, drained, and measured at intervals		At start	7.00	....	.1534	20.40 20.50	79.60 79.50	1.95	.60
			After 10 minutes	7.67	9.57	.1326	16.90 17.40	83.10 82.60	1.28	.19
			After 20 minutes	7.92	13.14	.1077	16.00 15.80	84.00 84.20	.92	.037
			After 30 minutes	8.12	16.00	.0968	15.40 15.40	84.60 84.60	.78	None.
			After 40 minutes	8.23	17.57	.0794	13.90 14.10	86.10 85.90	.67	None.
			After 60 minutes	8.24	17.71	.0623	13.30 13.40	86.70 86.60	.60	None.

24	Washed in regular tanks, with air agitation: Tank A, 30 minutes	10	At start	5.00	....	.1765	21.20 20.90	78.80 79.10	1.93	0.46
			After 30 minutes	6.32	26.40	.1142	15.30 15.40	84.70 84.60	.92	.03
	Tank B, 60 minutes		At start	5.00	....	.1765	21.20 20.90	78.80 79.10	1.93	.46
			After 60 minutes	7.08	41.60	.0930	14.00 13.90	86.00 86.10	.70	None.
	Tank C, 90 minutes		At start	5.00	....	.1765	21.20 20.90	78.80 79.10	1.93	0.46
			After 90 minutes	7.37	49.40	.0906	13.20 13.40	86.80 86.60	.69	None.
26	Regular commercial shipment. Washed with water and air, 30 minutes.	11	At start	5.00	....	.1571	21.40 21.00	78.60 79.00	2.10	0.63
			After 30 minutes	6.08	21.60	.1087	14.80 15.10	85.20 84.90	1.81	.05
Mar. 9	Regular commercial shipment. Washed with water and air, 30 minutes.	12	At start	7.00	....	.1747	21.80 22.60	78.20 77.40	1.88	.52
			After 30 minutes	9.50	35.70	.1100	15.30 15.50	84.70 84.50	.82	None.
9	Carried out in parallel with No. 12, except that wash water was 2.53 per cent salinity.	13	At start	5.00	....	.1747	21.80 22.60	78.20 77.40	1.88	0.52
			After 30 minutes	5.00	None.	.1610	21.20 21.10	78.80 78.90	1.72	.65
12	Washed on skimmer with hose and paddle, for 10 minutes.	14	At start	5.00	....	.1635	19.70 19.80	80.30 80.20	1.98	.64
			After 10 minutes	5.43	8.60	.1222	15.70 15.90	84.30 84.10	.93	None.
12	Washed in tank, with regular water current, but no air. Agitated by paddle, every 5 minutes.	15	At start	6.00	....	.1635	19.70 19.80	80.30 80.20	1.98	0.64
			After 30 minutes	7.25	20.30	.1176	15.00 15.10	85.00 84.90	.96	.04

From Table 6 it is apparent that oysters lose a marked proportion of their total solids, and therefore their nutritive value, during the process of washing. In speaking of these losses the following terms are used:

(*a*) "Apparent loss" denotes the entire loss shown by the analysis. This loss is due to both osmotic distention and solution or suspension in the wash water.

(*b*) "Osmotic loss" denotes the loss due to osmotic distention of the tissues of the oysters. This is not an actual loss of substance, but a replacement by an equal amount of water.

(*c*) "Actual loss" denotes the loss caused by solution or suspension of part of the oyster substance in the wash water. This loss is actual, as the substance thus dissolved or suspended goes to waste.

These losses have been calculated for the more important experiments, using as a basis the amount of each substance present in the shucked stock. The figures are tabulated in Table 7.

TABLE 7.—*Losses expressed in percentages of original amounts present.*

Experiment No.	Figure of osmosis.[1]	Amino-acid nitrogen.			Total solids.			Ash.		
		Apparent.[2]	Osmotic.[3]	Actual.[4]	Apparent.[2]	Osmotic.[3]	Actual.[4]	Apparent.[2]	Osmotic.[3]	Actual.[4]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3	78.3	27.0	21.7	5.3	40.9	21.7	19.2	47.7	21.7	26.0
4	100.0	None.	None.	None.	5.6	None.	5.6	27.6	None.	27.6
5	80.0	24.6	20.0	4.6	....	....	....	....	....	....
7	81.8	36.0	18.2	17.8	30.4	18.2	12.2	41.4	18.2	23.2
8	81.4	40.8	18.6	22.2	33.0	18.6	14.4	63.8	18.6	45.2
9–A	81.5	30.5	18.5	12.0	23.4	18.5	4.9	51.8	18.5	33.3
9–B	85.0	59.4	15.0	44.4	34.7	15.0	19.7	69.2	15.0	54.2
10–A	79.0	35.3	21.0	14.3	23.5	21.0	2.5	52.3	21.0	31.3
10–B	70.6	47.3	29.4	17.9	30.5	29.4	1.1	63.8	29.4	35.4
10–C	67.8	48.7	32.2	16.5	33.6	32.2	1.4	64.2	32.2	32.0
11	82.2	30.8	17.8	13.0	29.5	17.8	11.7	....	....	....
12	73.7	37.0	26.3	10.7	30.6	26.3	4.3	56.4	26.3	30.1
13	100.0	7.8	None.	7.8	4.7	None.	4.7	8.5	None.	8.5
14	92.0	25.2	8.0	17.2	20.0	8.0	12.0	53.0	8.0	45.0
15	82.7	28.1	17.3	10.8	23.8	17.3	6.5	51.5	17.3	34.2
Averages	....	....	17.60	14.30	....	17.46	8.59	....	17.46	32.77

[1] Percentage of original amount of each substance which would be present if the apparent loss were due to osmosis alone.
[2] The entire loss shown by analysis. This loss is due to both osmotic distension and solution or suspension in the wash water.
[3] The loss due to osmotic distension of the tissues of the oysters. This is not an actual loss of substance, but a replacement by an equal amount of water.
[4] The loss caused by solution or suspension of part of the oyster substance in the wash water. This loss is actual, as the substance thus dissolved or suspended is washed off and goes to waste.

Experiment 3.—Taking the amount of each substance present in the shucked stock as 100 per cent for a basis of calculation, it is seen that if the decrease in percentage of the various substances were due to osmotic distention alone each of these substances would have a value of 78.3 per cent at the end of the process, since the volume of the oysters increased from 90.86 liters to 116.06 liters. The actual figures obtained, however, are as follows: Total solids, 73 per cent; amino nitrogen, 59.1 per cent; ash, 52.3 per cent. Thus in this experiment the actual loss of total solids is only 5.3 per cent of the original amount present, probably soluble amino compounds and inorganic salts, while the actual loss of amino acids is 19.2 per cent and that of ash-forming substances is even greater, amounting to 26 per cent. As the osmotic loss is in each case 21.7 per cent, it is clear that the actual loss of total solids is relatively slight compared to it, while the actual loss of amino acids and other soluble constituents is as great as, or greater than, the osmotic loss. These figures do not represent commercial practice, however, for, in general, oysters are washed for about 30 minutes.

Experiment 4.—In this experiment the increase in volume and, therefore, the osmotic loss are zero. The actual loss of amino acids is also zero, and that of total solids is only 5.6 per cent. The actual loss of ash is rather high but is far lower than when the washing is done by the other method.

Experiment 5.—The results of this experiment show a gain in volume of 25 per cent. This makes the percentage figure for each substance 80 per cent and the osmotic loss 20 per cent. As the derivation of these figures already has been given in detail (Table 7), it will not be enumerated for this and the following experiments.

Experiment 7.—The maximum osmosis was observed at the end of 30 minutes of washing in this method. The maximum osmotic increase was 22.1 per cent, about 5 per cent less than that observed in the case of air agitation. As will be shown later, this lower value is due solely to the excessive handling inherent in this method of repeated measurement and not to any difference in the methods of agitation. The percentage of losses will be seen to correspond rather closely to those observed in the air-agitation experiments. It is interesting to note, however, that at the end of 40 minutes the loss of total solids stopped, probably because of shrinkage in volume caused by the excessive handling already mentioned. The percentage of amino acids, however, continued to fall. The ash was apparently reduced to a minimum, the remainder being practically all insoluble. The percentages in Table 7 are calculated from the results at the end of 30 minutes, so that they closely represent commercial practice.

Experiment 8.—In the calculated results of this experiment the 30-minute results are used, as these are representative of commercial practice. It will be observed that these results agree very closely with those obtained in Experiment 7, except in the case of ash. This difference is probably explained by the fact that the stock came from widely scattered beds, and the inorganic constituents were probably dissimilar.

Experiment 9.—These results show clearly that handling has a great effect in reducing the amount of increase. The contents of Tank A increased 22.8 per cent in volume in 30 minutes of continuous washing, while the contents of Tank B increased only 17.71 per cent in 60 minutes of equally vigorous but intermittent washing. The difference is caused by the intervals of draining and stirring about upon the skimmer, in which the oysters lose water.

Experiment 10.—From the results of this experiment it is apparent that oysters are capable of enormous distention and that the limit is not reached even with 90 minutes of washing. This experiment also seems to indicate that the great actual losses observed in Experiments 3, 7, 8, and 9–B were due to the excessive handling inherent in the method of measurement during washing. It is seen from this experiment that, even after 90 minutes' washing, the actual loss of total solids is comparatively slight and is probably accounted for almost entirely by the great actual losses of amino acids, ash, and salt. The osmotic losses, however, are very great, as 32.3 per cent of the total solids originally present have been replaced by water, and the apparent loss is 33.6 per cent. As in the hard northern oysters very little of this added water is given off in shipment, it is clear that the consumer may be paying oyster prices for a great deal of added water. In one case a 5-gallon commercial package of oysters which had been increased in volume 35.7 per cent was shipped to a market four days away, and arrived and was sold in apparently the best of condition. The meats were sound and plump, and the liquor above the oysters was only the usual thick, dense mucus.

Experiment 11.—These results are in accord with other results of similar experiments, showing a marked loss of solids. The ash figures are omitted, as the ash analysis showed a doubtful value which is not in accord with the other figures. It was too high, probably caused by the presence of a small fragment of shell.

Experiment 13.—The results of this experiment are very interesting, in that they show the increase in volume of oysters during washing to be due purely to osmosis, and the soluble parts of the oysters to be less soluble in salt water than in fresh.

Experiment 14.—This represents commercial practice in some oysterhouses, and the results of this experiment are comparable with those of Experiment 4, except in that the washing was continued for 10 instead of 5 minutes. A comparison of the two sets of results shows that the losses are much greater in the second case, as is to be expected. As has been pointed out, in this type of washing some of the solid matter of the oysters is forced through the perforations of the skimmer during washing and is thus lost.

Experiment 15.—By comparison of the results of this experiment with those of Experiment 9–A, which was run on the same kind of stock but with air agitation, it is seen that they are in very close agreement throughout. This shows that the air has little or no effect as such, its effect being only to keep the oysters in motion, so that osmosis will attain a maximum value. The results of Experiments 9–A, 10–A, 11, 12, and 15 all agree fairly well, though differences in stock and in methods of handling cause rather large discrepancies in some cases.

SUMMARY.

1. The determination of ammoniacal nitrogen by the Folin method is of very little value in estimating the amount of decomposition which has occurred in oysters during preparation for the market, because of the repeated washings to which they are subjected.

2. For the same reason the determination of amino-acid nitrogen also is useless in estimating decomposition in oysters undergoing commercial treatment, although it is a reliable index of the amount of washing or soaking which the oysters have received.

3. A marked loss of oyster solids and of ash constituents occurs on washing oysters with fresh water.

4. Oysters covered with water, but not agitated, are not appreciably affected by osmosis, except in relatively long periods of time. Solution proceeds slowly, but amounts to a large percentage of the solids originally present in the course of two or three days.

5. If oysters are agitated in fresh water, either by mechanical means or by means of a blast of air, a large increase in volume results in a short space of time, amounting to as much as 35 per cent in 30 minutes, and to as much as 50 per cent in 90 minutes in these experiments. This increase is believed to be due to osmotic action. As many shucked oysters prepared for the market are washed by this method and sold by measure, it follows that the consumer may be buying added water.

6. When oysters were washed in unpolluted water of approximately the same salinity as that in which they were grown, no increase in volume was found to occur, the actual loss of nutrients was slight, and the oysters were cleaned as effectually as they were by being washed in fresh water.

7. The old method of washing oysters on a skimmer with a hose and paddle gives much less osmotic loss, and, therefore, a much higher content of total solids than does the method of washing by a water current and air agitation.

8. The amount of osmotic distention of which oysters are capable has not been determined. It is at least 50 per cent of the original volume in the oysters under experimentation.

9. These experiments seem to indicate that there is no connection between soaking and "bleeding" in the commercial package (that is,

giving off the water, which forms a layer in the upper part of the container).

10. Interrupted washing (draining and measuring during washing) results in a smaller osmotic increase than does continuous washing for the same length of time.

11. The relation of osmotic loss to actual loss varies with the solubility of the substance in question. Thus, in the average of all the experiments, in the case of total solids made up of insoluble and soluble constituents, the ratio of osmotic loss to actual loss is approximately 2 : 1; for amino-acid nitrogen, all of which is soluble, but which goes into solution slowly, the ratio is approximately 1 : 1; and for ash-forming substance, which is composed largely of soluble inorganic compounds, the ratio is approximately 1 : 2.

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

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EFFECT OF GRAZING UPON ASPEN REPRODUCTION.

By ARTHUR W. SAMPSON, *Plant Ecologist.*

CONTENTS.

PURPOSE.

It is desirable that on lands bearing a stand of aspen (*Populus tremuloides*)[1] a proper balance be maintained between timber production and grazing. In many of the National Forests, particularly those in northern New Mexico and Arizona, in Colorado and Utah, and in portions of Idaho and Nevada, aspen is a tree of considerable commercial value. It is used chiefly for fuel, posts, corral poles, lumber, boxwood, excelsior, and mine props, and the demand for it is steadily increasing. As a protective cover for watersheds, aspen, by reason of its extensive lateral root system, is probably more valuable than any other tree species with which it commonly is found.

[1] Some taxonomists claim that the proper title of the western aspen is *Populus aurea* Tidestrom being distinguished from the more eastern *Populus tremuloides* Michaux by certain technical differences in the flowers and fruit, as well as by the fact that after frost the leaves of the former take on a golden-orange rather than a light-yellow hue. Without entering into the merits of the question, the present usage of the Forest Service is here adhered to.

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Beneath the aspen, which ordinarily grows in rather open stands, is usually a luxuriant understory of grasses, weeds, and browse that is grazed with relish by all kinds of live stock. As range land, the aspen type is much more valuable than either the spruce-fir type just above it or the oak-brush type just below it. Unfortunately, however, the stock, especially sheep, do not confine themselves to the forage, no matter how abundant and palatable it may be; they also eat the foliage and tender twigs of the young aspen. This, of course, means that the aspen reproduction is often badly injured or even killed, which makes it very difficult in many cases to secure a second stand of timber.

A study, the results of which are presented in this bulletin, has been made to determine the extent of injury to aspen reproduction by sheep and cattle, the effects of such damage on the development of the young trees, and the best method of protecting the reproduction from injury without unnecessarily restricting the grazing of live stock. Though the results are meant to apply especially to conditions in the National Forests, they may also be of value, possibly with slight modifications, in the case of farm woodlands in the East where the forage under aspen is converted into meat or butter fat.

METHOD.

The study, which covered a period of five years (1902 to 1916 inclusive), was conducted on the Manti National Forest, in central Utah, where the timber and forage are typical of the commercial aspen type in National Forests.

A general study was made on 122 sample plots in virgin and lightly thinned aspen, at elevations between 7,500 and 10,000 feet, in both sheep and cattle ranges and covering all variations in timber and forage.

A detailed study of the extent and growth of aspen reproduction and the extent of its injury by stock and other agencies was made on selected clear-cut areas, four of which were located on sheep range and two on cattle range. Two of the plots on the sheep range and one on the cattle range were securely fenced against stock (Plate I); the others were left open to grazing. The reason for selecting clear-cut areas for the intensive study of reproduction is that aspen reproduces mainly by sprouts from the roots of older trees and the best method of harvesting mature aspen is to cut the timber clear.

On each clear-cut area transect and quadrat sample plots were established so that the sprouts originally observed could be definitely located in future examinations.

In 1913 and 1914 all plots were examined twice—once in June and again in September. In subsequent seasons only the transects and quadrats on the clear-cut areas were examined twice during a season, the plots in the standing timber being examined only in the autumn.

The reproduction injured or killed was classified according to height, sprouts of from about 6 inches to 1½ feet constituting the youngest class, those from 1½ to 2½ feet the second class, and so on up to sprouts 4½ feet high. Record was also made of the intensity of grazing; that is, whether it was light, medium, or heavy. Plots were classed as "lightly grazed" where 50 per cent or less of the palatable vegetation had been cropped, "moderately grazed" where from 50 to 70 per cent of the forage had been consumed, and "heavily grazed" where more than 75 per cent of the palatable vegetation had been eaten.

INJURY TO ASPEN REPRODUCTION BY LIVE STOCK IN STANDING TIMBER.

EFFECT OF SHEEP BROWSING.

Injurious browsing of aspen reproduction means the removal by stock of terminal or lateral shoots, or both, to a sufficient extent to interfere more or less seriously with the subsequent growth and development of the sprouts. The removal of a single lateral twig or the mere nipping of the terminal bud are disregarded, since the study has shown that to interfere seriously with the food manufacturing power or with the form development of the young trees at least one-fourth of the total number of branches must be destroyed. If browsing is confined to the upper half of the sprout, including the terminal shoot, the damage is more serious, especially so far as concerns the ultimate form of the tree.

Table 1 summarizes the effects of sheep browsing on plots in standing timber, according to seasons and to the intensity of grazing. There is also given the number of sprouts injured by other things than live stock. Of a total of 16,631 sprouts observed during the five years of study, 17.1 per cent were killed and 27.3 per cent were more or less injured by browsing, while 37.5 per cent were uninjured. It is noteworthy that 11.7 per cent of the total number of sprouts were killed and 6.3 per cent injured by causes other than grazing. Unfavorable climatic conditions and the activities of bark-eating rodents were chiefly responsible for these results. It is evident that very few vigorous sprouts remain to perpetuate the stand where sheep grazing is continued.

Considerable variation in extent of injury to the reproduction occurs in different seasons. In the case of the lightly grazed plots, for example, only 3.7 per cent of the aspen reproduction was injured in 1912, but the percentage was 30.8 in 1913. Similar variations occur in the case of moderately grazed and heavily grazed plots.

They are probably due more or less to chance. No appreciable difference was observed in the extent and degree of injury by browsing during different portions of the season so long as the foliage remained intact. When the wood of the stems hardens the stems are browsed practically not at all by cattle and only to a limited extent by sheep.

The effect of the intensity of grazing on the vigor and growth of the reproduction is better shown by figures covering a number of years. These are given in Table 2, which summarizes the data on intensity of grazing presented in Table 1.

The lighter the grazing the greater is the percentage of uninjured sprouts. Thus, on the lightly grazed plots more than half (58.2 per cent) of the total number observed were uninjured; on the moderately grazed plots a little less than half (43.8 per cent); and on the heavily grazed areas only about a fifth of the stand (22.2 per cent) escaped injury.

TABLE 1.—*Injury to aspen sprouts on plots in standing timber.*

Grazing intensity and year of examination.	Total number of sprouts.	Uninjured sprouts.		Killed by grazing.		Injured by grazing.		Sprouts killed by causes other than grazing.		Sprouts injured by causes other than grazing.	
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
Lightly grazed:											
1912	108	104	96.3	......	......	4	3.7	......	......	......	......
1913	954	633	66.3	21	2.2	294	30.8	......	......	......	......
1914	1,169	652	55.7	89	7.6	219	18.7	......	......	......	......
1915	595	233	39.1	95	15.9	41	6.9	......	......	......	......
1916	267	176	65.9	36	13.5	40	15.0	......	......	......	......
Moderately grazed:											
1912	128	117	91.4	......	......	5	3.9	......	......	......	......
1913	880	617	70.1	......	......	252	28.6	......	......	......	......
1914	2,697	1,011	37.5	303	11.2	532	19.7	......	......	......	......
1915	1,864	571	30.6	327	17.5	227	12.1	......	......	......	......
1916	1,127	611	54.2	146	12.9	310	27.6	......	......	......	......
Heavily grazed:											
1912	154	138	89.6	9	5.8	3	1.9	......	......	......	......
1913	458	234	51.3	......	......	223	48.7	......	......	......	......
1914	2,471	624	25.2	412	16.7	1,192	48.3	......	......	......	......
1915	2,632	370	14.0	688	26.1	964	36.6	......	......	......	......
1916	1,127	151	13.4	712	63.2	239	21.2	......	......	......	......
Total	16,631	6,242	......	2,838	......	4,545	......	1,449	......	1,057	......
Average	....	......	37.5	......	17.1	......	27.3	......	11.7	......	6.3

TABLE 2.—*Injured, killed, and uninjured aspen sprouts on plots in standing timber subject to sheep grazing during a five-year period.*

Period of examinations and grazing intensity.	Total number of sprouts examined.	Uninjured sprouts.		Sprouts killed by grazing.		Sprouts injured by grazing.	
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
1912–1916:							
Lightly grazed	3,093	1,798	58.2	241	7.8	598	19.4
Moderately grazed	6,696	2,927	43.8	776	11.6	1,352	20.2
Heavily grazed	6,842	1,517	22.2	1,821	26.6	2,621	38.4

RELATION BETWEEN INTENSITY OF GRAZING AND INJURY TO SPROUTS.

The character of injury to sprouts will, of course, largely determine (1) the subsequent density of the aspen stand, (2) the ultimate form of the trees, (3) the subsequent rate of growth, and (4), to a considerable extent at least, the size of the trees and the commercial value of the timber. The removal of the leader or terminal shoots of aspen reproduction, for instance, may destroy the symmetry of the tree, especially if the leader is removed more than once. The injury caused by the destruction of lateral branches is chiefly physiological, the nutriment on which the specimen may build being roughly proportionate to the number of laterals; i. e., to the leaf area.

The extent of browsing of leaders and laterals, or both, the mortality due to excessive browsing, and the number of sprouts uninjured on the plots in standing timber during 1915 and 1916 are summarized in Table 3. The greatest number of specimens were under observation during these two years.

TABLE 3.—*Character and extent of injury to sprouts according to intensity of grazing, seasons 1915 and 1916. Plots in standing timber.*

Season and grazing intensity.	Total sprouts killed.	Ungrazed sprouts.	Leaders browsed.	Leaders and laterals browsed.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1915:				
Lightly grazed	15.9	39.1	4.5	2.3
Moderately grazed	17.5	30.6	4.3	7.7
Heavily grazed	26.1	14.0	21.5	15.1
1916:				
Lightly grazed	13.5	65.9	7.8	7.1
Moderately grazed	12.9	54.2	14.6	12.8
Heavily grazed	63.2	12.9	4.4	16.7

Both in 1915 and 1916 the mortality was practically the same on lightly grazed and on moderately grazed plots, the average percentage being 14.9 (fig. 1). On the heavily grazed plots, however, the mortality of sprouts was appreciably greater, being 26.1 per cent of the total in 1915 and 63.2 per cent in 1916. The percentage of ungrazed sprouts in 1916 was more than five times as much on the lightly grazed areas and four times as much on the moderately grazed areas as on the heavily grazed plots. The general tendency is the same in the 1916 figures. The averages for 1915 and 1916 on lightly grazed plots was 52.5 per cent, on the moderately grazed areas 42.4 per cent, and on the heavily grazed plots only 13.4 per cent.

The number of terminal shoots or "leaders" removed was practically the same (averaging 4.4 per cent) on lightly and on moderately grazed plots in 1915; but on the heavily grazed areas it was considerably larger, amounting to 21.5 per cent. In 1916 the terminal shoots of 7.8 per cent of the specimens were consumed on lightly grazed plots, of 14.6 per cent on moderately grazed areas, and of 4.4 per cent on heavily grazed plots. The small percentage on the heavily grazed plots is due to the high mortality of specimens on these plots in previous seasons, which left for observation relatively few specimens having terminal shoots. Table 5 shows that for the whole period from 1912 to 1916, inclusive, the greatest number of grazed sprouts, especially those up to a foot or so in height, were in general found on heavily cropped plots, and that the least injuries occurred on the lightly grazed plots. When the total number of sprouts occurring on the plots and the number injured are considered collectively for the five years, regardless of grazing intensity, a little less than half (40 per cent) is found to be injured by browsing. This is considerably lower than on the heavily grazed plots. On most plots the stature of the specimens was appreciably more reduced on the heavily grazed lands than on those where grazing was light or moderate, the portion of the specimens remaining often being mere snags, as is shown in figure 2 of Plate I and figures 1 and 2 of Plate II. In the most extreme cases all the leaves, much of the tender woody growth, some of the buds, and portions of the bark were eaten.

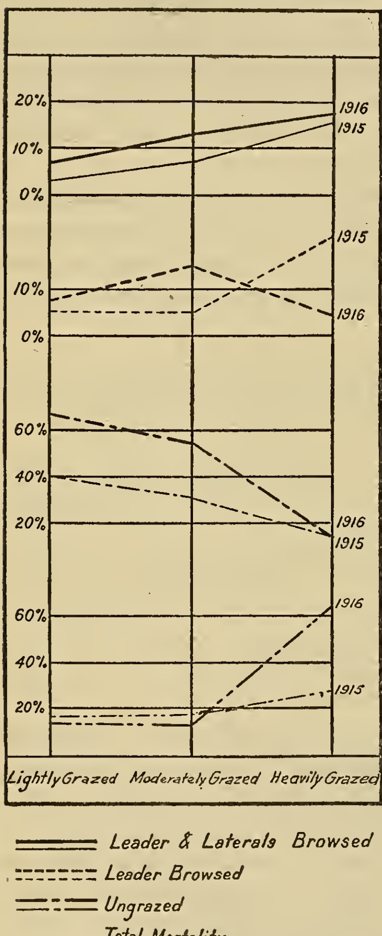

FIG. 1.—Relation of injury of sprouts to intensity of grazing seasons 1915 and 1916.

The proportion of specimens with both leaders and laterals browsed is least serious on the lightly grazed plots. On moderately grazed areas the percentage is considerably more, and on heavily grazed areas it is the highest of all. This holds true both for 1915 and 1916. For the five-year period 1912–1916, Table 4 shows that, regardless of height classes, the average percentage of injured sprouts is least on the lightly grazed plots, intermediate on the moderately grazed areas, and largest on the heavily grazed plots, the figures being 14.1, 24.9, and 53.1, respectively. The results are similar in the case of the number of killed sprouts, the percentages being 12.3, 14.5, and 16.9 on the corresponding plots. On the lightly grazed areas the average per cent of uninjured sprouts was 46.2, while on the moderately and heavily grazed plots it was 27.1 and 9.1, respectively.

RELATION BETWEEN INTENSITY OF GRAZING AND INJURY TO SPROUTS OF DIFFERENT HEIGHT CLASSES.

The extent of injury to reproduction of different height classes varies considerably. There appears to be no constant relation, however, between the different height classes of reproduction and the percentage of injured or killed sprouts. In Table 4 the sprouts under observation during the 5-year period have been grouped into height classes and assembled according to intensity of grazing.

TABLE 4.—*Extent of injury to sprouts in standing timber, according to height classes and grazing intensities.*

Grazing intensity.	Height class of reproduction.	Total number of sprouts.	Uninjured.		Sprouts killed by grazing.		Sprouts injured by grazing.	
	Feet.		*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
Lightly grazed	0.5 to 1.5	891	535	60.1	44	4.9	272	30.3
Do	1.5 to 2.5	235	96	40.9	31	13.2	43	18.3
Do	2.5 to 3.5	193	68	35.2	36	18.7	10	5.2
Do	3.5 to 4.5	173	84	48.6	22	12.7	5	2.9
Average (per cent)				46.2		12.3		14.1
Moderately grazed	.5 to 1.5	1,451	653	45.0	200	13.7	290	20.0
Do	1.5 to 2.5	709	217	30.6	123	17.4	206	29.1
Do	2.5 to 3.5	416	59	14.2	73	17.5	142	34.1
Do	3.5 to 4.5	280	53	18.9	26	9.3	46	16.5
Average (per cent)				27.1		14.5		24.9
Heavily grazed	.5 to 1.5	1,395	246.	17.6	318	22.8	665	47.7
Do	1.5 to 2.5	628	26	4.1	131	20.8	373	59.4
Do	2.5 to 3.5	241	23	9.5	21	8.7	159	66.0
Do	3.5 to 4.5	109	6	5.5	17	15.6	43	39.5
Average (per cent)				9.1		16.9		53.1

The number of specimens remaining on the plots decreases with the increase in height class. Thus in the 3½ to 4½ foot class is found the sparsest stand of reproduction examined, all intensities of grazing considered. This is accounted for by the number of sprouts killed by adverse climatic conditions and by rodents, as well as by the number killed by browsing.

The shoots of the first year's sprouts (6-inch to 1½-foot class) are more succulent than those of sprouts of greater age, but the new twigs and branches produced each season by the older specimens are quite as palatable as are the shoots of younger sprouts. Hence, while the terminal shoot is less liable to injury in the case of the taller and older sprouts than sprouts 1½ feet or less in height, the taller specimens are nevertheless subject to injury of varying seriousness so long as the branches are within reach of the sheep. Furthermore, the sprouts listed in Table 5 which have the least height growth, viz, those "less than one season old" and those "below 6 inches, one season old," are undoubtedly protected from grazing by the rather luxuriant cover of herbaceous vegetation which characteristically occurs in the aspen type after about August 1 and hides much of the reproduction from view. The sprouts in these classes show a considerably smaller percentage of grazing than those of greater height. However, the loss chargeable to grazing is considerable, and owing to the succulence of the entire aerial parts during the first season of growth there were numerous individual sample plots representing large areas where on account both of the climatic conditions and of browsing the greatest injury to sprouts was inflicted during the initial season of growth.

In view of the mortality of 1-year-old sprouts due to browsing and causes other than browsing, it may be concluded that even light cropping of the lands is sure to have a determining effect on the ultimate timber stand. The extent to which the land should be grazed when the sprouts are just beginning to appear, therefore, should be determined by the timber stand ultimately desired.

TABLE 5.—*Injuries to sprouts 1½ feet or less in height according to varying intensities of grazing; data grouped by seasons and height classes and according to intensity of grazing. Plots in standing timber.*

Season and height class.	Lightly grazed.			Moderately grazed.			Heavily grazed.			Total number grazed all intensities.	Per cent grazed all intensities.
	Total number.	Number grazed.	Per cent grazed.	Total number.	Number grazed.	Per cent grazed.	Total number.	Number grazed.	Per cent grazed.		
1912	98	......	......	122	5	4.09	154	16	10.38	21	5.61
1913	899	287	31.92	871	262	30.08	458	224	48.90	773	34.69
1914	783	299	38.18	1,826	737	40.36	2,150	1,462	68.00	2,498	52.48
1915	386	54	13.98	1,405	261	18.56	2,192	1,363	62.18	1,678	42.00
1916	216	30	13.90	924	248	26.80	848	88	10.30	366	18.40
Total	2,382	670	......	5,148	1,513	......	5,802	3,153	......	5,336	......
Average	......	......	28.19	......	......	29.38	......	......	54.34	......	40.02
Height class:											
Sprouts less than 1 season old	551	107	19.4	1,711	365	21.3	1,861	983	52.8	1,455	35.2
1-year-old sprouts 1 to 1.5 feet	315	66	20.9	1,103	202	18.3	1,592	820	51.5	1,088	26.0
Sprouts below 6 inches (1 season old)	625	146	23.4	991	328	33.0	854	323	37.8	797	32.1
6 inches to 1.5 feet (1 season old)	891	355	39.9	1,343	486	36.2	1,395	1,026	73.7	1,867	51.4

SUMMARY.

The effect of sheep browsing in standing aspen timber may be summarized as follows:

(1) Of the total number of sprouts examined during 1912 and 1913, inclusive, the percentage of seriously injured and killed sprouts was

FIG. 1.—CLEAR-CUT PROTECTED ASPEN AREA ON SHEEP RANGE AS IT APPEARED AFTER FENCING IN THE SPRING, 1913.

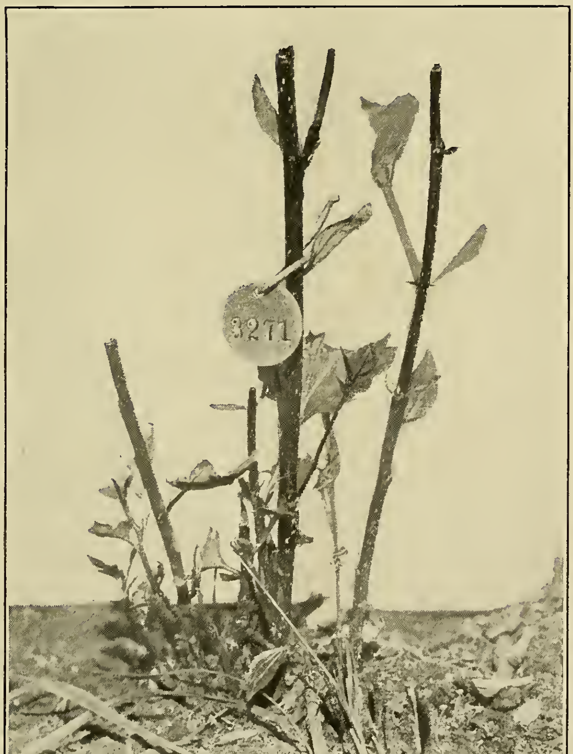

FIG. 2.—TYPICAL RESULTS FROM BROWSING BY SHEEP OF LEADERS OF ASPEN SPROUTS OF THE FIRST SEASON'S GROWTH ON HEAVILY GRAZED PLOT

Following such browsing the specimens usually die, as was the case in this instance.

FIG. 1.—TWO-YEAR-OLD SPROUTS ON HEAVILY GRAZED PLOT, THE SHOOTS OF WHICH WERE KILLED BY THE BROWSING OF THE TERMINALS DURING THE FIRST SEASON OF GROWTH.

The second set of shoots, produced from adventitious buds, were subsequently seriously browsed. The latter sprouts died at the end of the season, after which no more shoots were produced.

FIG. 2.—THREE-YEAR-OLD SPROUTS ON HEAVILY GRAZED PLOT (ON THE READER'S LEFT), SHOWING THE REPLACEMENT OF THE LEADER BY LATERAL SHOOTS SUBSEQUENTLY BROWSED. ON THE READER'S RIGHT, SERIOUS BROWSING OF LEADER AND LATERALS OF ASPEN SPROUT 40 INCHES HIGH.

The specimens were photographed in 1914. In 1915 the specimen to the left died, while the specimen to the right in 1915 and 1916 made very little growth and no terminal had at that time been produced.

considerably larger than the percentage of the remaining uninjured sprouts. In addition to the mortality and injury due to browsing, 11.7 per cent of the sprouts were killed and 6.3 per cent injured in varying degrees of seriousness by causes other than browsing.

(2) The extent of injury to and mortality of sprouts in standing timber was in direct proportion to the intensity of grazing; also the character of injury, such as the removal of the leader, for example, was notably greater on heavily grazed plots than on moderately and lightly grazed areas. In 1915, for example, an average of 4.4 per cent of the leaders were removed on lightly and moderately grazed plots, while on the heavily grazed areas 21.5 per cent of the leaders were removed.

(3) Considerable variation in the extent of injury and mortality to the reproduction occurred in different seasons, the variation in injured sprouts being over 25 per cent and in killed sprouts over 10 per cent during the five years of study. Within a single season, however, no appreciable variation in degree and number of injured sprouts was observed so long as the leafage remained intact.

EFFECT OF CATTLE BROWSING.

Plots in standing aspen timber grazed exclusively by cattle were selected early in the spring of 1915. In addition to the detailed data on character and extent of injury to aspen reproduction by cattle in 1915 and 1916, data on the extent of injury by browsing prior to the establishment of the sample plots were afforded by the older specimens under observation. Accordingly, injuries covering a great many years were recorded.

The general grazing injuries to the reproduction are summarized in Table 6. The data are grouped according to intensity of grazing, both as to total injury regardless of the height classes of the sprouts and as to injury to the different height classes. Table 6 shows that the extent of injury in 1915 and 1916 varies directly with the closeness to which the range was grazed, being least, indeed practically nominal, on lightly and moderately cropped plots and relatively heavy (17.5 per cent in 1915 and 36.1 per cent in 1916) on heavily grazed areas. While the number of browsed sprouts was fairly large on the closely grazed plots, the injuries were in no instance especially serious, nor was the extent of damage anywhere near as great as that caused by sheep. The damage done by cattle to reproduction of a given height was in no case severe. The average per cent of injury to sprouts above 1½ feet in height was approximately the same as that of sprouts of the 6-inch to 1½-foot class. Thrifty aspen reproduction of varying age and size is found throughout the aspen type in localities where cattle only have been permitted to graze moderately for a number of years. This would indicate that controlled cattle grazing, such as has been carried out in the vicinity of these plots, and the perpetuation of the aspen stand are not necessarily antagonistic.

The young, tender aspen shoots are browsed more or less by cattle, however, and the damage inflicted may increase in proportion to the density of the reproduction. Hence, where sprouts are produced in sufficient numbers to attract stock and accustom the animals to browse upon aspen, a greater per cent of damage may occur than where the stand of sprouts is sparse, as in standing timber. A maximum number of sprouts invariably follows clear-cutting, and accordingly the extent of injury by grazing to dense stands of reproduction can best be determined on clear-cut plots.

TABLE 6.—*Total number of sprouts the laterals and terminals of which were removed by cattle browsing on plots in standing timber; data grouped according to intensity of grazing and height classes.*

Season and height class.	Lightly grazed.			Moderately grazed.		
	Total number sprouts.	Number browsed.	Per cent browsed.	Total number sprouts.	Number browsed.	Per cent browsed.
1915	150			379	3	0.78
1916	166	5	3.2	311	13	4.20
Height class:						
6 inches to 1.5 feet	31			41	2	4.87
1.5 feet to 2.5 feet	99			83	2	2.41
2.5 feet to 3.5 feet	40			78	2	2.56
3.5 feet to 4.5 feet	31			52	1	1.92

Season and height class.	Heavily grazed.			All intensities of grazing.	
	Total number sprouts.	Number browsed.	Per cent browsed.	Total number sprouts.	Per cent browsed.
1915	40	7	17.50	10	1.75
1916	36	13	36.10	31	6.20
Height class:					
6 inches to 1.5 feet	6			2	2.60
1.5 feet to 2.5 feet	15	4	26.60	6	3.20
2.5 feet to 3.5 feet	7			2	
3.5 feet to 4.5 feet	4			1	1.60

INJURY TO ASPEN REPRODUCTION BY GRAZING ON CLEAR-CUT LANDS.

EFFECT OF SHEEP BROWSING.

Because of the high mortality due to natural causes the most authentic data showing the effect of grazing on the stand and the condition of the sprouts can probably be obtained by comparing the stands on similar fenced and unfenced clear-cut plots. Four plots were selected on typical aspen range and clear-cut in the fall of 1912; two of these were fenced against stock and the other two left unfenced.

The data recorded on the two sets of plots are summarized in figures 2 and 3. Figure 2 shows for each season during which the observations were made (1) the rate of sprout production on normal grazed clear-cut aspen plots, (2) the number of sprouts (a) injured and (b) killed by browsing, (3) the number uninjured, and (4) the number injured by causes other than grazing. Figure 3 shows seasonally (1) the sprouting ability of clear-cut aspen protected from grazing, (2) the number of sprouts injured (a) by barking by rodents and (b) by frost, and (3) the number killed by (a) barking by rodents and (b) by frost.

In 1913 practically the same number of sprouts per acre were produced on the protected and on the unprotected plots—namely, about 80,000 per acre. In the summer of 1914, when the sprouts were retallied, the number had increased to 105,589 per acre on the unprotected plots and to 90,480 on the protected plots. In the fall of 1914, 103,241 specimens were recorded on the unfenced plots—a slight decline over that of the previous count—while on the fenced areas the number had decreased to 58,324. From that time on there was a sharp but uniform decline on both sets of plots until in the fall of 1916 not one living sprout remained on the grazed plots (Plate III), though 2,646 vigorous sprouts per acre were recorded on the protected plots, most of which had attained a height beyond that at which sheep browse (Plate IV, fig. 1). While this number is ample for the establishment of a full aspen stand, a great many more sprouts have been found on plots established elsewhere.

The number of uninjured sprouts was notably greater on the ungrazed than on the grazed plots (Figs. 2 and 3). On the grazed plots there was a drop in the number of uninjured sprouts in the summer of 1914, due probably to slightly more intensive grazing at that time. This was followed by an increase and then from the fall of 1914 to the summer of 1916 the number of sprouts declined rather uniformly to zero. On the protected plots the number of uninjured sprouts decreased at approximately the same ratio as the total number produced. On the grazed plots there were no uninjured sprouts in the summer of 1916, but on the plots protected from grazing there remained 2,646 sprouts per acre.

The rate of mortality even on the ungrazed plots is surprisingly high. Usually a large proportion of the sprouts are killed, often within a season, by the injuries caused by bark-eating rodents, chiefly field mice, gophers, and rabbits (Plate IV, fig. 2). Besides, a very large proportion of the specimens recorded as merely injured by rodents and by frost died later from such injuries. The reproduction is often completely girdled, and not uncommonly several belts of bark an inch or more in width are removed. While the adverse factors of inclement weather and bark-eating rodents are active in the elimination of reproduction on the fenced and unfenced plots alike, such injury is insignificant compared with the injury chargeable to sheep grazing on the unfenced plots.

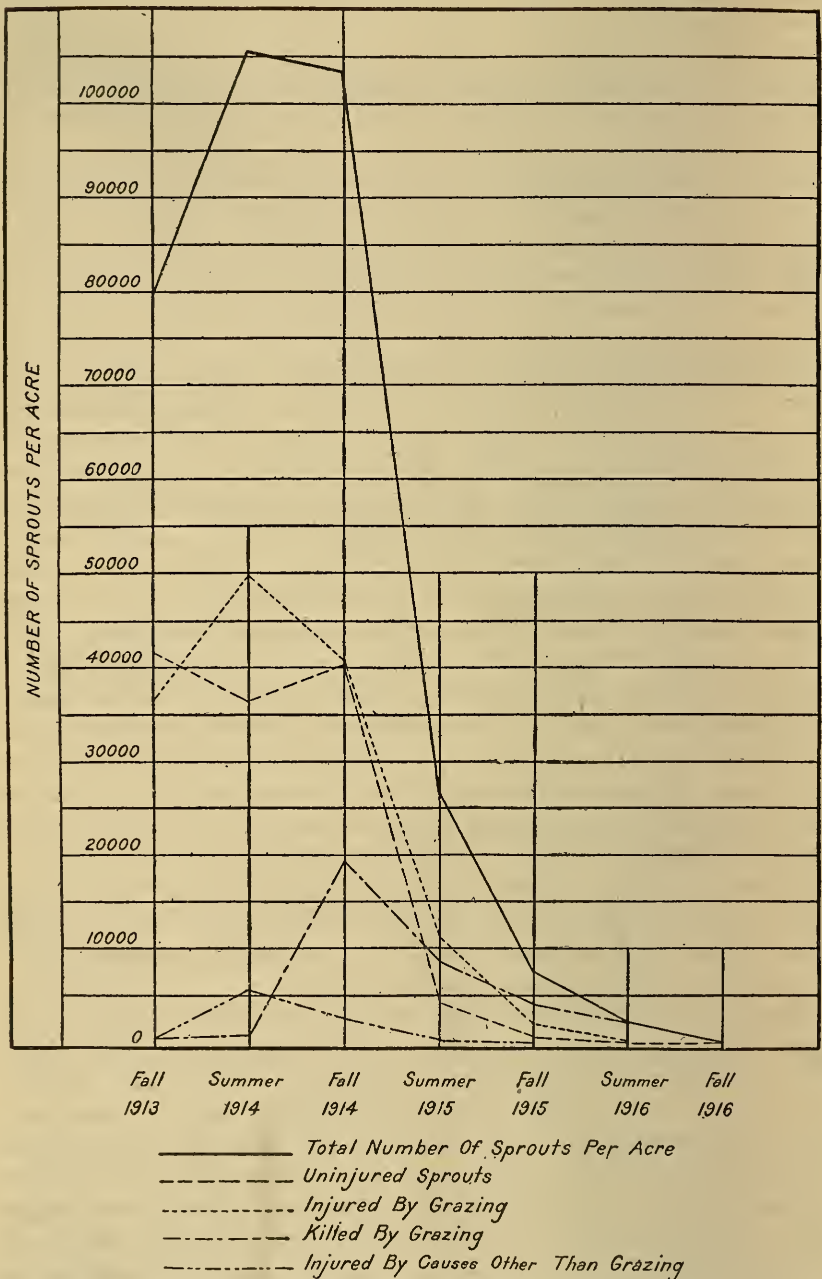

FIG. 2.—Number of sprouts per acre on clear-cut plots and their injury and mortality. (Area unfenced.)

FIG. 1.—CLEAR-CUT ASPEN PLOT NO. 1, UPON WHICH NORMAL SHEEP GRAZING HAS BEEN UNRESTRICTED.

In 1914 there were 103,241 specimens of aspen sprouts per acre; in 1916 not a specimen remained. The shrubby vegetation is mountain elder (*Sambucus microbotrys*).

FIG. 2.—CLEAR-CUT ASPEN PLOT NO. 2, UPON WHICH, LIKE PLOT 1, THE TIMBER WAS REMOVED IN THE FALL OF 1912 AND THE AREA SUBSEQUENTLY GRAZED NORMALLY BY SHEEP.

The density of the reproduction on this plot was practically the same as on plot 1 the first two seasons after the timber was removed, but in the fall of 1916 not a living specimen was to be found. A luxuriant stand of the palatable mountain brome grass (*Bromus marginatus seminudus*), has occupied the soil since clear cutting. The luxuriance of the brome-grass cover is evidence of the fact that the aspen reproduction was not destroyed as a result of overgrazing.

FIG. 1.—FENCED PLOT, COMPLEMENT TO UNFENCED PLOT SHOWN IN PLATE III, FIG. 1.

At the end of the third season following cutting there remained 3,800 vigorous sprouts per acre of an average height of approximately 4 feet. This number three years after cutting is more than ample for the establishment of a full aspen stand.

FIG. 2.—THREE-YEAR-OLD ASPEN SPROUTS ON CLEAR-CUT FENCED PLOT KILLED BY BARK-EATING RODENTS.

Note extent of removal of bark at various places along main stem and at base of large lateral branch.

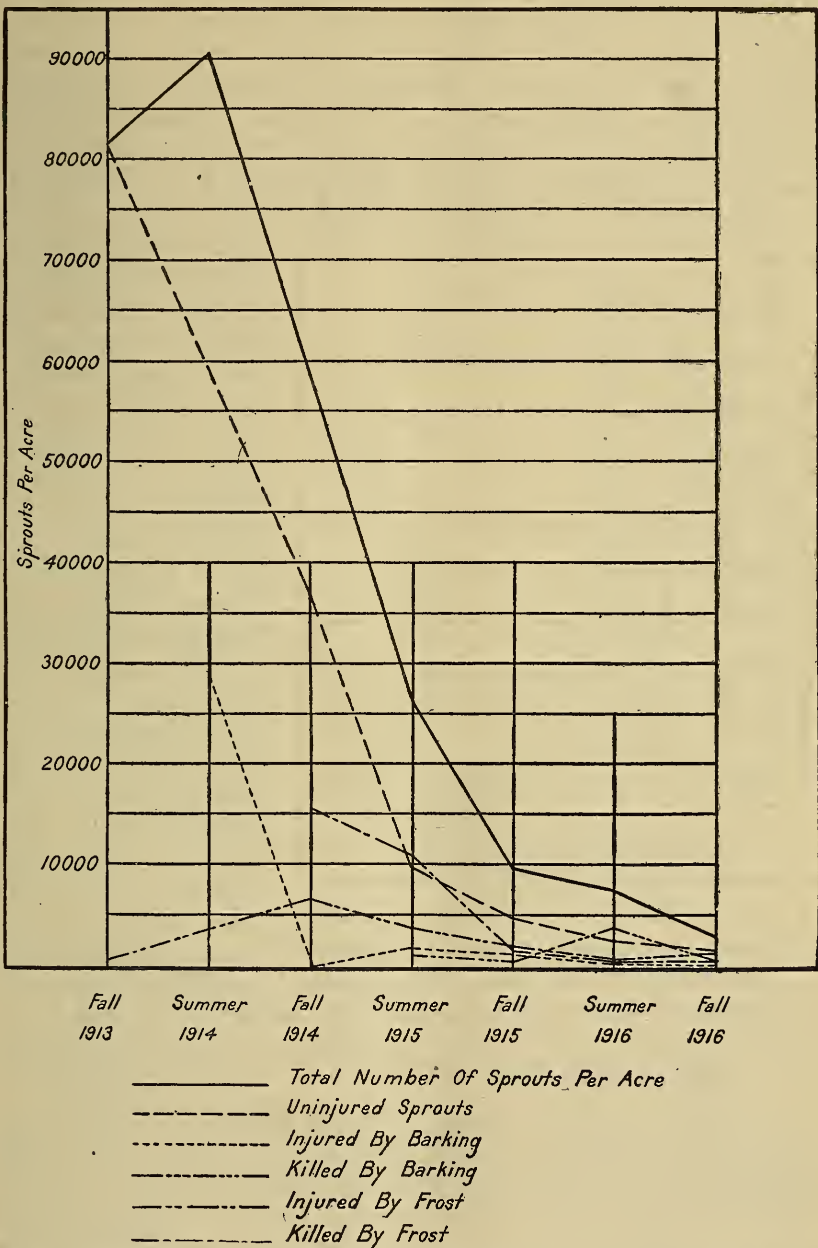

FIG. 3.—Number of sprouts per acre on clear-cut plots and their injury and mortality due to causes other than grazing. (Area fenced.)

On the clear-cut lands protected from grazing and where the mortality of the reproduction was not abnormally heavy, no new sprouts appeared after two years following clear-cutting (fig 4). On the clear-cut unprotected plots, on the other hand, where a large proportion of the sprouts were destroyed by browsing, considerable reproduction was produced not only in the first two seasons but in the third season following cutting, though not subsequently. The removal of practically the entire aerial portion of the sprouts by browsing prevents the transfer and utilization of the large stores of plant food deposited in the elaborate root system of the parent plant, and this nutritive material apparently tends to stimulate the production of sprouts in the third season following the removal of the timber. The majority of these third-year sprouts were produced between 2 and 5 weeks later than those sent up during the first two seasons after cutting, and instead of individual specimens appearing more or less uniformly over the area, as in the case of sprouts produced during the first two years, they appeared in bunches of from about 3 to 15 specimens.

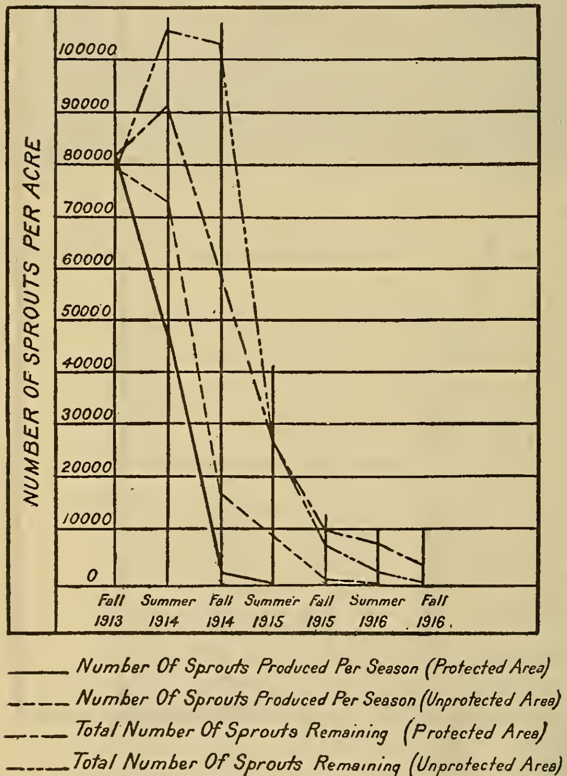

FIG. 4.—Number of sprouts produced on clear-cut aspen plots computed on acreage basis, 1913 to 1916 inclusive.

The sprouts produced during the third season distinctly lacked vigor and were, for the most part, killed by frost or other unfavorable climatic factors. Only a very small percentage, even when not injured by inclement weather, possessed sufficient vitality to become permanently established. Thus only a sparse, uneven, and weak aspen stand may be expected from sprouts originating on grazed lands during the third season after cutting, even though grazing is discontinued the second year after the timber has been removed.

EFFECT OF CATTLE BROWSING.

Injury to reproduction on clear-cut aspen plots chargeable to browsing, trampling, and rubbing by cattle was observed during the seasons of 1915 and 1916 in the same detail as in the case of the plots located on the sheep allotments. Early in the spring of 1915 two representative areas located at an elevation of approximately 8,800 feet were cleared of timber, and sample plots and quadrats were established, by means of which the rate of sprouting and the exact character of damage caused exclusively by cattle were noted. The clear-cut areas were comparable in every way, except that one was subject to normal grazing while the other was fenced against stock.

In recording the damage to the reproduction, account was taken of the injury and mortality due both to the presence of cattle and to causes other than grazing. The data were grouped according to grazing intensity. The results are summarized in Table 7, and for purposes of ready comparison the data recorded in 1915, which are practically the same as for 1916, are shown graphically in figure 5.

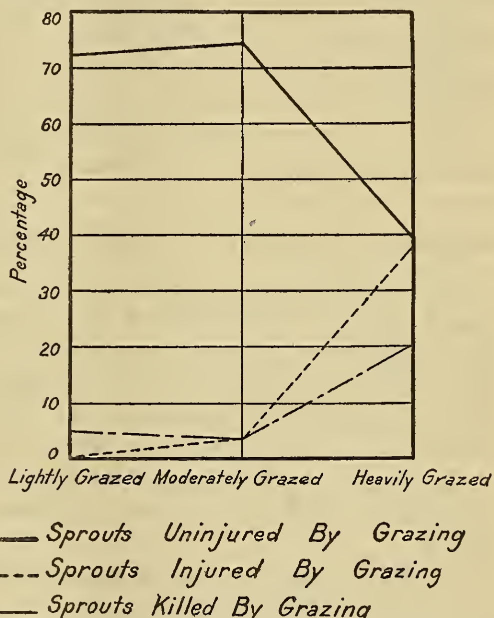

FIG. 5.—Relation of cattle grazing to number of uninjured and killed sprouts, season 1915.

In 1915 the number of uninjured sprouts was highest on the lightly and moderately grazed plots (72.7 and 74.4 per cent, respectively) and notably lower on the heavily grazed areas (40 per cent). In 1916 the relation was similar. There was practically no difference in the per cent of injured and killed sprouts on the lightly grazed and on the moderately grazed plots, while on those heavily grazed there was an appreciable increase in the percentage of both injured and killed sprouts.

A considerable proportion of the sprouts on these plots, as in the case of sprouts on plots previously reported on sheep range, were injured or killed by causes other than grazing. Eight per cent of the sprouts died and 5.9 per cent were injured by causes other than grazing, while only 2.6 per cent were killed and 5.7 per cent injured by grazing.

TABLE 7.—*Summary of aspen sprouts killed and injured by cattle grazing on clear-cut plots.*

Grazing intensity and year of examination.	Total number sprouts.	Uninjured sprouts.		Killed by grazing.		Injured by grazing.		Total number dead sprouts not killed by grazing.		Injury not due to grazing.	
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
Lightly grazed:											
1915	150	109	72.7	7	4.6	......	......	20	13.3	14	9.4
1916	166	140	84.4	......	......	6	3.6	4	2.4	16	9.6
Moderately grazed:											
1915	379	282	74.4	12	3.2	15	3.9	46	12.2	24	6.3
1916	311	274	88.1	......	......	14	4.5	13	4.2	10	3.2
Heavily grazed:											
1915	40	16	40.0	8	20.0	15	37.5	1	2.5	......	......
1916	36	21	58.3	1	2.8	12	33.3	2	5.6	......	......
Total	1,082	842	......	28	......	62	......	86	......	64	......
Mean of all grazing intensities	......	......	77.8	......	2.6	......	5.7	......	8.0	......	5.9

COMPARATIVE INJURY TO ASPEN SPROUTS BY SHEEP AND CATTLE.

The damage to reproduction on sheep range, on the plots established both in standing timber and on clear-cut lands, was considerably different in character and extent from that on cattle range. This difference in the degree of damage was evident in all localities where the study was conducted, and especially where plots had been grazed to practically the same degree of intensity.

On plots in standing timber the comparative damage by sheep and by cattle may be summarized as follows (data given in Tables 1, 2, and 6):

(1) The average per cent of reproduction injured by sheep grazing from 1912 to 1916, inclusive, was 27.3, and from 1915 to 1916, inclusive, 19.9. During the latter period the average per cent of injury on cattle range, where the forage had been cropped to practically the same extent, was but 3.97.

(2.) The average per cent of reproduction killed on the plots scattered over the sheep allotments from 1912 to 1916, inclusive, was 17.1, and during 1915 and 1916, 24.8. During 1915 and 1916 less than 0.5 per cent of the reproduction on the plots grazed by cattle was killed by browsing.

On the clear-cut plots the damage to reproduction by sheep as compared with that by cattle is proportionately much more serious than on plots in standing timber. The seriousness of normal sheep grazing on clear-cut aspen lands may be summarized in the statement that in the third year following the removal of the standing timber it may be expected that no sprouts whatsoever will be found on the lands. If any sprouts remain, they are usually so mutilated as either to die after a season or two or so deformed as to produce timber of questionable value. Reproduction on clear-cut lands located on cattle range, on the other hand, while damaged more or less by browsing, appears to occur in sufficient density over the plots under observation to insure a maximum stand of first quality mature timber.

Practically without exception there are no young aspen sprouts on range grazed annually by sheep during the period that the sprouts are being produced. The few sprouts found are almost invariably lacking in vigor and are often more or less seriously diseased. On the range used exclusively by cattle it is the exception not to find at least a partial stand of sprouts varying in age, most of which are vigorous and healthy. Cattle naturally prefer the leafage of herbs, especially grasses, to shrubs and other woody plants, and while they browse aspen reproduction, the damage they do seldom endangers the permanent establishment of the stand unless the range is stocked with cattle beyond its natural carrying capacity.

An analysis of the character of the injuries showed that the proportion of terminal and lateral shoots browsed was practically the same on cattle and on sheep allotments. It was quite evident, however, that the cattle browsed the foliage more and the woody tissue less than sheep; consequently the complete removal of terminal and lateral shoots was less commonly observed on the cattle ranges than on the sheep ranges. The difference would appear to account for the more rapid and complete recovery of injured sprouts on cattle allotments.

Practically no damage is caused to aspen reproduction by rubbing and trampling by cattle. Rubbing is generally confined to young conifer saplings characteristically scattered through the aspen type, the needles and bark of which afford the friction desired, or to aspen specimens of about pole size. Young aspen sprouts are so limber that stock seldom break the branches or otherwise distort them by rubbing. Sheep, of course, not being addicted to the rubbing habit like cattle, cause virtually no damage in this way. Trampling by either class of stock causes very slight mortality or permanent injury. On sheep ranges the young sprouts are either killed or seriously damaged long before the formation of prominent trails which might otherwise result in trampling out the reproduction. On cattle allotments there is occasionally a small amount of damage to young sprouts by trampling, portions of the bark being removed along the main stem or the specimen being broken; but such injury is negligible on lands stocked according to their actual carrying capacity and on which the animals are properly distributed. Where cattle have a tendency to congregate, however, near watering and salting places, for instance, both browsing and trampling have a telling effect on the density and vigor of the reproduction.

HEIGHT AT WHICH REPRODUCTION IS EXEMPT FROM GRAZING INJURIES.

The factor which chiefly determines the time of exemption of the reproduction from destructive browsing is the height of the sprouts. Observations have shown clearly that as soon as the terminal shoots and some of the lateral branches have attained a growth beyond which stock generally browse, the reproduction is no longer in danger of serious damage. Since sheep are particularly destructive to young aspen reproduction, detailed observations as to the height at which they browse were recorded both on the open range and on controlled plots. The height to which cattle browse was observed under range conditions only.

HEIGHT TO WHICH SHEEP BROWSE.

The height to which sheep browse depends, of course, upon the palatability of the plants that grow within the reach of the animals, as well as upon the particular breed of sheep. Sheep relish woody plants, and they browse the aspen reproduction at as great a height as other highly palatable species. The sheep under observation consisted of about equal numbers of ewes and lambs of the Rambouillet and merino breeds, chiefly the former. The animals of both breeds were of about average size.

In observing the height of grazing on the range it was necessary to adhere almost entirely to reproduction in standing timber, as relatively little aspen timber on the sheep allotments has as yet been clear-cut or heavily thinned. For this reason the height of the sprouts, the stand of which was usually quite sparse and scattered, was uneven and often considerably below the maximum height at which sheep may browse. Accordingly, to determine the height of aspen browsed with unquestionable accuracy, and to secure a basis for future management of grazing in the aspen type, the observations on the range were supplemented by a carefully planned experiment on a clear-cut fenced inclosure where the sprouts varied in height from 20 to 70 inches, the majority having a height of about 45 inches.

The plot was one-fourth of an acre in area. Two 5-year old ewes and three lambs 3 months old were grazed on the plot as long as the feed, consisting of a luxuriant undergrowth of grasses, pea vines, a variety of weeds, and some shrubby growth, was sufficient to sustain the animals at their original weight. Accordingly, the plot was grazed much more closely than would be possible over the range generally where the lands are handled on the basis of a sustained annual yield. The plot in question was clear-cut late in the autumn of 1913 and the sheep were placed on it in August, 1916, so that the major portion of the reproduction was about 3 years of age. At the time the sheep were turned on there was a stand of 30,056 sprouts per acre (Plate V, fig. 1). The condition of the sprouts before and after grazing was noted on a transect 2½ feet wide and 40 feet long running across the plot. The results are given in Table 8.

TABLE 8.—*Character and extent of sheep browsing on clear-cut aspen plot and height at which injuries were inflicted.*

Sprout No.	Height of sprout.	Height browsed.	Condition of sprout.[1]	Character of injuries.
	Inches.	*Inches.*		
1	53.0	43.0	V	Laterals grazed.
2	44.5	39.0	V	Do.
3	47.5	41.0	V	Do.
4	38.0	38.0	V	Laterals and terminal grazed.
5	39.0	35.0	V	Laterals grazed.
6	36.0	32.0	V	Do.
7	42.0	35.0	V	Do.
8	55.0	36.0	V	Do.
9	47.0	36.0	V	Do.
10	33.0	26.0	W	Do.
11	29.0	29.0	V	Laterals and terminal grazed.
12	37.0	37.0	V	Do.
13	59.0	40.0	V	Laterals grazed.
14	49.5	37.0	V	Do.
15	31.0	31.0	V	Laterals and terminal grazed.
16	32.0	32.0	W	Do.
17	40.0	40.0	V	Do.
18	48.0	36.0	V	Laterals grazed.
19	61.0	36.0	V	Do.
20	55.5	40.0	V	Do.
21	43.5	43.5	V	Laterals and terminal grazed.
22	40.5	38.0	V	Laterals grazed.
23	54.0	40.0	V	Do.
24	50.0	40.0	V	Do.
25	55.0	38.0	V	Do.
26	36.0	36.0	V	Laterals and terminal grazed.
27	32.0	32.0	V	Do.
28	50.0	38.0	V	Laterals grazed.
29	51.0	41.0	V	Do.
30	31.0	31.0	W	Laterals and terminal grazed.
31	39.0	33.0	V	Laterals grazed.
32	48.0	42.0	V	Do.
33	21.0	21.0	W	Laterals and terminal grazed.
34	32.0	32.0	V	Do.
35	49.0	38.0	V	Laterals grazed.
36	39.0	39.0	V	Laterals and terminal grazed.
37	69.0	40.0	V	Laterals grazed.
38	40.0	40.0	V	Laterals and terminal grazed.
39	29.0	29.0	W	Do.
40	59.5	45.0	V	Laterals grazed.
41	71.0	40.0	V	Do.
42	72.0	41.0	V	Do.
43	43.0	43.0	W	Laterals and terminal grazed.
44	39.5	37.0	V	Laterals grazed.
45	45.0	39.0	V	Do.
46	62.5	39.0	V	Do.
47	43.0	43.0	V	Laterals and terminal grazed.
48	69.5	38.0	V	Laterals grazed.
49	45.0	45.0	V	Laterals and terminal grazed.
50	51.5	40.0	V	Laterals grazed.
51	58.0	41.0	V	Do.
52	54.0	44.0	V	Do.
53	47.0	47.0	W	Laterals and terminal grazed.
54	69.0	44.0	V	Laterals grazed.
55	58.0	45.0	V	Do.
56	70.0	45.0	V	Do.
57	73.0	43.0	V	Do.
58	61.5	36.0	V	Do.
59	70.0	40.0	V	Do.
60	54.5	42.0	V	Do.
61	66.0	40.0	V	Do.
62	39.0	39.0	W	Laterals and terminal grazed.
63	61.0	40.0	V	Laterals grazed.
64	55.0	38.0	V	Do.
65	71.0	42.0	V	Do.
66	71.0	45.0	V	Do.
67	57.0	32.0	V	Do.
68	40.5	34.0	V	Do.
69	52.0	35.0	V	Do.

[1] V indicates that the sprout was in vigorous and normal condition after grazing. W signifies that it was weak and likely subsequently to die from the injuries caused by browsing.

Table 8 shows that while the plot was grazed much more closely than would be warranted on the basis of sustained forage yield, only 8 of the 69 sprouts on the transect (11.6 per cent) were seriously grazed and thus likely subsequently either to die or become very deformed. All the other sprouts were in vigorous condition; and though they were browsed slightly, the damage was not such as to manifest itself in the future development of the stand. In most instances the browsing was confined to the lateral branches, only 20 of the 69 sprouts (29 per cent) having both the terminals and the laterals removed. Only 3,483 of the 30,056 sprouts to the acre were seriously weakened by browsing, leaving 26,571 vigorous specimens for the establishment of the stand, a number exceeding by more than 24,000 the quantity necessary to restock the land fully.

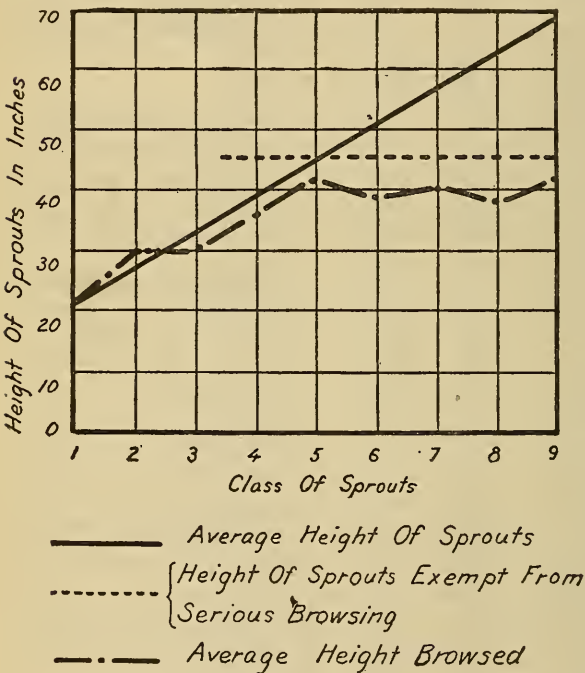

FIG. 6.—Heights at which sprouts are browsed.

The most significant fact brought out by the experiment is that the maximum height of sheep browsing was 47 inches, and this occurred only in the case of a single specimen. To show more clearly than in Table 8 the average height at which the browsing occurred, the sprouts were grouped into 6-inch height classes and the average height of the browsing in the case of each height class recorded. The figures are given in Table 9 and the results are shown graphically in figure 6.

TABLE 9.—*Summary of heights at which aspen sprouts are browsed by sheep.*

Height class No.	Number of specimens in each height class.	Height class.		Average height grazed.
		Average.	Mean.	
		Inches.	*Inches.*	*Inches.*
1	1	18 to 23	21	21.0
2	2	24 to 29	27	29.0
3	6	30 to 35	33	30.7
4	13	36 to 41	39	36.8
5	10	42 to 47	45	41.1
6	10	48 to 53	51	39.0
7	12	54 to 59	57	40.1
8	5	60 to 65	63	38.2
9	10	66 to 71	69	41.8

The height of browsing increases gradually with the increase in the height classes of the reproduction up to the fifth class; i. e., from 21 to 41.1 inches. From this point on up to the ninth class the height of the browsing varies slightly above or below the 40-inch mark. In the ninth class occurs the maximum average height of 41.8 inches. The average height at which the 69 grazed sprouts in the transect were grazed was 38.1. This is about the height of the top of the heads of mature Rambouillet and merino sheep.

Sprouts the terminal shoots of which have attained a height of 40 inches or so are apt to suffer only slight permanent injury, and extensive observations on the range and on the various check plots have shown that reproduction having an average height of 45 inches is practically exempt from serious injury. Hence lands supporting reproduction averaging 45 inches in height may be grazed with practically no injury to the terminal shoots. Moderate browsing of some of the lateral branches will occur, of course, as long as they are easily within the reach of sheep, but the effect of such browsing is insignificant so far as concerns the development and health of the specimen.

HEIGHT TO WHICH CATTLE BROWSE.

It has been pointed out that reproduction only a few inches or so in height is subject to about the same degree of browsing by cattle as is reproduction of greater heights. Thus, contrary to what might be expected, sprouts two or three feet high which by virtue of their greater conspicuousness might be presumed to afford more convenient browsing than the shorter specimens are nevertheless damaged as little as any of their younger associates.

Considerable variation is observed in the height of the browsing by cattle. Isolated instances have been recorded of the removal of leafage to a height of about 70 inches, but browsing at such a height is exceptional and of little economic significance. Damage of greater severity occurs between heights of 55 and 60 inches, the latter figure, however, being about the minimum at which twigs and stems are eaten. Thus in localities where cattle are apt to drift and linger and where it is desired to reforest the lands fully the reproduction should be permitted to attain a growth of not less than 5 feet prior to heavy stocking. Obviously, then, lands which are to be reforested should not be used as salting grounds until a sufficient portion of the reproduction has attained a height beyond which destructive browsing is likely to occur.

RATE OF GROWTH OF ASPEN REPRODUCTION.

In the management of grazing on cut-over lands it is necessary to know, in order to make the most judicious use of the knowledge of the height which aspen reproduction must attain to be exempt from serious damage by sheep and cattle, (1) the rate of growth of the reproduction and the age at which the major portion of the stand is exempt from serious browsing, and (2) the density of the stand that may be expected, and accordingly the extent of thinning, if any,

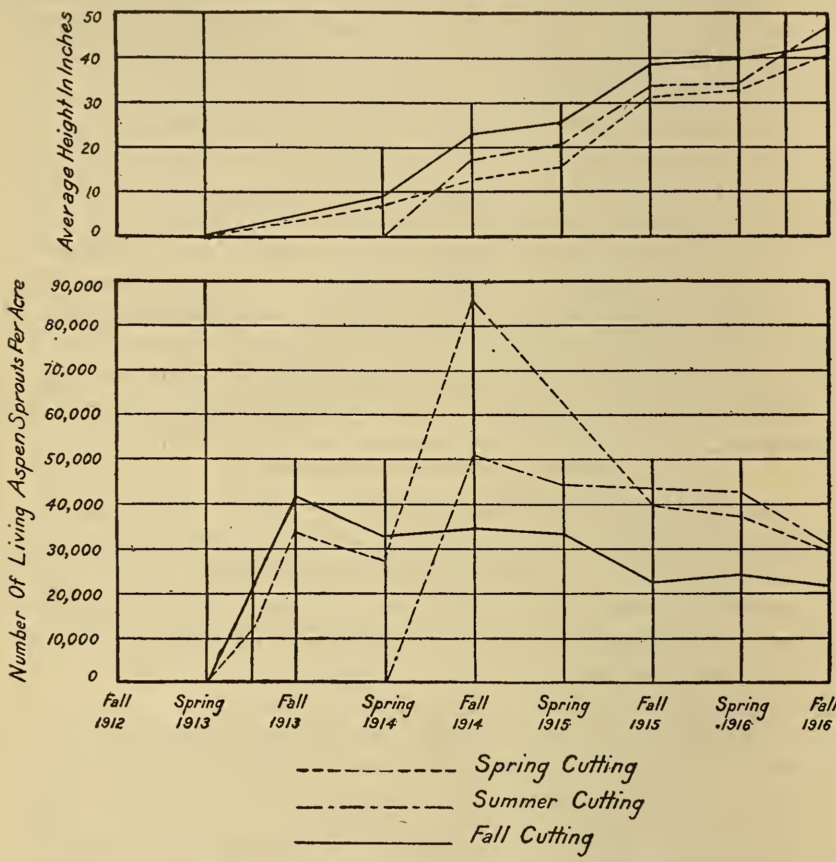

FIG. 7.—Number of sprouts and average height growth according to season of cutting.

that may be permitted by browsing and that will leave enough reproduction to secure the number of trees which the lands will well support.

To determine the sprouting capacity of aspen and the corresponding vigor and rate of growth of the resulting sprouts when the lands are clear-cut in different seasons, the timber was removed on three plots of even-aged aspen, each one-half acre in size. One of the plots was clear-cut in the fall of 1912, another early in the spring of 1913, and the third in midsummer 1913. In Table 10 is summarized the number of living sprouts per acre on these plots and the height growth per season according to the time of cutting. To facilitate comparison of results the data are assembled graphically in figure 7.

TABLE 10.—*Sprouting capacity and height growth of aspen reproduction on clear-cut plots.*

Date of examination.	Fall cutting, 1912.		Spring cutting, 1913.		Summer cutting, 1913.	
	Number of living sprouts per acre.	Average height.	Number of living sprouts per acre.	Average height.	Number of living sprouts per acre.	Average height.
		Inches.		*Inches.*		*Inches.*
Summer, 1913			11,600			
Fall, 1913	41,700		33,800			
Spring, 1914	32,670	8.6	27,590	7.3		
Fall, 1914	34,700	23.4	85,520	12.5	50,960	16.9
Spring, 1915	32,810	25.5	62,580	15.5	44,140	20.3
Fall, 1915	22,210	39.2	39,920	31.4	43,850	34.0
Spring, 1916	24,100	39.8	37,609	32.5	42,730	34.1
Fall, 1916	21,920	43.1	29,910	41.2	31,070	46.6

Table 10 shows that the production of sprouts is heavy on all areas, regardless of season of cutting, and that in general the maximum number of sprouts is in evidence within a season following the removal of the timber. Considering the number of mature, well-developed trees that may occupy the ground, more than enough sprouts are produced on the respective plots regardless of season of timber removal. The most vigorous sprouting occurred on the plot the timber of which was removed in the spring, and the least vigorous on the autumn-cut plot. On the spring-cut plot, however, the death rate of sprouts was greatest. The rate of growth was relatively uniform and approximately the same on each plot, and the annual increment averaged about 15 inches, the height growth being practically the same from season to season.

From the above facts it may be concluded that (*a*) regardless of season of cutting a sufficient number of aspen sprouts is produced on clear-cut lands to restock the lands fully, provided grazing is properly controlled; and that (*b*) in general the reproduction will have attained sufficient height by the end of the third year of growth to be exempt from destructive browsing by sheep, and by the end of the fourth, or more certainly the fifth year, to be out of danger from cattle.

SILVICULTURAL MANAGEMENT OF ASPEN.

METHODS OF CUTTING.

Experimental evidence gathered from variously treated plots points to the fact that if the lands are to be devoted permanently to the production of aspen, clear-cutting or repeated heavy thinnings are the best means by which to secure vigorous sprouting and an evenly distributed stand.

As is shown by the sparse stand of sprouts on the plots established in the standing timber, aspen is practically unable to reproduce under its own shade. Light thinnings are of some value, but a very large percentage of the sprouts soon succumb because of insufficient sunlight. The surviving sprouts are forced into intensive competition with various shade-enduring, aggressive, shrubby, and herbaceous species. This, coupled with inadequate light, renders the sprouts weak and not uncommonly diseased. If the slender specimens are not killed outright by fungous attacks, sooner or later they fall easy victims to the wind.

The average stand of prop timber, the diameter breast-high of which does not exceed 10 inches, consists of about 480 trees per acre. To insure a stand of this number of trees at the average rate of mortality of the sprouts, a stand of 2,500 specimens per acre the third year after cutting is sufficient, even though the lands are moderately grazed by cattle or sheep after the terminal shoots are no longer subject to browsing. In practically any type of aspen properly protected from stock, the stand following clear-cutting will generally be 2,500 specimens per acre. Thus in the case of the plot pictured in figure 2 of Plate V, representing the sprouting capacity following the clear-cutting of an 80-year old stand, there are more than 30,000 specimens at the end of the third year. The sprouting appears to be quite as vigorous when younger stands are clear-cut.

METHODS OF BRUSH DISPOSAL.

Various methods of disposing of the brush are in practice, some of which tend to expose the sprouts unduly and others to protect them. Piling and burning the brush is the most popular; but this method, owing to the complete opening up of the lands, is responsible for highly destructive browsing, especially by sheep, the result being that the stand is materially thinned and correspondingly mutilated. The method appears to endanger the establishment of the stand approximately in proportion to the number of spaces burned.

Experiments have been made in scattering the brush over the cutting without lopping the nonmerchantable parts. The method which has given the best results, and which at the same time lends itself to general field practice, is that of scattering the unlopped ones about the stumps, the butts of the discarded portions being placed next to the stumps in such a manner as to have the branches extend out in all directions from the stump. Since the major portion of the reproduction originates from superficial roots near the parent plant, the tops are located where they will afford the greatest possible protection to the new sprouts.

This light screen of unlopped branches, arranged as described, is surprisingly effective against repeated visitations by sheep during the first three seasons after the cutting, which is the most critical period. While, to be sure. there is usually not a sufficient supply of

FIG. 1.—VIEW SHOWING STAND AND HEIGHT OF ASPEN SPROUTS ON CLEAR-CUT PLOT ADJACENT TO AREA FENCED OFF AND GRAZED BY SHEEP.

Photographed three years after clear cutting and one month after the completion of the grazing experiment on control plot.

FIG. 2.—LUXURIANT STAND OF ASPEN REPRODUCTION AS IT APPEARS ON FENCED PLOT THREE YEARS AFTER CLEAR CUTTING.

Over 30,000 specimens, approximately 75 per cent of the terminal shoots of which are beyond the height of sheep browsing, are growing on the area. At this stage of growth there is very little danger of sheep thinning the stand beyond the maximum timber-carrying capacity of the lands. The removal of part of such a luxuriant stand by browsing would be a distinct benefit. The understory of herbaceous vegetation is luxuriant and consists of the choicest of forage species.

tops to cover effectively the entire ground surface and thus prevent the entrance of stock, the method permits the establishment of a fairly good stand of vigorous, well-formed trees.

Observations covering a five-year period have made it evident that the tops of aspen scattered over a clear-cutting in such a manner as to protect the sprouts are well along in decay in the third year after scattering; and usually by the end of the fifth year only the central axis of the top remains, this portion often being pretty thoroughly decayed. The absence of turpentine and other volatile and highly inflammable oils, coupled with the relatively high precipitation in the aspen type and the tendency of the species to absorb and retain a large percentage of moisture when lying on the ground, makes the fire risk due to the scattering of the brush practically negligible.

Another means of protecting the sprouts from browsing is to pile the tops in windrows, as it were, thereby fencing out the stock during the period required for partial decay of the nonmerchantable parts This method, however, is not particularly applicable to field operations, and instead of fostering the sprouts by protecting them from frost, the sun's excessive heat, evaporation, and other adverse factors, exposes the reproduction to the elements in much the same way as when the brush is piled and burned.

SUMMARY.

(1) Aspen, a tree of high commercial value on many National Forests in the West and on some of the farm woodlots and lands adjacent thereto in northeastern United States, is often reproduced with difficulty where the lands are made to serve the double purpose of timber and meat production.

(2) The leafage, young twigs, and branches of the reproduction are browsed with varying degrees of relish by both cattle and sheep. Over 90 per cent of the damage inflicted by stock is chargeable to browsing, the injury due to trampling, rubbing, and similar causes being negligible.

(3) Sheep are responsible for severe damage to the reproduction, both as it occurs in standing timber and on clear cuttings, regardless of the variety and supply of choice forage. Cattle cause some damage, but the extent of injury is usually slight, except where the lands are overgrazed or where the animals are inclined to congregate for more or less lengthy periods.

(4) The injury and mortality chargeable to the presence of live stock is roughly proportional to the closeness to which the lands are grazed. Observations covering a 5-year period in standing timber on sheep range showed that 27.2 per cent of the reproduction was either injured or killed on lightly grazed plots, 31.8 per cent on moderately grazed areas, and 65 per cent on heavily grazed plots. A

large proportion of the nonbrowsed sprouts are killed by causes other than grazing. In standing timber on cattle range also the injury varied according to grazing intensity, but was less than on the sheep range. During 1915 and 1916 the average percentage of injured and killed sprouts by cattle browsing was 1.6, 2.4, and 26.8 on lightly, moderately, and heavily grazed plots, respectively.

(5) On clear-cut lands, where the reproduction is conspicuous and the stand even, the annual mortality due to sheep grazing is exceedingly heavy. As a rule three years of successive sheep grazing on such lands results in the destruction of the entire stand. Some injury is also caused by cattle on clear-cut areas, but unless the range is stocked with cattle beyond its normal carrying capacity there is little danger of the reproduction being destroyed beyond the requirements necessary for the establishment of a full commercial stand.

(6) Only slight difference is recorded in extent and character of browsing either by sheep or by cattle on different height classes of reproduction, so long as the total height growth of the sprouts has not passed the limit at which stock find the food accessible.

(7) A comparison of the character and intensity of browsing shows that a notably greater proportion of the woody stems is consumed by sheep than by cattle. Even in the autumn after the leaves have dropped sheep devour a considerable quantity of the stems of a single season's growth regardless of the presence of an abundance of choice forage. In the case of cattle, however, the naked stems are practically untouched.

(8) Aspen sprouts are not necessarily permanently injured, nor will the mature tree be lacking in form or symmetry as a result of the removal once or twice of the terminal shoot. Nearly any one of the lateral branches which grow near the terminal shoot appears to be a potential terminal and may readily assume the function of the terminal itself. The destroyed leader is very commonly and promptly replaced by shoots originating from adventitious buds near the terminal. On the other hand, the removal of both the lateral branches and the terminal shoot to such an extent as to interfere appreciably with photosynthesis and the nutrition of the specimen readily weakens and decreases its subsequent rate of growth materially. If the normal leaf surface is not readily replaced and then maintained, death is the inevitable result.

(9) On lands protected from grazing aspen sprouts are produced only during the first two seasons after cutting. On grazed lands a considerable number of sprouts are sent up for three successive seasons following the removal of the timber. The third year's reproduction, however, appears from two to five weeks later than that produced in the two previous seasons and is, for the most part,

eliminated shortly after its appearance by adverse climatic factors, chiefly frost.

(10) A surprisingly large proportion of the reproduction produced even on the most favorable sites is killed during the first three years of its growth by causes other than grazing. Frost and bark-eating mammals, notably gophers, field mice, and rabbits, are mainly responsible for such mortality. Much of the damage caused by gophers and mice is done under the snow during winter or early spring.

(11) The factor that chiefly determines the time of exemption of the reproduction from destruction by sheep and cattle is the height of the sprout. The average maximum height at which sheep browse is approximately 42 inches. Sprouts averaging 45 inches in height are found to be exempt from destructive browsing by sheep. In the case of cattle there is some damage to sprouts between 55 and 60 inches in height, but seldom to those of any greater height. Reproduction averaging 5 feet in height, therefore, is practically free from damage by cattle browsing.

(12) The annual rate of height increment of the aspen reproduction averages about 15 inches. Hence sprouts 3 years of age are exempt from serious injury by sheep, and those from 4 to 5 years of age are free from serious injury by cattle.

(13) Aspen is practically unable to reproduce under its own shade, and the best means of obtaining vigorous and dense reproduction, and at the same time of harvesting the timber economically, is to clear-cut the lands or to thin the stand heavily.

(14) In the logging operations various methods are used in disposing of the branches and tops, the most common practice being to pile and burn them. This method of brush disposal is not conducive to the best results on typical aspen lands, as it exposes the reproduction unduly both to grazing and to unfavorable climatic conditions. Protection from live stock and from frost, excessive insolation, evaporation, and other adverse factors is obtained by arranging the unlopped tops about the stumps so as to protect the on-coming sprouts. In three or four years, when the reproduction is practically exempt from serious browsing, the brush is for the most part decayed and out of the way. Furthermore, such a disposition of the brush does not make the danger from fire any greater.

RECOMMENDATIONS.

From the results given in the preceding pages certain recommendations may be made for managing grazing in the aspen type so as to secure the highest possible economic use of the lands, both in the way of timber output and meat production. If properly handled, live stock will not prove antagonistic to the establishment of the reproduction, the understory of palatable forage will not be wasted, and by the consumption of the herbage the fire risk to the timber may be greatly minimized.

Being unable to reproduce in its own shade, aspen must be well opened up either by heavy thinnings or by clear-cutting, preferably the latter, if the lands are to be fully restocked.

When the logging is done on sheep range, or on a combination sheep and cattle range, the forthcoming reproduction will be destroyed almost to the last sprout if the areas are even moderately grazed by sheep during the first three years following the cutting. To avoid destruction of the young aspen cover, then, only three courses are open: (1) Entire exclusion of grazing for three successive seasons following logging, (2) exceedingly light grazing by sheep, and (3) moderate grazing by cattle.

Obviously, the first of these possibilities does not appeal either to the timberman or the stockman. The entire exclusion of grazing animals means increased fire risk and additional fire patrol, the cost of which must be met by the timberman. For the stockman whose farm operations generally, including to a large extent the marketing of the crops produced, are dependent upon the grazing afforded in the aspen type, entire exclusion of stock may spell ruin.

The second possibility, very light grazing by sheep, would upon first thought appear to meet the requirements, and guarantee establishment of the reproduction. But the sheepman who will graze his sheep *very lightly over the choicest of forage*, such as invariably becomes established on clear-cut or heavily thinned aspen lands, has not yet been discovered. Naturally the sheepman's interests lie in the production of the maximum mutton and wool consistent with sustained forage yield; he has little interest in the production of timber. Since the standards of grazing intensity vary with the individual, what may be declared as very-light cropping by the average stockman might be classed as moderately heavy by the grazing expert or the silviculturist. Furthermore, the intensity of the grazing, at least so far as the stockman is concerned, would, of course, be judged by the extent of cropping of the herbaceous cover rather than by the seriousness of the browsing of the aspen reproduction, whereas, owing to the tendency of sheep to browse rather than graze, the aspen would probably be badly damaged before much of the herbage would be consumed. Accordingly only the very lightest grazing, coupled with the most expert handling of the flocks during the first three seasons, could be expected adequately to protect the reproduction, and exceedingly few herders would be qualified to assume such responsible management.

This brings us to the third course open to avoid the destruction of the young aspen cover; viz, moderate grazing by cattle. The aspen type occupies lands of moderate elevation usually characterized by gentle topography, and the forage is made up quite as much of herbaceous as of woody species, so that this type is fully as well suited to the grazing of cattle as of sheep. Moderate cattle grazing during the first three or four seasons following cutting would insure a satisfactory stand of timber, while at the same time the forage crop could be utilized to its full capacity and the profits from grazing left unimpaired. Furthermore, it is well known that a temporary change in the class of stock generally grazed on the lands materially increases and improves the forage, as the species relished by cattle may be quite different from those relished by sheep. This reverse of close cropping by cattle of species grazed lightly by sheep for many years and light cropping of the species previously weakened by continued close grazing would permit the species especially relished by sheep not only to regain their full vigor, but to reproduce abundantly, and thus maintain themselves against competition with other species. Shifting from sheep to cattle for a three-year period, then, would accomplish two important things: (1) It would guarantee the establishment of a full aspen stand, and (2) it would improve the carrying capacity of the range for sheep grazing.

Obviously on cattle range no change in grazing is required, provided the lands are not too heavily stocked. Care should be taken, however, to have the stock properly distributed over the range at all times. This may best be accomplished by the proper location of salting grounds and watering places. Where the animals are inclined to drift on the lands so early in the season as to be forced to subsist on browse of second choice, such as aspen reproduction, in the absence of more choice feed, drift and division fences should be built to facilitate judicious distribution of the stock.

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BULLETIN No. 742

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WM. A. TAYLOR, Chief

Washington, D. C. ▼ January 15, 1919

PRODUCTION OF AMERICAN EGYPTIAN COTTON.

By C. S. Scofield, T. H. Kearney, C. J. Brand, O. F. Cook, and W. T. Swingle.

CONTENTS.

COMMUNITY PRODUCTION OF COTTON.

The purposes of this bulletin are to tell how Egyptian-cotton production became established in the Southwest as a result of community action, to describe the present status of the industry, and to give the reasons for encouraging the growing of this type of cotton in the United States. Attention is also directed to the conditions which appear to be indispensable to successful commercial production in this country. It is believed that Egyptian cotton can not be profitably grown except under irrigation and in the absence of the boll weevil. This would exclude it from consideration in any portion of what is generally known as the cotton belt.

The principle of community action in cotton production implies the growing of only one variety, the variety selected being that which

[1] This bulletin is largely a revision of Department Bulletin No. 332, entitled "Community Production of Egyptian Cotton in the United States," by C. S. Scofield, T. H. Kearney, C. J. Brand, O. F. Cook, and W. T. Swingle, issued on January 13, 1916.

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is best adapted to the physical and economic conditions of the locality.[1] In no other way is it possible to maintain a supply of pure seed and to market year after year a uniform high-grade product. These objects can be attained only by effective cooperation on the part of the growers. The lesson taught by this successful application of the community principle should make the present publication interesting to many who are engaged in growing, selling, or manufacturing cotton, even though they may not be concerned with the special subject of Egyptian-cotton production.

SOURCES OF LONG-STAPLE COTTON.

The three most important types of long-staple cotton are (1) Sea Island cotton, (2) long-staple Upland cotton, and (3) Egyptian cotton.

Sea Island cotton is grown on the islands along the coasts of South Carolina and Georgia and in certain counties on the mainland of Georgia and Florida, as well as to a limited extent in portions of the West Indies. During recent years the crop of Sea Island cotton in the United States has ranged from 60,000 to 120,000 bales[2] per annum. The staple of Sea Island cotton ranges from 1½ to 1⅝ inches in the Georgia and Florida product to 2 inches in the best qualities grown on the Sea Islands proper.[3]

Long-staple Upland cotton has long been produced chiefly in the so-called Delta region of western Mississippi. In recent years the production of this type of cotton has been extended into eastern Arkansas and northeastern Texas, and a small quantity has also been grown in the Carolinas. Still more recently the growing of long-staple Upland cotton has been established on irrigated lands in the Imperial Valley of California, the industry in that locality being based on the Durango variety. The quantity of long-staple Upland cotton produced annually in the United States is not definitely known. A recent publication of the Bureau of Crop Estimates[4] places the total for 1916 at slightly more than 1,000,000 bales of cotton having a staple of 1⅛ inches or longer. While a few varieties of long-staple Upland cotton sometimes produce fiber having a staple of 1½ inches or longer, the bulk of the crop is less than 1⅜ inches in length.

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[1] Cook, O. F. Cotton improvement on a community basis, *In* U. S. Dept. Agr. Yearbook, 1911, p. 397–410, 1912. See also Swingle, W. T., The fundamentals of crop improvement, in U. S. Dept. Agr., Bur. Plant Indus. Cir. 116, pp. 3–10, 1913.

[2] The Sea Island cotton bale averages in weight slightly less than 400 pounds. For further information, see Meadows, W. R., Economic conditions in the Sea Island cotton industry, U. S. Dept. Agr. Bul. 146, 18 p., 1914.

[3] A small proportion of the island product reaches a length of 2¼ and rarely even 2½ inches.

[4] Monthly Crop Report for June, 1917, p. 52. See also Taylor, Fred, and Sherman, W. A., Spinning tests of Upland long-staple cottons, U. S. Dept. Agr. Bul. 121, 1914, p. 19.

Egyptian cotton until very recently has been produced commercially only in the delta and lower valley of the Nile River, in Egypt. During the 10-year period from 1907 to 1916 the Egyptian crop averaged annually the equivalent of 1,292,400 bales of 500 pounds (see Table I).

CHARACTER AND SUPPLY OF EGYPTIAN COTTON.

Egyptian cotton is a distinct type, both botanically and commercially, comprising several varieties and having staples ranging from 1¼ to 1⅝ inches. The history of cotton growing in Egypt since the present definite type was developed in that country about 65 years ago has been marked by the successive appearance of numerous varieties. Each of these, after having been extensively grown for a number of years, has shown marked deterioration due to intercrossing.

The most striking characteristics of the Egyptian fiber are its length of staple combined with great strength and fineness. The older varieties, Ashmuni and Mit Afifi, are characterized by a brown or, more properly, pinkish buff color of the fiber, but the Sakellaridis variety, which is now highest in favor among spinners, is nearly white, or almost as light in color as Sea Island cotton. In 1916 this variety occupied 62 per cent of the total cotton acreage of Egypt.

Egyptian cotton is used especially in the manufacture of goods in which strength or fineness or a combination of both qualities is desired. Some of the principal articles manufactured from this cotton are sewing thread, hosiery, automobile-tire fabrics, and fine and fancy dress goods. Until a few years ago mercerized fabrics were made only from Egyptian cotton, but the process of mercerization has now been developed so that other cottons can be successfully treated. "Balbriggan" underwear was formerly manufactured exclusively from the brown Egyptian cottons, but dyed white cottons are now also employed for this purpose.

The cotton crop of Egypt is grown entirely on irrigated land in a climate which is practically rainless throughout the period of development of the cotton plants. The absence of rain during the picking season favors the production of clean cotton. During the 10-year period from 1907 to 1916, the area in cotton in Egypt averaged 1,684,000 acres, and the average yield per acre was about 380 pounds.[1]

The recent annual production of cotton in Egypt is shown in Table I.

About 60 per cent of the Egyptian crop is exported to Great Britain. Imports into the United States during the period from 1908 to

[1] These averages are computed from data given in Monthly Return, Ministry of Agriculture (Egypt), Nov. 30, 1917, p. 5.

1913 averaged about 10 per cent of the total, but the proportion has recently increased, this country having received 19, 35, and 17 per cent, respectively, of the cotton produced in Egypt in the calendar years 1914, 1915, and 1916.

TABLE I.—*Total annual production of cotton in Egypt during the 10-year period from 1907 to 1916, inclusive.*[1]

Year.	500-pound bales.	Year.	500-pound bales.
1907	1,431,000	1912	1,484,000
1908	1,335,000	1913	1,517,000
1909	990,000	1914	1,277,000
1910	1,484,000	1915	945,000
1911	1,461,000	1916	1,000,000

[1] Computed from data given in Monthly Return, Ministry of Agriculture (Egypt), Nov. 30, 1917, and Dec. 31, 1917.

AMERICAN CONSUMPTION OF EGYPTIAN COTTON.

Notwithstanding the fact that nearly two-thirds of the American cotton crop is exported[1] for manufacture in foreign countries, a large quantity of raw cotton is imported for manufacture in the United States. By far the larger part of this imported cotton is obtained from Egypt. Table II shows the imports of Egyptian cotton for the past 10 years.

TABLE II.—*Annual imports of Egyptian cotton into the United States for the crop-distribution years*[1] *during the 10-year period from 1907–8 to 1916–17, inclusive.*

Year.	500-pound bales.	Year.	500-pound bales.
1907–8	120,187	1912–13	191,075
1908–9	129,985	1913–14	137,355
1909–10	102,217	1914–15	261,220
1910–11	183,786	1915–16	339,854
1911–12	175,835	1916–17	198,805

[1] The crop distribution year covers the period from September 1 to August 31, inclusive. The figures shown in Table II are compiled from data given in publications of the Bureau of the Census, the imports for the years 1908 to 1912 from Bulletin 117 (1913), p. 9; those for the years 1913 and 1914 from Bulletin 128 (1914), p. 10; and those for 1915 to 1917 from Bulletin 135 (1918), pp. 65–66. In order to complete the 12 months' total for 1917, the imports during the month of August, 1917, were taken from the monthly postal-card report issued by the Bureau of the Census.

The imports markedly declined during the crop-distribution year 1917–18, having amounted to the equivalent of 119,126 bales of 500 pounds each, which is about 60 per cent of the quantity imported during the preceding year.

The shorter kinds of Egyptian cotton (1¼ to 1⅜ inch staple), the so-called brown Egyptian and Upper Egypt cottons, produced by the Mit Afifi and Ashmuni varieties, respectively, are used by American manufacturers largely as a substitute for American long-staple Uplands of corresponding lengths, the substitution being profitable

[1] This applies to the years preceding the outbreak of the war in Europe. Of the crops produced in 1914, 1915, and 1916, only about one-half was exported.

when the price of American long-staple cottons is relatively high. There is also a certain amount of substitution of the longest Egyptian, especially of the Sakellaridis variety, for the shorter lengths of Sea Island cotton, depending upon the relative prices of the two types. There remains, however, a certain proportion of the imported Egyptian cotton for which no other fiber appears to be a satisfactory substitute.

In view of this fact, the question has been frequently asked whether Egyptian cotton could not be produced in the United States in sufficient quantity to supply at least a part of the home demand. Conditions which have arisen in Egypt since the first attempts were made to answer this question have emphasized the importance of undertaking the production of Egyptian cotton in this country. It has been found that the maintenance of a uniform quality of any of the Egyptian varieties is rendered precarious by the fact that in Egypt distinct varieties are often grown in adjacent fields. There is also a general contamination of the whole Egyptian crop with an inferior and distinct type of cotton known as Hindi.

These conditions make it almost impossible to maintain in Egypt a supply of pure seed of a variety which has reached the stage of commercial production, because all these types of cotton cross freely with each other and adequate precautions are seldom taken to keep the seed of the different kinds separate at the gin. Furthermore, the cotton crop of Egypt suffers severely from insect enemies, notably in recent years from the ravages of the pink bollworm. This pest threatens a serious reduction of the crop, or at least a wide fluctuation in total production from year to year. Thus, it appears unsafe for the numerous American users of this type of cotton to depend solely upon Egypt for their supply of raw material, and the desirability of developing an independent source of supply in the United States has recently been emphasized by the uncertainty attending transportation under war conditions as well as by the need of extra-staple cotton for aeroplane and balloon fabrics and for other military purposes.

PRODUCTION OF EGYPTIAN COTTON IN AMERICA.

Although experiments with the production of Egyptian cotton in the southwestern United States were begun in 1902, it was not until 1912 that it was deemed advisable to recommend the commercial production of the crop. In the spring of that year seed was distributed by the Department of Agriculture to a number of farmers in the Salt River Valley in Arizona and the Imperial Valley in California. As a result of this distribution about 480 acres of cotton were brought through to harvest, and the crop of 1912 amounted to 375 bales of 500 pounds each.

In 1913 the production of Egyptian cotton was confined to the Salt River Valley, where a total of 3,800 acres was planted. Not all of this acreage came to harvest, but the crop for the year amounted to 2,135 bales of 500 pounds each.

In 1914 the area planted in the Salt River Valley amounted to approximately 12,000 acres. On much of this area the conditions were not favorable for large yields because of deficient soil fertility, inadequate preparation of the land, or faulty management of the irrigation. The total crop for the year amounted to 6,187 bales of 500 pounds each. While the average yield per acre shown by these figures is not high, a number of farmers having good land and using good methods obtained more than one bale per acre.

In 1915, owing to the low prices which followed the outbreak of the war in 1914, the area in the Salt River Valley was reduced to 2,330 acres, of which about 2,000 acres were brought through to harvest. In 1916, under the influence of rising prices, 7,433 acres were planted, and about 6,800 acres were harvested.

Prior to 1917 the commercial production of Egyptian cotton in the United States had been practically confined to the Salt River Valley in Arizona. In that year, however, in addition to the 29,000 acres which were harvested in the Salt River Valley, some 4,000 acres were grown on the Yuma Reclamation Project (Arizona and California), and approximately 200 acres were grown in the Imperial Valley in California.

In 1918 the total acreage planted to Egyptian cotton in the United States is estimated at 86,500, including about 78,000 acres in the Salt River and Gila Valleys in Arizona, about 3,000 acres on the Yuma Reclamation Project, about 3,000 acres in the Imperial Valley, approximately 2,000 acres in the San Joaquin Valley, Cal., and more than 500 acres in the Palo Verde Valley, Cal. The experience of previous years has shown, however, that a certain percentage of the acreage planted is sure to be abandoned before picking time, in most cases because of failure to get a good stand. Probably a conservative estimate of the acreage of Egyptian cotton in Arizona and California which was harvested in 1918 is 70,000 acres.

The status of the industry during the first six years of its existence is summarized in Table III.

Several ginning establishments, devoted exclusively to ginning Egyptian cotton, have been erected in the Salt River Valley and on the Yuma Reclamation Project. Each of these is equipped with from 10 to 15 roller gins of the type used for ginning Sea Island cotton. A number of cottonseed-oil mills are operated in the Salt River, Yuma, and Imperial Valleys.

In staple and quality of fiber the American-grown Egyptian cotton is comparable with the best varieties produced in Egypt, although some spinners prefer the Sakellaridis variety for certain purposes. The crops so far produced have also been of very good grade, comparing favorably with that of the best imported cotton. A large portion of the Egyptian cotton imported into the United States is of low grade or of relatively short staple, i. e., $1\frac{1}{4}$ to $1\frac{3}{8}$ inches. The American-grown Egyptian cotton does not come into competition with the latter class, but only with the better and higher priced varieties.

Table III.—*Number of bales, estimated value of the lint, and estimated value of the seed of Egyptian cotton produced in the United States in the years 1912 to 1917, inclusive.*

Year.	Cotton lint in 500-pound bales.	Estimated value—		
		Of lint.	Of seed.	Of total crop.
1912	375	$39,000	$5,000	$44,000
1913	2,135	197,000	28,000	225,000
1914	6,187	483,000	50,000	533,000
1915	1,095	119,000	10,660	129,660
1916	3,331	699,500	86,400	785,900
1917	15,966	5,482,000	619,770	6,101,770

FUTURE POSSIBILITIES OF THE INDUSTRY.

As to the ultimate possible extension of the industry, the Salt River Valley and the neighboring portion of the Gila Valley could probably grow annually from 75,000 to 100,000 acres of Egyptian cotton, taking into account the entire area capable of irrigation both by gravity and by artesian water. This estimate is based upon the belief that in order to maintain a well-balanced agriculture in an irrigated district not more than one-quarter of the total acreage should be annually in cotton. On the same basis the Yuma Valley could grow about 20,000, the Palo Verde Valley about 15,000, and the Imperial Valley about 100,000 acres of Egyptian cotton annually. In the more northern valleys of California the industry is still in the experimental stage, and it is difficult to estimate the possible ultimate production in that locality. An annual area of at least 100,000 acres in the San Joaquin Valley would seem possible.

Heretofore the entire acreage planted to Egyptian cotton has yielded annually an average of about 250 pounds of fiber per acre. But in view of the results which have been obtained every year by farmers skilled in the management of this crop on land which has been enriched by crops of alfalfa, the average yield should ultimately approach one bale (500 pounds) per acre. With a total acreage of 300,000 an annual production in the United States of from 150,000 to 250,000 bales of cotton of the Egyptian type appears to be well within the limit of probability, provided that the prices of the fiber and seed remain somewhere near the present levels and that labor can be obtained for picking so large an acreage.

COMPARISON OF AMERICAN AND EGYPTIAN CONDITIONS.

The commercial production of Egyptian cotton in the United States involves the marketing of the product in direct competition with the crop of Egypt. This fact warrants a brief consideration of the status of the cotton industry in that country and a comparison between the conditions there and in the southwestern United States. The production in Egypt of cotton having a staple comparable with that of the Salt River Valley product is limited to what is known as Lower Egypt—that is to say, the Nile Delta, north of Cairo. This region includes about 3,250,000 acres of irrigated land, of which about 40 per cent is annually devoted to cotton.

This land is heavily capitalized, and the cost of irrigation water is high. These features are best expressed by rental values, which range for the best land from $50 to $75 a year per acre. It is probable that the average rental value of land in Lower Egypt is not far from $40 per acre, being much higher than the average rental value of land in the southwestern United States having similar capabilities of crop production.

While the cotton growers of Arizona and California have the advantage in respect to land rental or interest on land investment, those of Egypt are able to get their cotton picked at much less cost, owing to the cheapness and abundance of labor in that country. Aside from these two items, the cost of production is probably not very different in the two countries, since the low wage paid to farm laborers in Egypt is offset by the fact that the American farmer works with large fields and uses horse-drawn implements extensively. Much of the Egyptian crop, on the other hand, is grown by peasant farmers in small fields and with the use of very primitive implements.

The Egyptian industry suffers two serious disadvantages which do not exist in Arizona and California. One of these is the difficulty of maintaining pure seed, due to the widespread occurrence of Hindi, or "weed," cotton, which is discussed more in detail elsewhere in this bulletin. The other is the existence of certain insect pests, notably the pink bollworm, which has recently caused serious and extensive damage and is still spreading.

It is probable that the higher valuation of land in Egypt, together with the less efficient methods of tillage, nearly or quite offsets the higher cost of labor in the United States. The crop-producing capabilities of the land in the two regions are much the same. The commercial value of the Arizona crop compares favorably with the best of the Egyptian crop. Finally, the Egyptian cotton grown in the United States is practically free from Hindi contamination, and the pink bollworm has not yet found its way into Arizona and California.

In the matter of transportation the Egyptian cotton crop enjoys certain natural advantages over the product of the new American industry. It also has the advantage of long-standing occupation of the market and of a well-organized, though rather expensive, system of commercial distribution.

The entire Egyptian crop is assembled in Alexandria, where it is sorted, classed, compressed, and forwarded. Practically none of the cotton is manufactured locally. This centralization of the marketing business permits, though it does not insure, efficiency and economy in the handling of the product. The freight rates from Alexandria to manufacturing centers, transportation being by water, are low in comparison with the rates from Arizona, which include a long rail shipment. Freight rates, particularly ocean freight rates, are subject to continual fluctuations, but it is probable that previous to the outbreak of the war the rates from Arizona and California[1] to manufacturing points in New England were about three times as high as those from Egypt to the same points. Under present conditions, however, the cost of shipment from Arizona is probably lower than from Egypt.

The large volume of the Egyptian crop and the centralized methods of handling also permit a standardization of types and a system of future selling against these types which are very important commercial advantages. To find favor in the market a consignment of cotton must not only show good grade and staple, but must represent a type which has had its merit established through actual use. A manufacturer having determined what types of cotton meet his particular requirements will endeavor to duplicate these types in his annual purchases. For this reason Egyptian brokers establish definite types and maintain them from year to year. This system of dealing on types is possible with the Egyptian crop in spite of the continued deterioration of the varieties, because each broker has a large volume of cotton offered to him at Alexandria from which to select his stocks.

The American growers will need to recognize this feature of the market for Egyptian cotton if they expect to secure full value for their product. While the American crop remains small, it is of the utmost importance that the quality be kept uniform from year to year.

[1] The Arizona cotton is usually shipped by rail to Galveston, Tex., and thence by water to New England. The freight rate on baled cotton from Salt River Valley points to New England is about $1.30 per 100 pounds, this rate including the charge for compressing in transit.

It is possible to maintain this uniformity of type in the American crop if the growers exercise proper care in the selection of seed for planting. Unless the seed is selected carefully and consistent effort is made by good tillage and careful picking and ginning to maintain uniformly high quality in the crop, it will be difficult, if not impossible, to maintain the new industry on a profitable basis.

EARLY ATTEMPTS TO ESTABLISH EGYPTIAN-COTTON GROWING IN THE UNITED STATES.

The Department of Agriculture on several occasions prior to 1900 imported seed of Egyptian cotton and distributed it in small lots to farmers throughout the cotton belt. This procedure did not result in establishing the industry in any locality, a fact that ceased to be surprising when the necessity for community action in the commercial production of a new type of cotton came to be appreciated. The tests of the imported seed in various localities gave diverse results as to yield and quality of the fiber produced, but serious difficulties were always encountered in communities where Upland cotton was already being grown. Some of these difficulties may be stated as follows:

(1) Pickers disliked the small bolls, which made it appear that picking would be much more difficult and expensive than in the case of the big-bolled Upland types which are generally popular in the South.

(2) Only saw gins were available for separating the fiber from the seed, and as a result the fiber was invariably injured in ginning.

(3) Marketing small lots of a new type of fiber, with which the local buyers were unfamiliar, was found to be extremely difficult.

(4) The Egyptian cotton was grown in the neighborhood of fields of Upland cotton, and consequently it was found impossible to keep the seed pure.

The seed of several of the best varieties grown in Egypt was imported in larger quantities by Mr. David Fairchild following his visit to that country in 1900 as an agricultural explorer for the Department of Agriculture.[1] Dr. H. J. Webber, then in charge of the plant-breeding work with cotton in the Department of Agriculture, undertook systematic tests of these varieties during the next two or three years at various localities in the cotton belt and in irrigated districts of the Southwest. In the main cotton belt fairly favorable results were obtained in certain localities, but owing to the difficulties mentioned the experiments did not result in the establishment of commercial production.

BEGINNING OF EXPERIMENTS IN THE SOUTHWEST.

The irrigated lands of southern Arizona and southeastern California, where the climatic conditions more nearly resemble those of Egypt than in the cotton belt, were found to offer the most promis-

[1] The first plantings of Egyptian cotton in Arizona appear to have been made with some of this seed, which was sent to the State (then the Territorial) experiment farm at Phoenix and to Dr. A. J. Chandler, at Mesa. This was a year or two before the beginning of experimental work with this crop in Arizona by the Department of Agriculture.

ing field for the introduction of this type of cotton. In the early stages of the work, however, serious difficulties were encountered in this region also. The most important of these were the following: (1) The lack of proper facilities for carrying on the plant-breeding work and the investigations of cultural methods; (2) lack of uniformity in the imported stocks of seed and slow progress in the development of a productive type having fiber of sufficiently good quality and uniformity to warrant its recommendation for commercial production; and (3) lack of information as to the proper methods of irrigation and culture under the climatic and soil conditions of the region.

It also become apparent that, even if these cultural difficulties could be overcome, certain economic problems would need to be solved before commercial production could be undertaken with any hope of success. These problems were as follows: (1) The scarcity and high price of labor in this thinly populated region, which threatened to make the picking so expensive that no profit could be anticipated; and (2) the difficulty of ginning and marketing the crop grown in a small way by farmers in localities remote from established cotton markets.

The first-mentioned difficulty was overcome when the Department of Agriculture established two well-equipped experiment farms where the plant-breeding work and the study of cultural methods could be carried on from year to year on the same soils and under the same management. One of these farms is the Cooperative Testing Garden at Sacaton, Ariz., conducted by the Bureau of Plant Industry in cooperation with the Office of Indian Affairs, Department of the Interior, and under the superintendence of Mr. S. H. Hastings (formerly of Mr. E. W. Hudson[1]). The other farm, at Bard, Cal., on the Yuma Reclamation Project, is conducted by the Bureau of Plant Industry in cooperation with the United States Reclamation Service and is under the superintendence of Mr. R. E. Blair (formerly of Mr. W. A. Peterson).

UNSATISFACTORY CHARACTER OF THE ORIGINAL STOCKS.

During the earlier years of the breeding work in Arizona the behavior of the plants was very unpromising. They made an extremely rank growth, but were relatively unfruitful and late in maturing. The bolls were small and often opened imperfectly. There was also

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[1] Mr. Hudson, while superintendent of the Cooperative Testing Garden at Sacaton, took a very active part in the establishment of the industry in the Salt River Valley.

Mr. Argyle McLachlan, now president of the Imperial Valley Long-Staple Cotton Growers' Association, served for several years as field agent of the Department of Agriculture in the Southwest, and while his attention was devoted mainly to the Durango cotton industry in the Imperial Valley, he also aided effectively in the work with Egyptian cotton.

a pronounced lack of uniformity in the imported stocks and in the strains which were first selected from them.[1]

Mr. O. F. Cook, as a result of observations upon Egyptian varieties grown in Arizona from newly imported seed, reached the conclusion that the difficulty in obtaining uniformity was largely attributable to the presence among the Egyptian stocks of a very different and inferior type of cotton, the Hindi, the resulting cross-pollination having led to serious contamination of the Egyptian varieties. The matter seemed of sufficient importance to warrant an investigation in Egypt by Mr. Cook in 1910. The degree of Hindi contamination observed in that country was surprisingly great.[2]

Nearly every cotton field inspected was found to contain Hindi plants, and in some fields as many as 20 per cent of the plants were of the Hindi type. The percentage of pure Hindi plants does not represent the full extent of the damage, since this type crosses readily with the Egyptian cotton and the final result is a series of hybrids possessing in varying proportions the characters of each parent. Commencing with a mixed population of this sort, a uniform cotton can be developed only by the selection of an individual plant which possesses the characters desired and which breeds true, thus permitting the segregation of a pure stock.

Even if there were no Hindi cotton in Egypt, the conditions would be unfavorable for the maintenance of uniform varieties, since a number of distinct types of Egyptian cotton are grown, often in adjacent fields, and the pollen is readily carried from field to field by insects, leading to the production of intervarietal hybrids. Furthermore, until very recently no adequate precautions were taken to avoid the mixing of seeds at the gins.

DEVELOPMENT OF MORE UNIFORM VARIETIES.

Success in the effort to obtain a variety which could safely be recommended for commercial production was not attained until the variety called "Yuma" was segregated in 1908.[3] Although selected from a stock of Mit Afifi, the Yuma cotton is very distinct from that variety in the characters of the plants and of the fiber. The lint averages $1\frac{1}{2}$ inches in length and has the pale pinkish buff color of the Jannovitch rather than the deeper buff color of the Mit Afifi. The lint percentage averages about 28.

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[1] Cook, O. F., McLachlan, Argyle, and Meade, R. M. A study of diversity in Egyptian cotton. U. S. Dept. Agr., Bur. Plant Indus. Bul. 156, 60 p., 6 pl. 1909.

[2] Cook, O. F. Hindi cotton in Egypt. U. S. Dept. Agr., Bur. Plant Indus. Bul. 210, 58 p., 6 pl. 1911.

[3] For a more complete description of this variety and a more detailed account of its history, see Kearney, T. H., Breeding new types of Egyptian cotton, U. S. Dept. Agr., Bur. Plant Indus. Bul. 200, 39 p., 4 pl., 1910. The Yuma and Pima varieties are also described by Mr. Kearney in an article entitled "Mutation in Egyptian cotton," in Jour. Agr. Research, v. 2, no. 4, p. 287–302, pl. 17–25, 1914.

Yield tests and spinning tests of the Yuma cotton carried on during several years demonstrated that a stable variety, uniform in its characters and producing fiber of good spinning quality, had at last been obtained. Seed was therefore placed in the hands of farmers in the Salt River and Imperial Valleys in 1912, with the results described on preceding pages.

From the Yuma variety there has originated another very distinct new type, which has received the name "Pima" and which surpasses the parent variety in earliness, size of the bolls, and length and quality of the fiber. The staple of the Pima variety ranges from 1⅝ to 1¾ inches and the fiber is lighter colored than that of the Yuma variety. In cooperation with the Tempe Exchange, one of the cooperative growers' associations in the Salt River Valley, Pima seed was distributed from the Sacaton station in 1916 for planting 252 acres in an area isolated from all other cotton. These fields yielded at the rate of 1 bale per acre, 251 bales of 500 pounds having been produced. The Pima cotton having found immediate favor with spinners, the resulting seed was used in 1917 to plant 6,700 acres in the same district, which produced approximately 3,000 bales. Nearly 95 per cent of the cotton acreage in the Salt River Valley and the entire acreages of Egyptian cotton in the Yuma and Imperial Valleys are now (1918) of the Pima variety.

SOLVING THE PROBLEMS OF COMMERCIAL PRODUCTION.

As the work of establishing the new industry progressed it became apparent that the economic and agricultural problems could best be met by enlisting the cooperation of several men representing different lines of experimental work in the Department of Agriculture, each of whom was able to contribute special knowledge and experience. The cooperation was at first informal, but later, as the responsibilities increased, it was thought advisable to create a special committee to carry on this work. A "Committee on Southwestern Cotton Culture" was therefore appointed in 1910 by the Chief of the Bureau of Plant Industry.[1]

[1] The personnel of the committee is now as follows:

K. F. Kellerman, Associate Chief of the Bureau of Plant Industry, is chairman of the committee.

C. J. Brand, Chief of the Bureau of Markets, has charge of the investigations in classing, marketing, and transportation.

O. F. Cook, Bionomist in Charge of Crop-Acclimatization and Cotton-Breeding Investigations, conducts investigations of the factors involved in the acclimatization of different types of cotton in the Southwest and of the relation of these factors to cultural methods. He has also taken the lead in developing the idea of community cotton growing as a means to the maintenance of uniform varieties.

T. H. Kearney, Physiologist in Charge of Alkali and Drought Resistant Plant Investigations, has charge of the breeding work with Egyptian cotton and of the investigations of the effect of alkali and other soil conditions upon the production of this crop.

C. S. Scofield, Agriculturist in Charge of Western Irrigation Agriculture, has charge of those phases of the work which involve cooperation with the United States Reclama-

It has been the policy of the committee since its organization to avoid a sharp segregation of the different fields of investigation. As a result, each member has felt free to offer suggestions and even to assume responsibility beyond the limits of his own field, while the more important issues which have successively arisen in connection with the establishment of the industry have been decided by the whole committee. It is believed that this committee cooperation has been of the greatest importance in the successful establishment of the industry, since it has resulted in focusing upon the problems the different points of view and different mental equipment and training of several independent investigators.

Cooperative action having thus been provided, the economic problems were attacked, as follows:

(1) The principle of community effort in cotton production was applied in the organization of associations of growers.

(2) A supply of labor sufficient for the earlier requirements of the industry was developed through the employment of Pima and Papago Indians as cotton pickers, the first experiments having been made at the Cooperative Testing Garden at Sacaton under Mr. Swingle's direction. Frank M. Thackery, formerly superintendent of the Pima Indian Reservation and now chief supervisor of farming in the Office of Indian Affairs, rendered effective cooperation in this work.

(3) Methods for classing the new product were worked out, and grade and staple types were established, first for the Yuma variety and later for the Pima variety, by J. G. Martin and George Butterworth, of the Bureau of Markets.

(4) The American and European markets for this type of cotton were investigated by representatives of the associated growers and of the Department of Agriculture, contacts with buyers and spinners were established, and outlets for the product on the basis of full market value were thus obtained.

(5) In cooperation with the associated growers, measures were taken to insure a supply of pure seed for planting each year.

COOPERATIVE ORGANIZATION OF THE GROWERS.

When the Yuma variety of Egyptian cotton developed by the Department of Agriculture had been shown to possess the qualities needed for successful commercial production, it was pointed out that the industry could be successfully established only by community effort and that the department stood ready to furnish a supply of seed for planting, provided the growers were able to form a cooperative association. Farmers in the Salt River Valley had watched with interest the experiments with Egyptian cotton at Sacaton and had conferred with the superintendent of the cooperative garden

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tion Service and has also conducted certain investigations of market conditions in the United States and in Europe.

W. T. Swingle, Physiologist in Charge of Crop Physiology and Breeding Investigations, has charge of those phases of the work which involve cooperation with the Office of Indian Affairs, including the arrangements for securing Indian labor.

Fred Taylor, Cotton Technologist of the Bureau of Markets, has the immediate supervision of the classing, marketing, and technological problems.

there regarding the outlook for commercial production and the methods of growing the crop. They were therefore ready to adopt the point of view of the department, and in the spring of 1912 about 30 farmers in the vicinity of Mesa organized an association. In the following year similar organizations were formed at Chandler and Tempe. Finally, in the spring of 1914, a central organization, known as the Salt River Valley Egyptian-Cotton Growers' Association was formed, with the Mesa, Chandler, and Tempe associations as its constituent members. The central organization was designed to look after the marketing of the crop and the maintenance of a supply of pure seed for the entire valley, while the local organizations continued to provide for the ginning of the cotton grown by their members and for financing the crop during the growing period.

The Mesa and Tempe associations now operate well-equipped ginning plants. The gin at Chandler has been leased and operated by a private company, and there is also a privately owned ginning plant at Phoenix. Additional gins have been built recently at these and other points in the Salt River Valley by a corporation which manufactures automobile tires and which has bought or leased extensive tracts of land for the growing of Egyptian cotton.

During the present year cooperative associations of Egyptian-cotton growers have been organized on the Yuma Reclamation Project, in the Imperial Valley, and in Fresno County, Cal.

It is not likely, nor is it necessary to the success of the industry, that all of the growers in a community will become active members of the cooperative growing and marketing associations, but it is of the utmost importance that all should adhere to the policy of the organizations as regards the production of a single variety and the use of carefully selected seed. The commercial reputation of the cotton produced in the region and hence the best interests of every individual cotton grower can be secured only by this means.

LABOR FOR PICKING.

From the beginning of the experiments with Egyptian-cotton production in the Southwest it has been realized that the high cost of picking would be one of the most difficult problems to overcome. Hand labor is neither abundant nor cheap in these southwestern irrigated districts, yet a cheap and abundant supply of hand labor has generally been regarded as essential to successful cotton production. Picking Egyptian cotton requires greater care and is more expensive than picking Upland cotton, owing to the smaller size of the Egyptian bolls and the necessity of avoiding an admixture of such trash as leaves and pieces of bolls. In picking long-staple cotton it is especially important to keep the seed cotton clean; otherwise the grade of the lint is impaired and its selling value is much reduced. The Egyptian-cotton growers of the Salt River Valley have had to pay their pickers at least twice as much per pound of seed cotton as the growers of big-bolled Upland cottons in the Imperial Valley.

Notwithstanding these natural disadvantages, the problem of picking the crop of the Salt River Valley has been met successfully. The work has been paid at rates which allowed the pickers to make satisfactory wages. Although the industry has developed rapidly, no serious shortage of labor has yet been experienced. This has been due to the fact that the growers, through an active organization, have attacked the problem in a businesslike way. In the first place, many of the farmers had only small acreages and they and their families were able to do most of the picking. This distribution of the acreage among small farmers is very desirable and should be encouraged. There remained, however, a large acreage for which pickers had to be procured, in addition to the home supply of labor. For this purpose the floating population of the valley was drawn upon and Indians were brought in from near-by reservations.

There are two tribes of Indians in southern Arizona which include a large number of industrious and capable workers. The Pimas, who occupy a reservation adjoining the Salt River project, have taken up cotton growing to some extent on their own lands and have also been employed as cotton pickers by the white settlers. The Papagos occupy a large tract of land lying south of the Pima Reservation. There are several thousands of these Indians, and, as they lead a rather nomadic existence because of the uncertainty of the desert water supply, they find a season of cotton picking a congenial method of employment and have taken to it readily. In recent years several hundred of them have been engaged in the work throughout the picking season, with very satisfactory results to themselves and to the cotton growers. The rapid expansion of the industry in the last two years has necessitated tapping the sources of labor supply still farther afield. In 1917 numerous white cotton pickers from Texas and other States in the main cotton belt came to the Salt River Valley, and several hundred laborers were brought in from Mexico. Even more strenuous efforts were required to procure a sufficient number of pickers for the greatly increased acreage of 1918.

The present indications are that if the labor problem can be satisfactorily solved, the future of the industry is assured, at least so long as prices remain anywhere near their present level. While the cost of picking is high, the other costs of production are not excessive, and if the yields are good the value of the crop is sufficiently great to carry the picking cost and leave a satisfactory margin of profit to the grower.

COMMUNITY CREDIT FOR FINANCING THE CROP.

The production of cotton in a new region involves some arrangement for financing the crop until it can be sold. The expenses of production up to the time of picking are not much greater than with other farm crops, but ordinarily the pickers must be paid promptly, and the cost of picking, together with the cost of ginning, requires an outlay of funds greater than farmers can ordinarily meet without special credit arrangements. This is particularly true when cotton growing is being undertaken in a new region, because the marketing of the crop takes more time than when the industry is well established. Under such conditions the crop can rarely be sold as soon as it is ginned. It must be classed and assembled into uniform lots, and must move to market gradually if the best prices are to be obtained. Even in the case of the well-established cotton industry in Egypt the crop moves to the market very gradually, much of it not reaching the manufacturer until the following spring or summer. Meanwhile it must be financed.

In view of the uncertainties attending the marketing of long-staple cotton from a new locality, brokers are not likely to risk paying what they believe to be the full value of the crop if asked to take it unclassed in round lots, as it comes from the gin. For that matter, even when they have the advantage of a well-established market, farmers would probably benefit by holding their cotton in storage until it can be classed into even-running lots and sold with the least element of risk to the cotton merchant or the spinner.

The associated growers in the Salt River Valley have met this problem of financing the crop by a plan of community credit. Arrangements were made with local banks to secure the necessary funds. Each bale of cotton, as soon as it was ginned, was placed in storage and a receipt was issued against it, these receipts being used as collateral for loans through the association. In this way it was possible for the grower to procure money to defray his expenses for picking and ginning without losing possession of his cotton until it was finally sold to the manufacturer. In the absence of such a system of community credit, it probably would have been necessary for the grower to sell his cotton as soon as it was ginned for whatever price he could obtain.[1]

GINNING IN RELATION TO PRODUCTION.

The roller gin which is used for Egyptian cotton can not be operated as rapidly or as cheaply as the saw gin which is used for Upland

[1] In 1917 many growers in the Salt River Valley executed contracts with a corporation manufacturing automobile tires which undertook the financing of their crops in return for an option on the product.

cotton. The charge made for ginning Egyptian cotton in the Salt River Valley was until recently about $10 per bale, but was increased to $14 in 1917.

Instead of depending upon custom ginning two of the associations of cotton growers in the Salt River Valley operate their own plants. The experience of these farmers, which is in accord with that of farmers in the eastern cotton belt, indicates that the best results are obtained when the ginning is under the control of the producers. The market value of cotton may be very greatly reduced by careless ginning, and when the gin operator has no other interest than to secure the largest possible outturn the commercial value of the product is likely to be impaired.

Cotton ginning is a technical operation which requires experience and skill to secure the best results. The cooperative ownership and management of a gin by the growers does not in itself insure capable and efficient management, but it does afford the owners of the crop an opportunity to insist upon the work being properly done. This opportunity is seldom afforded when the cotton is handled by custom gins. In either case it is of the utmost importance to the growers that the crop be classed or graded by a capable and impartial expert as soon as it leaves the gin. Prompt grading serves to warn the farmer if either the picking or ginning is being poorly done and gives him this warning in time to enable him to have better work done.

The grower is interested in the way the ginning is done, not only because of its effect on the value of his lint, but also because of its relation to his supply of seed for planting. Where only uncontrolled custom ginning is available the grower has small chance of maintaining the purity of his seed.[1]

The opinion appears to be gaining ground among students of cotton production that the improvement of the industry depends fully as much upon good ginning as upon good cultivation or good picking. The surest way to obtain good ginning is by cooperative ownership and operation of the gins.

GRADING THE CROP.

It was pointed out on a preceding page that uniform grades of Egyptian cotton must be established and maintained from year to year if the crop is to find ready sale at its full value. In recognition of this fact steps were taken in 1913 to establish standards of the different types and grades produced in the crop of Yuma cotton of

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[1] Experiments that demonstrate in a striking manner the readiness with which seeds of different varieties of cotton become mixed in commercial ginning establishments have been described recently by D. A. Saunders and P. V. Cardon. (Custom ginning as a factor in cotton-seed deterioration. U. S. Dept. Agr. Bul. 288, 8 p., 5 fig. 1915.)

that year. A cotton-grading expert was detailed from the Office of Markets and Rural Organization (now the Bureau of Markets) to cooperate with the growers' association for this purpose. The work was continued in 1914, the standards having been perfected and arrangements having been made for spinning tests in order that the cotton might be placed on a sound basis of market value. The scope and preliminary results of this standardization work were described in a report from the Office of Markets and Rural Organization.[1] In 1916 and 1917 similar investigations were conducted with the new Pima cotton, which, because of its longer and lighter colored fiber, required the establishment of new standards of grade and staple.

MARKETING THE CROP.

In the six years of commercial production of Egyptian cotton in Arizona the marketing of the crop has been attended by various vicissitudes, and the problem has not yet been completely solved. Until very recently the quantity produced was too small to permit active competitive buying, and at times the danger of monopoly by a single buying firm has been acute. Moreover, the small quantity of the product also made it difficult for buyers to interest spinners in these new cottons even when their spinning value had become well recognized. The growers have not thus far succeeded in establishing an effective selling organization on a cooperative basis, but if this can be done and the transportation difficulties which have recently been experienced can be overcome, the rapidly increasing size of the crop should greatly facilitate its disposal. Although differences of opinion exist among spinners as to the comparative merits of American Egyptian, Sakellaridis, and Sea Island cottons, there is substantial agreement that the Arizona and California product meets a real requirement in the long-staple cotton market.

It should be noted that ever since the establishment of the industry the crop has been sold each year in open competition with the vastly larger crop produced in Egypt. The effective organization of the Arizona growers and the intelligent application of the best principles in growing, handling, and marketing the crop and in maintaining the seed supply are largely responsible for this satisfactory result.

MAINTENANCE OF THE SEED SUPPLY.

It was pointed out in an earlier publication[2] what steps should be taken by the associated growers and what kind of assistance the

[1] Martin, J. G. The handling and marketing of the Arizona-Egyptian cotton of the Salt River Valley. U. S. Dept. Agr. Bul. 311, 16 p., 3 pl. 1915.

[2] Kearney, T. H. Seed selection of Egyptian cotton. U. S. Dept. Agr. Bul. 38, 8 p. 1913.

Department of Agriculture could furnish in guarding against the deterioration of the seed used for planting.

The growers in the Salt River Valley having signified their desire to cooperate with the department along these lines, experts were detailed during the summer of 1913 to rogue [1] a limited acreage of well-grown Yuma cotton in order to obtain seed for increase during 1914 and for general planting in 1915. In 1914 the department's experts, assisted by representatives of the Salt River Valley Egyptian-Cotton Growers' Association, rogued about 100 acres which had been planted with seed from the fields which were rogued in 1913. Every plant in this acreage was examined, and the unproductive and off-type plants, amounting to about 1 per cent of the total, were removed. The work was done early in July, soon after blossoming began, in order to take out the inferior plants before their pollen should contaminate those left in the field. Of the cotton grown from seed produced by fields which were rogued in 1914, about 100 acres were rogued during the summer of 1915, somewhat less than 1 per cent of the plants being removed.

In a 20-acre field of Yuma cotton which was rogued in 1916, 2 per cent of the plants were removed as being "off type."

A large part of the acreage planted to the Pima variety in 1916 and 50 acres of this variety in 1917 were rogued. The much greater uniformity of the new type was shown by the fact that whereas from 10 to 20 plants in every thousand of the Yuma variety had been removed, only from 2 to 4 plants per thousand of the Pima variety were taken out in roguing, although the latter variety was rogued much more rigorously than the Yuma.

The growers' association on its part has had the seed from the rogued fields ginned under such conditions as to avoid mixing with other seed, and also has had the seed sacked and tagged as it comes from the gins, in order to prevent mixture while it is held in storage. The rogued seed is placed by the association in the hands of careful farmers having good land sufficiently remote from other cotton to prevent crossing. The fields planted under these conditions are inspected during the summer, and the product of those which are properly grown and are otherwise satisfactory is ginned separately, in order to furnish seed for general planting the second year after the roguing is done. Thus, the seed used for general planting in 1918 was derived from the fields which were rogued in 1916, and that which will be used for general planting in 1919 has been derived from the fields rogued in 1917. It is believed that the seed from

[1] The importance of early roguing cotton fields intended to furnish seed for planting and the practicability of recognizing "off-type" plants in the early stages of their growth have been pointed out by Mr. O. F. Cook. (Cotton selection on the farm by the characters of the stalks, leaves, and bolls. U. S. Dept. Agr., Bur. Plant Indus. Cir. 66, 23 p. 1910.)

inspected fields can be sold for planting at a price very little above current oil-mill prices, thus removing the temptation to plant unselected seed because it is cheaper.

The fact that this plan for handling the supply of planting seed of the Yuma variety was in successful operation when the time came to introduce the Pima variety in the same locality made it possible to solve what would otherwise have been the very difficult problem of substituting one variety for another and yet keeping the new stock from being mixed with the old. Through the hearty and efficient cooperation of this growers' association it has been possible to supply, in 1918, pure seed of the Pima variety for planting approximately 70,000 acres, all of which was derived from the 250 acres planted near Tempe in 1916.

If the growers' associations continue to follow year after year the plan thus outlined, it is expected that deterioration, if it occurs, will be so gradual that there will be time for the substitution of another pure strain selected and multiplied at the plant-breeding station.

It is to be hoped that the associated growers in other communities which have undertaken the production of Egyptian cotton will deal with the problem of pure-seed maintenance in an equally effective manner.

AGRICULTURAL RELATIONSHIPS OF THE CROP.

The outstanding agricultural feature of cotton production in the Southwest is the value of the crop in the farm rotation. Alfalfa occupies a large part of the irrigated land in that region and is the basis of its agriculture; but the alfalfa fields after a few years become so badly infested with Bermuda grass and other weeds that their value is greatly impaired. It has been found that these old alfalfa fields, when thoroughly broken up and worked into good tilth, yield large crops of cotton. At the same time the intertillage of the cotton crop while the plants are young and the complete shading of the ground later in the summer effectually rid the land of weeds. One or two well-tilled crops of cotton following alfalfa will leave the land clean and in excellent condition for reseeding with alfalfa or for growing other crops. Because of its renovating value in the farm rotation, cotton is a valuable crop for irrigated land, quite aside from the cash returns it brings.

Less water is needed for the production of cotton than for the production of alfalfa, particularly early in the season. In fact, the total seasonal quantity of water needed for irrigating cotton is probably not much more than half that needed for the irrigation of alfalfa. The significance of this point lies in the fact that there is more irrigable land in Arizona and southern California than can be supplied with irrigation water. Hence, the growing of a crop which permits economy of the water supply may permit the ultimate extension of the irrigated area.

Another advantage of cotton as a crop for the irrigated Southwest is the fact that the product is a staple and nonperishable commodity. Practically all of the other crops yielding high cash returns per acre are perishable and involve the hazard of deterioration or total loss if the market is temporarily oversupplied. Cotton, on the other hand, is not subject to rapid deterioration if properly protected and need not be sold while prices are unsatisfactory.

TILLAGE METHODS.

Methods of preparing the land for Egyptian cotton and of irrigating and cultivating the crop have been described in an earlier publication of the Department of Agriculture.[1] The essential features of these methods are: Early and thorough preparation of the land; careful leveling, so that the entire field can be irrigated uniformly; early planting, with precautions for getting the seed into moist soil, so that prompt germination and good stands can be secured;[2] late thinning, leaving the plants close together in the row; the sparing use of irrigation water until the plants blossom; thorough cultivation as long as the size of the plants permits; and frequent light irrigation after blossoming begins until the crop is fully matured.

Unless the land is properly leveled satisfactory control of irrigation is out of the question. In some parts of a field the cotton may fail to germinate or may remain stunted by drought, while elsewhere in the same field the crop may suffer for the opposite reason, overwatering of the plants, which results in too luxuriant growth, late opening of the bolls, greater damage from frost, and more difficult picking. Planting early is desirable not only to secure the advantage of the longer season but because the young plants are likely to show more normal habits of branching and fruiting if very hot weather is not encountered during the early stages of growth. Withholding irrigation from the young plants has the same object of avoiding too rapid growth, and the methods of thinning and spacing permit additional control of the behavior of the plants in the interest of early and abundant fruiting. Overluxuriance and late bearing are among the most frequent causes of low yields.

LATE THINNING AND CLOSE SPACING.

The Egyptian-cotton plant makes a very luxuriant growth on the irrigated lands of the Southwest. Because of this fact, it was

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[1] Hudson, E. W. Growing Egyptian Cotton in the Salt River Valley, Arizona. U. S. Dept. Agr., Farmers' Bul. 577, 8 p. 1914.

[2] A method of accomplishing this has been described. See Hastings, S. H.. A lister attachment for a cotton planter, U. S. Dept. Agr., C. P. & B. I. Cir. 2, 3 p., 1 fig., 1917.

thought necessary at first to plant the rows wide apart (as much as 5 feet) and to thin severely, leaving the plants finally $2\frac{1}{2}$ to 3 feet apart in the row. Under these conditions each plant attained a large size and produced several long vegetative branches, or "limbs." It was also customary at first to do the thinning, or "chopping" as it is called, when the plants were very small and had only two or three leaves in addition to the seed leaves. While this system of planting and thinning sometimes gave good yields, it was found that the crop was so late in maturing as to be in danger of frost injury in the autumn, and also that the large size of the plants and their numerous vegetative branches made the picking very difficult and expensive.

Closer investigation of the branching habits of the plant developed the fact that these troublesome vegetative branches could be suppressed by delaying the thinning until the plants are 8 to 10 inches high and have 10 to 12 normal leaves, and by leaving the plants closer together in the row.[1]

The best spacing distance for the plants has been found to depend somewhat upon local and seasonal conditions. Mr. E. W. Hudson states that on rich alfalfa land and with irrigation properly managed 6 to 8 inches is about the right distance, while on new land the plants can safely be left 4 inches apart. This conclusion was reached, however, as a result of experiments with the Yuma variety. Plants of the Pima variety, being less inclined to become limby and having their lower fruiting branches better developed, should probably be spaced not closer than 10 to 12 inches on rich land. The thinning should be done in such a way as to result in suppressing practically all of the vegetative branches without stunting the growth of the central stem or shading too much the lower fruiting branches.

If growth becomes more luxuriant than was expected at the time of thinning, injurious crowding may still be avoided by taking out every second or third plant. Another expedient is the cutting out of every third row, which may be justified under extreme conditions of luxuriance, even after the plants have reached the flowering state, in order to keep the vegetation from becoming too dense to permit a normal development of the fruiting branches. That more space is required for plants that have not been held in check sufficiently in the early stages does not mean that advantages could be gained by wide spacing at first, which would result in still larger numbers of vegetative branches. The principle to be kept in mind is that the suppression of the vegetative branches makes it possible to

[1] These investigations were made by Mr. O. F. Cook and his assistants, and the details of the investigations, as well as the cultural recommendations resulting from them, have been published in several bulletins and circulars, for the titles of which see the last section of this paper on the literature of the industry.

secure a better development of the lower fruiting branches, those that contribute to the production of an early crop.

This new method of delayed thinning and of closer spacing of the plants has resulted in a much earlier development of the crop, as well as in making the picking much easier and cheaper. The time and manner of thinning are so important that they merit the closest personal attention of the grower, the more so as it is impossible to lay down general rules which will be equally well suited to each type of soil and to each season.

UNDESIRABILITY OF RATOONING EGYPTIAN COTTON.

The winters of southern Arizona and California are often mild enough to allow many of the old cotton stumps to remain alive in the ground, and it is possible to grow a second crop from them. This has suggested the ratooning of Egyptian cotton, a practice which has recently had some advocates in the Salt River Valley. Ratooning was formerly practiced in Egypt, but the system was discontinued in that country because of the poor quality of the fiber produced. The practice has also been thoroughly tested with Durango cotton in the Imperial Valley, where the results were unsatisfactory.

While ratooning saves the labor of spring planting and results in the earlier maturity of the crop, it has no other advantage. A perfect stand can rarely be had, and the seedling plants with which the gaps must be filled ripen later than the ratooned plants and produce fiber of different length and quality, making it impossible to obtain a uniform product from the field. It is questionable whether the very early ripening of the ratooned cotton is really a benefit, since it necessitates picking during the hottest season of the year. It would also be difficult to keep the land from becoming weedy if this method were followed. Finally, the practice of leaving the old stumps in the ground would favor the increase of such injurious insects and fungi as might gain a foothold in the locality. The advisability of replanting the fields each year with the best seed obtainable can not be too strongly urged.

ENEMIES OF THE CROP.

Fortunately, no very serious diseases or insect enemies of the crop have yet appeared in the Salt River Valley. A weevil, very closely related to the Mexican cotton boll weevil and capable of feeding upon and depositing its eggs in the bolls of cotton, is native to the mountains of southern Arizona, occurring on a wild plant somewhat nearly related to the cotton plant.[1] Neither this weevil nor the true Mexican boll weevil has as yet been observed in the cotton fields

[1] Cook, O. F. A wild host plant of the boll weevil in Arizona. *In* Science, n. s., v. 37, no. 946, pp. 259–261. 1913.

of the Salt River Valley. An aphis commonly attacks the young plants, and in 1914 it persisted in large numbers until late in the summer, but it has not been shown that this insect causes serious damage to the crop. Bollworms occur in small numbers, but have not thus far been a source of appreciable damage. The dreaded pink bollworm, which has recently played havoc with the cotton crop of Egypt and of Mexico, was discovered in 1917 at a few localities in Texas, but has not been observed in Arizona and California. It is to be hoped that measures taken by the Federal Horticultural Board will prevent its becoming established in the United States.

A sucking bug, of the group known as "cotton stainers," has recently caused some damage to cotton in Arizona.[1]

Certain fungous diseases, while rather common, do not appear to be severely injurious. The seedling cotton plants are subject to attack, especially when cold weather occurs after planting, by a species of Rhizoctonia, causing the disorder known as "sore shin." When this disease is very prevalent, some replanting is likely to be necessary, but the plants which survive soon cease to show any effects of the trouble. Small areas, particularly in old fields which have previously been in alfalfa, are subject to a root rot, which toward the end of the summer causes the cotton to die rapidly in well-defined spots. The percentage of the total acreage thus affected is small, and the disease does not appear to spread rapidly through the soil or to be a serious factor in production when a suitable rotation of crops is followed.

The cotton seedlings are also subject to a disorder known as leaf-cut,[2] which is apparently a physiological derangement not associated with a parasitic organism. The symptoms are mutilation of the leaves and sometimes the abortion of the growing point of the stem, resulting in the malformation of the plants most seriously affected. Since the plants are subject to this disorder only while very young, the system of late thinning eliminates its effects by permitting the "chopping out" of the malformed plants.

CONDITIONS OF SUCCESSFUL EGYPTIAN-COTTON PRODUCTION.

The experience gained in connection with the establishment of the community growing of Egyptian cotton in the Salt River Valley

Bailey, Vernon. The wild cotton plant (*Thurberia thespesioides*) in Arizona. *In* Bul. Torrey Bot. Club, v. 41, no. 5, pp. 301–306, 2 fig. 1914.

Coad, B. R. Relation of the Arizona wild cotton weevil to cotton planting in the arid West. U. S. Dept. Agr. Bul. 233, 12 p., 4 pl. 1915.

[1] Morrill, A. W. Eighth Ann. Rpt., Arizona Comm. Agriculture and Horticulture, 1916, pp. 46–48.

[2] Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 120, pp. 29–34, 1 fig. 1913.

makes it possible to formulate the conditions which appear to be indispensable to the successful production of this crop in the United States. These are, briefly, (1) a growing season of about nine months, or several weeks longer than is required to mature a full crop of Upland cotton; (2) a reliable supply of water for irrigation; (3) labor sufficient to pick the acreage planted; (4) absence of other types of cotton in the locality, as otherwise pure seed and a uniform fiber can not be maintained; (5) an acreage sufficient to warrant the purchase of roller gins and other equipment and the employment of a competent classer in order to market the cotton in even-running lots of commercial size; and (6) the cooperative organization of the growers for the purpose of maintaining the seed supply, operating the gins, and marketing the crop.

Communities in which all of the above conditions can not be met are advised not to undertake the growing of Egyptian cotton. In any event, a new community which contemplates the growing of this crop should experiment at first on a small scale and under expert advice, in order to make sure before investing capital in the enterprise that the climatic and soil conditions are favorable to producing large yields and a good quality of fiber.

CONCLUSION.

The history of the establishment of Egyptian-cotton production in the Salt River Valley is believed to have more than a special or local interest, since it offers a good illustration of the numerous biological, agronomic, social, and economic difficulties encountered in developing a new agricultural industry and furnishes suggestions as to how these complex and diversified problems may be successfully solved. That cooperation is the keynote of success has become very clear in the progress of the present enterprise. In this instance cooperation has been maintained along the following lines:

(1) Cooperation among the investigators has brought to the solution of the special problems different equipments of technical training and knowledge and different points of view, while their collective judgment has been focused upon matters of general policy. The cordial and effective cooperation of the administrative officers of the Department of Agriculture has also been an important factor in this connection.

(2) Cooperation among the growers has made it possible to produce and market the crop economically and to maintain the uniformity and high quality of the variety grown.

(3) Cooperation between the growers and the investigators has made it possible to put into effect without delay the most improved methods of production and marketing. This cooperation has been maintained by personal contact, since, in addition to the field agents

of the department who have worked constantly in the community, members of the Committee on Southwestern Cotton Culture have made frequent visits to the Salt River Valley. The attitude of the officers and members of the growers' associations in their cooperation with the Department of Agriculture has been of the most cordial and helpful character and has been a very important factor in the establishment of the industry.

(4) Cooperation with the cotton manufacturers on the part of both investigators and growers has also contributed largely to the development of the industry. Manufacturers have assisted most willingly and effectively in making spinning tests of the product from time to time, and in furnishing both to the Department of Agriculture and to the growers' associations useful information concerning the cotton. This information has guided the growers to better methods of handling the product and has given the investigators helpful suggestions in connection with the breeding work. Some of the manufacturers interested in this type of cotton have visited the Salt River Valley in order to learn at first hand the condition and prospects of the industry, while representatives of the growers' associations and of the department have been welcome visitors at mills where the cotton is being utilized.

The policy of the Department of Agriculture in encouraging the production of long-staple cotton on the community basis is beginning to be appreciated by manufacturers and buyers, many of whom now realize that in order to obtain year after year ample quantities of cotton of unchanging character they must look to localities where the farmers are organized to grow only one kind of cotton, to prevent deterioration of the type by seed selection, and to class and market their crop as a unit.

LIST OF PUBLICATIONS BEARING ON EGYPTIAN-COTTON GROWING IN THE SOUTHWESTERN STATES.

The following is a list of publications dealing with the activities of the United States Department of Agriculture in connection with the establishment of Egyptian-cotton growing in the Southwest. Several of the publications listed do not deal directly with Egyptian cotton, but are included because they describe different phases of the investigations which have formed the basis for the establishment of this industry.

Egyptian cotton in the southwestern United States. By Thomas H. Kearney and William A. Peterson. Bureau of Plant Industry Bulletin 128. Issued June 13, 1908.

Suppressed and intensified characters in cotton hybrids. By O. F. Cook. Bureau of Plant Industry Bulletin 147. Issued April 7, 1909.

Experiments with Egyptian cotton in 1908. By Thomas H. Kearney and William A. Peterson. Bureau of Plant Industry Circular 29. Issued April 16, 1909.

A study of diversity in Egyptian cotton. By O. F. Cook, Argyle McLachlan, and R. M. Meade. Bureau of Plant Industry Bulletin 156. Issued July 24, 1909.

Local adjustment of cotton varieties. By O. F. Cook. Bureau of Plant Industry Bulletin 159. Issued September 28, 1909.

Origin of the Hindi cotton. By O. F. Cook. Bureau of Plant Industry Circular 42. Issued December 11, 1909.

Mutative reversions in cotton. By O. F. Cook. Bureau of Plant Industry Circular 53. Issued March 21, 1910.

Cotton selection on the farm by the characters of the stalks, leaves, and bolls. By O. F. Cook. Bureau of Plant Industry Circular 66. Issued August 13, 1910.

Breeding new types of Egyptian cotton. By Thomas H. Kearney. Bureau of Plant Industry Bulletin 200. Issued December 23, 1910.

Dimorphic branches in tropical crop plants: Cotton, coffee, cacao, the Central American rubber tree, and the banana. By O. F. Cook. Bureau of Plant Industry Bulletin 198. Issued January 14, 1911.

Hindi cotton in Egypt. By O. F. Cook. Bureau of Plant Industry Bulletin 210. Issued May 11, 1911.

Arrangement of parts in the cotton plant. By O. F. Cook and R. M. Meade. Bureau of Plant Industry Bulletin 222. Issued October 3, 1911.

Dimorphic leaves of cotton and allied plants in relation to heredity. By O. F. Cook. Bureau of Plant Industry Bulletin 221. Issued November 22, 1911.

Cotton improvement on a community basis. By O. F. Cook. Yearbook, U. S. Dept. of Agriculture, for 1911, pp. 397–410.

Suggestions on growing Egyptian cotton in the Southwest. By Carl S. Scofield. Bureau of Plant Industry Document 717. Issued January 9, 1912.

Results of cotton experiments in 1911. By O. F. Cook. Bureau of Plant Industry Circular 96. Issued July 17, 1912.

The branching habits of Egyptian cotton. By Argyle McLachlan. Bureau of Plant Industry Bulletin 249. Issued September 20, 1912.

Improved methods of handling and marketing cotton. By Charles J. Brand. Yearbook, U. S. Dept. of Agriculture, for 1912, pp. 443–462.

Morphology of cotton branches. By O. F. Cook. Bureau of Plant Industry Circular 109, pp. 11–16. Issued January 4, 1913.

Heredity and cotton breeding. By O. F. Cook. Bureau of Plant Industry Bulletin 256. Issued January 13, 1913.

Preparation of land for Egyptian cotton in the Salt River Valley, Arizona. By E. W. Hudson. Bureau of Plant Industry Circular 110, pp. 17–20. Issued January 18, 1913.

Fiber from different pickings of Egyptian cotton. By Thomas H. Kearney. Bureau of Plant Industry Circular 110, pp. 37–39. Issued January 18, 1913.

Egyptian cotton as affected by soil variations. By Thomas H. Kearney. Bureau of Plant Industry Circular 112, pp. 17–24. Issued February 8, 1913.

A wild host plant of the boll weevil in Arizona. By O. F. Cook. Science, n. s., v. 37, pp. 259–261. Issued February 14, 1913.

A new system of cotton culture. By O. F. Cook. Bureau of Plant Industry Circular 115, pp. 15–22. Issued March 1, 1913.

The fundamentals of crop improvement. By W. T. Swingle. Bureau of Plant Industry Circular 116, pp. 3–10. Issued March 8, 1913.

The abortion of fruiting branches in cotton. By O. F. Cook. Bureau of Plant Industry Circular 118, pp. 11–16. Issued March 22, 1913.

Leaf-cut, or tomosis, a disorder of cotton seedlings. By O. F. Cook, Bureau of Plant Industry Circular 120, pp. 29–34. Issued April 5, 1913.

Factors affecting the production of long-staple cotton. By O. F. Cook, Bureau of Plant Industry Circular 123, pp. 3–9. Issued April 26, 1913.

Egyptian cotton culture in the Southwest. By Carl S. Scofield. Bureau of Plant Industry Circular 123, pp. 21–28. Issued April 26, 1913.

Agriculture on the Yuma Reclamation Project. By Carl S. Scofield. Bureau of Plant Industry Circular 124, pp. 3–8. Issued May 3, 1913.

Cotton farming in the Southwest. By O. F. Cook. Bureau of Plant Industry Circular 132, pp. 9–18. Issued July 19, 1913.

The occurrence of a cotton boll weevil in Arizona. By W. Dwight Pierce. Journal Agricultural Research, v. 1, no. 2, pp. 89–96. Issued November 10, 1913.

Seed selection of Egyptian cotton. By Thomas H. Kearney. U. S. Dept. of Agriculture Bulletin 38. Issued November 19, 1913.

Cotton as a crop for the Yuma Reclamation Project. By the Committee on Southwestern Cotton Culture. Bureau of Plant Industry Document 1009. Issued December 1, 1913.

Notes on the entomology of the Arizona wild cotton. By W. D. Pierce and A. W. Morrill. Proceedings Entomological Society of Washington, pp. 14–36, v. 16, no. 1. Issued March 1, 1914.

The relation of cotton buying to cotton growing. By O. F. Cook. U. S. Dept. of Agriculture Bulletin 60. Issued February 16, 1914.

Growing Egyptian cotton in the Salt River Valley, Arizona. By E. W. Hudson. U. S. Dept. of Agriculture, Farmers' Bulletin 577. Issued March 14, 1914.

Mutation in Egyptian cotton. By Thomas H. Kearney. U. S. Dept. of Agriculture, Journal of Agricultural Research, v. 2, no. 4, pp. 287–302. Issued July 15, 1914.

The wild cotton plant (*Thurberia thespesioides*) in Arizona. By Vernon Bailey. Bulletin Torrey Botanical Club, v. 41, pp. 301–306. Issued May 29, 1914.

Single-stalk cotton culture. By O. F. Cook. Bureau of Plant Industry Document 1130. Issued December 14, 1914.

Relation of the Arizona wild cotton weevil to cotton planting in the arid West. By B. R. Coad. U. S. Dept. of Agriculture Bulletin 233. Issued May 27, 1915.

Single-stalk cotton culture at San Antonio. By Rowland M. Meade. U. S. Dept. of Agriculture Bulletin 279. Issued August 24, 1915.

Custom ginning as a factor in cotton-seed deterioration. By D. A. Saunders and P. V. Cardon. U. S. Dept. of Agriculture Bulletin 288. Issued September 7, 1915.

The handling and marketing of the Arizona-Egyptian cotton of the Salt River Valley. By J. G. Martin. U. S. Dept. of Agriculture Bulletin 311. Issued November 26, 1915.

Community production of Durango cotton in the Imperial Valley. By Argyle McLachlan. U. S. Dept. of Agriculture Bulletin 324. Issued December 22, 1915.

Community production of Egyptian cotton in the United States. By C. S. Scofield, T. H. Kearney, C. J. Brand, O. F. Cook, and W. T. Swingle. U. S. Dept. of Agriculture Bulletin 332. Issued January 13, 1916.

Comparative spinning tests of the different grades of Arizona-Egyptian with the Sea Island and Sakellaridis Egyptian cottons. By Fred Taylor and William S. Dean. U. S. Dept. of Agriculture Bulletin 359. Issued March 30, 1916.

Tests of Pima Egyptian cotton in the Salt River Valley, Arizona. By Thomas H. Kearney. U. S. Dept. of Agriculture, A. & D. R. P. I. Circular 1. Issued December 6, 1916.

Cotton pests. By A. W. Morrill. Eighth Annual Report, Arizona Comm. Agriculture and Horticulture, pp. 45–49. Issued December 30, 1916.

A lister attachment for a cotton planter. By Stephen H. Hastings. U. S. Dept. of Agriculture, C. P. & B. I. Circular 2. Issued March 27, 1917.

A plant industry based upon mutation. By Thomas H. Kearney. In Journal of Heredity, v. 9, pp. 51–61 (1918).

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 743

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. April 17, 1919

THE AVOCADO IN GUATEMALA.

By Wilson Popenoe,

Agricultural Explorer, Office of Foreign Seed and Plant Introduction.

CONTENTS.

IMPORTANCE OF THE AVOCADO.

Probably no other country possesses such an abundance of fine avocados as Guatemala. Not all Guatemalan avocados are exceptionally choice, but scattered throughout the highlands of the Republic are many trees of unusual merit. A wide variation in characteristics exists. Fruits of some varieties are no larger than hens' eggs; others weigh fully 3 pounds. The shapes range from long and slender to oblate. The surface is sometimes rough and warty, sometimes smooth. The color may be green, maroon, purple, or almost black. Many varieties have proportionately large seeds, others small. Most important of all, there are numerous varieties whose deep yellow flesh is of the smoothest texture and has the richest, most agreeable flavor.

Since the soil was cleared in the lower Motagua Valley for banana plantations—now thousands of acres in extent—the production of avocados is insignificant in comparision with that of bananas; but to the native Guatemalans, especially the Indians, who represent more than half the total population, the avocado is still in most regions the more important. Bananas are grown mainly for export, while the entire avocado crop is consumed locally.

The abundance of avocados, their cheapness, and the long season during which they are available make it possible for even the poorest natives in all the principal avocado regions to use them as a daily article of food throughout more than half the year. An avocado, four or five tortillas (small round cakes of coarsely ground maize), and a cup of coffee—by many Indians these are considered the constituents of a good meal. The cost of such a meal is seldom over 2 cents, for outside the larger cities avocados are rarely sold for more than half a cent each.

The three races of avocados at present cultivated in the United States are all found in Guatemala, but the Guatemalan race is the only one which is very common. The West Indian race is limited to the lowlands up to 2,500 feet in altitude, and even in this zone is much less abundant than the Guatemalan in the higher zone which it occupies, extending from 2,500 feet (rarely lower) to 7,500 feet, and above this in occasional instances to 8,500 feet. The Mexican race is found only in the highlands, and few trees are in cultivation. A distinct species of Persea, closely resembling the avocado and known as coyo or shucte, is as extensively grown in some sections of the country as the avocado itself.

EXTENT OF AVOCADO CULTURE IN GUATEMALA.

No orchards or regular plantations of avocados are found in Guatemala. Most of the trees occur singly or in small numbers around the houses of the natives. The avocado in Guatemala is essentially a dooryard tree. In certain regions, however, considerable numbers of trees are found in coffee plantations, owing indirectly to the use of shade for coffee bushes. Avocado trees often spring up in the plantations from seeds cast aside by laborers or coffee pickers after eating the fruit. Where they do not interfere seriously with other trees these avocados frequently are allowed to grow (Pl. I), ultimately becoming a part of the shade-tree system and at the same time in many cases furnishing fruit of commercial value.

Naturally the number of avocado trees in coffee plantations is comparatively small. Even the largest fincas, which contain thousands of shade trees, contain not more than one or two hundred avocados, and it is unusual to find more than 50 or 75.

No data regarding the annual production of avocados in Guatemala are available. While avocados are grown in practically all parts of Guatemala, certain regions are especially renowned for their product and supply most of the fruits sold in the larger cities and towns. These regions all lie at elevations above 2,500 feet and are not only the greatest producers of avocados but the great horticultural centers of the republic. Favored by climatic conditions and possessing an exceedingly fertile soil, they have long been cultivated intensively by the Indians.

Antigua, the former capital of Guatemala, which lies about 25 miles from the present capital, is the center of one of the leading avocado regions, perhaps also one of the greatest in the world both for quality and quantity of the fruit, though in quantity it soon will be outclassed by the avocado districts of Florida and California.

Antigua lies in a beautiful valley (Pl. II), whose floor is about 5,100 feet[1] above the level of the sea. It is protected on the north, east, and west by towering volcanos and high hills, and to the south there is an opening toward the ocean which permits warm breezes to enter from the Pacific and keep the valley at a fairly equable temperature throughout the year. The soil is of volcanic origin, deep, friable, moist, and very fertile. Practically every foot of ground in the valley is planted to some agricultural or horticultural crop. Coffee is the principal commercial product, but maize and black beans are grown extensively, and many fruits abound in the dooryards of the inhabitants. Besides the avocado, there are oranges, cherimoyas (called anonas in Guatemala), mombins or jocotes (*Spondias mombin* L.), guavas, injertos (*Achradelpha viridis* O. F. Cook), loquats, white sapotes or matasanos (*Casimiroa edulis* La Llave), and peaches. During the first six months of the year large quantities of avocados are carried from the gardens and coffee fincas of Antigua to the markets of the city of Guatemala.

Another important center of avocado culture is Panajachel, on the northern shore of Lake Atitlan, at an elevation of about 5,300 feet. This town lies on an alluvial plain at the mouth of a small valley, sheltered from cold winds off the highlands to the north by its position at the foot of high bluffs. It grows much coffee and immense quantities of onions, which are carried to all parts of the Republic on the backs of Indians. Many avocado trees are scattered through the coffee plantations and gardens of this little valley, and from here the fruit is carried by the Indians to Solola, Quezaltenango, and other towns of the highlands.

Far to the north of the city of Guatemala, in the great Vera Paz coffee district, lies the town of San Cristobal, situated on the border of a small lake in a valley surrounded on all sides by high hills. The elevation is about 4,500 feet, the climate being warm and moist. Considerable numbers of avocado trees are found in the dooryards and coffee plantations of San Cristobal. From here much of the crop goes to Coban, which is the capital of the Department of Alta Vera Paz and one of the principal cities of the Republic. Some of the avocados of San Cristobal are among the very finest in all Guatemala.

[1] The elevations given in this bulletin, with a few exceptions, were obtained with an aneroid barometer of standard make. Frequent comparisons of barometer readings with railway levels at some of the more important stations in Guatemala showed the former to be dependable within a range of 100 feet. This is a sufficient degree of accuracy for the practical purposes of this work.

Amatitlan, a small town about 25 miles from the city of Guatemala, at an elevation of 3,900 feet, produces a large proportion of the avocados marketed in the capital, Antigua being the other principal source of supply. Owing to the lower elevation, the avocados of Amatitlan ripen earlier than those of Antigua.

Momostenango, to the north of Quezaltenango, at an elevation of 7,400 feet, is the highest point at which avocados are abundant, and they probably would not be common here were it not for the fact that the town is particularly sheltered by its location and has a warmer climate than is usual in Guatemala at this altitude. A large part of the crop is marketed in Quezaltenango. Because of the elevation, the season of ripening is much later than at Panajachel; hence, avocados from the two regions do not compete in the Quezaltenango market.

In addition to the places mentioned, avocados are abundant in many other regions, but in some the quality of the fruit is uniformly poor. For example, the avocados of Senahu, in Alta Vera Paz, are small and have very large seeds.

The regions mentioned produce only the Guatemalan race of avocados. The West Indian race is found along the coast and up the valleys of the principal rivers to elevations of about 2,500 feet. Nowhere, however, are large numbers of trees of this race grown. Here and there one is seen in a dooryard, and in such towns as Livingston there are a few, but they are never seen in such abundance as trees of the Guatemalan race in places like Antigua and Amatitlan.

POPULAR USES OF THE AVOCADO.

In Guatemala nearly all the products of the soil are used in the simplest manner possible; hence little ingenuity is exhibited in the methods of utilizing avocados.

The Guatemalan Indians, who are among the greatest consumers of avocados in the world, merely break the fruit in halves (rarely is it cut with a knife) and sprinkle a little salt over it. Even the salt sometimes is dispensed with. The soft pulp—the Indians rarely eat the avocado until the flesh has lost its firmness—is then scooped out of the skin with the fingers or a bit of tortilla.

Among Guatemalans of European blood the pulp of the avocado is very commonly added to meat soups at the time of serving. It is the custom in many hotels to place a ripe avocado in front of each guest, who opens the fruit, removes the pulp, and places it in his soup. The flavor imparted is exceedingly pleasant. This mode of serving the avocado seems worthy of adoption in the United States. Another common practice is to serve a salad called guacamól. This is composed of thoroughly mashed avocado pulp, vinegar, salt,

AN AVOCADO TREE IN A COFFEE PLANTATION AT ANTIGUA.

Several kinds of quick-growing trees are used in coffee plantations to furnish shade for the delicate coffee bushes. Avocados spring up from seeds dropped by workmen, and where they do not interfere with other trees they are often allowed to grow and form part of the shade system. Some of the best avocados in Guatemala are found in such situations as the one here shown. In order to keep them from interfering with the coffee bushes the lower limbs are usually pruned off, and a slender, erect form of tree is encouraged. (Photographed at Antigua, Guatemala, May 3, 1917; P17250FS.)

GUATEMALA'S GREATEST CENTER OF AVOCADO CULTURE.

The valley of Antigua, once the seat of the Spanish colonial government for all the territory between Panama and southern Mexico, is a rich agricultural region. Its principal crop is coffee, but it also produces large quantities of maize, beans, vegetables, and fruits. Among the latter the avocado takes first place. Both for quality and quantity of fruit, Antigua must be considered one of the greatest centers of avocado culture in tropical America. The city can be distinguished in the right center of the picture. (Photographed near Santa Maria de Jesus, Department of Zacatepequez, Guatemala, October 20, 1916; P16882FS.)

pepper, and finely chopped onion. It is a popular and very tasty dish, though not especially attractive in appearance.

An oil to be used as a pomade and as an emollient for burns is said to be produced from the avocado. Many Guatemalans profess to be familiar with this oil, but none was found who could furnish a sample. By some it was said also to be used as a cooking fat, but this was not verified. The oil is said to be extracted as follows: Slightly overripe avocados are selected and the flesh scooped out and thrown into a large kettle, which is then placed over the fire without the addition of water. After boiling slowly for about two hours, to exhaust most of the water contained in the pulp, the kettle is removed from the fire and the pulp placed in a muslin bag between two heavy stones, arranged so that the oil, as it percolates through the cloth, will run to one side of the lower stone and collect in a dish placed to receive it. The amount of oil obtained by this process can be only a small proportion of that contained in the fruit.

Among the Guatemalan Indians, avocado pulp is often rubbed upon the hair and scalp, it being considered highly efficacious in stimulating the growth of the hair. This practice has given rise to the maufacture of avocado soap, which is recommended for washing the hair. To prepare this soap, avocado pulp is mixed with some kind of fat. The product is manufactured commercially in Guatemala, but it seems open to question whether all the brands on the market really contain avocado pulp.

Among the Kekchi Indians of northern Guatemala the avocado is considered an excellent diet for caged song birds. Young birds, recently caught and caged, are fed daily on avocados in order that they may learn to sing promptly and well.

It is also considered, in certain parts of Guatemala, that avocados are excellent food for laying hens, greatly stimulating the production of eggs.

Hogs thrive on avocados. To North Americans, accustomed to paying 50 cents for a single fruit, this may seem an expensive diet for hogs, but where inferior avocados can be purchased for 6 or 7 cents a hundred and lard is 25 cents a pound it is a good investment to turn avocados into pork.

The medicinal uses of the avocado are few. For those suffering from acute rhinitis (cold in the head) the fruit is considered by the Kekchi Indians to be an excellent food. The seed is sometimes used as a remedy for dysentery and diarrhea. For this purpose it is pulverized and boiled in a small quantity of water, after which the liquid is taken internally. Its beneficial effect is probably due to tannin, of which the seed contains large quantities.

The wood of the avocado tree has little value. It is light in color and does not check (crack or split) upon drying. For this reason it is used by one factory in Antigua for the manufacture of potato mashers, rolling pins, and similar articles. It burns rapidly and gives off little heat; consequently it is not even esteemed as firewood, though it is commonly so used by the Indians.

CLIMATIC ZONES OF GUATEMALA.

In Guatemala, as in Mexico and some other parts of tropical America, three climatic zones are generally recognized. These are the tierra caliente (hot region), extending from sea level to an altitude of about 2,000 feet; the tierra templada (temperate region), comprising the territory between 2,000 and 6,500 feet; and the tierra fria (cold region), which extends from 6,500 feet to the upper limit of cultivation, about 10,000 feet.

It is not to be inferred that the temperate region has a climate similar to that of the Temperate Zone proper, but only that it is cooler than the lowlands of the hot region. The cold region, in turn, is not necessarily visited by snowstorms in winter, but is merely cooler than the temperate region, owing to its greater elevation. The lower and upper limits of each zone are exceedingly indefinite and are variously fixed by different writers.[1]

For the study of a particular horticultural product, such as the avocado, a clearer idea of conditions can perhaps be obtained if the climatic zones are based upon the presence of certain fruit trees whose requirements with regard to temperature are fairly well known to residents of the warmer portions of the United States. Working from this angle, it seems more appropriate to term the three zones tropical, subtropical, and semitropical, thus indicating more accurately the character of their climates viewed from a horticultural standpoint. However, it is impossible to fix definitely the limits of each zone, since the characteristic trees will be found occasionally in sheltered situations considerably above the ordinary limits of the zone, just as some of the tropical fruit trees which can not be grown in ordinary situations in California or Florida occasionally succeed in a protected spot. The limits must be fixed at the altitude where under ordinary conditions the characteristic trees commonly cease to be grown. With this understanding, the three zones of climate, or more properly of temperature, since rain-

[1] Pittier's classification of the climatic zones, based upon the distribution of vegetation with relation to temperature, though applying primarily to Costa Rica, doubtless will hold good in Guatemala as well. It seems one of the most accurate of these classifications, though, as explained by Pittier himself, it is artificial, the transition from one zone to another being quite unnoticeable. It is given here for comparison with the classification based upon the presence of characteristic fruit trees which is followed in this bulletin: Lower zone, from sea level to 3,300 feet (approximately), mean temperature 82° to 70° F.; intermediate zone, from 3,300 to 8,500 feet, mean temperature 70° to 57° F.; upper zone, from 8,500 feet to the highest summits, mean temperature 59° to 41° F.—(From "Plantas Usuales de Costa Rica.")

fall does not yet enter into the discussion, may briefly be described as follows:

Tropical zone.—The tropical zone includes the seacoast, the coastal plains, and the valleys of the larger rivers for a considerable distance back from the coast. It includes practically the entire department of El Peten, in northern Guatemala, but this region is very sparsely inhabited and of little horticultural importance. The characteristic trees of this zone are those which are commonly found on tropical seacoasts and will not tolerate cool weather. The breadfruit tree (*Artocarpus incisa* L.) is one of the best known. The most tropical of the anonas, such as the custard-apple (*Annona reticulata* L.) and the soursop (*A. muricata* L.), are at home in this zone. The tamarind (*Tamarindus indica* L.), although it can be grown in the lower edge of the subtropical zone, reaches its greatest development only in this. The same is true of the mango. The star-apple (*Chrysophyllum cainito* L.) is found only in this zone. All the commercial banana plantations of Guatemala lie within this zone, but the banana is cultivated on a small scale in the subtropical zone up to altitudes of 5,500 or 6,000 feet. The pineapple is grown commercially only in this zone. The only race of avocados commonly cultivated is the West Indian. The mamey (*Mammea americana* L.) and the sapote (*Achradelpha mammosa* (L.) O. F. Cook) are two other characteristic fruits.

The upper limit of altitude of this zone may be placed between 2,500 and 3,000 feet. The breadfruit tree is not cultivated quite as high as 2,500 feet, but on the other hand the mamey and the sapote are sometimes found above the 3,000-foot line. The highest point at which the West Indian race of avocados has been found is 2,500 feet.

Subtropical zone.—It may be considered, in general, that the principal horticultural zone of the Republic is the subtropical, which begins at the upper limit of the tropical zone, at altitudes between 2,500 and 3,000 feet, where the climate is decidedly warm but without the intense heat of the coast. At 4,000 to 6,000 feet it is rarely hot enough to be uncomfortable, but on the other hand there never are severe frosts. Toward the upper limit of this zone, which can be placed at 7,000 to 7,500 feet, frosts are more common, but rarely severe. Only in the semitropical zone are killing frosts experienced.

It is in this zone that the orange is most extensively grown. It is also the most important zone of avocado culture in Guatemala, being the one in which the Guatemalan race is cultivated. This race ascends occasionally into the semitropical zone, but most of the important centers of avocado culture lie at altitudes between 3,000 and 6,500 feet. The loquat is commonly seen in gardens throughout this zone. The cherimoya (*Annona cherimola* Mill.), the jocote (*Spondias mombin* L.), and the white sapote or matasano (*Casimiroa edulis* La Llave) are other fruits which may be considered characteristic.

The climate of certain parts of this zone will receive more detailed consideration under the discussion of the Guatemalan race of avocados.

Semitropical zone.—In the semitropical zone the principal fruits are those which have been introduced from farther north and are well known in the Temperate Zone. The peach, the apple, the pear, and the quince are abundant, replacing the avocado, the loquat, the orange, and the other fruits of lower elevations. The upper limit of orange culture seems to be about 7,500 feet. Taking this as the boundary of the subtropical zone, it is found that several of the characteristic fruits of that zone extend into the lower edge of the semitropical. Ascending above 7,500 feet, the cherimoya is the first to disappear, 8,000 feet seeming to be its uppermost limit; the avocado follows next, growing as high as 8,500 feet; and, finally, the matasano, which reaches 9,000 feet at the town of San Francisco el Alto, but was not found at greater elevations.

The fig is also grown in this zone; and the indigenous cherry (*Prunus salicifolia* H. B. K.), which is very common in gardens, descends into the subtropical zone, but is most frequent at elevations of 7,000 to 9,000 feet.

The upper limit of this zone is the upper limit of cultivation. One of the highest towns in Guatemala is San Francisco el Alto, north of Quezaltenango, at an elevation of 9,000 feet, but above this there are occasional huts, around which a few fruit trees may be found, while the grain fields extend to 10,000 feet or higher.

Summing up the characteristics of the three zones, it may be said that the lower or tropical zone is a region of comparatively high temperatures throughout the year, never experiencing cold weather, and hence adapted to the cultivation of those fruits which horticulturists term strictly tropical in their requirements. The subtropical zone, owing to its greater altitude, is free from the extreme heat of the tropical zone, but is never subjected to severe freezing. The lower levels of this zone are fairly warm throughout the year, but toward the upper limit the winters are decidedly cool, strongly resembling those of southern California. The uppermost zone, here called the semitropical, is too cold for the orange and the lemon, yet does not experience the type of winter weather familiar to residents of the eastern United States. Its minimum temperatures probably more closely approach those of southern Texas and central Florida. The principal fruits grown in this zone are the apple, peach, and pear.

In regard to rainfall, the quantity varies greatly in different parts of Guatemala, but the season during which it occurs is more or less the same throughout a large part of the country. Figures for several regions are given in considering the Guatemalan race of avocados. In general, it may be said that the rainy season begins in May and continues until October, being at its maximum during August and September. In the Vera Paz district of northern Guatemala, however, it rains during most of the year, the only dry months being March and April. On the coast the precipitation is usually much heavier than in the highlands, and in certain regions, such as the valley of the Motagua River between El Rancho and Gualan, there is comparatively little rainfall at any time of the year. In the highlands the dry season is often severe, practically no rain falling from November until April or May. The roads become deep in dust, the herbage turns brown, and many of the woody perennials drop their foliage.

CLASSIFICATION OF AVOCADOS.

The classification of avocado varieties has been the object of much investigation in California and Florida during the last few years. As with many other cultivated fruits, it has been found that the horticultural varieties fall into several distinct groups. Three of these, termed generally the Guatemalan, West Indian, and Mexican, are now recognized by most investigators.

Material on which to base a classification has been somewhat inadequate in the United States. Hence it has been thought that when the great avocado regions of tropical America came to be explored groups or races not yet known in the United States might be discovered. A canvass of the avocado-producing regions of Guatemala, however, has failed to bring to light any new groups, the investigations tending only to confirm the classification already in use in the United States. Mexico, with its vastly greater area of territory, may perhaps yield groups as yet unknown to horticulturists, but no critical study of the avocados of that country has yet been undertaken.

Perhaps the horticultural groups have been derived from distinct species of Persea. If not, they have at least become differentiated through the accumulation of variations during a long period of cultivation under different environmental conditions. In order to determine their exact status it becomes highly desirable to locate the wild prototype of each, if such a wild prototype still exists. This has not yet been done by anyone having in mind the classification of the cultivated avocados. The task is made difficult by the fact that the southern Mexican and Central American region, where the wild prototypes are probably to be sought, has been the scene of intense agricultural activity for centuries. The primitive forest has been leveled to the ground to make way for maize fields; the maize fields have been abandoned, the inhabitants of the region have emigrated to other parts, and the forest has again taken possession. After a period new peoples have arrived upon the scene, and the process has been repeated. This is indicated by archæological remains in many parts of this region.

Under these conditions the wild species from which our cultivated avocados are derived may have disappeared, and, on the other hand, trees which are found in the forest at the present day and have every appearance of being indigenous may have been placed there by the hand of man.

Lacking exact knowledge of the wild prototypes of these cultivated races, a comparison of the most primitive forms which can be found at present will bring out more racial characters, or at least emphasize existing ones more strongly, than will a comparison of the highly developed varieties found in cultivation, for cultivation tends to conceal the racial characters by bringing the various races to a common level. Thus, the exceedingly thick and hard outer covering of the fruit which is typical of the Guatemalan race and conspicuously present in the primitive avocados of Alta Vera Paz becomes thinner in many of the cultivated varieties and closely approaches the skin of the West Indian race in character. The fruit increases vastly in size, assumes various shapes, and the seed becomes proportionately smaller. Since cultivation tends to work the same changes in all of the races, it tends at the same time to conceal many of their distinguishing characteristics.

The term "race," which is here applied to the groups of varieties known in cultivation, seems more appropriate than the term "type," which is commonly used. The word "type" in this connection means nothing; the word "race," on the other hand, has a definite horticultural meaning which seems to be applicable here. A race is a group of seedlings which possess certain well-defined characteristics in common and will transmit these characteristics to their seedling progeny. This applies to the avocados under consideration, for each race has certain characteristics which never fail to be inherited by its seedlings.

The three cultivated races may be distinguished by the following characters:

Guatemalan race.—The foliage of the Guatemalan race is not anise scented; hence, is easily distinguished from the Mexican. It is usually deep green in color, a somewhat deeper green than that of the West Indian. The flowers are not so heavily pubescent as those of the Mexican. The fruit varies greatly in form and size, but always has a woody outer covering one-sixteenth to one-fourth of an inch thick. In some of the cultivated forms the skin or outer covering is scarcely thicker than in the West Indian race, but it is rarely so soft and pliable. The seed is comparatively smooth, and the two thin closely united seed coats adhere closely to it. The seed is very rarely loose in the cavity within the fruit.

West Indian race.—In the West Indian race the foliage is slightly lighter in color than in the Guatemalan, but, like the latter, devoid of the anise scent. The flowers are sometimes less pubescent than those of the Guatemalan, never more so, and always less pubescent than in the Mexican race. The fruits are variable in form and size, but the outer covering is soft and pliable and is rarely more than one-sixteenth of an inch thick. The seed is often rough, and the two seed coats frequently are thick and separated, at least over the distal end of the seed, one adhering to the cotyledons and the other being loose or adhering to the lining of the seed cavity.

Mexican race.—The foliage and sometimes the fruit of the Mexican race are distinctly anise scented, and both are usually smaller than in the Guatemalan and West Indian races. The flowers are more heavily pubescent than in either of the latter. Its fruits have a very thin, often membranous skin. The seed is commonly smooth; the seed coats are thin, either closely united and adhering to the cotyledons (occasionally three in number), as in the Guatemalan race, or separating, as in the West Indian.

AVOCADO CULTURE IN THE GUATEMALAN HIGHLANDS.

In reading the statements which follow it must be kept in mind that the Guatemalan race of avocados is being considered. None other is grown to any extent in the highlands, the Mexican race rarely occurring in Guatemala and the West Indian being confined to the lowlands. Separate paragraphs will be devoted to these two races farther on.

ORIGIN OF CHOICE VARIETIES OF THE PRESENT DAY.

The splendid avocados of to-day are doubtless the product of centuries of more or less unconscious selection on the part of the Guatemalan Indians, just as the choice fiberless mangos of East India have been produced through selection by the Hindus. In the case of the mango, however, the Hindu has been enabled to perpetuate an unusually choice variety by resorting to vegetative propagation. This appears never to have been practiced in Guatemala; hence, when a choice avocado tree grows old and dies the variety is lost.

Because of the moist climate of Alta Vera Paz, an avocado seed dropped by the roadside nearly always sprouts and develops into a tree. This has led to the avocado being found in a semiwild state throughout that region, often in the edge of the forest and at such distance from any present habitation as to suggest that the species is truly indigenous. The suspicion always arises, however, that a seed may have been dropped by some passing Indian or that a hut may have stood close to the spot at some past time. When going to work in their clearings the Indians commonly carry avocados with them as part of their noonday lunch. The seeds of these fruits, cast aside wherever the Indian chances to be at midday, give rise to many avocado trees in little-frequented places.

Though a careful search was made in the most promising sections of Alta Vera Paz for the wild avocado, no trees were found which it was felt could safely be considered indigenous. The primitive, half-wild forms so commonly seen, however, can without doubt be looked upon as the nearest approach to the wild species in so far as character of fruit is concerned, and a comparison of these forms with the choicest varieties in cultivation brings out some striking differences.

These half-wild avocados of Alta Vera Paz (Pl. III) are nearly always round, small in size, with a hard, thick outer covering and a very large seed, leaving little flesh. The smallest are no larger than walnuts. Most of them are little more than 2 inches in diameter. The shell—for it can be called such—is either green or purple and rough externally; in texture it is so hard and brittle that it breaks irregularly when an attempt is made to cut it. Occasionally it is as much as a quarter of an inch thick. The flesh is of good quality, but the quantity is very small. The seed is tight in the cavity, with the cotyledons smooth and the thin seed coats adhering closely. The fact that nearly all of these fruits are round would indicate that this can be considered the primitive shape, the pyriform and elongated avocados being found in cultivation.

When such fruits as these are contrasted with the splendid varieties of the Antiguan fincas, for example, the development which has been brought about in the avocado appears quite equal to that which has taken place in the northern fruits. The latter have been in the hands of horticulturists who have called to their aid not only the art of grafting but much skill in cultivation. The improvement of the avocado, on the other hand, has scarcely been a conscious process and has been carried on by a people who are preeminently agriculturists and not horticulturists.

Cook and others have spoken of the intimate knowledge which the Indians of Central America possess concerning the plants among which they live and of their specialized methods in the cultivation of staple food crops. They have a name for nearly every tree in the forest, are familiar with the habits of many plants, and possess well-defined beliefs concerning the medicinal uses of a large number. Their agricultural practices, though based upon tradition, are in many respects admirable. They have highly specialized varieties of maize to meet the various conditions of climate which are found throughout the region which they occupy, and they are well acquainted with the particular merits of these varieties.

They seem, however, to have devoted all their energies to the cultivation of field crops, fruits having received very little attention. With regard to the avocado, for example, it does not appear that the Indians cultivate the soil around the base of the tree, apply fertilizers of any sort, prune the tree, or bestow any care upon it. Ideas regarding the age at which seedling trees come into bearing are nearly always vague and rarely based upon accurate observation of even a single instance. It is rather remarkable, in fact, that the Indians should have so few definite ideas regarding a fruit which plays such an important part in their daily life as the avocado, for they are an intelligent and in many ways a capable people.

It can not be doubted, however, that the avocado has been planted by the Indians in their dooryards since a remote time. The native name for the fruit, *oh*, *okh*, or *on* in the principal Maya dialects of Guatemala,[1] and many other circumstances, indicate that it has been known to the Guatemalan Indians since the earliest times. The evolutionary processes which can be observed at the present day have doubtless been going on for centuries, and could the Indians have taken advantage of vegetative propagation to perpetuate the best varieties obtained by selection, avocados even more

[1] The aboriginal names of the avocado in the dialects of southern Mexico and Guatemala, according to Dr. Karl Sapper (Das Nördliche Mittelamerika), are as follows: *Ju* (Huasteca, according to Stoll); *ou* (Chicomulcelteca); *on* (Maya of Yucatan, according to Stoll); *on* (Maya of Peten, according to Stoll); *um* (Chol); *un* (Chorti); *un* (Chontal, according to Stoll); *on* (Tzental); *un* (Tzotzil, according to Stoll); *on* (Tozolabal); *on* (Motozintleca); *oj* (Mam); *on* (Jacalteca); *oj* (Aguacateca, according to Stoll); *oj* (Quiché, according to Stoll); *oj* (Cakchiquel, according to Stoll); *oj* (Tzutihil); *oj* (Uspanteca); *o* (Quekchi); *oj* (Pokonchi, according to Stoll); *oj* (Pokomam of Jilotepeque); *oj* (Pokomam, according to Stoll).

remarkable than those of to-day would certainly have been the result. Seed propagation has prevented the perpetuation of choice varieties, and it is only by raising the general level of the whole species that improvement has been accomplished.

Among the several factors working in unison toward the horticultural development of the avocado, the first which must be mentioned is the change brought about by removing the tree from its native home in the forest and planting it in dooryards and gardens, where the struggle for existence is eliminated and more favorable conditions for growth are supplied. This in itself would undoubtedly tend to increase the size of the fruit.[1] Among many trees seen in a half-wild state in northern Guatemala, growing among thick scrub along the roadside or maintaining a foothold in the edge of the forest, not one produced fruits of large size. It is not reasonable to believe that all of these trees are from seeds of inferior fruits, since many of them come from avocados brought from the villages by the Indians. Unfavorable conditions of growth must have an important effect in limiting the development of the fruit.

Once removed from the forest and planted around the huts of the Indians, other factors come into play. The most important of these, as far as can be observed at present, are (1) the destruction of trees producing inferior fruit and the preservation of good ones, and (2) the carrying to market of nothing but the best fruits, thus disseminating seeds of good parentage and restricting the dissemination of poor ones. Both these factors perhaps can be considered unconscious selection on the part of the Indians. The second is not the result of a desire to improve the avocado by disseminating good seeds, but is due to the market demand for good fruits.

Both factors can often be seen in operation. In coffee plantations, when it is necessary to cut down avocado trees to make room for coffee or other crops, the trees known to produce inferior fruits are taken first and the best ones are often spared. The Indians when cutting out old trees around their houses will frequently save the avocado which bears the best fruits.

During the ripening season the fruit from the best trees is the first to be picked and taken to market, many of the poorer trees going unpicked, in which case the fruits fall to the ground and are eaten by the zopilotes (buzzards). The fruits purchased in the market are often carried many miles, since the Indians come into the small towns of Guatemala from great distances. When the fruits are eaten the seeds are cast aside. The climatic conditions are so favorable, at least during a part of the year, that a seed dropped upon the ground will sprout, take root, and develop into a tree. Once sprouted and estab-

[1] Increase in the size of the fruit due to increased supplies of food is believed at the present time not to be inherited.

lished, the Indian is loath to destroy it; hence, many new trees are started each year. It appears that comparatively few avocados are intentionally planted by the Indians, most of the trees being volunteers.

SOILS.

The principal avocado districts of the highlands differ considerably in their soil types. Clays, alluvial loams, and loose soils of volcanic origin are most common.

Alta Vera Paz is a limestone region in which most of the soils are clays or clay loams of reddish, tawny, or blackish color. When wet many of these soils have an almost greasy consistency. They are usually of considerable depth. In the Valley of San Cristobal, the most important avocado center in northern Guatemala, blackish clays predominate. In many spots there is a surface deposit of rich loam washed off the hillsides.

The clay soils of Vera Paz seem to produce a large and long-lived tree (Pl. IV). In no other part of Guatemala were larger avocados seen than in the vicinity of Coban and San Cristobal. If not well drained these soils would be objectionable, but Vera Paz is of such rough, rugged contour that it is rare to find an avocado standing on level ground.

Typical alluvial loam occurs at Panajachel, on the border of Lake Atitlan. This town lies at the mouth of a small valley, scarcely more than half a mile broad, with the mountains rising abruptly on both sides. When viewed from above, it can plainly be seen that the sediment carried down this valley is gradually building a delta in the lake. Most of the gardens which contain avocado trees are situated about half a mile up the valley from the present shore of the lake. The valley floor at this point is level, the soil varying from a fine black alluvium to gravelly loam, most of the cultivated area possessing rich black loam, easily worked and well adapted to the growing of truck crops and coffee, for which it is used. The avocado succeeds excellently here.

At Momostenango, north of the city of Quezaltenango, a curious mixture of red clay and volcanic tufa is encountered. Large masses of tufa, many feet in depth, are frequently exposed by erosion.

In the Antigua district the soil is more uniform in character than in many other sections of Guatemala. It is a loose, black, sandy loam of volcanic origin, mixed with alluvium and becoming a true loam on the valley floor, while on the slopes it is often so loose and coarse in texture as to suggest cinders. In most of the coffee plantations the soil seems to be of uniform character to a considerable depth. It is easily worked, fertile, and from several points of view an admirable avocado soil. Even at the end of the long dry season it is found to be moist a short distance below the surface, and it never becomes hard or cracks open, as the heavy clays do. It does not seem to produce quite so large a tree as the clay soils of Alta Vera Paz.

Everything considered, it seems that the clay loams or light clays are best adapted to avocado culture. Other soils, however, give good results. In the United States the avocado will succeed under a wide range of soil conditions; witness the excellent growth made in Florida on very sandy soils and in California on heavy clays of the adobe type, heavier and more tenacious than any seen in Guatemala.

GROWTH AND HABIT OF THE AVOCADO TREE.

At elevations of 4,000 to 5,000 feet in Guatemala the growth of the avocado tree is not so rapid as it is in California and Florida. This is mainly due to the mildness of the climate; there is none of the hot summer weather which produces such rapid growth in the United States. Another cause is the prevailing lack of cultural attention. Naturally a tree which is manured regularly and irrigated when rainfall is lacking will make more rapid growth than one which is supplied with an abundance of water during part of the year, is forced to withstand a long drought during the remainder, and never receives manures or fertilizers in appreciable quantities. In Guatemala, it must be remembered, many avocados are not even planted in favorable situations, but spring up from seeds cast aside by the natives. Under these conditions the first few years are often a severe struggle with the surrounding vegetation.

Under the comparatively favorable conditions of coffee plantations, the most trustworthy accounts place the bearing age of seedlings at six to eight years. In a few instances it was possible to verify the age at which certain trees produced their first fruits; this was never found to be less than 5 years and sometimes as much as 10. Many large trees with no fruit may be seen in practically any district, but these are trees that have borne in previous years.

Many large trees in Guatemala still in profitable bearing are said to be 50 or 60 years old. A 50-year-old tree seems to yield just as good fruit as younger ones. Some avocado growers affirm that a tree does not produce its best fruit until it is 20 or 25 years old.

In habit of growth there are two types of trees, the slender, erect type and the broad, spreading type, though there is no lack of intermediate forms.

Most of the trees seen in Guatemala have straight trunks which do not branch within 6 feet of the ground, and the crowns are broad, dome shaped, and fairly dense. The erect, slender type of tree with an open crown is less common except in Alta Vera Paz. The average size of mature trees, those 15 to 25 years of age, as seen in coffee plantations and gardens, is 30 to 40 feet in height, with a spread of equal distance when the trees are of the broad, spreading type, or with a spread of about 20 feet when they are of the slender type (Pl. V). Such trees as these have trunks 12 to 18 inches thick.

A tree 50 feet in height may be considered large, and one which is 60 feet has probably reached its maximum development under most conditions. The trunk of such a tree may be 4 feet thick, and the crown may be 50 or 60 feet in spread. Probably these dimensions are not attained until a tree is at least 50 years old.

There are differences in the character of the growth—its stiffness, brittleness, size, and so on—which do not appear of importance in old trees, but which will stand out more prominently when young budded trees are planted in the orchard and must be trained to a desirable form. In some trees the growths are long and slender, supple, and scarcely able to bear their own weight. Ultimately these growths tend to produce descending branches, keeping the crown close to the ground. Other trees make very short, weak growths, seeming to indicate a lack of vigor. In still others the wood is so brittle that the branchlets snap off when bent. The best trees make strong, healthy-looking growths, smooth and round (angular branchlets frequently indicate a weak grower), with the leaves placed about an inch apart and the axillary buds short, plump, and well developed.

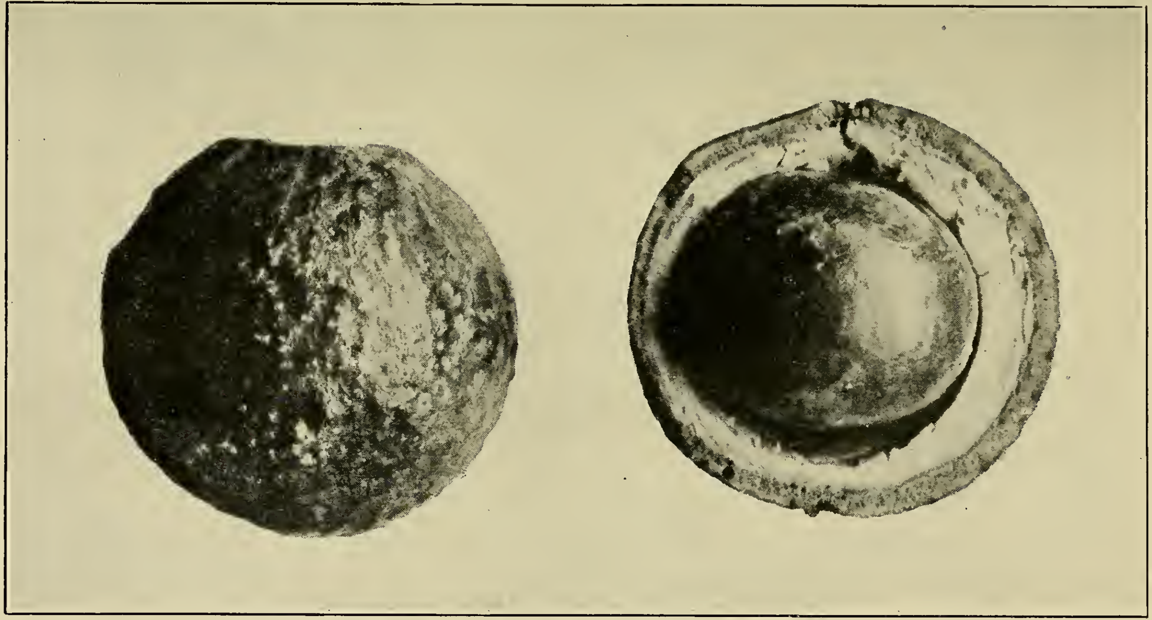
CULTURAL PRACTICES.

The amount of systematic attention given the trees by Guatemalan avocado growers is almost negligible. It is of interest, however, to consider the cultural conditions under which the trees occur and the apparent effect of these conditions upon growth as well as fruit production.

As already stated, comparatively few avocados in Guatemala are planted intentionally. It speaks well for the climate and soil that trees which develop under such conditions can reach large size and produce fruit. They do not receive the least attention from any one; the ground is never cleared of weeds or undergrowth, and the tree must in some instances carry on a constant struggle for existence.

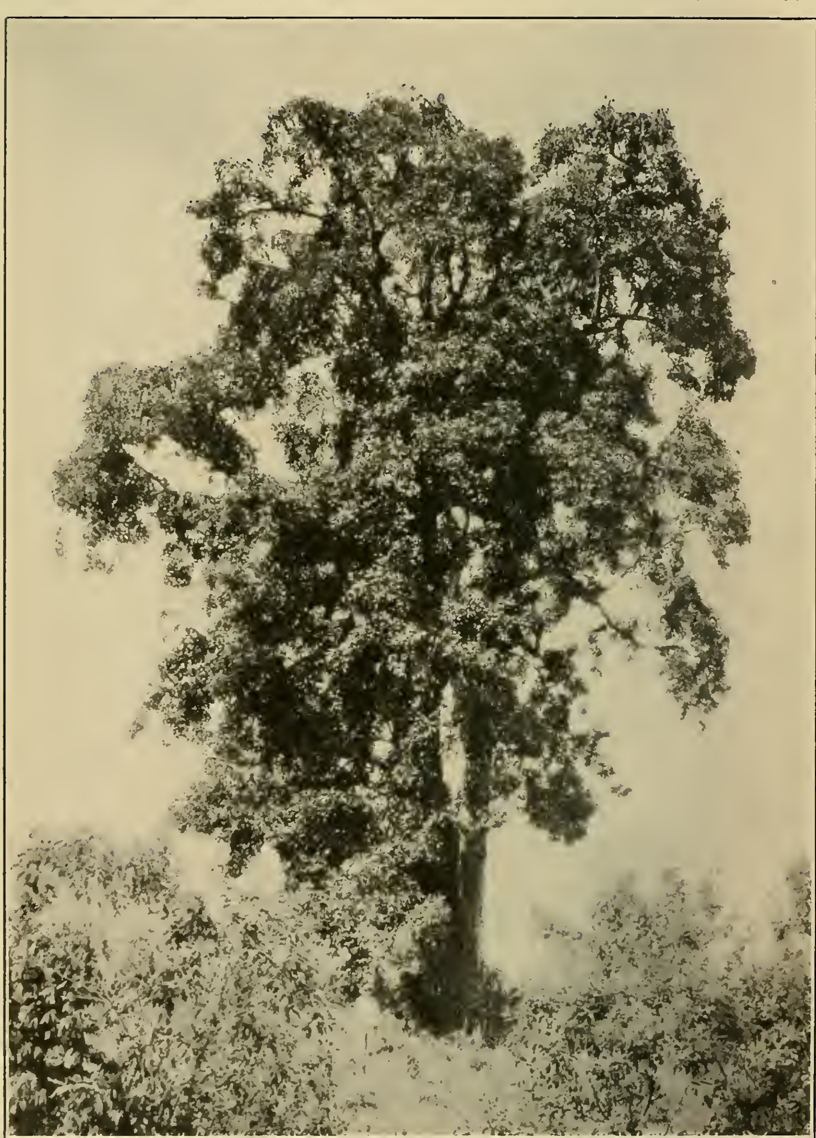
In coffee plantations or in dooryards of the natives, however, conditions are more favorable. Especially is this true of coffee plantations, since the cultural attention given the coffee bushes necessarily affects the near-by avocado trees as well. Two or three times a year the ground is cleared of weeds with a heavy hoe. It is never cultivated deeply, and, in fact, the surface beneath avocado trees in many instances is not even scratched, since a heavy mulch of leaves collects and few weeds require to be removed.

The only pruning practiced is the removal, when the trees are young, of the lower branches, in order that the crown may be formed above the tops of the coffee bushes. This means that the trunk frequently does not give off any branches at less than 8 to 12 feet from



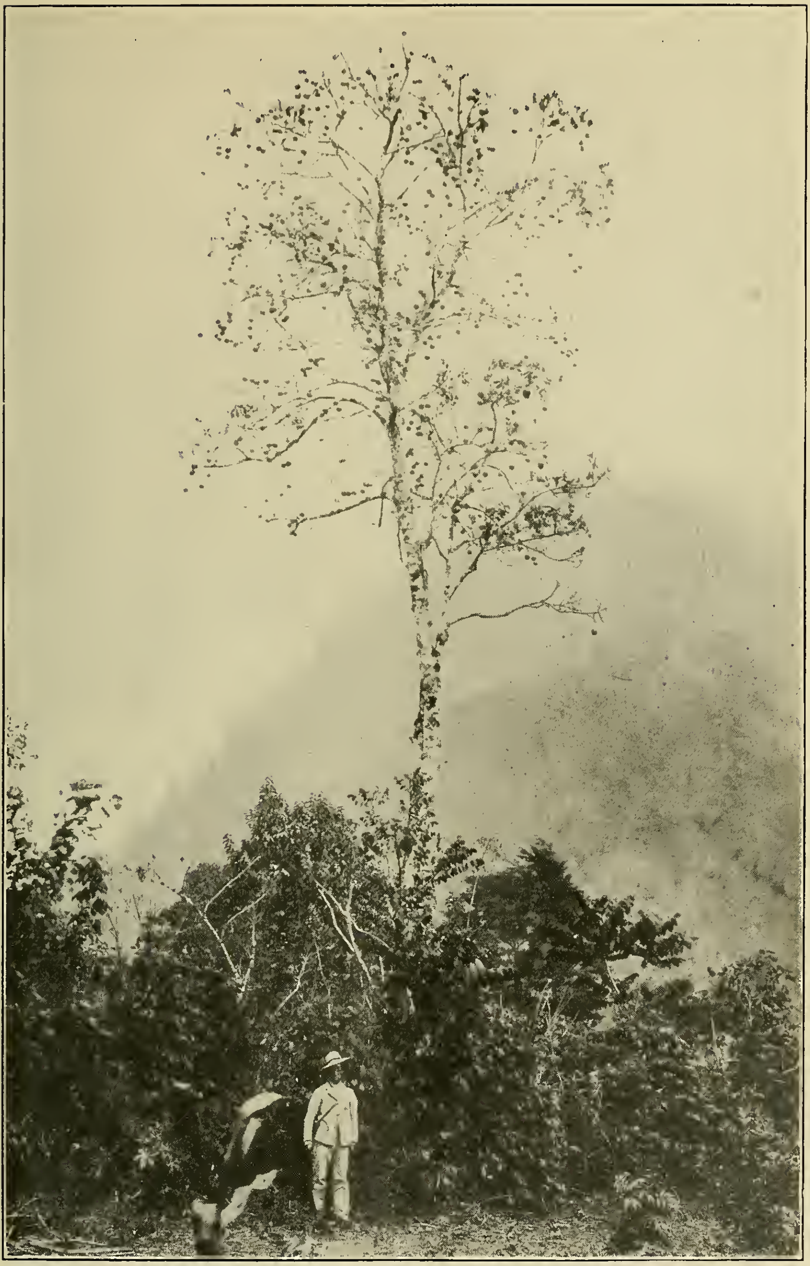
A PRIMITIVE FORM OF THE GUATEMALAN AVOCADO.

This fruit, which was produced by a half-wild tree on the edge of the forest near Senahu, Alta Vera Paz, is the most primitive in character of all those seen in Guatemala and probably may be considered as representing closely the prototype of the splendid varieties of the Guatemalan race which are found in dooryards and coffee plantations throughout the Guatemalan highlands. The outer covering is so thick and hard that it is difficult to break it without the use of some heavy instrument, and the seed is so large that there is little room for flesh. It is noteworthy, however, that there is no fiber running through the flesh, as is commonly the case in primitive avocados of the Mexican race. (Photographed, natural size, at Sepacuite, Alta Vera Paz, Guatemala, November 27, 1916; P16960FS.)



A LARGE AVOCADO TREE IN NORTHERN GUATEMALA.

The maximum size attained by the avocado in Guatemala is illustrated by this magnificent tree, which is growing near the town of Santa Cruz, Alta Vera Paz. The soil here is a heavy clay loam, the altitude about 4,500 feet, and the climate very moist. While its age is not known, the tree can not be much less than a hundred years old, and it is probably more. It is still bearing fruit, though it does not produce such heavy crops as younger and more vigorous trees. (Photographed at Santa Cruz, Alta Vera Paz, Guatemala, December 11, 1916; P16986FS.)

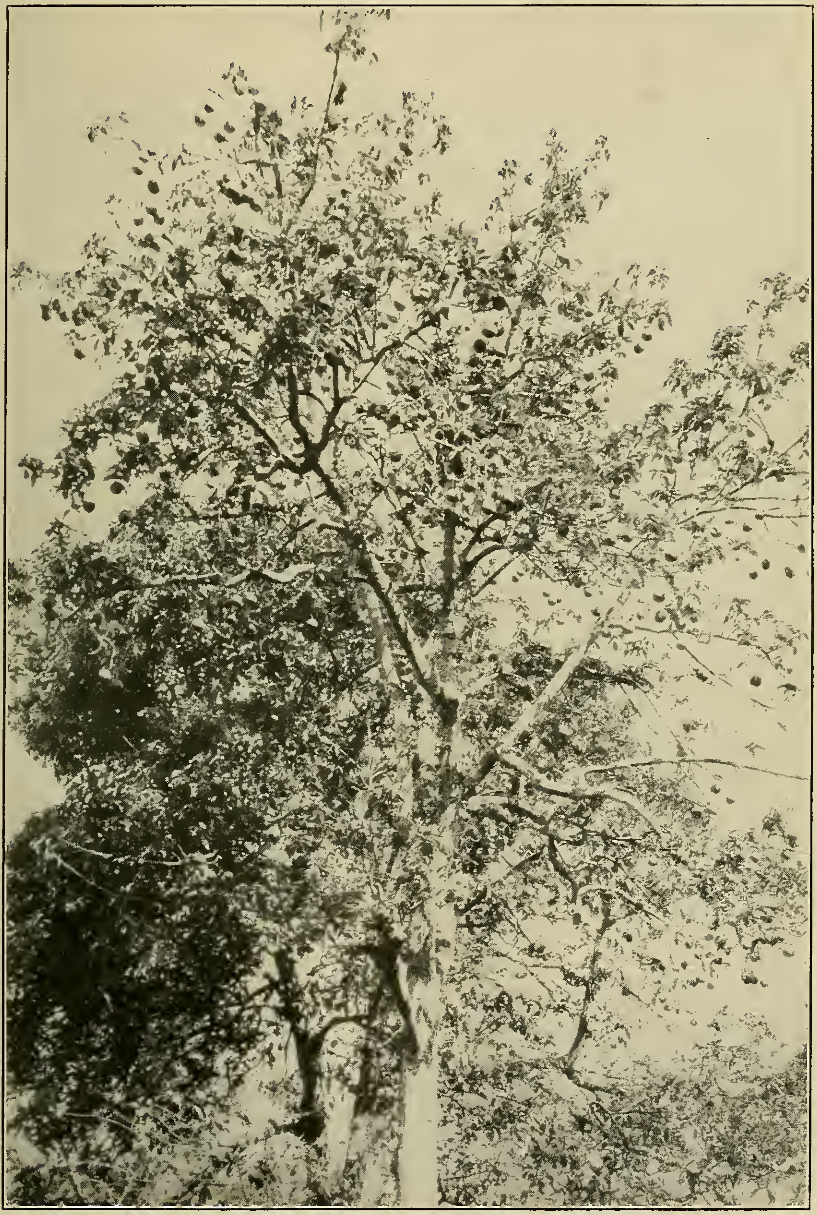


AN AVOCADO TREE DURING THE FLOWERING SEASON.

At the time of coming into flower the Guatemalan avocado commonly sheds most of its foliage, the new growth which appears bringing with it flowers as well as foliage to replace that which has been lost. The fruit is generally considered to be ripe when the tree comes into bloom, but it will remain on the tree for several months longer if allowed to do so, the flavor becoming richer with the passage of each month. The tall, slender tree here shown illustrates the common form which the avocado assumes in the moist climate of northern Guatemala. (Photographed at Purula, Baja Vera Paz, Guatemala, March 27, 1917; P17159FS.)

AN AVOCADO TREE OF GOOD FORM.

The common tendency in Guatemala is for avocado trees to become tall and slender. Trees such as the one here shown are of more desirable form, as they possess much more fruiting wood. It would be advisable, however, to head the tree much lower except for the fact that the Guatemalans desire to have the lowest limbs far enough above the ground to permit the soil to be worked close around the tree. Black beans have been planted under this tree, while maize, or Indian corn, can be seen in the background. (Photographed at Antigua, Guatemala, January 28, 1917; P17055FS.)



AVOCADO TREE AT ANTIGUA IN FULL BEARING.

This tree, which is growing in a coffee plantation, is not carrying an unusually heavy crop for a variety whose fruits do not weigh more than 1 pound. Rarely, however, will two such crops as this be produced consecutively, the Guatemalan avocados showing a strong tendency to irregularity in bearing. It will be noted that the fruit is all in the top of the tree. It is the custom in coffee plantations to prune off the lower branches of avocado trees to prevent their interfering with the growth of the coffee bushes. (Photographed at Antigua, Guatemala, February 22, 1917; P17100FS.)

AVOCADOS ON SALE IN ONE OF THE MARKETS OF THE CITY OF GUATEMALA.

Among the Guatemalans avocados are looked upon more as a food than as a salad fruit; hence, they are offered in the markets alongside bananas and coconuts, two other staple foodstuffs. The avocado is one of the cheapest foods obtainable, and there is scarcely a day in the entire year when an abundance of them is not offered for sale in this market. Avocados like those seen in the photograph are sold singly for the equivalent of half a cent, and a hundred of them can be purchased for 30 to 40 cents. (Photographed at the city of Guatemala, October 29, 1917; P17375FS.)

the ground (Pl. VI), and the lowest limbs in the crown are far out of reach. Where high winds are unknown, as in Guatemala, this method is not disadvantageous except that it reduces greatly the amount of fruiting wood and makes it somewhat difficult to pick the fruit. Even when not grown in coffee plantations the trees usually are encouraged to branch high, the crown being formed at least 6 or 8 feet above the ground.

During the dry season, which is long and severe in Antigua and several other regions, the trees are not irrigated. Yet they do not often show the effects of drought. Apparently the soil in Antigua is retentive of moisture, though toward the end of April orange trees in Antigua gardens often turn yellow and wilt from lack of water, while avocados in the same garden appear in perfect condition. This is not saying, of course, that avocado trees in the United States (or in Guatemala, for that matter) should not be abundantly irrigated during the dry season, for experience indicates that they should.

In Alta Vera Paz the climate is exceedingly moist, the rainfall exceeding 100 inches in some sections, distributed over 10 or 11 months of the year. The avocado seems perfectly at home in such a climate. Evidently it is able to stand extremes of moisture or drought without suffering.

As to the effect of unfavorable conditions upon fruit production, trees growing by the roadside or in waste places are often very productive, but their fruit is never as large as that from trees grown in the more favorable environment of the coffee plantations and the dooryards of the natives. Half-wild trees nearly always produce small fruits containing very large seeds. Often these fruits are so inferior that the natives do not even pick them.

REGULARITY OF BEARING.

Practically all Guatemalan avocado growers admit that the trees do not bear regularly; that is, a good crop is not produced every year. It is generally considered that a heavy crop will be followed by a light one or even by a crop failure, but no rule can be laid down which will apply to all trees. Individual trees differ in regularity of bearing. Some have been seen which bore a heavy crop one year and nothing the next; others which bore a heavy crop one year and an equally heavy one the next. While it may perhaps be stated as a general principle that a heavy crop will usually be followed by a lighter one, the question must be studied from the standpoint of each particular variety.

Irregularity in bearing is doubtless encouraged in Guatemala by the failure to practice thinning when an unusually heavy crop is produced and by inattention to cultural details. In the spring of 1917 there was a prolonged dry spell at the time when the young avocados were the size of marbles, and many trees cast their fruit. It seems quite probable that irrigation at this time would have saved the crop. In another case a crop was lost through the attacks of some insect when the fruits were about one-third grown. In many instances trees are allowed to overbear one season, crop failures the following year being the natural result.

Doubtless much can be done in the United States to control this matter. The most important thing, however, is to plant a variety which bears fairly regularly. There is certainly a wide range of variation in this respect.

YIELD.

Very large trees of the smaller varieties, whose fruits weigh 6 to 8 ounces, produce as many as 3,000 fruits in a single crop. Larger varieties, whose fruits are 18 ounces in weight, may produce as many as 1,000 fruits provided the tree is of mature size. A few examples of good production may be cited to illustrate what can be expected of Guatemalan varieties. A young tree in Amatitlan, not over 20 feet high, produced in 1916 a crop of 125 fruits, each weighing 16 to 18 ounces. In 1917 this tree produced double the number. A young tree in Antigua, scarcely 20 feet high, very slender, and with little fruiting wood, produced 300 fruits weighing 8 to 12 ounces each. Another young tree in Antigua, about 25 feet high, produced 100 fruits weighing 20 ounces each. This also was a very slender tree with little fruiting wood. Another, 35 feet high, with a broad well-branched crown, produced 300 fruits, each weighing 14 to 16 ounces.

These trees are not branched close to the ground, as they would be grown in the United States, and hence have much less fruiting wood than trees of similar height in a California or Florida orchard. They are commonly branched about 10 feet from the ground. A count of numerous trees ranging from 30 to 40 feet in height, which is about the average size for trees 15 to 25 years old, showed that they were producing from 50 to 500 fruits each (Pl. VII). The average was about 200 or 250 and the average size from 12 to 14 ounces. This can be considered a very satisfactory yield, considering the small amount of fruiting wood which these trees possess.

Most of the Guatemalan avocados produce their fruits singly, but there are occasional trees which have clusters of two to five fruits. No very large varieties have been observed to fruit in clusters, but the small and medium-sized ones, whose fruits are from 6 to 15 ounces in weight, occasionally do so.

SEASON.

It has been remarked by travelers that avocados are present in the markets of the city of Guatemala every month in the year (Pl. VIII). This observation, accurate enough in itself, has led to the assumption that the avocados of Guatemala must exhibit unusually wide variation in season. The fact that the capital city is supplied with avocados from several different regions has been overlooked, and this oversight has been responsible for a misconception; for these several regions lie at different altitudes, and in Guatemala elevation is the factor which determines the ripening season of avocados.

In any given avocado district of Guatemala it is not possible to market ripe avocados more than six or seven months of the year. There may be an occasional tree which lengthens this period (it may be mentioned in passing that these occasional trees which fruit out of season are the very ones which are of greatest interest to avocado growers in the United States), but such trees are so scarce that their influence is not felt in the market. By picking immature fruits, a common practice in Guatemala, the market is often supplied during two months more.

The variation in the ripening season, due to differences in elevation, may best be shown by the following list of important avocado districts, with their main seasons of ripening; that is, the periods during which fully ripe fruits are available in abundance:

Senahu, Alta Vera Paz	3,200 feet,	November to February.
Amatitlan	3,900 feet,	January to April.
San Cristobal, Alta Vera Paz	4,600 feet,	February to May.
Antigua	5,100 feet,	March to June.
Purula, Baja Vera Paz	5,100 feet,	March to June.
Panajachel, Solola	5,300 feet,	February to May.
Chimaltenango	6,000 feet,	April to July.
Momostenango, Totonicapam	7,400 feet,	May to August.

Ascending from 3,000 to 7,000 feet, the change from a warm to a comparatively cool climate produces a corresponding retardation in the ripening season. For every thousand feet of altitude ripening is retarded at least one month, except in those rare cases where unusual conditions come into play. Panajachel, for example, at an elevation of 5,300 feet, has an earlier season than Antigua, at 5,100 feet; this can be accounted for by the peculiar situation of Panajachel, in a sheltered valley opening toward the south on a large body of water, whose influence upon the climate must be considerable. This section is doubtless much warmer than most other towns in Guatemala which lie at similar elevations.

In general the ripening season at various altitudes may be considered approximately as follows:

3,000 feet	November to February.
4,000 feet	January to April.
5,000 feet	March to June.
6,000 feet	April to July.
7,000 feet	May to August.

To what elevations in Guatemala do the climates of southern California and southern Florida correspond? It appears that the climate at 6,000 to 7,000 feet in Guatemala corresponds very closely in so far as its effect upon the development and ripening of avocados is concerned to that of the citrus-growing regions of California. The maximum temperature may not be as high as in California, but the time required for avocados to develop and ripen appears to be about the same. Southern Florida, on the other hand, seems more nearly to approximate an elevation of 3,000 to 4,000 feet in Guatemala.

If an avocado which ripens at Senahu (3,200 feet) from November to February is planted in California, it would be an error to assume that it will ripen during the same months in that State. It would probably be at least three months later, making its season January to April. If planted in Florida, however, it would be expected to ripen only slightly later than at Senahu.

In any given section of the Guatemalan highlands nearly all avocados ripen at approximately the same season. Very early or very late varieties are exceedingly rare. Considering Antigua as an example, out of the hundreds in that region only a very few trees were found which commenced to ripen their fruits in October and November. Most of the trees do not begin to ripen any fruits until late in February, and the height of the season is during March, April, and May.

The length of time avocados will remain on the tree after they have reached maturity depends mainly upon two factors: (1) The variety and (2) the condition of the soil as regards moisture. Some trees carry their fruits much longer than others in the same location. In very moist regions, such as Senahu, however, no trees carry fruit after maturity for as many months as the trees of Antigua, a much drier section. At Senahu rainfall is abundant from November to February, and avocados fall quickly after reaching maturity. At Antigua it is quite dry from November to May, and after that it is not excessively moist until August. As a result many trees carry their fruits until late in July.

The earliest varieties, as a rule, are of inferior quality, not having the rich flavor possessed by some of the later sorts. Occasionally an early variety of satisfactory quality is encountered. The very best avocados in point of flavor are the midseason and late sorts when they have been allowed to hang on the tree three or four months after reaching maturity.

PICKING, RIPENING, AND MARKETING THE FRUIT.

When is an avocado ripe? Because of the fact that the fruit does not soften while it remains on the tree, or in the case of green-fruited varieties change its color appreciably upon maturing, it is often difficult to determine when it is ready to be picked. Among the Guatemalans there is a rule covering this point which, if experience proves it will hold good in the United States, may be useful to avocado growers. *The earliest moment at which avocados may be picked is when the tree has come into full bloom.* At this time they are usually mature enough to be of satisfactory flavor and do not wilt or shrivel on softening, but the flesh becomes of a deeper yellow color and much richer flavor if the fruit is allowed to remain on the tree two to four months longer.

In the case of purple varieties, there is another indication of maturity. When immature the fruits are green in color and only assume a purple shade on approaching maturity. At the first appearance of this purple color they are considered ready for picking, but are not at their best until the color has become deep and pronounced over the entire fruit.

In order to supply the markets of the city of Guatemala during October, November, and December, many fruits are picked in Antigua while still immature. On softening, these fruits wilt and often shrivel around the stem end, while the flavor is sweetish, lacking in richness, and at times almost unpalatable. Thousands of these immature fruits are picked every year. This practice is one which must be guarded against in the United States. Unless evidences of wilting are present, the purchaser, even though he be familiar with avocados, can not distinguish with certainty an immature fruit from a mature one solely by examining its exterior. The only exceptions are those varieties known to change color on ripening.

The methods of picking employed in Guatemala are primitive and can offer nothing but negative suggestions to North American orchardists. Frequently the fruits are knocked from the tree with a club thrown by a person standing on the ground, or they may be broken off with a long bamboo pole and allowed to fall to the ground. It is fortunate that the avocado can stand such severe treatment without serious injury.

When the fruit must be carried several miles to market it is usually shipped as soon after picking as possible, since it would be impossible for the Guatemalans, with only the most primitive means of transportation in many cases, to ship it without bruising if it had commenced to soften. The commonest means of transportation in regions remote from the railway are oxcarts, pack animals, and Indian cargadores—men who carry on their backs a load of about 150 pounds.

When picked for marketing in the immediate vicinity the fruits are ripened in the house and carried into the plaza on market day in a fully ripened condition.

It is almost universally believed in Guatemala that avocados must be picked when the moon is full. If not, it is believed that they do not ripen evenly, one end remaining hard after the other is soft and ready for eating. Many growers will refuse to pick an avocado if the moon is not in the right phase.

Ripening is commonly effected by placing the fruits among straw, litter, pine needles, or leaves in large wooden boxes, which are kept in a warm place. Even when the fruits are from the same tree, however, they do not all ripen at the same time; hence, the box is gone over every day or two and the ripe ones picked out. The time required for ripening is 3 to 10 days, fully mature fruits commonly requiring 5 or 6 days. Much depends on how warm the fruits are kept.

If ripened in a moist place the fruits often develop rot, fungous spores probably getting a foothold through bruises or injuries to the skin, the result of careless picking. If ripened in the sun, the fruits commonly soften on one side while remaining hard on the other. If ripened in a very cool place, they take a long time to soften. In order to keep them warm they are sometimes placed upon the rafters in the Indian huts, directly over the fireplace. Here the smoke and heat reach them very effectively.

In the larger cities of Guatemala avocados are sold in the public markets by all the fruit dealers, and throughout the city in the small tiendas, or shops, which deal in foodstuffs. In the smaller villages the Indian women bring in small baskets of avocados (Pl. IX) on the regular market days, which are commonly Thursday and Sunday. In the cities, where avocados are sometimes brought from great distances, single fruits bring from 2 to 4 reals each, or the equivalent of five-eighths to 1¼ cents; in the villages the price is rarely more than 2 reals. When avocados are sold in Guatemala at more than 1 cent each they are considered very high in price.

THE FRUIT.

The character of the fruit is subject to nearly as much variation in the Guatemalan race as it is in the West Indian and Mexican. It is impossible, in fact, to find two seedlings whose fruits are identical in every respect. In order to present in detail the range of variation which has been found in Guatemala, it is well to consider each of the important fruit characters separately.

Form.—In the primitive or semiwild state, avocados of the Guatemalan race seem to be nearly round in form. Under cultivation, a variety of shapes are seen, ranging from oblate through spherical, broadly oval, obovoid, elliptical, pyriform, and slender pyriform to slender, almost oblong. Most of the small fruits are round, while among the large fruits oval and pyriform are the prevailing shapes. The largest ones found were pyriform.

SELLING AVOCADOS IN AN INDIAN VILLAGE.

Once or twice a week the Indians of the Guatemalan highlands take their produce to the nearest village, where a public market is held in the plaza, or central square. During a large part of the year avocados are conspicuous in these markets, the choicest varieties produced in the vicinity being brought together here. Seeds from these fruits are scattered widely, and many of them give rise to new trees. Having good parentage, these trees are apt to produce superior fruit. The process amounts to seed selection and probably has a marked effect in improving the general level of the avocado in many regions. (Photographed at San Cristobal, Alta Vera Paz, Guatemala, April 2, 1917; P17188FS.)

Considering the fruits of medium size, which constitute the vast bulk of those seen in the markets, round and pyriform are the two predominant shapes. In Alta Vera Paz there are a good many more round fruits than pyriform ones, while in Antigua oval and pyriform avocados are more common.

Size.—The smallest variety seen in Guatemala weighed 3 ounces, while the largest weighed 3 pounds. Between these extremes are many weighing 8 to 16 ounces, and a few from 16 to 24 ounces. Avocados weighing less than 6 ounces are not common in cultivation, but trees growing in abandoned clearings or by the roadside frequently produce fruits weighing no more than 4 or 5 ounces. Most of the fruits seen in the markets weigh from 10 to 14 ounces. Avocados weighing more than 24 ounces are very rare.

In some sections of the country large varieties are unknown. In the Senahu district of Alta Vera Paz, for example, no fruits were seen which weighed more than 10 ounces.

In Antigua, in Amatitlan, and in the vicinity of the city of Guatemala, on the other hand, large varieties are comparatively common.

To the average Guatemalan the value of an avocado depends mainly upon its size. The largest fruits are the most highly prized, even though they may have very large seeds. The quality of the flesh, however, justly receives much consideration. If a tree produces large fruits of good quality it usually gains a local reputation.

Surface.—The rough surface, which is often considered typical of the Guatemalan race, occurs almost invariably in small half-wild fruits, but in the large varieties found in the coffee fincas of Antigua and in other regions the surface is often quite smooth. It must not be assumed, therefore, that an avocado which does not have a rough surface is not a Guatemalan.

Roughness of surface is correlated with thickness of skin. The thickest skinned varieties, such as the small round avocados of Alta Vera Paz, are usually very rough and even warty externally. In medium-sized or large varieties the skin is often much thinner and at the same time smoother on the surface. No avocados were seen in which the skin was very thick and yet smooth on the surface, and, conversely, no thin-skinned forms were observed which had very rough surfaces. The surface of the thinner skinned varieties is sometimes pebbled or very slightly roughened, especially around the base of pear-shaped or elongated fruits.

In some smooth-surfaced varieties a decided tendency toward glossiness is notable in the ripe fruit. This adds greatly to its attractiveness, especially when the fruit is purple or maroon in color.

Color.—The two common colors of ripe avocados are dull or deep green and deep purple. When immature, all Guatemalan avocados are green in color. As they become mature they may either remain green or turn purple, according to the variety. In all parts of Guatemala these two colors seem to be about equally common.

Besides the common green and purple, variations of these two colors are often seen. A light yellowish green is not rare, and a bright maroon-purple is sometimes encountered. Very rarely a variety is crimson-maroon, and very rarely also one is of such deep purple as to suggest black.

Seedlings grown in California from a tree producing green-colored fruits have in some instances produced green, in others purple fruits. It appears, therefore, that the color of a variety is not necessarily the same as that of its parent.

Skin.—While its thickness may vary from a sixteenth to a quarter of an inch, the skin of all Guatemalan avocados is coarsely granular in texture, becoming hard and brittle when it is removed from the fruit and dried. It is always sharply differentiated from the flesh. If the fruit is at the proper stage of ripeness, the skin can usually be peeled from it as from a banana; in some varieties the skin is so thick, however, that it is not sufficiently pliable to peel. In most cases the skin peels readily if the fruit is fully ripe but still firm, with the flesh the consistency of soft cheese.

Commonly the skin of Guatemalan avocados is about one-eighth of an inch thick. It is often thicker toward the apical end of the fruit than toward the base, but in some varieties the reverse is the case, and in others it is of about the same thickness throughout. The thickest skin seen was that of an avocado from Santa Cruz, Alta Vera Paz. This skin measured slightly more than a quarter of an inch in thickness. Many of the Vera Paz avocados have thick skins, and as these skins are very brittle and can not easily be cut with a knife the common practice is to open an avocado by breaking it in half. When an attempt is made to cut such fruits, the hard woody shell breaks indiscriminately, and a smooth cut can not be made.

The thickest skins are not found at the highest altitudes, as has sometimes been thought. Thickness of skin seems to be in no way correlated with elevation. At 7,500 feet there is the same range in thickness as at 4.000 or 5,000 feet. The thickest skin seen in Guatemala was at an elevation of 4,500 feet.

No sharp distinction can be drawn between the thickest skinned and the thinnest skinned varieties of the Guatemalan race. Each is the extreme of variation in this particular character, and there are all intermediate stages between the two. There are no other characters which differentiate the thick skinned and the thin skinned; hence, they must both be considered nothing more than variations of the same race. A classification attempting to consider them as distinct groups is purely artificial.

Flesh.—There is a great deal of difference in the color and texture of the flesh among Guatemalan avocados. Assuming that fully ripe specimens are being considered (immature ones are very common in the markets during a certain portion of the year), it will be found that in some the flesh is a pale cream color, in others a deep-cream color, while in a very few it is of a rich, bright yellow, almost identical with that of creamery butter. In a general way, the color of the flesh indicates the flavor, for pale cream-colored varieties are nearly always lacking in richness. They may have, however, a peculiar nuttiness which is very agreeable.

It was noted that a few varieties which possessed deep-yellow flesh and promised at first glance to be of rich flavor had a pronounced bitter taste which disqualified them for market use. These varieties could be distinguished, it was found, by a peculiar translucence of the flesh, a character which is not possessed by most avocados.

The very best varieties seen in Guatemala have flesh of deep cream-yellow or yellow color, quite opaque, firm, and when fully ripe cutting like soft cheese. The texture is dry, fine grained, and oily.

The remnants of the vascular system, which persist in many avocados in the form of fine, stringlike fibers running through the flesh from the stem of the fruit to the base of the seed, are rarely found in Guatemalan avocados. The position of these fibers can frequently be traced by slight discolorations in the flesh, but the presence of stringy fibers, which are often noticeable in the other races, especially in the Mexican, was not noted in Guatemala among fruits of the Guatemalan race. Many varieties were found in which there was not even the slightest discoloration of the flesh. Those in which there is a slight discoloration are just as good for eating, but they are not equal in appearance to those with perfectly clear flesh; hence, they are less valuable commercially.

The percentage of Guatemalan avocados which have deep-yellow flesh free from all discoloration is small. Many have cream-colored flesh, often somewhat watery in texture. This is correlated with poor flavor and quality. No variety with pale, watery flesh has been found to be of excellent quality.

Flavor and quality.—These two closely related characters must be considered the most important of all, since an avocado of poor quality is undesirable, no matter how attractive its appearance may be. Fortunately, the best of the Guatemalan avocados not only present an attractive exterior but are nowhere excelled in texture and flavor of flesh.

The subtle differences which distinguish the flavor of many varieties are impossible of description. Inferior varieties, of which there are many, lack richness and may even have a rank or bitter flavor which is disagreeable. They may be watery and sweetish, especially if picked before they are fully mature. The best varieties, on the other hand, are characterized by a delicate richness which is highly pleasing to the palate. When combined with a smooth, fine-grained flesh of attractive appearance, the result is a variety of excellent quality. Many such varieties are found in Guatemala, yet they do not constitute more than a small percentage of the total number of trees. The proportion of good fruits varies in different localities; in some it is difficult to find a single one of really good quality; in others, such as Antigua and San Cristobal, as many as 10 per cent of the trees examined may be quite satisfactory in this respect.

Seed.—The size of the seed and its condition in the seed cavity are the two points which interest horticulturists. With regard to the latter, it may be said that, with a single exception, all the avocados of the Guatemalan race which were examined had seeds which fit snugly in their cavities, with both seed coats adhering closely to the cotyledons. The exception noted was a variety from Amatitlan in which the seed was loose in the cavity, as it often is in the West Indian race. Possibly this was not a true Guatemalan variety.

The size of the seed is commonly larger in proportion to the size of the fruit than is considered desirable by North American avocado growers. This defect, in fact, disqualifies more of the varieties than any other. Round or oblate varieties are especially likely to have large seeds, but in an occasional one the seed is medium sized or even small. Not every round avocado has a large seed, but until an examination has been made a large seed may be expected.

Pyriform and elongated fruits are not so likely as round fruits to have objectionably large seeds, yet in many instances they do have them. The proportion of such fruits with comparatively small seeds is not large.

The best means of judging the size of the seed is by comparing its weight with that of the entire fruit. If it is not over 10 per cent of the whole fruit, it may be considered that the seed is small; if it is 15 per cent, it is not objectionably large; but if it is 20 per cent or more, it is undesirably so.

The shape of the seed conforms to that of the fruit; oblate varieties have round or oblate seeds, round varieties the same; pyriform and oval varieties have ovoid or conical seeds. The great extremes in seed form which are found in the Mexican race are not seen in the Guatemalan, the range being from oblate to conical. The cotyledons are always smooth or nearly so, differing in this respect from those of the West Indian race, which are often rough and warty toward the apex.

CLIMATIC CONDITIONS IN THE PRINCIPAL AVOCADO REGIONS.

Climatic conditions are by no means uniform throughout that portion of the Guatemalan highlands in which avocados are grown.

Differences of elevation, the proximity of mountain ranges which interfere with the passage of moisture-bearing clouds, the presence of large bodies of water in the immediate vicinity, and many other factors are responsible for local variations in temperature and rainfall.

Antigua may be taken as one of the most interesting avocado regions of the Republic. As has already been stated, this town lies in a small valley, protected on the north, east, and west by towering volcanos and high hills, while to the south there is an opening through which warm breezes enter from the Pacific Ocean. This region is not a cold one, as is shown by the presence of coffee plantations, and even more definitely by magnificent royal palms (*Roystonea regia* (H. B. K.) Cook) reaching 40 feet or more in height. As everyone knows, the royal palm is not a species which withstands much frost.

Lacking meteorological observations, the temperature and rainfall of the city of Guatemala may be taken as offering a very close approximation to those of Antigua, since the two towns are at practically the same level and not more than 15 miles apart in a direct line. According to the observations of the Laboratorio Químico Central in the city of Guatemala, the mean (average) maximum and minimum temperatures during each month of the year 1902 were as shown in Table I.

TABLE I.—*Mean monthly temperatures at the city of Guatemala for the year 1902.*

Month.	Mean maximum.	Mean minimum.	Month.	Mean maximum.	Mean minimum.
	° *F.*	° *F.*		° *F.*	° *F.*
January	72.1	50.9	July	78.9	59.7
February	78.9	55.5	August	79.8	59.1
March	82	55.7	September	78	68.2
April	82.9	57.3	October	76.4	59.7
May	81.3	60	November	75.7	57.5
June	82	60	December	72.6	54.8

The mean temperature for the entire year (1902) was 65.3° F., as opposed to a mean temperature of 65.1° for the year 1901. The highest temperature recorded during the year was 90.3°, on April 4; the lowest temperature was 42°, on January 1.

Table I, it must be remembered, contains mean temperatures. The absolute maxima and minima during the 12 months of the year 1906 are shown in Table II.

The lowest temperature recorded at the city of Guatemala by the Laboratorio Químico Central during the past 15 years was 39° F.

TABLE II.—*Maximum and minimum monthly temperatures at the city of Guatemala for the year 1906.*

Month.	Maximum.	Minimum.	Month.	Maximum.	Minimum.
	° F.	° F.		° F.	° F.
January	83	47	July	85	58
February	88	49	August	83	57
March	90	48	September	86	59
April	89	50	October	82	53
May	92	52	November	78	50
June	92	58	December	82	41

As will easily be deduced from the above tables, the climate of this region is notable for the very limited range in temperature. The minima are not so low as in either California or Florida or the maxima nearly so high as in California.

The total amount of rain which fell annually in the city of Guatemala during nine years is shown in Table III.

TABLE III.—*Annual precipitation at the city of Guatemala for the 9-year period, 1894 to 1902, inclusive.*

Year.	Precipitation.	Year.	Precipitation.	Year.	Precipitation.
	Inches.		Inches.		Inches.
1894	41.13	1897	51.36	1900	60.59
1895	38.07	1898	56.07	1901	52.06
1896	45.64	1899	41.57	1902	52.32

From these figures it will be noted that the rainfall is considerably greater than in the avocado-growing districts of California, closely approaching the rainfall of southern Florida.

The distribution of the rainfall during the 12 months of the year is also of interest. Table IV shows the number of rainy days and the total precipitation during each month at the city of Guatemala.

TABLE IV.—*Monthly precipitation at the city of Guatemala for the years 1915 and 1916.*

Month.	1915		1916		Month.	1915		1916	
	Rainy days.	Precipitation.	Rainy days.	Precipitation.		Rainy days.	Precipitation.	Rainy days.	Precipitation.
		Inches.		Inches.			Inches.		Inches.
January	0	0	1	0.03	August	22	11.99	25	10.56
February	1	.01	3	.20	September	20	7.76	24	13.24
March	10	2.36	2	.02	October	15	4.02	13	5.01
April	1	.25	10	2.13	November	6	.97	6	.58
May	9	3.38	19	8.76	December	3	.11	0	0
June	22	12.83	20	8.14					
July	19	10.88	25	10.81	Total	128	54.56	148	59.48

Most of the precipitation in this region occurs during the months from May to October, inclusive. January is quite dry, there being nothing more than a light shower at most. February and March are about the same, but toward the end of March there are sometimes a few good showers. April is usually dry, and the heat becomes most intense in this month. In May the rainy season commences. Coincident with the first good rains comes a change in temperature, the hot weather being dispelled, not to return until the following year. The rainfall during June, July, August, and September is heavy. Toward the middle of October the rains cease almost suddenly.

The following notes on the climate of this region, taken from "La America Central Ante la Historia," by Antonio Batres Jáuregui, are of interest in connection with this study:

> The temperature of the capital of Guatemala is mild, with the well-marked characteristics of the intertropical regions. In 1797 there was a severe drought in all Central America, causing sickness and famine, and being followed in the south by a terrible plague of locusts. In 1802 the same disaster was repeated. In 1803 the rains commenced in March and ended in July, being followed by a terrible drought. In 1826 the extreme heat caused immense losses in Guatemala. In 1861 excessive rains resulted in very injurious floods. In 1864 extraordinarily strong north winds blew during January and February. In 1869 Quezaltenango suffered a disastrous flood. After three years of scanty rainfall a plague of locusts overtook the country, until the present year (1915), when it seems to be disappearing, due to the heavy rainfall we have had. The seasons have varied somewhat, the weather occasionally being hot in November and December and cold in February and March, contrary to the usual sequence. The minimum temperature is ordinarily 46° F., the maximum 82°, and the mean 64°. On the 24th of December, 1856, it went down to 39°, and as low as 37° on the 29th of January, 1863; but these are unusual cold spells, produced by northeast winds.

Turning now to a consideration of the conditions in other parts of the republic, Alta Vera Paz is one of the most interesting and important regions. Here the range of temperature is even less than at the city of Guatemala, and the rainfall is much greater. Observations of the temperature at San Cristobal, the most important center of avocado culture in Alta Vera Paz, are not available; lacking them, data from Coban may be taken as offering a close approximation, since Coban and San Cristobal are at approximately the same altitude and but a few miles distant from each other. The figures in Table V, covering a period of nine years (1892 to 1900), show the mean or average maximum and minimum during each month of the year.[1]

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[1] The tables showing temperature and rainfall at Coban and rainfall at Senahu and San Cristobal are taken from "Die Alta Vera Paz," by Dr. Karl Sapper (Mittheilungen der Geographischen Gesellschaft in Hamburg, Bd. 17, 1902).

TABLE V.—*Monthly maximum and minimum temperatures of Alta Vera Paz, Guatemala, during the 9-year period from 1892 to 1900, inclusive.*

Month.	Mean maximum.	Mean minimum.	Month.	Mean maximum.	Mean minimum.	Month.	Mean maximum.	Mean minimum.
	°F.	°F.		°F.	°F.		°F.	°F.
January	73	52	May	79	58	September	77	60
February	75	52	June	77	60	October	75	59
March	77	53	July	76	59	November	72	56
April	78	55	August	77	59	December	75	53

The rainfall and the number of rainy days during each month at Coban, averaged for a period of 10 years, are shown in Table VI.

TABLE VI.—*Monthly precipitation at Coban, Guatemala, during the 10-year period from 1891 to 1900, inclusive.*

Month.	Rainy days.	Precipitation.	Month.	Rainy days.	Precipitation.	Month.	Rainy days.	Precipitation.
		Inches.			Inches.			Inches.
January	13.5	5.18	June	22.3	11.03	November	20.5	9.02
February	10.1	4.36	July	24.9	11.31	December	17.3	6.78
March	9.0	4.09	August	22.3	8.50			
April	9.5	3.39	September	23.1	9.82	Total	211.8	94.60
May	16.2	8.03	October	23.1	13.09			

The rainfall at San Cristobal is slightly less than at Coban. Few figures are available, but observations for the year 1900 (Table VII) may be compared with the figures given above for Coban.

TABLE VII.—*Monthly precipitation at San Cristobal, Guatemala, for the year 1900.*

Month.	Precipitation.	Month.	Precipitation.	Month.	Precipitation.
	Inches.		Inches.		Inches.
January	1.01	June	10.35	November	4.05
February	1.48	July	19.34	December	1.79
March	1.87	August	7.48		
April	3.68	September	12.71	Total	80.34
May	9.04	October	7.52		

San Cristobal lies in the western part of the Department of Alta Vera Paz. In the eastern part the rainfall is much heavier than at Coban or San Cristobal. Since the town of Senahu has been mentioned several times in this bulletin, it may be worth while to present figures (Table VIII) showing the rainfall in that region.

TABLE VIII.—*Monthly precipitation at Senahu, Guatemala, for a 2-year period, 1892 and 1893.*

Month.	Precipitation.	Month.	Precipitation.	Month.	Precipitation.
	Inches.		Inches.		Inches.
January	5.77	June	30.61	November	7.95
February	2.30	July	28.62	December	5.88
March	2.57	August	19.82		
April	4.17	September	17.82	Total	165.24
May	19.85	October	16.88		

It is in the Senahu region that the avocado grows almost spontaneously, springing up everywhere from seeds dropped by the Indians. The appearance of the trees, however, is not so healthy and vigorous as in San Cristobal, where the rainfall is approximately half as great.

The distribution of rainfall in Alta Vera Paz seems to be less regular than it is in the vicinity of the city of Guatemala, at least during the first four months of the year. The rainy season in this city is well defined and nearly the same every year; the inhabitants are accustomed to expect the first heavy rains about May 15 and the last ones about October 15. In Alta Vera Paz the "dry season," January to April, is sometimes characterized by a considerable amount of precipitation every month; in other instances there is almost no precipitation for one or more months.

The climate of San Cristobal, besides being drier than that of Senahu, is characterized by a greater range of temperature. It is considerably warmer during the first four months of the year (the dry season), and the minima are slightly lower because of the greater elevation of San Cristobal. In neither of these regions, however, are freezing temperatures ever experienced.

Purula (5,150 feet), in the Department of Baja Vera Paz, is considerably cooler than San Cristobal; much more so, in fact, than the comparatively slight difference in elevation would lead one to expect. It is considered by natives to lie within the "tierra fria," or cold zone, because it grows many peaches, quinces, and apples. It lies in a small mountain valley opening to the west. Judging from several visits to the spot during the coldest portion of the year, it experiences lower temperatures than Antigua, but the plants which are grown indicate that it can not ordinarily be subjected to greater cold than 35° to 40° F. Clouds sweep up the valley and hang over the town much of the time, making it a very moist spot, which receives much less sunshine than Antigua or the city of Guatemala. It never becomes very warm.

Returning across the Sierra de las Minas, which divides the moist Vera Paz from the comparatively dry plateau of central Guatemala, the town of Amatitlan (3,900 feet) comes up for consideration. This town lies only a few miles from Antigua, but is separated by the broad slopes of the Volcan de Agua. Its situation is such as to give it a warm climate, since it is in the upper end of a valley opening toward the Pacific Ocean and is in close proximity to Lake Amatitlan, a body of water 10 miles or more in length. The presence of the soursop (*Annona muricata*) and the mamey (*Mammea americana*) in Amatitlan shows that it must have a warmer climate than is usual in Guatemala at this elevation. Its rainfall closely approximates that of the city of Guatemala.

Panajachel, westward from the city of Guatamala some 60 miles, has already been mentioned as enjoying a particularly favorable situation. Its climate seems to be slightly warmer than that of Antigua, though its elevation is practically the same. Its rainfall is in general that of Antigua and the city of Guatemala.

Momostenango (7,400 feet), the highest point at which avocados are extensively grown in Guatemala, has a cooler climate than any of the other regions which have been considered, but it is not so cold as most towns in Guatemala which lie at this elevation, owing to its protected situation. Little is known regarding its temperatures, since it is a remote spot. A mango tree of good size was seen at this place; it is safe, therefore, to assume that it does not get very cold.

Going to the other extreme, Mazatenango (1,150 feet), on the west coast of Guatemala, and Chama (1,000 feet), in Alta Vera Paz, are the lowest situations at which Guatemalan avocados were seen in bearing. Both have hot climates, typical of tropical lowlands, with no cold weather and a heavy rainfall. It is generally believed that avocados of the Guatemalan race do not succeed at low elevations. The trees seem to grow well, but they are said to fruit very sparingly. Judging from the very few instances in which trees of this race were found at elevations lower than 2,500 feet, it seems that there must be some basis for this belief.

HARDINESS OF THE GUATEMALAN AVOCADO.

Severe frosts are not experienced in Guatemala at altitudes lower than 7,000 feet. In searching for avocados of the Guatemalan race likely to prove unusually hardy in the United States it is necessary, therefore, to ascend to 8,000 or 8,500 feet, at which altitude the winters are sufficiently cold to injure varieties not particularly frost resistant, thus bringing to light the hardiest.

At 5,000 feet in Guatemala avocados are subjected to a mild, and at times cool, climate, but never enough frost to test their hardiness severely. At 7,500 feet, the upper limit of orange culture, severe frosts are probably occasional, but no meteorological data are available to show the minimum temperatures experienced. It seems very doubtful whether the temperature goes as low at this elevation as it does occasionally in the orange-growing districts of California and Florida.

Above 8,000 feet it is cold enough to freeze large trees of the Guatemalan race, and trees at this elevation which show no frost injury after a hard winter must either be more resistant than the average or must be grown in a protected situation. (Pl. X.)

There are no records of minimum temperatures at elevations of 8,000 or 8,500 feet in Guatemala, to show how much cold avocados

THE UPPER LIMIT OF AVOCADO CULTIVATION IN GUATEMALA.

The city of Totonicapan, at an altitude of 8,500 feet, in western Guatemala, is the highest point at which the avocado is cultivated in this Republic. Its existence here is precarious, as is shown by the condition of this tree. Heavy frosts occur from time to time, and unless an avocado tree is unusually hardy it may be injured severely. The only other subtropical fruit grown in Totonicapan is the matasano, or white sapote (*Casimiroa edulis*). Apples, peaches, and pears are characteristic of the region, but citrus fruits are not grown above altitudes of 7,500 feet. (Photographed at Totonicapan, Guatemala, May 25, 1917; P17327FS.)

A SERIOUS AVOCADO PEST.

In some parts of the Guatemalan highlands many avocados are attacked by the insect shown above, a larva of the genus Conotrachelus. The larvæ, several of which are seen here, tunnel in the seed, sometimes reducing it to powder. Later, they burrow out through the flesh and drop to the ground, where they pupate and emerge as small grayish brown weevils. It is of the utmost importance that pests such as this be prevented from becoming established in the avocado orchards of California and Florida. (Photographed, natural size, at Panajachel, Department of Solola, Guatemala, January 10, 1917; P17034FS.)

have withstood without serious injury. In general, nothing was found to indicate that certain strains of the Guatemalan race are particularly hardy or that certain individual trees appear to be characterized by greatly superior frost resistance. One tree was found in Totonicapam (8,500 feet) which gave evidence of being somewhat hardier than the average, and bud wood was obtained for introduction into the United States.

It is true that the avocado is cultivated in Guatemala a full thousand feet above the zone in which citrus fruits, even the orange, are grown. It must not be assumed, however, that this indicates greater hardiness in the avocado than in the orange. Experience in the United States does not lead to any such conclusion, and though the varieties found at high elevations in Guatemala may be slightly hardier than those at present grown in the United States, it may also be true that the Guatemalans have not pushed orange culture to its uppermost limit. It is the custom in California and Florida to grow tropical fruits right up to the frost line, so to speak; they are planted where protection is necessary in winter and where severe losses are experienced occasionally from an unusual degree of cold. In Guatemala conditions are different. If the orange when left to care for itself did not succeed at 7,000 feet, it would die off, and its culture would be restricted to lower levels. With attention and slight protection it might succeed far above 7,000 feet, but since this attention and this protection are lacking in Guatemala, it would not be found far above 7,000 feet by the traveler who chanced to pass through the country.

The question of hardiness in the avocado seems to depend to a much greater degree upon race than upon variety. No variety of the West Indian race has yet been found which is nearly as hardy as many of the Guatemalan, and no variety of the Guatemalan has been discovered which will stand as much cold as the Chappelow or other varieties of the Mexican race. For this reason the proper classification of varieties is essential. Within the race there doubtless is a certain variation in hardiness, but experience indicates that the amount of variation is not so great, expressed in degrees of temperature, as the difference in the average hardiness of the three races now known to horticulture.

ENEMIES OF THE AVOCADO.

Everything considered, the avocados of Guatemala are less subject to the attacks of insect and fungous parasites than would be expected. Citrus trees in all parts of the highlands are commonly infested with scale insects (notably the purple scale, *Lepidosaphes beckii*) to a severe degree. Avocados in the same region are comparatively free from serious parasites. This is not saying that the avocado does not have insect enemies; it is merely stating that the tree seems to be less seriously affected by parasitic insects than citrus trees under the same environmental conditions.

One insect stands out above all others observed in Guatemala, both for the damage which it occasions and the apparent difficulty of controlling it. This is a small brownish gray weevil (*Conotrachelus* n. sp.[1]), whose larvæ are found sometimes in mature avocados purchased in the markets.

No external evidence of its presence is noticeable (at least to the unskilled observer), but on cutting the fruit in half the seed is found to be more or less riddled with large, round tunnels (Pl. XI), and 1 to 10 or more fat, wriggling larvæ, varying from white to pinkish in color, greet the eye. While the larvæ are rarely seen working in the flesh itself, they often burrow along the outside of the seed in contact with the flesh, discoloring the latter with their brownish powdery castings. In some avocados examined the seed had been so thoroughly honeycombed that it was reduced almost to powder.

Needless to state, a fruit attacked by this insect is rendered practically unfit for use. Even though the flesh itself may not have been damaged, the sight of the white larvæ and their tunnels in the seed is sufficient to nauseate any housewife. The widely known Mediterranean fruit fly (*Ceratitis capitata*) produces no more disgusting results than this insect.

The distribution of this weevil in Guatemala seems to be wide. It was found from El Rancho on the eastern slope to Mazatenango on the western, and from Antigua in central Guatemala to the Vera Paz district in the north. The lowest elevation at which it was found was about 1,000 feet, the highest 5,300. It was seen most abundantly at Panajachel, where most of the fruits offered in the market in early January, 1917, were found to be infested. Little is known of its life history. The larva is about one-half inch long, with a brown head and 12 white segments composing its body. After tunneling in the fruit it works out through the skin and drops to the ground, where it pupates, the mature weevil emerging some days later. Nothing has been learned with regard to the habits of the adult.

Next to this insect, which easily outranks all others in destructiveness, as far as was observed during the course of a year's work in Guatemala, among the most troublesome pests are gall-making psyllids,[2] which are abundant in the Antigua region and fairly common in several others. Probably more than one species are represented. These insects produce elongated conical galls which stand erect on the upper surfaces of the leaves. They are sometimes so thickly placed

[1] This species is described by H. S. Barber (Proc. Ent. Soc. Wash.; in press).

[2] Probably *Trioza koebelei* Kirkaldy.

as scarcely to leave space for even one more. Unquestionably they must have an injurious effect upon the tree.

The avocado weevil (*Heilipus lauri* Boh.), whose presence in Mexico has been the chief motive for the quarantine order prohibiting the importation of avocado seed from that country into the United States, was not observed in Guatemala, nor were any specimens found among more than 25,000 seeds shipped from Guatemala to Washington in 1916 and 1917. Another weevil, however, was found in these shipments. This species, the broad-nosed grain weevil (*Caulophilus latinasus* Say), is already known in the United States. According to Chittenden (Bull. 96, pt. 2, Bureau of Entomology), it appears to be permanently established in this country as an enemy of dried cereals and other food materials. In Guatemala it was observed to be exceedingly abundant in avocado seeds which had remained for some days upon the ground beneath the trees, and it was also common among seeds obtained from the markets, where they had been stored for two or three weeks. It bores in the seeds, leaving small tunnels.

Larvæ of a small brownish gray moth (*Stenoma* sp.) were found in a few avocados purchased in the markets of the city of Guatemala. They burrow in the seed and are similar in size and general appearance to the weevil larvæ (*Conotrachelus* sp.), but the damage which they occasion is by no means so great. The presence of these larvæ can be detected by a small round hole on the surface of the seed. No instances of severe infestation were observed.

Numerous scale insects attack the avocado in Guatemala, though severe infestations are very rare. At Almolonga, near Quezaltenango, a tree was found rather badly infested with *Pulvinaria floccifera* West. Other scale insects which are found on the avocado in various parts of the country are the following: *Aspidiotus lataniae*, *A. subsimilis*, *Chrysomphalus dictyospermi*, *C. perseae*, *C. personatus* (masked scale), *C. scutiformis*, *Diaspis boisduvalii*, *Pseudoparlatoria ostreata*, and *Lepidosaphes miniosarum*. These were all determined by the officers of the Federal Horticultural Board from material sent to Washington.

While none of the scale insects mentioned are very destructive in Guatemala, their introduction into the avocado groves of California and Florida must be strictly guarded against. Under the different environmental conditions which exist in those States, they might quickly become much more serious than they are to-day in Guatemala.

Of parasitic fungi, three species were found on material sent to Washington from Guatemala. One of these, *Colletotrichum gloeosporioides*, is already well known in California and Florida, especially in the latter State, where it is particularly injurious to the mango. The two other species are *Diplodia perseana* and an undetermined species of Fusarium.

THE WEST INDIAN RACE OF AVOCADOS IN GUATEMALA.

It is safe to state that 95 per cent of all the avocados in Guatemala belong to the Guatemalan race. From this it will readily be seen that the West Indian race is of little importance there. Its cultivation is limited to the lowlands, the highest point at which trees were seen being near Sanarate, Department of Guatemala, at an elevation of about 2,500 feet. On the Pacific slope, a few trees were seen at Mazatenango, Coatepeque, and Ayutla. Doubtless they are to be found scattered here and there all along the coastal plain which stretches from Mexico to Salvador. On the Atlantic slope, occasional trees were seen in the Motagua Valley from El Rancho down to the sea; in the Polochic Valley they were seen at Panzos. The best varieties encountered were at Chiquimula; while of good quality, they were not equal to those grown in Florida and Cuba. Guatemala does not appear to possess any varieties of this race worthy of introduction into other countries.

In the Motagua Valley, trees of this race flower in February and mature their fruits from the latter part of June until the end of August. Both the flowering and the fruiting seasons correspond very closely, therefore, to those of the West Indian race in Florida.

The quantity of fruit produced is by no means sufficient to supply the markets of lowland towns; hence, fruits of the Guatemalan race, brought from the highlands, are frequently seen in these towns. It is noteworthy, however, that the avocado is not consumed so extensively in the lowlands as it is in the highlands; as previously stated, it is a staple article of diet in the latter regions, while in the lowlands its consumption is limited.

It is strange that the West Indian race is never seen in such towns as Amatitlan and Antigua. Experience in Florida indicates that the trees will withstand more cold than is experienced in either of these regions, and both of them are only a few miles from the tierra caliente where the West Indian race is grown. It must be assumed that during the long period in which both races have been grown in Guatemala each has become restricted to the zone in which it is most successful. The West Indian race might succeed in Antigua, but by nature it is much better adapted to the lowlands. The Guatemalan race, as has been noted, is occasionally seen at low elevations, and in some instances may be reasonably successful there; but only in the cooler climate of the highlands does it appear to be really at home.

THE MEXICAN RACE OF AVOCADOS IN GUATEMALA.

Only two trees of the Mexican race were seen in Guatemala, one growing by the roadside near Santa Maria de Jesus (6,900 feet) in the Department of Zacatepequez, and the other at Chimaltenango (6,000 feet). In the latter place the Cakchiquel Indians have a name for this race, matuloh, distinguishing it from the Guatemalan race, which is called simply oh. Conversation with the Indians brought out the information that a few trees of this race were known in the vicinity of Tecpam (7,500 feet) and Chimaltenango, and also on the slopes of the Volcan de Agua, but at best the race must be considered exceedingly rare in Guatemala.

The fruits of the two trees examined were primitive in character, broadly obovoid in form, and scarcely 2 inches long. The pronounced anise scent possessed by the foliage, the heavy pubescence on the flowers, and the membranous skin of the fruit left no doubt that they were of the true Mexican race. It is much easier to distinguish this race from the other two than it is to distinguish between the other two, Guatemalan and West Indian, themselves.

Among the Indians who know this race its fruits seem to be held in very little esteem. This is not strange, in view of the fact that the varieties found in Guatemala are the most primitive imaginable. In the fruits examined the seed was so large that there was scarcely enough flesh to pay for the trouble of eating it.

Choice varieties of this race, such as some of those which have reached the United States from central and northern Mexico, would be of great value for cultivation in Guatemala at high elevations, where the Guatemalan race is injured by the cold.

THE COYO.

It is strange that a fruit so well known in northern Guatemala as the coyo should have escaped the attention of horticulturists in other countries, but aside from a brief reference to the species by Collins in his bulletin on the avocado[1] nothing seems to have been written regarding it.

While the fruit so closely resembles that of the avocado as to deceive one at first glance, the tree is distinct in foliage and flower. The coyo and the avocado are two distinct species of Persea.[2]

The coyo is found in Guatemala both wild and cultivated. Like the avocado, it varies greatly in the form and character of its fruit. Most coyos are very inferior in quality, having large seeds and many coarse fibers running through the flesh, but an occasional one is found

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[1] Collins, G. N. The avocado, a salad fruit from the Tropics. U. S. Dept. Agr., Bur. Plant Indus. Bul. 77, p. 23. 1905.

[2] Nees's description of *Persea schiedeana* appears to cover the coyo, but his herbarium specimens are not available (they are supposed to be in Austria), and the fact can not now be definitely determined.

which has a small seed and flesh quite free from fiber. A coyo of this character is a worthy rival of the best avocados. The flavor is distinct and agreeable. Indeed, it is considered by many people in Alta Vera Paz to be superior to that of the avocado.

DISTRIBUTION AND COMMON NAMES.

While adapted to a greater range of elevation than the Guatemalan race of avocados, the coyo is not so widely distributed in Guatemala as the latter. It is grown most extensively in the Department of Alta Vera Paz. It is frequently met with in the mountains of this part of Guatemala, where it grows among other trees in the forest and has every appearance of being indigenous. It is also common in most of the villages and towns, where it is planted in gardens and dooryards. In San Cristobal it is particularly abundant, there being about as many coyo trees as avocados in the dooryards of the inhabitants.

Directly south of Alta Vera Paz, across the Sierra de las Minas, the coyo is found in the Motagua Valley from El Rancho down to Gualan. At Zacapa and Chiquimula it is well known. With the exception of a single tree at Amatitlan, however, it was not seen on the Pacific slope of Guatemala.

The lowest elevation at which the coyo was found is about 500 feet, the highest 5,500. It seems to be quite successful at both these elevations.

North of the Sierra de las Minas, in Alta Vera Paz, the species is known as coyo, coyocte, or kiyau. South of the Sierra de las Minas it is called shucte, chucte, or chaucte. It has been stated that the coyo and the coyocte are different fruits; a careful investigation in Alta Vera Paz, however, indicates that they are not specifically distinct. Many Indians who were questioned on the subject were unable to define the difference between the two, and trees which were pointed out as coyo and coyocte proved to be of one and the same species. As far as could be determined the difference in nomenclature is as follows: Trees which are planted in dooryards or gardens are always called coyo, while those growing wild in the mountains are sometimes called coyocte. The coyocte, or wild, trees usually produce very poor fruit.

THE COYO TREE.

It is not difficult to distinguish the coyo tree from the avocado. In both habit and character of growth it is quite distinct. While the tree is about the same size as that of the avocado (Pl. XII), the branches have a tendency to extend horizontally from the trunk, and the young branchlets are stouter and stiffer than in the avocado, with the leaves clustered toward the ends of the growths. The tips of the branchlets as well as the lower surfaces of the leaves are covered with a heavy brown pubescence, not seen in the avocado. The leaves differ somewhat in form from those of the avocado, being as a rule broader and less pointed at the apex.

The coyo flowers during the same season as the avocado, which in Alta Vera Paz is from February to April. As pointed out by Collins, however, it matures its fruit in less time than the Guatemalan avocado; hence, coyos are all gone before avocados appear in the market. The flowers of the coyo are borne on shorter and stouter racemes than those of the avocado and are easily distinguished from the latter by the blotch of deep orange or red at the base of each segment of the perianth; the perianth segments have the appearance of petals, but as the corolla is absent in this species they can not properly be called by this name. All parts of the inflorescence are covered with a heavy pubescence.

When grown from seed, the coyo seems to come into bearing somewhat later than the avocado. While it was impossible to obtain accurate information on this subject, it is the general opinion among Guatemalans that the trees commence to bear when 8 to 10 years old. As with the avocado, all coyo trees in Guatemala are seedlings; consequently nothing is known concerning the behavior of budded or grafted trees.

Unquestionably the trees live to great age. Old specimens, however, do not seem to bear so well as younger ones, i. e., those between 15 and 30 years of age.

THE COYO CROP.

It is noticeable that the coyo, as a general thing, does not produce such heavy crops as the avocado. For this reason coyos, even in a region like that of San Cristobal, where the trees are as plentiful as those of the avocado, are never so abundant in the market as avocados and consequently are never so cheap. It was noticed, however, that an occasional tree produced very heavily. From this it can be assumed that it will be possible to obtain varieties of satisfactory productiveness for cultivation in the United States.

In the Motagua Valley, at elevations of 500 to 1,500 feet, the coyo ripens from the latter part of June until August, the season thus corresponding to that of the West Indian race of avocados. In Alta Vera Paz, at elevations of 3,000 to 5,000 feet, the season is from July to October, with a few fruits available until the first of December. As in the avocado, there is a certain amount of variation in the season of ripening among different trees.

When mature, the fruits are picked and placed in the house to ripen. The ripening process requires less time than it does with avocados, three or four days usually sufficing. When the fruits yield to pressure of the thumb they are ready for eating and are carried to the market for sale. In San Cristobal they bring 1 to 2 reals each (one-fifth to two-fifths of a cent), while avocados rarely sell in the same town for more than a real and often two for a real.

THE FRUIT.

A good coyo (Pl. XIII) strongly resembles in appearance a medium-sized avocado of the West Indian race, such as many of those grown in Florida and Cuba. The color of the flesh, however, easily distinguishes it from all avocados.

In form most of the coyos are slender and bottle necked, with a slender neck, sometimes 3 inches long. The best varieties are broadly pyriform, somewhat like the Pollock avocado in shape. A few obovoid varieties were seen, but no round ones. Irregularly shaped and deformed fruits are much more common than they are in the avocado.

The size varies from about 6 ounces to more than 2 pounds. In the Vera Paz the commonest size is 6 to 10 ounces. The best varieties in this region weigh 16 to 20 ounces. At El Rancho one variety was seen which weighed about 2 pounds. The 16 to 20 ounce fruits seem to be the most desirable.

Most coyos are light green in color when ripe, with numerous large yellowish green dots. Sometimes a bronze-colored fruit is seen, or a deep brown one. The deep-purple color found in the avocado has not been observed in the coyo.

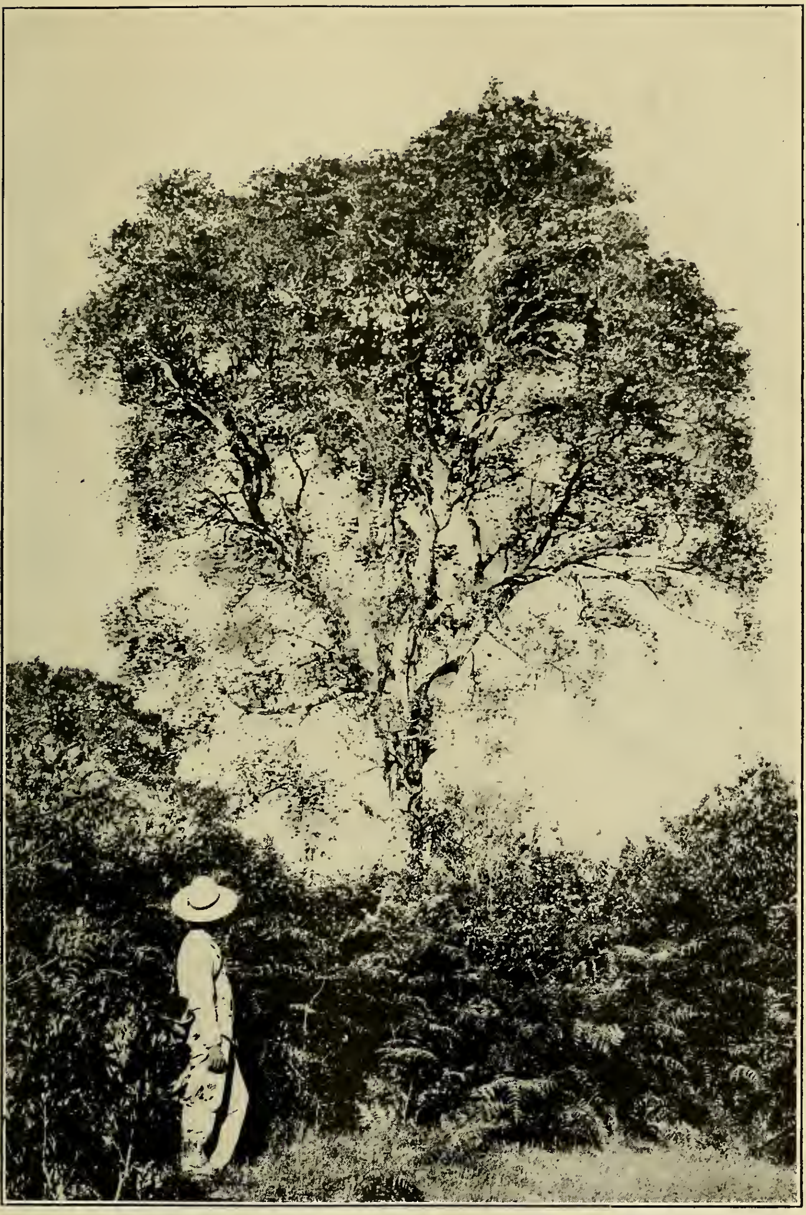
The skin is thick, but soft and pliable, resembling in texture the skin of the West Indian avocados, but approaching in thickness the thickest skinned varieties of the Guatemalan race. At the proper stage of ripeness the skin peels readily from the flesh.

The surface, like the texture of the flesh, is similar to that of the West Indian avocados. It is commonly slightly undulating, but never warty or very rough.

The color of the flesh, as has already been noted, is distinct from that of all avocados. It varies from brownish white to pale brown. In the best varieties it is brownish white and free from fiber, but in 90 per cent of the coyos seen in the Vera Paz there are coarse, tough fibers running through the flesh from the stem end of the fruit to the base of the seed. When squeezed, a milky juice exudes from the flesh. The latter is commonly of about the same texture as the flesh of a good avocado. It is coarser in many of the inferior varieties.

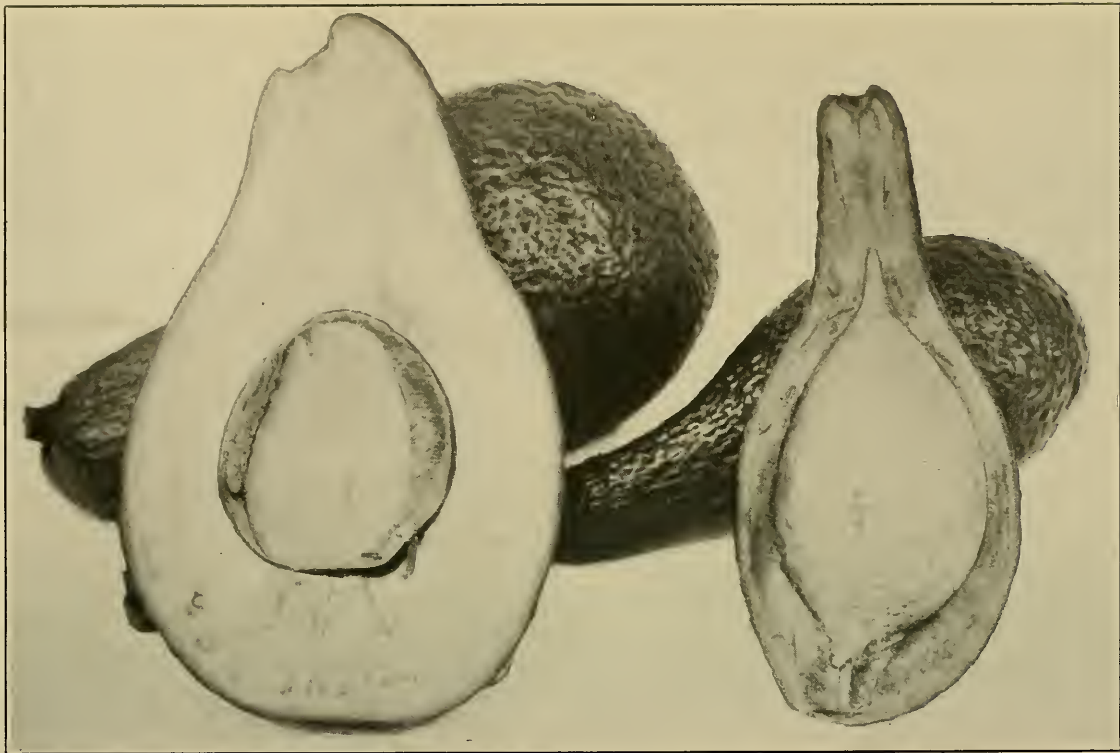
In flavor the coyo is quite distinct from all avocados at present known in the United States. It has a peculiar and very agreeable richness, similar to that of the avocado, but is characterized by a well-marked flavor of ripe coconut. Good coyos are exceedingly rich in flavor and for this reason are referred by many Indians, as well as some of the American and European coffee planters of Alta Vera Paz, to the best avocados. The coyo is eaten in the same way as the avocado.

The quality of 90 per cent of the coyos seen in Guatemala is poor, owing to the unattractive color of the flesh and the presence of ob-



A COYO TREE DURING THE FLOWERING PERIOD.

Like the Guatemalan avocado, the coyo sheds most of its foliage during the flowering period. The tree here shown is in full bloom and at the same time is making new growth, which will soon result in an abundance of leaves. In size and general habit of growth the coyo strongly resembles the avocado. The branchlets, however, are stouter and stiffer than those of the avocado, and the leaves and new growths are covered with a heavy reddish down or pubescence. (Photographed near Tactic, Alta Vera Paz, Guatemala, March 30, 1917; P17168FS.)



INFERIOR AND GOOD VARIETIES OF THE COYO.

The coyo strongly resembles the avocado, yet it belongs to a distinct species of the genus Persea. The fruit of the average seedling, of which the specimen on the right is a good example, has a large seed, much fiber running through the flesh, and is in general greatly inferior to the average avocado; occasionally, however, seedling variation results in the production of a very superior variety, such as the one shown on the left in this illustration. This fruit will stand comparison with the best avocados and seems to merit cultivation in other countries. The flavor is distinct from that of the avocado, being very rich and suggesting a ripe coconut. (Photographed at Tactic, Alta Vera Paz, Guatemala, October 7, 1917; P17364FS.)

jectionable fibers. In a few varieties, however, the quality is very good. Two trees were found in Alta Vera Paz whose fruits would stand comparison with the best avocados.

As a rule, the seed is proportionately larger in the coyo than in the Guatemalan race of avocados. In many coyos the layer of flesh between the seed and the skin is not half an inch thick. In the best varieties, however, the seed is proportionately no larger than in good avocados. In all the coyos seen in Guatemala the seed was tight in its cavity. The seed coats are much thicker than in the avocado, the outer one being somewhat corky in texture.

The coyo seed is much more perishable than that of the avocado and can be kept or shipped only with great difficulty. It is quickly killed by drying in the sun. If kept too wet it rots very soon. It must be kept moist, but not excessively so; it was noticed that seeds lying on the ground beneath trees in the Vera Paz kept for several weeks in good condition, finally sprouting and sending up vigorous shoots. Such seeds were in the shade and were moistened practically every day by rain, but the drainage furnished by the fallen leaves upon which they lay and the exposure to the air kept them from rotting.

CULTURAL REQUIREMENTS.

The coyo tree grows under a wide variety of conditions. In the valley of the Motagua, between El Rancho and Gualan, it is found near the banks of streams. There is little rainfall in this part of Guatemala, and the air is exceedingly hot and dry during a large part of the year. The hillsides are covered with typical desert vegetation—cacti, euphorbiads, and thorny leguminous shrubs. Contrasted with these conditions, the upper Polochic Valley, in Alta Vera Paz, is a very moist region, with a rainfall of approximately 150 inches per annum.

Like the Guatemalan race of avocados, the coyo is abundant at elevations of 4,000 to 5,000 feet; unlike the former, it is fairly common in the tierra caliente, or hot zone, at elevations of 500 to 1,000 feet. Whether it will stand as much cold as the Guatemalan avocado can not be stated, but everything indicates that it is reasonably hardy.

Judging from its behavior in Guatemala, the coyo ought to be successful in both California and Florida. It grows on soils of various types, from sandy loam, at El Rancho and Zacapa, to heavy clay in some parts of Alta Vera Paz. It withstands the heat of the tropical zone and the cool climate of the subtropical equally well. It is a vigorous, robust tree, requiring no more care than the avocado and apparently subject to the attacks of no more enemies. The coyo can be recommended as a fruit worthy of attention on the part of horticulturists in the warmest regions of the United States, as well as in the Tropics and subtropics generally.

SELECTED GUATEMALAN AVOCADO SEEDLINGS INTRODUCED INTO THE UNITED STATES.

The 23 avocados described on the following pages have been introduced into the United States for trial in California and Florida. They were carefully selected from a large number of trees examined in the Guatemalan highlands, special consideration being given to characteristics of commercial value. Some of them promise to ripen very early in the season; others are late. Fruits of various shapes and sizes are represented, as well as all the common colors found in Guatemala. The quality of every variety was critically tested, and no variety was included in the collection which did not appear entirely satisfactory in this respect.

In order to distinguish these avocados from varieties originated in the United States, names taken from one of the Maya dialects have been given them. Inasmuch as they come from the Maya territory, this may not be inappropriate. Following the name of each variety is the number under which it was collected in Guatemala, these numbers running from 1 to 36, inclusive. It will be noted that several of the numbers are missing; the varieties originally represented by these were found, upon later examination, to have certain defects which disqualified them, and they were dropped from the collection before its introduction into the United States. Following the collection number is the serial number under which the introduction is recorded in the inventory of the Office of Foreign Seed and Plant Introduction.

LAMAT. (No. 3.) S. P. I. No. 43476.

The Lamat is a variety combining unusual productiveness with good size, attractive appearance, and good quality of fruit. In addition, it seems to ripen earlier than many other avocados, which suggests it for trial as a winter-ripening variety in California. It has no claim to unusual hardiness, since it is grown at an altitude where frosts are not experienced.

The parent tree is growing in the chacara of Angel Samayoa in the town of Amatitlan (elevation 3,872 feet). It stands close to the corner of a small field in which tomatoes and maize are planted annually. The soil is a loose sandy loam, apparently of excellent fertility and considerable depth. The age of the tree is not known, but judging from its size it is probably 6 to 8 years old. It stands about 20 feet high, with an erect crown, extending almost to the ground, about 10 feet broad, and well branched. The trunk is 6 inches thick at the base. The tree shows every indication of being a strong, vigorous grower, as its branches are stout and shapely and not so brittle as in many weak-growing varieties. The bud wood furnished by the tree is quite satisfactory; the growths are of suitable length, and the eyes are strong and well developed, showing no tendency to drop at an early date, as they do in some varieties.

During the period in which this tree was under observation it showed a peculiarity in flowering which was not noticed elsewhere in Guatemala. In November, 1916, flowers were produced and a few fruits set. Since a heavy crop was produced in 1916, it was thought that the fruits set from the November bloom were all that would be developed during 1917, but in January the tree flowered again and set a very heavy crop of fruit.

The production in 1916 amounted to more than 100 fruits, which can be considered a heavy crop when the size of the fruits and the small size of the tree are considered. The crop for 1917 promised to be considerably larger. In 1916 the fruits were practically all picked in November, at which time they were considered by the owner to be mature. Doubtless they would have been much better if left on the tree two or three months longer.

The fruit is broadly oval, quite uniform in shape, with a smooth green surface when ripe. The weight varies from 14 to 20 ounces. The skin is about as thick as in the average variety of the Guatemalan race, which is one-sixteenth of an inch or slightly more. The flesh is free from fiber, clear, of good texture, and of pleasant flavor. Specimens sampled in November, 1916, were not as rich as would be desired, but it may reasonably be assumed that they would have been much better if they had been left on the tree two or three months longer. Perfectly ripened specimens of this variety have not been tested; hence, the quality of this fruit when at its best must remain somewhat in doubt until it comes into bearing in the United States. The seed is comparatively small and always tight in its cavity.

A formal description of this variety follows.

Form uniformly oval; size above medium to large, weight 14 to 18 ounces, at times up to 20 ounces, length 4½ inches, greatest breadth 3½ inches; base rounded, with the stem inserted obliquely without depression; stem stout, about 6 inches long; apex rounded, with the stigmatic point to one side and slightly elevated; surface nearly smooth, slightly undulating, and sometimes obscurely ribbed, deep green in color, almost glossy, with a few scattering, large, yellowish green dots; skin thick, slightly over one-sixteenth of an inch at base, nearly one-eighth of an inch at apex, coarsely granular, brittle; flesh cream color, pale green near the skin, of fairly rich flavor, and free from fiber or discoloration; quality very good; seed rather small in comparison to the size of the fruit, almost spherical, about 2½ ounces in weight, tight in the cavity, with both seed coats adhering closely to the nearly smooth cotyledons.

KANOLA. (No. 6.) S. P. I. No. 43560.

The Kanola variety (Pl. XIV) possesses several valuable characteristics. It is one of the earliest found in the Antigua region, commencing to ripen at the end of October. This makes it of particular interest to avocado growers in California, since early-ripening varieties are much desired in that State. The tree is exceedingly productive, and the fruit, though small, is of desirable round form and attractive glossy purple color. The flesh is yellow, free from fiber, and of rich flavor, while the seed is comparatively small for a fruit of round or oblate form.

The parent tree is growing in the sitio of Victor Garcia, who keeps a small estanco on the road from Antigua to San Antonio Aguas Calientes, just above the church of San Lorenzo del Cubo. The elevation is approximately 5,600 feet. Beneath the tree, which stands on a rather steep hillside, coffee has recently been planted. The soil is a very loose black sandy loam, doubtless of volcanic origin. Judging from the crops grown in the vicinity it must be quite fertile. The age of the tree is not definitely known. Victor Garcia says that it was already of large size when he was a lad, so it may be considered at least 40 years of age; most likely 50 or more. It stands about 35 feet high, with a spreading but rather open crown 35 feet broad. The trunk is 1½ feet thick at the base. The first branches are about 8 feet above the ground. The young growths are stout, shapely, and vigorous. The indications are that the variety will be a strong grower. The bud wood is excellent, having strong well-developed eyes well placed on the round, smooth, clean young twigs. There is no tendency for the eyes to drop from the young twigs, as there is in some varieties. The wood is not unusually brittle.

Varieties growing at this altitude in Guatemala are not subjected to severe frosts, but should be as hardy as the average of the Guatemalan race.

The flowering season of the parent tree is from the end of October to the first of December. It flowers very profusely and in good seasons sets heavy crops of fruit. The crop which ripened at the end of 1916 was enormous. It was impossible to make an accurate count, but a conservative estimate would place the number of fruits at 1,500 to 2,000. After such a heavy crop, it is to be expected that a light crop will follow. Very few fruits were carried to ripen at the end of 1917. Victor Garcia states that at least a few fruits are always produced; that some seasons the crop is small, while in others it is very heavy, as it was in 1916. This is commonly the case with Guatemalan avocados.

As already stated, the fruits commence to ripen at the end of October. Maturity is indicated by the appearance of a purple blush on one side of the fruit. At this stage it is considered ready for picking, but its flavor is much richer if left on the tree some months longer until the entire fruit is deep purple in color. Apparently this variety has an unusually long fruiting season, for a few fruits (which had been overlooked in picking) were found still hanging on the tree at the end of April, 1917. As observed during the past harvest, the ripening season appears to be as follows: First fruits maturing at the end of October; most of the crop maturing in November and December, but better if left on the tree until January; a few fruits, at least, remaining on the tree until March and April.

The fruit is uniformly oblate in form, resembling a grapefruit. In size it is small, weighing from 6 to 10 ounces. Under better cultural conditions, however, the weight will probably go up to 12 ounces. The color when the fruit is fully ripe is deep purple. The surface is pebbled, not distinctly roughened. The skin is of good thickness, hard, and brittle. The flesh is deep yellow in color, free from fiber, but with slight fiber discoloration (not, however, of an objectionable nature), of fine texture, and rich, oily flavor. The quality can be considered excellent. The seed is round, not large for a fruit of round or oblate form. It is generally found that fruits of this shape have seeds considerably larger in proportion to the size of the fruit than is common in good varieties of pyriform or oval shape. As in nearly all Guatemalan varieties, the seed is quite tight in the cavity.

A formal description of this variety follows.

Form roundish oblate; size small to below medium, weight 6 to 10 ounces, length 2¾ to 3 inches, greatest breadth 3 to 3¼ inches; base truncate, the stem inserted squarely without depression; stem fairly stout, 4 inches long; apex flattened, sometimes slightly oblique; surface pebbled, deep purple in color, sometimes almost glossy, with numerous small yellowish dots; skin one-sixteenth of an inch thick at basal end of fruit, about one-eighth of an inch thick at apex, separating readily from the flesh, rather finely granular, woody, brittle; flesh deep cream yellow to yellow near the seed, changing to very pale green near the skin, quite free from fiber and with unobjectionable fiber discoloration, firm in texture, and of rich, oily flavor; quality excellent; seed small in comparison to size of fruit, oblate, about 1½ ounces in weight, sometimes excentric, tight in the seed cavity, with both seed coats adhering closely.

ISHKAL. (No. 7.) S. P. I. No. 43602.

Few avocados are grown in the city of Guatemala which are considered to be of excellent quality. This tree is looked upon as one of the very best and has a considerable reputation locally for the rich flavor of its deep-yellow flesh.

The parent tree is growing in the patio of the Masonic Building, Callejon Manchen No. 4. The elevation here is approximately 4,900 feet. Apparently the tree is old, at least 50 years, and probably nearer 75. It is about 60 feet high, with a trunk more than 2 feet in diameter at the base, branching about 15 feet from the ground. The crown is erect, dense, with abundant foliage of good color. The bud wood is excellent, having well-developed eyes which are not inclined to drop and leave a blind bud. Everything seems to indicate that the variety will be a reasonably strong grower, as the branchlets are long, stout, well formed, and vigorous.

Avocados growing at this altitude in Guatemala are not subjected to heavy frosts, but should be as hardy as the average of the Guatemalan race.

The tree did not produce any fruit in 1916, but bore a good crop from the 1917 bloom. The great age of the tree and the unfavorable conditions under which it is growing seem to have resulted in the fruit becoming small and inferior of late years, according to the story of the caretaker. Specimens examined were not large in size, and they had undesirably large seeds, but under better cultivation the size of the fruit might be increased greatly without the seed becoming any larger. The quality of the fruit is so good and its reputation so great that the variety seems worthy of trial in the United States, though it can not be recommended with as much confidence as many other varieties included in this series of importations.

In productiveness the variety promises to be satisfactory. In season of ripening it is a little earlier than the average, the fruits commencing to mature in January. They are not at their best, however, earlier than March. Some of them will remain on the tree until June or July.

The fruits examined were small, but they are said to be normally nearly a pound in weight. In form they are spherical to broadly obovoid. The surface is rough and deep purple in color. The flesh is deep yellow, clear, and free from fiber, and of very rich and pleasant flavor.

The fruit, as produced in 1917, may be described as follows:

Form spherical to obovoid; size small, weight 6 to 8 ounces; length 3 to 3¼ inches, greatest breadth 2¾ to 3 inches; base rounded to pointed, the stem inserted obliquely without depression; apex slightly flattened obliquely; surface rough, deep purple when ripe, with very few large yellowish dots; skin moderately thick, one-sixteenth to one-eighth of an inch, coarsely granular and woody; flesh deep yellow in color, free from fiber discoloration and of very rich and pleasant flavor; quality excellent; seed large, nearly spherical in form, 1¾ to 2 ounces in weight, tight in the seed cavity, with both seed coats adhering closely to the smooth cotyledons.

COBAN. (No. 8.) S. P. I. No. 43932.

The Coban variety possesses something of a reputation in Coban as an avocado of unusually fine quality. In addition, it has a small seed and other good characteristics, which combine to make it a promising sort.

The parent tree stands in the sitio of Filadelfo Pineda, in Coban, Department of Alta Vera Paz. The elevation is 4,325 feet. The ground beneath the branches is given over to a vegetable garden with the exception of that to the east side, which is cut off by a tall hedge of chichicaste (*Loasa speciosa*). The soil is a heavy clay loam, probably underlain by stiff clay. According to the owner, the tree is 30 or more years of age. It is about 40 feet high, with a dense, dome-shaped crown fully 40 feet broad. The trunk is 18 inches in diameter at the base, branching some 10 feet from the ground. At present the tree is badly attacked by several insect pests and is not in good condition. It appears normally to be reasonably vigorous in growth, the young branches being somewhat slender but not very brittle. The bud wood furnished by the tree is fairly good, the eyes being well developed and showing no tendency to drop at an early age. The twigs are at times slender and angular.

The climate of Coban is mild; hence, there is nothing to indicate that this variety will be any hardier than the average of the Guatemalan race.

The flowering season is February and March. Up to a few years ago the tree is said to have borne large crops of fruit, but at present it does not seem to be doing so well, perhaps owing to weakened condition as a result of the attacks of insects and other pests. When first examined in December, 1916, there were only a few fruits on the tree, perhaps a dozen, and after the flowers which were produced in 1917 had fallen only a few fruits were found to be left on the tree for the next season, most of them having fallen before they attained the size of walnuts. They were malformed, as though from the attacks of some parasite. The ripening season is said to be February to March, a few fruits being picked in December and January and some hanging on the tree until April or May.

This is a fruit of medium size, weighing about 15 ounces. In form it is pear shaped, tending to obovoid. The surface is slightly rough, deep green in color, while the skin is moderately thick, hard, and woody. The flesh is of unusually deep yellow color, quite free from discoloration of any kind, smooth and oily, and of unusually rich flavor. The seed is rather small in comparison to the size of the fruit and is perfectly tight in the seed cavity.

This variety may be formally described as follows:

Form obovoid, obovoid-pyriform, or pyriform, slightly oblique; size above medium, weight 15 ounces, length 4$\frac{5}{8}$ inches, greatest breadth 3$\frac{3}{8}$ inches; base rounded, the stem inserted obliquely without depression; apex rounded; surface slightly rough, deep green in color, with a few small yellowish dots; skin moderately thick, one-eighth of an inch or slightly more, coarsely granular, woody, and brittle; flesh deep yellow in color, changing to pale green near the skin, of fine, smooth texture and free from discoloration of any sort; the flavor rich and pleasant; quality excellent; seed rather small in comparison to the size of the fruit, rounded oblate in form, about 1$\frac{3}{4}$ ounces in weight, with both seed coats adhering closely and fitting tightly in the seed cavity.

KASHLAN. (No. 10.) S. P. I. No. 43934.

In quality the Kashlan variety is one of the finest avocados in the series. It has the additional advantages of good size, convenient shape for handling, and a seed which is unusually small. Taken all around, it seems to be an exceptionally promising variety, and it ripens earlier than many others, which makes it particularly worthy of trial in California, where early-ripening varieties of the Guatemalan race are greatly desired.

The parent tree stands among coffee bushes in the sitio of Diego Muus in the town of San Cristobal. The elevation here is 4,550 feet. Close to the tree, on the west, is a much larger avocado tree which crowds it considerably, and there is an inga tree a few feet away on another side. The tree must be considered, therefore, to be growing under unfavorable conditions. The soil is a heavy clay loam, blackish and very fertile. While the owner is not certain as to the exact age of the tree, it is thought to be 8 or 10 years old. It is about 25 feet high, with a slender, open crown rather sparsely branched. The trunk is 8 inches thick at the base, branching about 8 feet from the ground. The tree bears every indication of being a strong grower; the young branchlets are stout, long, and extremely healthy in appearance. The wood is no more brittle than the average. The bud wood furnished by the tree is excellent, having strong, vigorous eyes which are not inclined to drop at an early stage. The twigs are smooth, round, stout, with the eyes conveniently placed for cutting buds, i. e., not too close together.

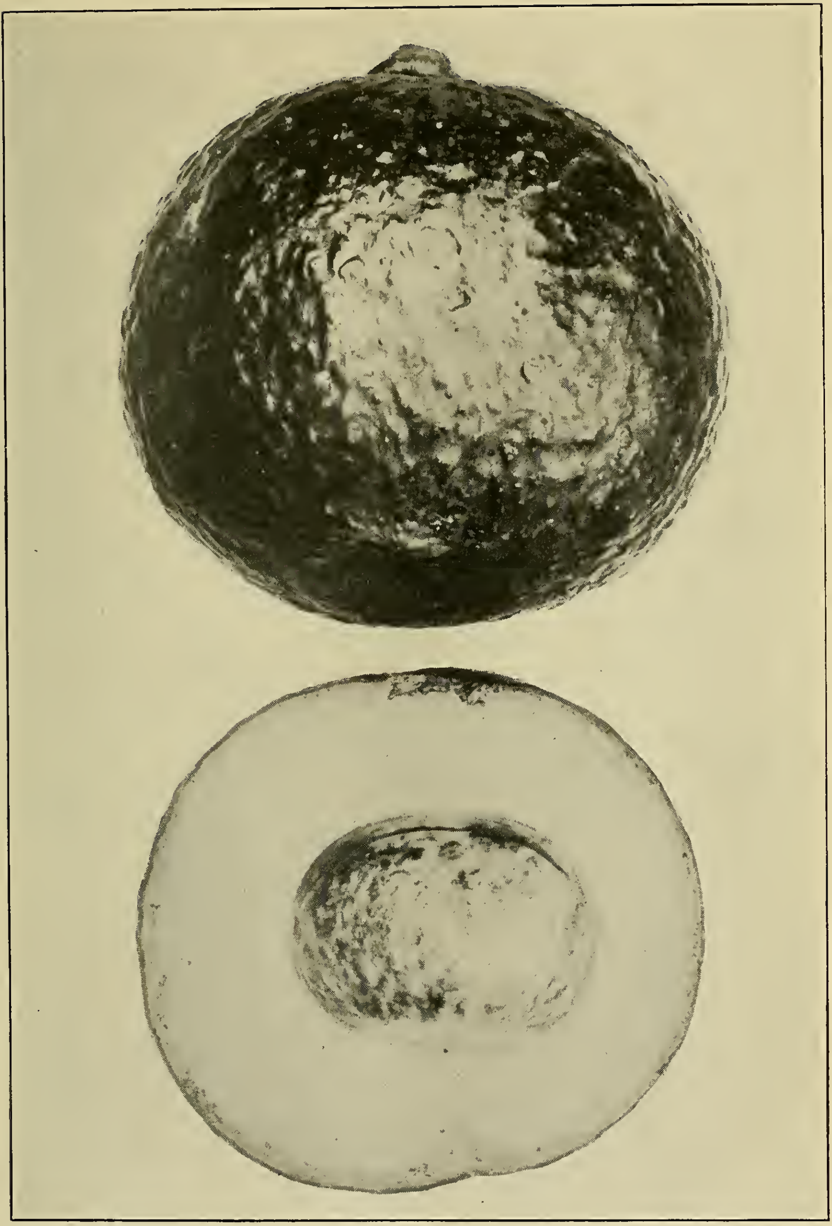
No frosts occur in San Cristobal; hence, there is no means of determining whether varieties growing here are hardier than the average. Until further evidence is obtained in the United States it must be assumed that varieties from elevations such as that of San Cristobal are of average hardiness.

The flowering season is February. The tree is said to have come into bearing three years ago. It produced an excellent crop the past season, considering the size of the fruit and the unfavorable conditions under which it is growing. In 1917 it set no fruit. The crop which developed in 1916 was picked in January and February, 1917, at which time the fruit was considered to be mature. None was left on the tree, so it is impossible to say how late the fruits might hang on if they were allowed to do so.

This fruit is broadly oval in form, slightly oblique, and weighs 20 to 22 ounces. It is green in color when ripe, practically smooth on the surface, with a hard, brittle, but not unusually thick skin. The flesh is smooth, deep yellow in color, clean, and free from fiber. The flavor is very rich and pleasant. The seed is unusually small, weighing but 2 ounces, and fits tightly in its cavity.

Following is a formal description of this variety.

Form broadly oval, slightly oblique; size very large, weight 20 to 22 ounces, length 4½ inches, breadth 4 inches; base obliquely flattened, the stem inserted without depression; apex obliquely flattened, slightly depressed around the stigmatic point; surface pebbled, deep green in color, with



THE KANOLA AVOCADO, AN EARLY VARIETY OF GOOD QUALITY.

Among the many seedling avocados in Guatemala, very few are distinctly early in season. The variety here shown, from San Lorenzo del Cubo, near Antigua, ripens its fruits three to four months earlier than most of the trees in the same region. While early varieties are commonly lacking in flavor or otherwise undesirable, the Kanola is a fruit of good quality. It weighs 6 to 10 ounces, is deep purple in color, with a woody outer covering and yellow flesh of rich flavor. The parent tree bore a heavy crop in 1916 (Photographed, natural size, at the city of Guatemala, November 1, 1916; P16923FS.)

A CROP FROM THE PARENT TREE OF THE NABAL AVOCADO.

Fruits to the number of 315 are here shown at the base of the parent Nabal avocado tree, growing in the finca Santa Lucia at Antigua. As indicated by the small size of the trunk, the tree is quite young, and the crown, which is formed 10 feet above the ground, is slender and sparsely branched. The crop may therefore be considered a heavy one. The fruits weigh about 12 ounces each, have rather small seeds, and are of excellent quality. (Photographed at Antigua, Guatemala, January 28, 1917; P17051FS.)

numerous rather large yellowish dots; skin one-sixteenth of an inch thick, slightly thicker over some portions of the fruit, coarsely granular, and brittle; flesh of an unusually rich yellow color, changing to pale green near the skin, free from fiber or discoloration, and of very rich flavor; quality excellent; seed very small in proportion to the size of the fruit, oblate, weighing 2 ounces, tight in the cavity, with both seed coats adhering closely to the cotyledons, which are slightly rough for this race.

CHISOY. (No. 11.) S. P. I. No. 43935.

As a commercial variety the Chisoy avocado seems to be particularly promising. In form and size it is almost identical with the Trapp avocado of Florida, but it has a smaller seed. The quality is excellent, and the tree has borne two heavy crops in succession, which indicates that it will probably be as satisfactory in productiveness as any in the series. Taken all around, the Chisoy variety seems to be one of the best.

The parent tree is growing in the cafetal (coffee plantation) of Señor Don Eusebio de la Cruz, in the town of San Cristobal. The elevation is 4,550 feet. Eusebio de la Cruz is the alcalde, or mayor, of San Cristobal and owns coffee plantations containing many avocado trees, but he always reserves the fruits of this particular tree for his private consumption and to present to his friends. Beneath the broad-spreading branches of this tree are numerous large coffee bushes, which benefit by the shade cast by the avocado. The soil is a heavy blackish clay loam, of excellent fertility. No one knows the exact age of the tree; it is very large and probably very old. Fifty years can be considered the minimum. It is fully 50 feet high, with a broadly spreading much-branched crown which is 60 feet in diameter. The trunk of the tree is 4 feet thick at the base. It branches about 12 feet above the ground. The growth seems to be vigorous, though the young branchlets are not so long as they would be if the tree were much younger. The wood is no more brittle than the average, and the branchlets are well formed and stout. The bud wood furnished by this tree is good; owing to the age of the tree the twigs are not so long as would be desired for most convenient handling, but the eyes are well formed and show no tendency to drop at an early stage.

The hardiness of the variety can not be ascertained, since there is no frost in San Cristobal. Until subjected to cold weather in the United States it can only be assumed that the variety is of average hardiness for the Guatemalan race.

The flowering season is slightly later than the average, the tree being in full bloom on April 1, 1917. The crop produced from the 1916 bloom was very large. No count could be obtained, but it may be said that the bearing habits of the tree, as indicated by the 1916 and 1917 crops, seem highly satisfactory. In spite of the heavy crop from the 1916 bloom, the 1917 bloom set an equally heavy one, which was carried to maturity. The fruits can be picked in February, but are probably not at their best until the first of March. The season, therefore, is a month or more later than the average. If allowed to remain on the tree many of the fruits will hang on until April, or perhaps even later.

The fruit is handsome, and its quality does not belie its looks. It is as large as a good grapefruit (20 to 24 ounces), with a slightly rough skin of yellowish green color, somewhat thicker than the average, so that the fruit is bruised with difficulty. The flesh is of deep-yellow color, firm and rather dry in texture, entirely free from discoloration of any sort, and of the richest possible flavor. No better avocado in point of flavor has been found in all Guatemala. The seed in large specimens of the variety is comparatively small, while in small specimens it is a trifle large, appearing to develop to more or less the same size in every case, independent of the size of the fruit. Under good cultural conditions in North America the fruits should be of large size, and if the seed remains small, as it does in the large specimens produced by the parent tree, this will almost surely be one of the choicest avocados of the series. It is scarcely necessary to add that the seed is tight in the cavity, for this is the case with all of the avocados included in this list.

This variety may be formally described as follows:

Form spherical to oblate; size large to very large, weight 17 to 24 ounces, length 3⅝ to 4⅛ inches, greatest breadth 4 to 4½ inches; base rounded, the stem, which is about 5 inches long and moderately stout, inserted somewhat obliquely without depression; apex slightly flattened; surface uniformly pebbled, somewhat coarsely so, deep green to yellow-green in color, with numerous large pale yellow-green dots; skin moderately thick for this race, varying from one-sixteenth to one-eighth of an inch, hard and woody; flesh rich cream yellow to yellow in color, changing to pale green near the skin, free from fiber or discoloration, not watery, but very oily, smooth, and of rich, very pleasant flavor; seed oblate, 2 to 3 ounces in weight, tight in the cavity, with both seed coats adhering closely to the cotyledons, which are slightly rough for this race.

PANKAY. (No. 12.) S. P. I. No. 44785.

The Pankay variety has been included in this list primarily for its probable hardiness. The parent tree is growing at an elevation of 8,500 feet, which is more than a thousand feet above the zone in which citrus trees are seen in Guatemala. Avocados are rarely found at this elevation. Several other avocado trees in the same town (Totonicapam) had been badly injured by a recent frost at the time Pankay was selected, but this variety had escaped practically untouched. How much may have been due to situation or other circumstances, however, is not known, and not too much confidence should be placed in the superior hardiness of this variety until it has been thoroughly tested in Florida and California. Since, in addition to its probable hardiness, it is a fruit of very good quality, it can be strongly recommended for trial in the United States.

The parent tree is growing in the patio of Jesusa v. de Camey, corner of Calle Cabanas and 10a Avenida Norte, Totonicapam. The elevation of this town is approximately 8,500 feet, perhaps a little higher. The situation is somewhat sheltered, since the tree stands in the patio of a house, close to the north wall. Since the top of the tree, however, extends 10 feet or more above the roof of the house, the protection can not be of great importance except from one point of view: The tree may have been effectively protected when young, being thus enabled to develop uninjured during the first few years of its growth, after which it was better able to withstand severe frosts. The age of the tree is said to be about 25 years; it stands 40 feet high, with a broadly oval, dense crown, the top of which has been cut out to avoid the danger of its breaking in high wind and falling upon the tile roof of the house. The trunk is about 20 inches thick at the base, dividing 8 feet from the ground to form two main branches, which give off secondary branches at 20 feet from the ground. While the tree appears to be vigorous and hardy, it may be found somewhat difficult to propagate, as it does not make the best type of bud wood. The "eyes" are not plump, but somewhat slender, with the outer bud scales falling early, and the bud itself shows a tendency to fall at an early stage. The wood seems to be rather brittle.

The flowering season is late April and May. The tree is quite productive, bearing its fruits often in clusters. It produced a good crop from the 1915 blooms and another good one from the 1916 blooms. Owing to the great elevation of Totonicapam and the consequent lack of heat, the fruits are very slow in reaching maturity. The season of ripening is from September until the end of the year, but the fruits which ripen at this time are those from the previous year's bloom; that is, flowers which appear in May, 1918, develop fruits which will not be fully ripe until September or October, 1919.

The fruit is of medium size, of attractive pyriform shape, smooth, and green in color. The flesh is of good quality, free from fiber, and the seed is comparatively small. It can be considered a fruit of very good quality and desirable from other points of view than that of its probable hardiness.

Following is a formal description of this variety.

Form pyriform, rather slender, and slightly necked; size medium, weight 12 ounces, length 4¾ inches, greatest breadth 3 inches; base tapering, narrow, the stem inserted almost squarely without depression; stem 3½ inches long, stout; apex rounded, slightly depressed around the stigmatic point; surface smooth or nearly so, light green and almost glossy, with numerous yellow dots; skin moderately thick, about one-sixteenth of an inch, woody, and brittle; flesh deep-cream color, changing to pale green near the skin, free from fiber, and of very rich flavor; quality excellent; seed rather small, conical, weighing about 1½ ounces, tight in the cavity, with both seed coats adhering closely.

NABAL. (No. 15.) S. P. I. No. 44439.

For productiveness combined with desirable form and excellent quality of fruit, the Nabal variety (Pl. XV) seems particularly worthy of trial in the United States. While not a large avocado, it is excellent in every way, having a smooth, green surface, rich yellow flesh of good flavor, and a seed not unduly large in comparison with the size of the fruit. In addition, it seems to be slightly earlier in season than the average.

In June, 1917, the parent tree was accidentally destroyed by a laborer who was planting coffee. It stood among coffee bushes in the finca Santa Lucia, 7a Calle Poniente, near the Alameda de Santa Lucia, Antigua. The soil in this finca is a rich black sandy loam of volcanic origin, deep and apparently very fertile. The tree was young, probably not more than 6 or 7 years old. It stood about 25 feet high, with a trunk 6 inches in diameter at the base, branching 10 feet from the ground. The crown was open, scantily branched, with little fruiting wood. The young growths were strong, stout, vigorous, and the bud wood was excellent, having large vigorous eyes. The variety should not be difficult to propagate, and the indications are that it will be a good grower, though it is impossible to speak with certainty in regard to the latter point. The wood is rather tough for an avocado.

The elevation of Antigua, 5,100 feet, is not great enough to insure unusual hardiness in a variety, but it seems reasonable to expect that varieties from this elevation will be as hardy as the average of the Guatemalan race. There is no way of determining whether they may be hardier than the average until they are tested in the United States.

The parent tree did not flower in 1917. Since flowers are nearly always produced at the same time as the spring flush of growth, however, it may be suspected that the flowering season of the variety will be rather late, since the spring growth did not appear this season until the end of March. The heavy crop of fruit produced last year probably prevented the tree from flowering this season. When first examined, in October, 1916, the tree was carrying more than 300 fruits. It ripened this crop—an unusually large one for such a small tree when the size of the fruit is considered—in February and March, 1917, at which time all the fruits were picked. They would probably have remained on the tree until June if they had been allowed to do so.

The fruit of this variety is nearly spherical in form, of convenient size for serving a half fruit as a portion. It weighs 10 ounces or a little more. The surface is smooth, bright green, very attractive in appearance. The skin is sufficiently thick to make the fruit a good shipper and is of the characteristic Guatemalan texture. The flesh is rich yellow in color, quite free from fiber or discoloration, and of very rich flavor. The seed is tight in the cavity and slightly below the average in size. Considered from all points of view, this bears every indication of being an excellent little fruit.

A formal description of this variety follows.

Form almost spherical; size below medium, weight about 10 ounces, length 3½ inches, breadth slightly over 3 inches, base scarcely extended, the stem inserted almost squarely without depression; apex rounded, with a slight depression around the stigmatic point; surface undulating to finely pebbled, dull green in color, with numerous very minute yellowish dots; skin not very thick, scarcely up to one-eighth of an inch over any portion of the fruit, separating readily from the flesh, woody, brittle; flesh yellow, greenish toward the skin, free from fiber or discoloration, of firm, smooth texture and rich flavor; quality excellent; seed rather small, nearly spherical in form, weighing slightly more than 1 ounce, tight in the seed cavity, with both seed coats adhering closely to the cotyledons.

NIMLIOH. (No. 17.) S. P. I. No. 44440.

It is rare to find a large-fruited avocado which is at the same time very productive. In the Nimlioh variety (Pl. XVI), however, both these characteristics are combined to an unusual degree. In addition, the quality of the fruit is excellent, the flesh being rich yellow in color, free from discoloration, and of very rich flavor. The habit of the tree and the character of the wood indicate that the variety may not be a very strong grower.

The parent tree is growing in a sitio belonging to Trinidad Hernandez, Callejon de Concepcion No. 28, Antigua. The elevation is approximately 5,100 feet. The soil is a very sandy loam, black, loose, deep, and undoubtedly very fertile. The tree stands close to a wall, with no other large trees close to it. It is very poorly cared for. Its age is not known, but is probably 15 years or more. It is about 25 feet high, the trunk 14 inches thick at the base, and the first branches 12 feet from the ground. The crown is broadly oval, of good form, and rather dense. It looks, however, as though the variety might be a diffuse grower when young, with long, heavy shoots inclined to droop. The wood is unusually brittle, and the bud wood very poor, the eyes being stalked or losing their bud scales and falling early. The tree is badly attacked by leaf-gall, and there are a good many scale insects on it.

The elevation of Antigua, 5,100 feet, is not great enough to insure unusual hardiness in a variety, and pending a test in the United States it can only be assumed that this avocado is of about average hardiness for the Guatemalan race.

The flowering season is from the latter part of February to the end of March. According to the owner of the tree, it always bears at least a few fruits, but it is to be expected that a tree which produces such a crop as this one did in 1917 will not bear heavily the following year. While an accurate count was not made, the crop this season was estimated at 300 to 400 fruits. The normal size of the fruits is between 2 and 3 pounds, but owing, doubtless, to the large number on the tree, many do not develop to a greater size than 1 pound. Probably good culture and thinning would result in a crop of uniformly large fruits. The season of ripening is earlier than some, most of the fruits being fully ripe in February and March.

In form this avocado is broadly oval, usually somewhat oblique. The surface is deep green and rather rough, while the skin is thick and woody. The flesh is rich cream yellow in color, smooth, and entirely free from fiber or discoloration. The flavor is of the very best, being rich, bland, and pleasant. The seed, while large, is not large in comparison to the great size of the fruit, and the proportion of flesh to seed is quite satisfactory.

Those who are interested in large avocados should by all means give this variety a trial. Its only visible defect is the tendency to produce weak branches, but if pruning and good culture can produce a reasonably shapely and vigorous growth the variety seems likely to prove of value in the United States.

A formal description of the fruit follows.

Form broadly oval, sometimes oblong-oval, and always more or less oblique; size extremely large, perfectly developed fruits weighing 36 to 45 ounces and measuring 5½ to 6 inches in length by 4½ to 5 inches in breadth; stem rather short and very stout, inserted obliquely without depression; base slightly flattened obliquely, not decidedly so; apex rounded to obliquely flattened; surface heavily pebbled in most instances, occasionally lightly pebbled, deep green in color, with numerous irregular large yellowish dots; skin moderately thick, one-sixteenth of an inch toward the base of the fruit and one-eighth of an inch toward the apex, separating readily from the flesh, coarsely granular, and brittle; flesh firm, oily, smooth, rich cream yellow, tinged with green toward the skin, free from fiber or discoloration, and of very rich, pleasant flavor; quality excellent; seed medium sized, roundish conic or oblate conic, weighing 4 ounces, tight in the cavity, with both seed coats adhering closely.

PANCHOY. (No. 18.) S. P. I. No. 44625.

The fruit of the Panchoy avocado is very thick skinned and of unusually good quality. It is rather above medium size (Pl. XVII), weighing 15 to 18 ounces, and is of pleasing form—broadly obovoid. The seed is small. Perhaps its most striking characteristic is its unusually thick skin; but its quality deserves even more notice, for in this respect it is one of the very best in the collection.

The parent tree is growing in the finca La Polvora in Antigua. The elevation is approximately 5,100 feet. The ground beneath the tree is planted to coffee bushes, which are now about 8 feet high. The soil is rich sandy loam, friable, black, and fertile. The tree is about

45 feet high, with a straight trunk 18 inches thick at the base, giving off its first branch 18 feet from the ground. The crown is not very broad, but open and sparsely branched, some of the limbs showing a tendency to droop. The age of the tree is not definitely known, but is probably 15 to 20 years. The character of the bud wood produced by the tree is fairly satisfactory; the growths are short, but the buds are well formed and show no tendency to drop.

Lacking a definite test in the United States, it must be assumed that the variety is about average in hardiness. The climate of Antigua is not sufficiently cold to demonstrate the hardiness of a variety.

The flowering season is February and March. The fruits ripen rather early for this region, the first ones commencing to drop in February, while a few hang on until April or May. The season may be called January to April. This rather early season of ripening is of especial importance to California, where the variety should have a careful trial. Its productiveness is satisfactory. The crop ripened in the spring of 1917 was good, but few fruits were set from the blooms of 1917. This is nothing unusual, since trees of the Guatemalan race do not as a rule bear heavily every year.

The fruit is broadly obovoid, 1 pound in weight, rough and yellowish green on the surface, with a skin almost as thick as a coconut shell, but easily cut. The flesh is almost as yellow as butter, clean and free from discoloration, and of very rich flavor, while the seed is comparatively small and tight in the cavity. The variety has every appearance of being an excellent one.

The fruit may be formally described as follows:

Form obovoid, slightly oblique at the apex; size above medium to large, weight 15 to 18 ounces, length 4½ inches, greatest breadth 3½ inches; base rounded or obscurely pointed; stem stout, 4 inches long, inserted obliquely without depression; apex obliquely flattened, depressed around the stigmatic point; surface heavily pebbled to rough, green to yellowish green in color, with numerous small rounded yellowish dots; skin thick, about one-eighth of an inch throughout, not thicker toward the apex than near the base, as in many avocados, woody, very brittle; flesh firm, smooth, rich yellow in color, tinged with green near the skin, fiber or discoloration entirely lacking, the flavor very rich and pleasant; quality excellent; seed medium sized or rather small, roundish conic in form, weighing 2 ounces, tight in the cavity, with both seed coats adhering closely.

TUMIN. (No. 20.) S. P. I. No. 44627.

The Tumin variety is remarkable for its unusual productiveness, the fruits often being borne in clusters of two to five, a characteristic which is quite rare in the Guatemalan race. The fruit is almost identical in form with the Trapp as grown in Florida; it weighs about a pound, and is of handsome appearance, with a smooth, glossy skin of purple-black color. The flesh is of excellent appearance and flavor. The seed is medium sized. Taken all around, this seems a very promising variety, especially for Florida, where many of the Guatemalan avocados do not bear heavily.

The parent tree is growing in the finca La Polvora in Antigua. The elevation is approximately 5,100 feet. On all sides of the tree, and crowding it somewhat, are large coffee bushes. The soil is a rich sandy loam of volcanic origin, deep and friable. The tree is probably 6 or 7 years old. It is 20 feet in height, very slender in habit, the trunk 6 inches thick at the base, branching at 8 feet from the ground. The crown is slender, sparsely branched, with very little fruiting wood. Its growth seems to be reasonably vigorous, the young branchlets being stout, though very short. The wood is rather brittle. The bud wood furnished by the tree is rather poor, owing to the shortness of the growths and the fact that the buds are too closely crowded together. The eyes, however, are well formed and show no tendency to drop and leave a blind bud. It may be found that the tree will require training when young to keep it stocky and of good form.

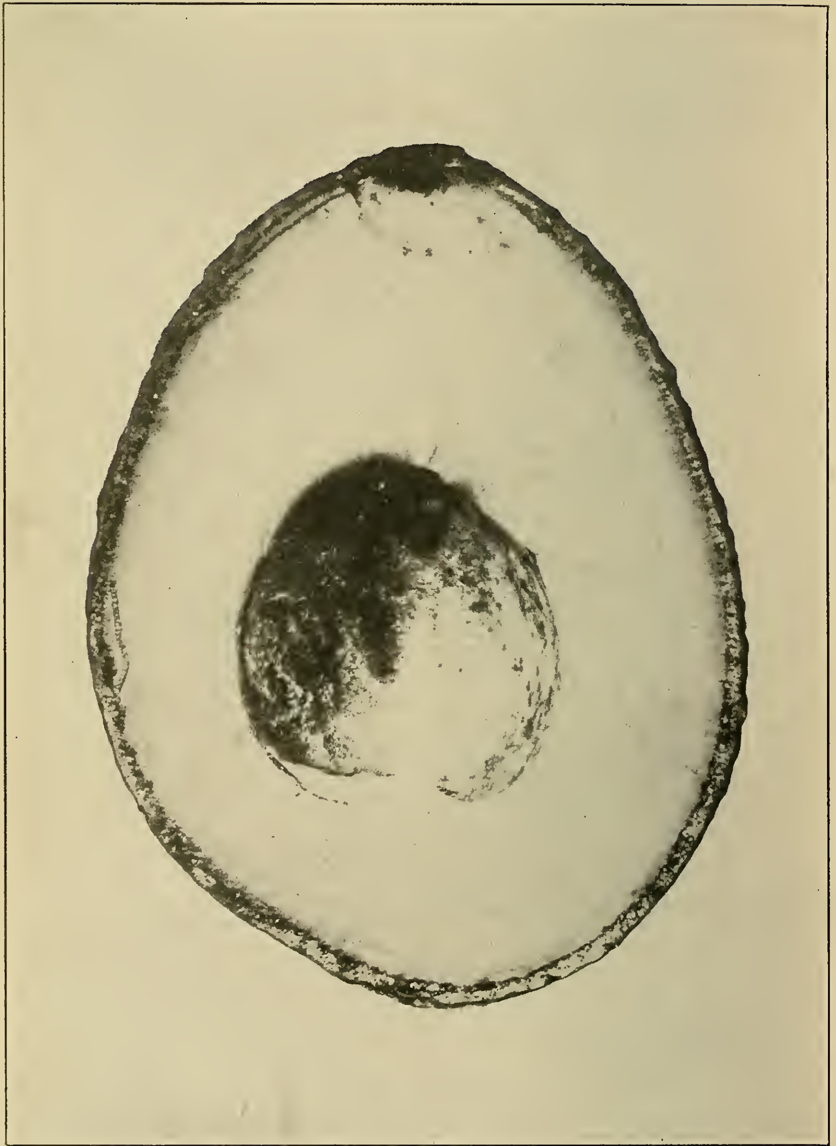
The hardiness of the variety can not be ascertained at present, since the climate of Antigua is not cold. It may be assumed, until a test is made in the United States, that it is about as hardy as the average of the Guatemalan race.

The tree did not flower in 1917, owing, most likely, to the heavy crop which it ripened from the 1916 blooms. Probably under better cultural conditions and by thinning heavy crops, greater regularity in bearing could be induced; in Guatemala, where no cultural attention is given to the trees, it is common for them to bear very heavily one season and fail to bear the next. Judging by the appearance of the spring flush of growth, which always accompanies the flowers, the variety will flower in March. The fruits ripen from March to May. Although the tree has very little fruiting wood, it produced 125 fruits in 1917, which can be considered a very heavy crop. Several of the branches, in fact, were broken by the weight of the fruits they were carrying.

The form of the fruit, as already mentioned, is practically the same as that of the Trapp—oblate or roundish oblate. The average weight is 12 to 16 ounces, but it may be expected that the weight of this and all other varieties in the collection will be slightly greater under good culture in the United States than it is in Guatemala, where the trees receive no attention. The skin is rather thin and smooth on the surface. The color is deep purple, almost black. Unlike most Guatemalan avocados, the surface possesses a decided glossiness. The flesh is rich yellow in color, free from discoloration or fiber, and of very rich flavor. The seed varies from small to slightly large. In this connection it may be noted that seeds of round or

THE NIMLIOH AVOCADO, A PRODUCTIVE AND LARGE VARIETY.

Few large varieties are as productive as this one. In 1917 the parent tree, growing in a dooryard in Antigua, bore so many fruits that it was unable to develop them all to normal size. The largest specimens weighed nearly 3 pounds; many were more than 2 pounds in weight. The quality of the fruit is excellent, the flesh being yellow, free from all discoloration, and of very rich flavor. While large varieties may not be as desirable as medium-sized ones for general planting in the United States, a limited demand for large fruits seems certain, and avocados such as this are promising. (Photographed at Antigua, Guatemala, February 21, 1917; P17085FS.)



THE PANCHOY AVOCADO, ONE OF THE VERY BEST.

For deep-yellow color of flesh and richness of flavor this variety is not excelled by any other in the entire series introduced into the United States from the Guatemalan highlands in 1916 and 1917. It is a medium-sized fruit from Antigua, green in color, with a very thick skin and an unusually small seed. The surface is rough, as is generally the case in very thick skinned varieties. (Photographed, natural size, at Antigua, Guatemala, February 24, 1917; P17115FS.)

THE BENIK AVOCADO, A HANDSOME PURPLE VARIETY.

Upon dividing this fruit into halves the contrast between the bright maroon-purple skin and the yellow flesh is exceedingly pleasing. The parent tree, which is growing in the finca La Polvora at Antigua, has proved to be very productive, and the quality of the fruit is excellent. (Photographed at Antigua, Guatemala, May 1, 1917; P17244FS.)

THE KEKCHI AVOCADO, A PRODUCTIVE EARLY VARIETY.

This is the smallest avocado included in the series introduced into the United States from the Guatemalan highlands in 1916 and 1917. It commonly weighs but 5 or 6 ounces. The surface is deep purple in color, the skin thick and woody. There is a slight amount of discoloration in the flesh, but no fiber. The flavor is rich, and the seed is not large. The fruits commence to ripen two to three months earlier than those of other trees in the same section (Purula, Baja Vera Paz), and continue through a period of nearly six months. The fruits being so small, the tree is able to carry a large number. (Photographed, natural size, at Tactic, Alta Vera Paz, Guatemala, April 4, 1917.)

oblate avocados frequently are found to vary considerably in size, even among the fruits of a single tree. In this particular variety the average is not large, but occasional fruits were found in which the seed was a trifle too large. In others it is comparatively small. It is always tight in the cavity.

The following is a formal description of the fruit.

Form roundish oblate or oblate; size medium to above medium; weight 12 to 15 ounces, length $3\frac{1}{4}$ inches, greatest breadth $3\frac{3}{8}$ to $3\frac{5}{8}$ inches; base rounded, the very short, stout stem inserted almost squarely and without depression; apex flattened, not depressed; fruits borne singly or in clusters of two to six; surface almost smooth or very lightly pebbled, deep purple in color, glossy, with very numerous, minute, yellowish dots; skin thin for this race, one-sixteenth of an inch at apex and slightly less toward the base of the fruit, pliable, peeling readily; flesh firm, smooth, rich cream yellow, changing to pale green near the skin, free from fiber or discoloration, and of rich, pleasant flavor; quality excellent; seed roundish oblate, variable in size, weighing $1\frac{3}{4}$ to 3, commonly 2, ounces; tight in the cavity, with both seed coats adhering closely to the cotyledons.

BENIK. (No. 21.) S. P. I. No. 44626.

The fruit of the Benik avocado is very handsome (Pl. XVIII) and of fine quality. When cut in half the contrast of its purplish maroon skin with its rich yellow flesh is very pleasing, the purple of the skin intensifying the yellow of the flesh. The tree is a good bearer, and the variety seems well worthy of a trial in the United States.

The parent tree is growing in the finca La Polvora in Antigua. It has recently been girdled, with the intention of killing it to make room for more coffee bushes, so that it will probably not be in existence by 1919. The elevation of this spot is about 5,100 feet. The tree stands among coffee bushes, some of which grow beneath its branches. The soil is a loose, sandy loam, deep and fertile. The tree is about 35 feet high, the trunk 18 inches in diameter at the base, and the first branches 12 feet from the ground. The age of the tree is not known, but it appears to be at least 20 years. The growth is vigorous and shapely, though the branchlets are rather short. The bud wood furnished by the tree is quite satisfactory, the eyes being well developed and not losing their outer bud scales or falling early. The bud sticks, however, are short.

The hardiness of the variety must be considered about average until the facts can be ascertained by a test in the United States. The climate of Antigua is not cold enough to show the hardiness of an avocado of the Guatemalan race.

The tree flowers in late February and March. It ripened a fairly good crop of fruit in 1917 from the 1916 blooms and set a very heavy crop to ripen in 1918. Its productiveness, therefore, seems to be above the average. The season of ripening is from February, when the fruits change from green to purple and thus indicate their maturity, to May, when the last ones fall to the ground. It is a midseason sort, commencing to ripen a trifle earlier, perhaps, than the average.

The fruit is broadly obovoid to pear shaped, about 20 ounces in weight, with a rough surface of rich purplish maroon color. It presents a very attractive appearance. The skin is rather thin and somewhat pliable, but coarsely granular in texture. The flesh is rich cream yellow in color, free from discoloration, and of very rich, pleasant flavor. The seed is medium sized and tight in the cavity.

A formal description of the fruit is as follows:

Form broad pyriform to obovoid; size very large, weight 20 ounces, length 5 inches, greatest breadth 3¾ inches; base pointed, the stem inserted obliquely without depression; apex rounded, slightly depressed immediately around the stigmatic point; surface pebbled to rather rough, deep purplish maroon in color, almost glossy, with few inconspicuous light-colored dots; skin rather thin for this race, about one-sixteenth of an inch throughout, fairly pliable and peeling from the flesh when fully ripe, the purplish maroon color of the surface extending clear through the skin; flesh rich cream yellow in color, changing to pale green close to the skin, firm, of rich flavor; quality excellent; seed medium sized, weighing about 3 ounces, roundish conical in form, tight in the cavity, with both seed coats adhering closely to the cotyledons.

KEKCHI. (No. 22.) S. P. I. No. 44679.

The remarkable little fruit of the Kekchi avocado (Pl. XIX) is valuable not only for its earliness and good quality, but the tree is also noted for its productiveness. The fruit commences to ripen in December, at least two months before most of the other avocados of the same region. Though small in size, the seed is proportionately small, leaving a good proportion of flesh of rich flavor. The variety has a long ripening season, which suggests its use as an avocado for the home garden.

The parent tree is growing in a sitio belonging to Santiago Mendoza in the town of Purula, Department of Baja Vera Paz. The elevation is approximately 5,150 feet. The soil is a heavy clay loam. The tree stands on a slope, in the midst of a small maize patch. It is about 35 feet in height, with a trunk 2 feet thick at the base, branching about 10 feet from the ground. The crown is broad and spreading, but sparsely branched. Judging from the size of the tree it must be at least 30 or 40 years old. It seems to be a vigorous grower, the branchlets being stout, well formed, and of good length. The bud wood is quite satisfactory, having well-developed eyes which do not show a tendency to drop and leave a blind bud. The tree is uncared for and has much dead wood in it.

While Purula is scarcely higher than Antigua, it has a colder climate. It is not, however, sufficiently cold to test the hardiness of avocados of the Guatemalan race.

The tree has not been seen in bloom, but probably flowers in February. In good seasons it carries an enormous crop of fruit. This would be expected of a small-fruited variety. The first fruits turn color about the first of December and can then be picked. The height of the season, however, is not until February, at which time the fruits are fully mature. If allowed to remain on the tree, many of them hang until April or May.

The fruit is pear shaped or obovoid, small, weighing not over 6 ounces (it will probably weigh more when grown under cultivation in California and Florida), somewhat rough on the surface, and maroon in color. The skin is thick and woody. The flesh is yellow, sometimes slightly discolored with fiber streaks, but with no objectionable fiber. The flavor is rich and pleasant. The seed is medium sized in comparison with the size of the fruit. In comparison with the seeds of most other 6-ounce fruits it would be called small.

The variety may be formally described as follows:

Form broadly obovoid to pyriform; size small, weight 5 to 6 ounces, length $3\frac{1}{4}$ to $3\frac{1}{2}$ inches, greatest breadth $2\frac{3}{8}$ to $2\frac{3}{4}$ inches; base tapering, the moderately stout stem, which is $5\frac{1}{2}$ inches long, being inserted slightly obliquely without depression; apex rounded or almost imperceptibly flattened; surface rough, deep dull purple-maroon in color, with rather few small russet dots; skin thick, one-sixteenth of an inch at base, nearly one-eighth of an inch toward the apex of the fruit, coarsely granular and woody in texture; flesh rich cream yellow, changing to pale green near the skin, sometimes marked with fiber traces but without any tough fibers, buttery in texture, of very rich and agreeable flavor; quality very good; seed roundish oblate, small to medium in size, weighing less than 1 ounce, tight in the seed cavity, with both seed coats adhering closely to the cotyledons.

MAYAPAN. (No. 23.) S. P. I. No. 44680.

The Mayapan avocado (Pl. XX) possesses several excellent commercial characteristics—round form, desirable size (nearly 1 pound), attractive purple color, thick, firm skin, and flesh of excellent quality. In this latter respect it is one of the very best varieties in the collection. The seed is not large and the tree is very productive. It seems a very promising avocado.

The parent tree is growing in a sitio owned by Arcadio Saguirre in the town of Purula, Department of Baja Vera Paz. The elevation of this town is approximately 5,150 feet. The soil is a heavy clay loam, black, very fertile, and retentive of moisture. The tree stands in the rear of the property, close to a chichicaste hedge. It is apparently not more than 15 or 20 years old, slender, about 40 feet high, with a trunk 1 foot thick at the base. The crown is slender, but well branched, with an abundance of fruiting wood. The young growths are shapely and vigorous, indicating that the variety will probably be a good grower. The bud wood is satisfactory, the branchlets being of good length, round, smooth, with the eyes well placed, strong, and not inclined to fall. If the young trees show a tendency to grow tall and slender, they can easily be kept in hand by judicious pruning.

The climate of Purula is colder than that of Antigua, though the elevation is about the same. It is not sufficiently cold, however, to test the hardiness of avocados of the Guatemalan race. It must be assumed that this variety is of average hardiness until it can be put to a test in the United States.

The flowering season of the parent tree is in March and early April. It blooms profusely and sets a heavy crop of fruit. The crop produced in 1917 from the 1916 blooms was very heavy, and another equally heavy one was set from the 1917 blooms. The productiveness of the variety gives promise of being well above the average. The ripening season commences about the middle of March and extends to the first of July. It can probably be termed midseason or slightly later than midseason.

The fruits are of attractive round form, nearly a pound in weight, with a slightly rough surface of purple color. The skin is much thicker than the average, but not very brittle. The flesh is rich yellow in color, absolutely free from discoloration of any sort, dry and oily, cutting like soft cheese. The flavor is exceptionally rich and nutty. The seed is rather small and is tight in the cavity. The size of the fruit conforms admirably to hotel and restaurant requirements, where it is desired to serve a half fruit as a portion, and the quality is so unusually good that it would seem that this variety is of exceptional promise.

Following is a formal description of the fruit.

Form spherical to roundish obovoid, sometimes slightly oblique; size medium to above medium, weight 13 to 16 ounces, length 3¾ to 4 inches, greatest breadth 3½ to 3¾ inches; base rounded or obscurely pointed, the stem rather slender, 7 inches long, inserted obliquely, without depression; apex rounded or slightly flattened obliquely; surface decidedly rough, greenish purple to dull purple in color, with numerous large greenish yellow dots; skin very thick, varying from as much as three-sixteenths of an inch near the stem, where it is thickest, to somewhat more than one-sixteenth of an inch near the apex, coarsely granular in texture, woody, but separating readily from the flesh at the proper stage of ripeness; flesh rich cream yellow in color, without fiber discoloration, firm, meaty, of rich and pleasant flavor; quality excellent; seed oblate-spherical to spherical in form, medium sized, weighing 1⅓ to 2 ounces, tight in the cavity, with both seed coats adhering closely to the smooth cotyledons.

KAYAB. (No. 25.) S. P. I. No. 44681.

Fruits of the Kayab avocado are of excellent quality and desirable shape. This variety resembles the Trapp of Florida and the Chisoy variety of this collection in form and size. Some of the specimens examined had large seeds, but the best ones had seeds which could be termed medium sized or almost small in comparison with the size of the fruit. In small specimens of any variety the seed commonly appears large. This variety was not studied as thoroughly as some of the others, but it is considered well worthy of a trial in the United States.

The parent tree is growing in the cafetal of Francisco Muus, called Chiquitop, in the edge of the town of San Cristobal, Department of Alta Vera Paz. The elevation is about 4,600 feet. The soil is heavy reddish clay, which is very tenacious when wet. The tree stands among coffee bushes 6 to 8 feet high. It is about 40 feet in height, with the trunk 18 inches thick at the base, branching 12 feet from the ground. The crown is broad and spreading, well branched, and dense. The branchlets are rather short, but of good appearance, being well formed and stout. The bud wood is good, but it is difficult to get long bud sticks from the parent tree. The eyes are well developed and do not drop early.

Varieties growing at this elevation in Guatemala are not subjected to severe frosts; hence, there is no way of telling whether they are hardier than the average until they are tested in the United States.

The tree probably flowers in late February and March. It is said to fruit heavily, but at the time it was examined in 1917 only a few fruits were left on it. The ripening season is from February to May, which is the main season for avocados at San Cristobal.

The fruit is round, about a pound in weight, yellowish green in color, with a moderately thick skin. The flesh is yellow, clear, dry, of very rich flavor, and free from any discoloration. The seed is medium sized in large specimens, being rather large in some of the smaller ones examined. In many instances the seed is placed to one side of the center of the fruit.

A formal description of the variety follows.

Form obliquely spherical, sometimes slightly narrowed toward the base; size medium to very large, weight 14 to 20 ounces, length 3¾ to 4 inches, breadth 3⅝ to 4 inches; base slightly flattened, oblique, the stem inserted obliquely without depression; apex obliquely flattened; surface pebbled, most conspicuously so around the base of the fruit, deep green to yellowish green in color, almost glossy, with numerous small russet or yellowish dots; skin moderately thick, one-sixteenth to one-eighth of an inch, hard and woody; flesh cream yellow in color, without fiber or discoloration, firm, dry, of very rich flavor; quality excellent; seed medium sized, weighing about 2 ounces, sometimes excentric, tight in the seed cavity, with both seed coats adhering closely to the cotyledons.

MANIK. (No. 26.) S. P. I. No. 45560.

The Manik avocado is a productive and rather early variety of excellent quality. The fruit is medium sized, of pleasing form, and has clear yellow flesh of unusually rich flavor.

The parent tree is growing in the finca La Polvora in Antigua. The elevation is about 5,100 feet. While it is growing among coffee bushes and grevilleas, the tree is not crowded and has developed to large size. It stands about 50 feet high, with a rather slender trunk and a dense crown, the trunk being 2 feet thick at the base and branching about 8 feet from the ground. The age of the tree is probably 30 years or more. It is badly attacked by leaf-gall, but in general has the appearance of a strong, vigorous variety, the branchlets being well formed, long, round, and stout. The bud wood is good, having strongly developed eyes well placed for cutting.

Antigua does not experience severe frosts; hence, it is impossible to determine in advance of a trial in the United States whether or not the variety is any hardier than the average of the Guatemalan race.

The flowering season is February and March. The tree blooms profusely and in some years sets enormous crops of fruit. In 1917 a very heavy crop was ripened. The 1918 crop is much smaller. In general, the bearing habits of the tree give promise of being unusually good, there being a tendency for the fruits to develop in clusters. The season of ripening is properly from February to June, but fruits picked early in December develop fairly good flavor upon being ripened in the house. The season may be termed early to midseason.

The fruit is more variable in form than that of most other varieties. The range is from oval to slender pyriform, nearly all the fruits being of the latter shape, without, however, a well-defined neck. The weight varies from 8 to 12 ounces. The surface is slightly rough and green in color. The skin is moderately thick, the flesh rich yellow in color, quite free from all fiber or discoloration, and of very rich and pleasant flavor. The seed is a trifle large in some specimens, small in others, being medium sized or rather small on the average. It is tight in the seed cavity.

The variety may be formally described as follows:

Form oval to elliptic-pyriform; size below medium to medium, weight $8\frac{1}{2}$ to 12 ounces, length $3\frac{3}{4}$ to $4\frac{3}{4}$ inches, breadth $2\frac{3}{4}$ to $3\frac{3}{4}$ inches; base rounded to pointed, the stem inserted slightly to one side without depression; apex rounded to broadly pointed; surface sparsely pebbled, uniformly so, bright green in color, with comparatively few small yellowish dots; skin not very thick for this type, one-sixteenth of an inch near the stem and slightly more toward the apex of the fruit, hard and coarsely granular; flesh rich cream yellow in color, free from fiber and with no discoloration, firm and unusually dry, of rich and pleasant flavor; quality very good; seed ovoid conical, medium sized, weighing 1 ounce more or less, tight in its cavity, with both seed coats adhering closely to the smooth cotyledons.

CABNAL. (No. 27.) S. P. I. No. 44782.

The Cabnal avocado is a very productive variety (Pl. XXI), whose fruits are of pleasing round form, good size, and rich flavor. It gives promise of being slightly later in ripening than most other Antiguan varieties.

The parent tree is growing in a sitio occupied by Atanasio Salazar in the outskirts of Antigua, a short distance beyond the first kilometer post on the Guatemala road. The elevation is approximately 5,100 feet. The tree stands beside a small stream, with several jocote trees (*Spondias mombin* L.) close around it. Its age is unknown, but it appears to be at least 25 years old, perhaps more. It stands about 30 feet high, the trunk, about 15 inches thick at the base, giving off its first branches 10 feet above the ground. The crown is rather broad, dense, and well branched. The young branches are erect, stout, stiff, and well formed, indicating that the tree is a vigorous grower. The wood is not unduly brittle. The bud wood is excellent, the branches being of good length with the buds well placed. The eyes are large, well developed, and show no tendency to fall and leave a blind bud.

The climate of Antigua is not cold enough to test the hardiness of Guatemalan avocados, but it may reasonably be assumed that this variety is of average hardiness.

The flowering season is late February and March. The tree produced a heavy crop of fruit from the 1916 blooms and set an equally heavy crop in 1917 to be ripened in 1918. The bearing habits of the variety give promise of being excellent. The fruit ripens in March and April, but can be left on the tree until June or even later. The ripening period may be termed midseason to late.

The fruit is round, weighing 12 to 16 ounces, rather rough, and dark green or yellowish green externally, with a skin of moderate thickness. It is attractive in appearance and of convenient and desirable size and form. The flesh is cream yellow, very oily in texture, and of rich flavor. There is a peculiar nuttiness about the flavor which is not found in the other varieties of this collection. It may, perhaps, be said to suggest the coconut. The seed is variable in size, but on the average is rather small for a round fruit. It is tight in the cavity.

A formal description of the fruit is as follows:

Form spherical; size below medium to above medium; weight 10 to 16 ounces; length $3\frac{3}{4}$ to $3\frac{7}{8}$ inches; breadth $3\frac{1}{4}$ to $3\frac{3}{4}$ inches; base rounded, the slender stem inserted slightly to one side without depression; apex flattened and slightly depressed around the stigmatic point; surface pebbled, usually rather heavily so, dull green in color with a few small yellowish dots; skin thick, about one-eighth of an inch, coarsely granular toward the flesh, hard and woody; flesh rich cream yellow in color, with no fiber and only very slight discoloration, pale green near the skin, fairly dry, and of rich, nutty flavor; quality very good; seed round or oblate, medium sized, varying from 1 to 2 ounces in weight, tight in the cavity, with both seed coats adhering closely to the cotyledons.

CANTEL. (No. 28.) S. P. I. No. 44783.

The parent tree of the Cantel avocado is just coming into bearing and produced but few fruits in 1917. While it is too early to know definitely what its bearing habits will be, the character of the fruit is so unusual as to make it worth while to test the variety in the United States. Most round avocados have medium-sized or large seeds. This one, however, has an unusually small seed, and if it proves desirable in other respects it will be well worth cultivating. In quality it is good.

The parent tree is growing in the finca La Candelaria in Antigua. The elevation is approximately 5,100 feet. The tree has been planted to shade coffee bushes and is still young, its age not being more than 5 or 6 years. It is tall and slender in habit, about 20 feet high, with a trunk 6 inches thick at the base. As is customary in fincas, the tree has not been allowed to branch low, the first branches being more than 6 feet from the ground. The growth looks unusually strong and healthy, the young branchlets being stout, long, stiff, and well formed. The bud wood is excellent, having the vigorous buds well placed.

Little can be determined regarding the flowering and fruiting habits of the tree at this early day. When it was first seen, early in May, 1917, it had only three fruits on it. It may have borne more, as the crop had already been harvested from most of the trees in the finca. The ripening season is probably March to May.

The hardiness of the tree can not be determined until it is tested in the United States, as it is never very cold at Antigua.

The fruit is round, about a pound in weight, green, with a moderately thick skin. The flesh is of good color and quality, and in quantity much greater than in the average round avocado, since the seed is quite small.

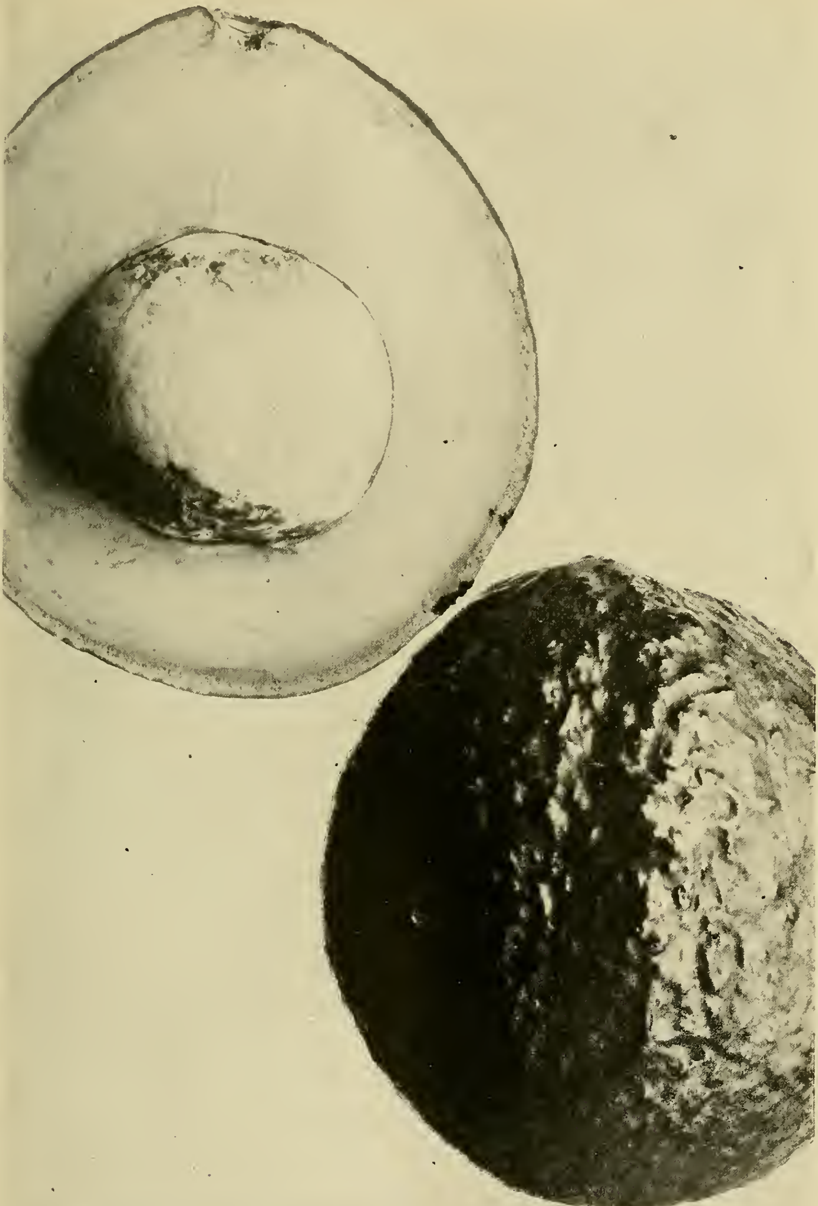
The variety may be described as follows:

Form oblate; size medium, weight 16 ounces, length 3½ inches, breadth 3¾ inches; base slightly flattened, the long slender stem inserted without depression almost in the longitudinal center of the fruit; apex flattened, slightly depressed around the stigmatic point; surface pebbled, deep yellow green in color, with numerous minute yellowish dots; skin not very thick for this race, one-sixteenth of an inch or slightly more, hard, granular toward the flesh; flesh cream colored around the seed, becoming pale green close to the skin, very slightly discolored, with brownish fiber tracing, but with no fiber; flavor rich and pleasant; quality very good; seed very small for a round fruit, oblate, weighing less than 1 ounce, tight in the cavity, with both seed coats adhering closely to the cotyledons.

TERTOH. (No. 30.) S. P. I. No. 44856.

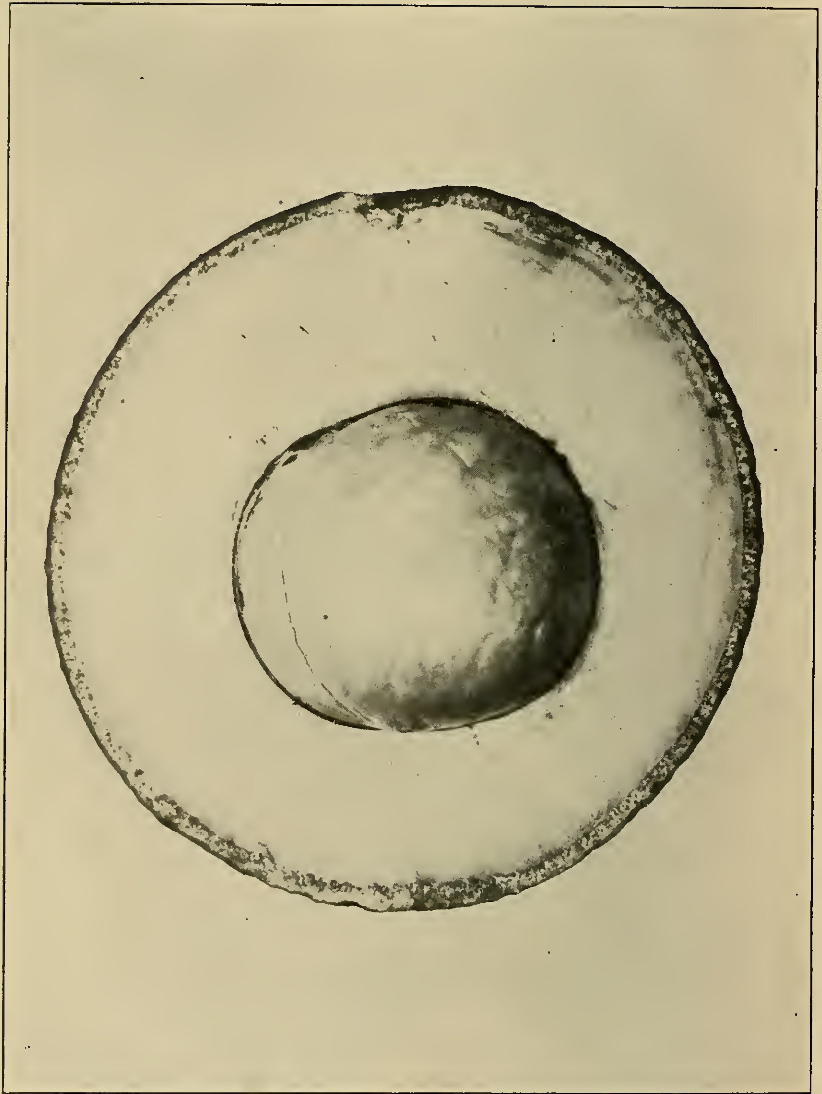
The Tertoh avocado is a famous variety from Mixco, near the city of Guatemala, noted for its immense size and excellent quality. (Pl. XXII.)

The parent tree is growing in the sitio of Leandro Castillo, just above the plaza of Mixco, at an elevation of approximately 5,700 feet.



THE MAYAPAN AVOCADO, A PRODUCTIVE MIDSEASON VARIETY OF EXCELLENT QUALITY.

This avocado is characterized by flesh of fine, smooth texture, deep-yellow color, and very rich flavor. In quality it is the equal of any variety in the collection. The surface is deep maroon-purple in color and the skin moderately thick. The seed is medium sized and tight in the cavity, as it is in nearly all avocados of the Guatemalan race. The parent tree is an excellent bearer, as far as can be judged from its behavior during two seasons. (Photographed, natural size, at Purula, Baja Vera Paz, Guatemala, April 10, 1917.)

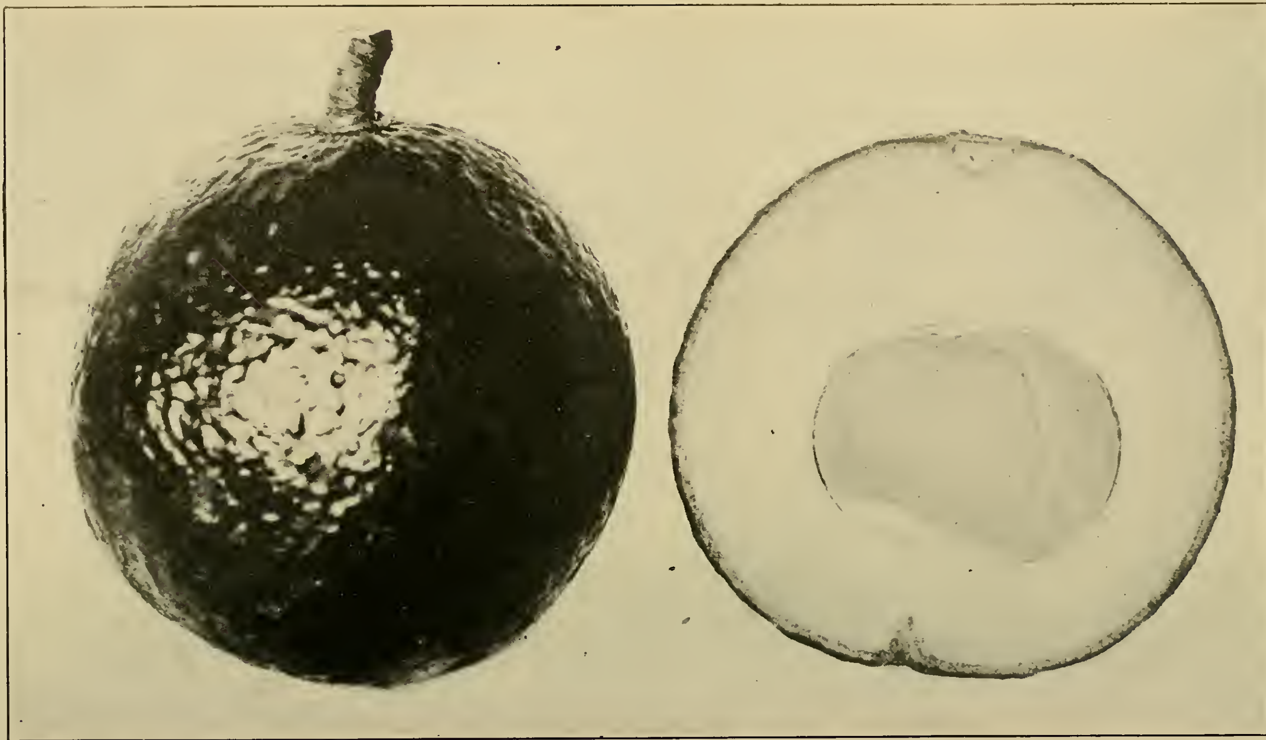


THE CABNAL AVOCADO, AN EXCELLENT MIDSEASON VARIETY.

The present ideal of avocado growers in the United States is a round fruit of about 1 pound in weight, with a small seed and flesh free from fiber and of rich flavor. In the variety here shown these characteristics are combined to an unusual degree. The surface is slightly rough and green in color, the skin thick and woody. The flesh is cream yellow in color and of distinctive flavor. The parent tree bore an excellent crop in 1917, ripening from March to June, which is about a month later than the average. (Photographed, natural size, at Antigua, Guatemala, May 4, 1917; P17262FS.)

THE TERTOH AVOCADO, ONE OF THE LARGEST GUATEMALAN VARIETIES.

The fruits here shown are not yet fully grown. Good specimens of this variety weigh 3 pounds and are of excellent quality, the flesh being rich yellow in color, free from all discoloration, and of nutty flavor. The seed, as will be noticed in the illustration, is comparatively small. This variety has a considerable reputation in the vicinity of the city of Guatemala, owing principally to its large size. Avocados weighing more than 2 pounds are rare in Guatemala. (Photographed at the city of Guatemala, December 2, 1917; P17466FS.)



THE KANAN, AN EARLY AVOCADO OF EXCELLENT FORM AND QUALITY.

This variety comes from the same region as the Kanola, and while not so early as the latter by at least one month it is a larger fruit and one of excellent quality. It weighs about 1 pound. The surface is green in color, the skin moderately thick and woody, while the flesh is cream yellow, free from fiber or discoloration, and of rich flavor. Round avocados usually have seeds somewhat larger in proportion to the size of the fruit than pyriform or elongated avocados, but in the case of the Kanan the seed is comparatively small. The fruits shown are here considerably reduced in size. (Photographed at Antigua, Guatemala, November 16, 1917; P17424FS.)

The tree is said by the owner to have been planted by his grandfather from a seed brought from Moran, a small village about 10 miles distant. While its age is not definitely known, it is estimated at about 60 years. It is about 25 feet high, broad and spreading in habit, with a trunk 15 inches thick at the base, branching 7 feet from the ground to form a dense crown fully 30 feet broad. A peculiarity of the tree is its very brittle wood. This may be against the variety in California and Florida, where strong winds occasionally do much damage. The growth seems to be vigorous, and the bud wood is very satisfactory, the twigs being stout, well formed, and supplied with vigorous buds.

The climate of Mixco is cool, but not cold enough to test the hardiness of the variety. This can only be determined by a trial in the United States.

The tree flowers in March. According to the owner, it has not borne as well in recent years as formerly. He attributes this to the fact that the tree is getting old, but it seems in addition to have been weakened by the attacks of insects. No fruits were produced from the 1916 blooms. The 1917 blooms resulted in a good crop, but many of the fruits dropped to the ground when nearly full grown. Upon examination they appeared to have been attacked by some insect, whose burrows could be seen toward the base of the fruit. The season of ripening is said to be from February to April, the fruits being at their best in March. They can, however, be picked as early as January. Toward the end of the season they become very rich in flavor.

The fruit is long and slender, tending toward pyriform. It weighs as much as 3 pounds in some instances. It is deep purple in color when fully ripe and has a rather thin skin for this race and deep cream-colored flesh of very rich flavor. The seed is very small in comparison to the size of the fruit.

An American relates that he once brought a fruit from this tree to his home in the city of Guatemala, where it sufficed to make salads for two meals for a household of 10 people.

The variety may be formally described as follows:

Form oblong to slender pyriform; size extremely large, weight 28 to 36 ounces, and occasionally up to 48 ounces, length 7 to 8½ inches, greatest breadth 3¾ to 4¼ inches; base broad to narrow, sometimes pointed, the slender stem about 5 inches long inserted slightly obliquely without depression; apex rounded; surface nearly smooth, deep dull purple in color with numerous russet dots and patches; skin moderately thick, about one-sixteenth of an inch or slightly more, coarsely granular and woody; flesh cream yellow in color, free from fiber or discoloration, and of fine texture; flavor rich and pleasant; quality excellent; seed very small, slender conical in form, about 1½ ounces in weight, tight in the seed cavity, with both seed coats adhering closely to the cotyledons.

AKBAL. (No. 32.) S. P. I. No. 45505.

The Akbal avocado is a variety noteworthy for earliness, and it has been included in this collection primarily because of this characteristic. It is, however, of very good quality and has no visible defects except a somewhat undesirable shape. Judging by its behavior in Guatemala, it should be the earliest variety in the collection, but it is not safe to depend upon its retaining this characteristic in the United States, since slight local variations in soil or climate sometimes affect the time of ripening very noticeably, and its earliness may not be altogether an inherent characteristic.

The parent tree is growing in the grounds of Eulogio Duarte, near Amatitlan. The location is known as Los Rastrojos and is about 2 miles from the plaza of Amatitlan, on the road which leads past the cemetery toward the hills. The altitude is approximately 4,200 feet. The tree is about 40 feet high, spreading but of compact growth, the crown being fairly dense. The trunk is about 20 inches thick at the base and branches 10 feet from the ground. According to the owner, the tree is 6 years old, but judging from its size it can not be less than 20. It seems to be vigorous and in good condition. The bud wood which it yields is fairly satisfactory, the growths being well formed though not very stout, while the eyes are vigorous and do not drop quickly.

This is rather a warm region; hence, there is nothing to indicate that the variety will be unusually hardy.

The crop harvested in the fall of 1917 was a good one. According to the owner, it was 600 fruits, but it seems probable that it was considerably more. The bearing habit of the tree gives promise of being very satisfactory. The flowering season is in November and December, and the fruit ripens from the following August to November. It is fully ripe and in perfect condition for picking by the middle of October, whereas the average variety of the same region is not mature until January at the earliest.

In two characteristics this variety does not seem to agree with the Guatemalan race. It has a thin skin and the seed coats do not adhere closely to the cotyledons. A few other varieties showing these same characteristics were seen in the same locality, and it is possible that they may not be true Guatemalan avocados, though in most respects they appear to belong to this race.

In form the fruit is long and slender, sometimes slightly curved, and sometimes becoming pyriform. It is medium sized, weighing about 12 ounces. The surface is smooth and deep green in color. The skin is thin and surrounds deep-yellow flesh of good quality, without fiber or discoloration. The seed is medium sized, and while it never rattles in its cavity it does not fit as snugly as it does in nearly all other Guatemalan varieties.

A formal description of this variety is as follows:

Form elongated to slender pyriform, sometimes curved; size medium, weight 12 ounces, length $5\frac{1}{2}$ to $6\frac{1}{2}$ inches, greatest breadth $2\frac{1}{4}$ to 3 inches; base narrow, rounded, the short, stout stem (2 to 3 inches long) inserted obliquely; apex rounded to broadly pointed, the stigmatic point slightly depressed; surface quite smooth, uniformly bright green in color, with very numerous minute yellowish dots; skin very thin, less than one-sixteenth of an inch, but firm and tough; flesh rich yellow near the seed cavity, changing to light green near the skin, firm, or fine texture, free from fiber, and of rich, nutty flavor; quality very good; seed medium sized, weighing about $1\frac{1}{2}$ ounces, conical to slender conical in form, the cotyledons smooth, with the seed coats adhering loosely.

ISHIM. (No. 34.) S. P. I. No. 45562.

While most avocados in the Antigua region do not ripen their fruits until February or March, the Ishim tree matures its entire crop by the end of November. It can be considered, therefore, a very early variety, and as such is worthy of a trial in California, where early varieties of the Guatemalan race are much desired. Its only visible defect is its somewhat large seed. The quality is good, and the fruit is attractive in appearance.

The parent tree is growing in a small coffee plantation belonging to Ignacio Hernandez, situated on the hillside above San Lorenzo del Cubo, a village some 3 miles from Antigua. The elevation is about 5,500 feet. The tree is about 35 feet high, broad and spreading in habit, with a fairly dense crown 40 or 45 feet broad, slightly inclined to droop. The trunk is divided into two main branches, one about 1 foot thick at the base, the other 9 inches. The larger branch divides 8 feet above the ground into two main limbs. The growth seems to be reasonably vigorous and the branchlets are well formed and stout. The bud wood appears to be quite satisfactory.

This location is not sufficiently high to experience very cold weather; hence, the variety must be assumed to be of average hardiness for the Guatemalan race until it can be tested in the United States.

The productiveness of the variety is somewhat in doubt. The crop harvested in 1917 was not large. The tree bloomed heavily in December, 1917, and was setting a good crop when last seen. The season of ripening extends from October to the first of December. Probably the fruits would remain on the tree later than December if allowed to do so, but as avocados are very scarce at that season of the year they are picked as soon as they mature.

The form of the fruits, pear shaped to obovoid, is attractive, as is the deep maroon-purple color which they assume upon ripening. They are of convenient size, about 12 ounces, and the flesh is yellow and of good quality. The seed is larger than in the best late varieties, but not unreasonably so. It is tight in the cavity.

Following is a formal description of the variety.

Form most commonly pyriform, but sometimes obovate; size below medium to medium, weight 10 to 12½ ounces, length 4 to 5 inches, greatest breadth 2⅞ to 3⅛ inches; base narrow to rounded, the stem inserted obliquely almost without depression; apex rounded or obtusely pointed, somewhat flattened around the stigmatic point; surface almost smooth, sometimes pitted, deep, dark maroon-purple in color, with numerous small light maroon dots; skin unusually thin for this race, slightly less than one-sixteenth of an inch, soft, tender, peeling fairly readily when the fruit is fully ripe; flesh fine grained, buttery, cream yellow in color, with slight fiber discolorations in some specimens but no actual fiber, the flavor moderately rich and nutty; quality good; seed large, broadly conical to nearly spherical in form, weighing 1½ to 2¼ ounces, tight in the seed cavity, with the seed coats adhering closely to the cotyledons.

KANAN. (No. 35.) S. P. I. No. 45563.

The Kanan avocado is an early variety (Pl. XXIII) from the Antigua region, of rather large size, desirable form, and excellent quality. Although a round avocado, the seed is not large in proportion to the size of the fruit, but on the contrary is rather small. On the whole this seems like a very promising variety.

The parent tree is growing in a small coffee plantation belonging to Ignacio Gonzales, situated on the road to San Antonio Aguas Calientes, just beyond the village of San Lorenzo del Cubo. The elevation is approximately 5,300 feet. The tree is about 35 feet high, with a trunk 30 inches thick at the base, dividing 2 feet above the ground to form two main limbs each 1 foot in diameter. These give off their first branches about 12 feet from the ground. The bud wood is excellent, the branchlets being stout, well formed, with vigorous buds conveniently placed.

The tree did not produce a heavy crop from the 1916–17 blooms, but is said to have borne more heavily in past seasons. It flowers in December and January and commences to mature its fruits the first of the following December. They are not at their best until January.

The climate of this location is not sufficiently cold to test the hardiness of the variety; hence, it must be assumed, pending a trial in the United States, that it is of about average hardiness for the Guatemalan race.

In form the fruit resembles the Trapp of Florida, being round to oblate. It also resembles the Trapp in size and color, but the surface is somewhat rough and the skin thick and hard. The flesh is cream yellow in color, free from discoloration, and of a rich and pleasant flavor. The seed is small and tight in the cavity.

The variety may be formally described as follows:

Form nearly spherical, varying to slightly oblate and more rarely to broadly obovoid; size above medium to very large, weight 16 to 20 ounces, length 3½ to 4½ inches, greatest breadth 3½ to 4 inches; base rounded, the stem inserted very slightly to one side and almost without depression; apex flattened; surface pebbled, bright green in color with a few large yellowish dots; skin moderately thick, nearly one-eighth of an inch, coarsely granular, woody, and brittle; flesh cream color, greenish close to the skin, free from fiber or discoloration, of rich and pleasant flavor; quality very good; seed rather small, weighing about 2 ounces, oblate in form, tight in the cavity, with both seed coats adhering closely to the smooth cotyledons.

CHABIL. (No. 36.) S. P. I. No. 45564.

The Chabil avocado is a small, early variety of attractive appearance, desirable form, and excellent quality. It is similar to the Kanola of this series and is from the same region.

The parent tree is growing in a small coffee plantation belonging to Ignacio Hernandez, situated on the hillside above San Lorenzo del Cubo, about 3 miles from Antigua. The elevation is approximately 5,500 feet. The tree is 45 feet high, the crown round, of good form, 45 feet broad, formed high above the ground. The trunk is 2 feet thick at the base and the branches are 15 feet above the ground. The age of the tree is not known.

The elevation of this location is not sufficient to show whether the variety is unusually hardy or not. It may be assumed to be of average hardiness for the Guatemalan race until it has been tested in the United States.

The crop ripened at the end of 1917 was a very large one, indicating that the productiveness of the variety is likely to prove satisfactory. The flowering season appears to be December and January, the fruiting season November to March.

The fruit is round, weighs about 9 ounces, and is deep purple when fully ripe. The skin is thick and woody. The flesh is of yellow color. The seed is rather small for a round fruit and is tight in the cavity.

Following is a formal description of the variety.

Form spherical or nearly so, usually slightly oblique; size below medium, weight averaging 9 ounces, length 3½ inches, greatest breadth 3⅜ inches; base slightly flattened, the stem inserted somewhat obliquely without depression; apex obliquely flattened but not prominently so; surface practically smooth, deep dull purple in color when fully ripe, with scattering large yellowish dots; skin thick, sometimes more than one-eighth of an inch, very coarsely granular, hard and woody, rather unusually so; flesh rich cream yellow in color, with a few fine and almost unobjectionable fibers running through it, flavor rich and nutty; quality good; seed medium sized, averaging about 1½ ounces in weight, oblate in form, tight in the cavity, with both seed coats adhering closely to the smooth cotyledons.

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JOHN R. MOHLER, Chief.

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COOLING MILK AND STORING AND SHIPPING IT AT LOW TEMPERATURES.

By James A. Gamble, *Market Milk Specialist, and* John T. Bowen, *Technologist, Dairy Division.*

CONTENTS.

SCOPE OF EXPERIMENTAL WORK.

The experimental work reported in this bulletin covers (1) the relative efficiency of cooling tanks of different construction handled under varying conditions; (2) the most efficient methods of cooling and storing milk on the farm; and (3) the transportation of milk at low temperatures to market.

THE PRINCIPLE OF COOLING.

If a warm body is placed in contact with a cold one, heat will flow from the warmer to the colder until both have reached the same temperature. The rate of this flow depends upon the difference of temperature between the two bodies. Heat flows most rapidly when there is the greatest difference in temperature, and the rate gradually decreases as the temperatures become equal.

The temperature of a body does not give a true indication of the amount of heat it contains. Heat is commonly measured by a unit called the British thermal unit, usually abbreviated B. t. u., which is the heat necessary to raise the temperature of 1 pound of water 1° F. The reason that the heat required to raise 1 pound of water 1° F. is taken as the unit is because water is one of the most difficult of all substances to heat. Practically all other substances require less heat to raise a unit quantity 1° F. For example, the heat necessary to raise 10 pounds of iron 100° F. is only $10 \times 0.113 \times 100 = 113$ B. t. u. In other words, while it takes 1 B. t. u. to raise 1 pound of water

1° F., it takes only 0.113 B. t. u. to raise 1 pound of iron 1° F. The specific heat of a substance is its ability or capacity, compared with water, to absorb heat.

All substances in nature contain more or less heat, but no way has been found for abstracting all the heat contained. In practice, however, we are not concerned with the total amount of heat a body may contain but with the changes that occur in the quantity; that is, how much heat is added or subtracted in raising or lowering the body through a given range of temperature. This is found by multiplying the weight of the body in pounds by its specific heat and then multiplying the product by the number of degrees change in temperature. For instance, if 100 pounds of warm water were cooled 100° F. the heat given up would be $100 \times 1 \times 100 = 10{,}000$ B. t. u.

The average specific heat of milk which contains $3\frac{1}{2}$ per cent butterfat is 0.93; therefore, the amount of heat required to raise 100 pounds of such milk 50° F. is $100 \times 0.93 \times 50 = 4{,}650$ B. t. u. If a like quantity of milk is cooled the same number of degrees, the B. t. u. given up are the same. In other words, the calculations are identical whether milk is heated or cooled.

Air and water are two natural cooling agencies. Cooling by means of air is not generally practicable because of its low heat-absorbing capacity and because its temperature is usually too high. Water, therefore, is the common cooling agency used. If it were possible to avoid all losses, 1 pound of milk in being cooled 1° F. would require 0.93 of a pound of water which would be raised 1° F. in temperature. In practice, however, a certain amount of cooling effect is always lost through radiation; consequently more water will be required, the exact quantity depending upon the efficiency of the cooling apparatus. This is assuming that the cooler was 100 per cent efficient. To determine the final temperature when milk is cooled by water and allowed to remain until both are practically the same temperature the following formula may be used:

$$t = \frac{(W \times S \times T) + (W_1 S_1 T_1) + (W_2 S_2 T_2)}{WS + W_1 S_1 + W_2 S_2}$$

t = Final temperature of whole.
W = Weight of water.
S = Specific heat of water.
T = Initial temperature of water.
W_1 = Weight of milk.
S_1 = Specific heat of milk.
T_1 = Initial temperature of milk.
W_2 = Weight of can.
S_2 = Specific heat of can.
T_2 = Final temperature of can.

For example, figure 1 shows a 10-gallon can of milk at an initial temperature of 85° F. being cooled in a tank containing 30 gallons of water at an initial temperature of 37° F. The weight of the can containing the milk is taken at 21 pounds and its temperature is approximately that of the milk, 85° F. The weights of the water, milk, and can are 250, 86, and 21 pounds, respectively, and their specific heats are 1, 0.93, and 0.113, respectively. Substituting these in the formula above and solving for the final temperature of the whole, we have:

$$t = \frac{(250\times1\times37)+(86\times0.93\times85)+(21\times0.113\times85)}{(250\times1)+(86\times0.93)+(21\times0.113)} = \frac{16252}{332.4} = 48.9° \text{ F.}$$

In practice, however, some heat is absorbed in the surrounding air so that the final temperature of milk and water is higher than that

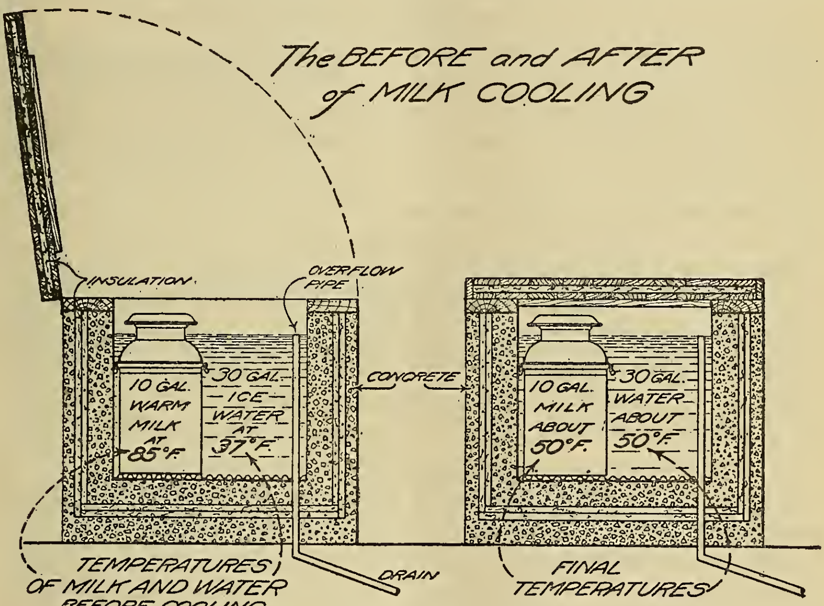

FIG. 1.—Initial and final temperature of milk and water in a concrete-insulated cooling tank.

given in the formula. In other words, the final temperature as calculated must be divided by the per cent efficiency of the tank. The efficiency of a good insulated tank of the size and construction of that shown in figure 1 was found to be about 97 per cent. The final temperature of the milk and water will, consequently, be 48.9 divided by 0.97 or 50.4° F.

Ice is usually necessary in order to lower the temperature of water to a point at which it will cool milk quickly and efficiently. One pound of ice has many times the cooling capacity of an equal weight of water at an initial temperature of 37° F. To change the temperature of 1 pound of water 1 degree requires the addition or extraction of only 1 B. t. u. To freeze 1 pound of water, however, requires the extraction of 144 B. t. u. In the process of freezing 1 pound of water 144 B. t. u. are extracted without change in temperature. In the melting of ice the reverse is true. This phenomenon is called the latent heat of fusion of ice. The heat required to melt 1 pound of ice, therefore, is sufficient to raise 1 pound of water 144° F. or 144 pounds of water 1° F.

COOLING MILK ON THE FARM.

Milk may be cooled most efficiently on the farm by running it over a surface cooler in which the available water supply is used at its coldest temperature and the cooling completed by storing the cans of milk in a tank of ice water. It is possible in that way within a short time to lower the temperature of milk to below 50° F. Frequently the water used for cooling milk is not used to the best advantage. Spring water is sometimes allowed to flow over the surface of the ground and is warmed several degrees before reaching the cooling apparatus. During the summer water from a storage tank aboveground is usually much warmer than that drawn directly from the well. It is best, therefore, to arrange the cooling system so that the water which flows through the surface cooler or cooling tank comes directly from the well or, if from a spring, it is conveyed in a pipe well below the surface of the ground. If ice is used in a cooling tank the quantity of water surrounding the cans should be as small as possible to give satisfactory results. Space enough should be provided between the sides of the tank and the cans of milk to allow for a sufficient quantity of ice and water to cool the milk properly. If a large volume of water has to be cooled much more ice will be necessary. If it is desired to cool milk quickly from an initial temperature of about 85° F. to one of 50° F. by setting the cans in a tank of ice water, the ice water in the tank should have a temperature of about 37° F. Under these conditions about 4 gallons of water will suffice for each gallon of milk.

EFFECT OF LOW TEMPERATURES ON BACTERIAL COUNT OF MILK.

It is commonly recognized that high bacterial counts in market milk are due largely to multiplication of bacteria rather than to inoculation. It is interesting, therefore, to note the effect of low temperatures in reducing the bacterial content of market milk. A survey of dairies in New England where high bacterial counts in the milk had been obtained was followed by instructional work emphasizing the importance of rapid and efficient cooling and demonstrating the best method of cooling at the least expense. A later survey illustrates the effect that prompt cooling and holding the milk at low temperatures had upon the bacterial content (fig. 2).

The average temperature of all samples of milk taken before the educational work was 62° F. and the average after the educational work was 54° F., or a drop of 8 degrees. The average bacterial count before was 27,000,000 per cubic centimeter, while after the instruction was given it was only 750,000 per cubic centimeter. In 18 of the poorest dairies the average bacterial count was 63,000,000 per cubic centimeter before and 2,600,000 after. The temperature before instruction was given was 63° F. while the temperature after was 56° F. Fifty-one of the best dairies had an initial count of 15,370,000 per cubic centimeter while after the demonstration the count

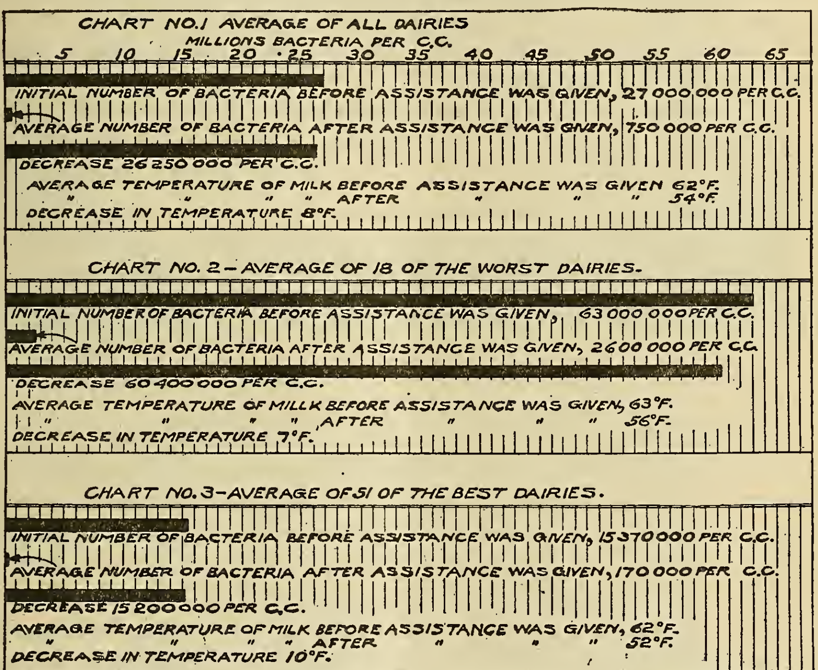

FIG. 2.—Showing improvement in milk supply of 102 New England dairies after assistance by U. S. Departure of Agriculture.

was reduced to 170,000 per cubic centimeter, a decrease of 15,200,000 per cubic centimeter. This decrease was due largely to the prevention of multiplication of bacteria because the milk was kept at a lower temperature. These examples serve to illustrate how important prompt cooling on the farm is in keeping down the bacterial count of market milk.

COOLING EFFICIENCY OF VARIOUS KINDS OF TANKS.

In order to cool and hold milk at low temperatures on the average farm a properly constructed cooling tank is necessary. In fact most dairy farms have some sort of tank in which water or water and ice are used to cool and store milk. According to a recent questionnaire approximately 80 per cent of the dairy farms producing market milk use some sort of cooling tank. The total number of dairies that reported approximated 40,000, located in 32 States. Nineteen per cent of the tanks were reported to be of metal, 25 per cent of wood, 31 per cent of concrete, and the construction of the remaining 25 per cent was not mentioned. Very few tanks were insulated, and in most cases no effort was made to minimize the loss of cooling effect due to the surface of the tank. When an abundant supply of cold running water continually passes through the tank it is unnecessary to go to the expense of insulation, but under other conditions, especially during hot weather, the loss of cooling effect from an uninsulated tank is considerable.

The location of the tank with reference to the wind and sun has an important bearing on its ability to maintain low temperatures. In order to determine the best construction and location for the cooling tank, tests were conducted to ascertain the relative milk-cooling efficiency of tanks made of galvanized iron, concrete, wood, and cork-insulated material, both indoors and outdoors, and with and without covers. All the tanks used had the same inside dimensions, namely, 30 inches in width, 60 inches in length, and 25 inches in depth, as shown in figures 3, 4, 5, and 6. The covers were made of two layers of $\frac{7}{8}$-inch tongue-and-groove boards.

All tests were made for a period of 9 hours, beginning at 8 a. m. and ending at 5 p. m. The average air temperature throughout the series of tests was about 80° F. All the thermometers used were compared with a standard thermometer and variations from true readings corrected. The thermometer used for taking the air temperature was protected from the direct rays of the sun. Air and water temperatures were taken every hour and before taking the ninth-hour reading of the water in the tank it was thoroughly stirred. Each tank contained 1,100 pounds of water at an initial temperature of 54° F.

The conditions of the tests were in brief as follows: In test No. 1 the tanks were left uncovered and set side by side in the sun. The average air temperature for the 9 hours was 84.2° F. In test No. 2 the tanks were covered and the air temperature averaged 83.5° F. In test No. 3 the tanks were sheltered from the sun by a building and were uncovered. The average air temperature was 85.2° F. In test No. 4 the tanks were sheltered by a building, were covered, and at an average air temperature of 83.4° F. Except as noted all conditions were similar for each test.

Figures 7 to 10, inclusive, show the curves of the change in temperature of the air and water under the various conditions of the

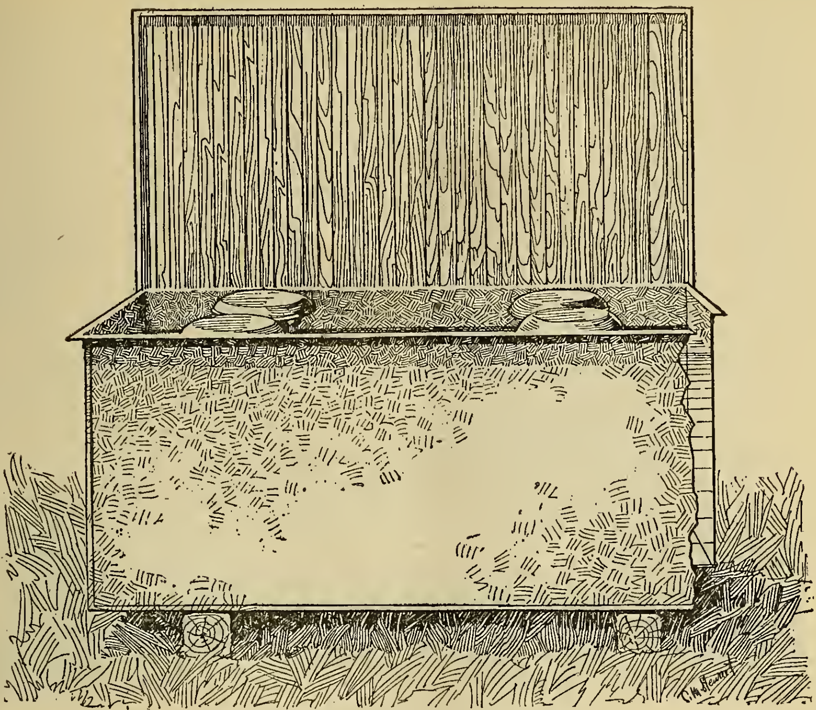

FIG. 3.—Galvanized-iron milk-cooling tank.

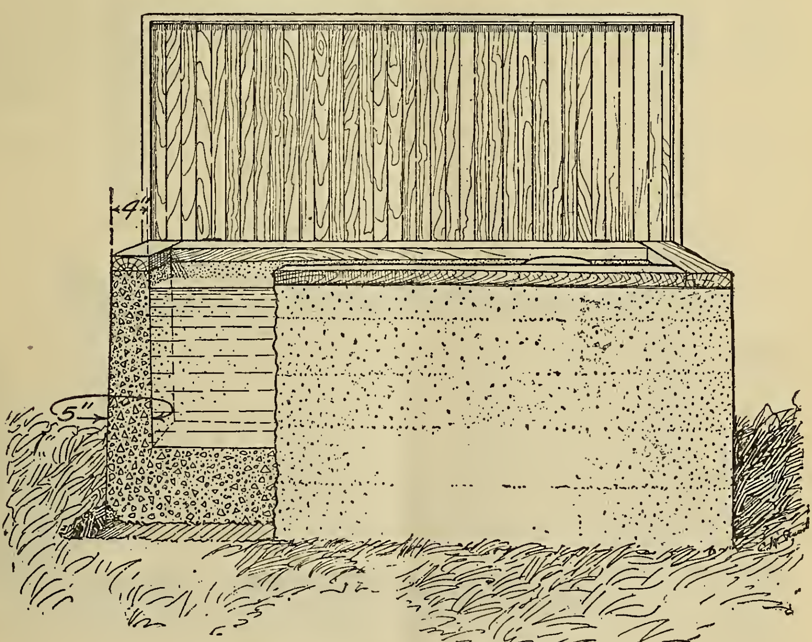

FIG. 4—Concrete milk-cooling tank.

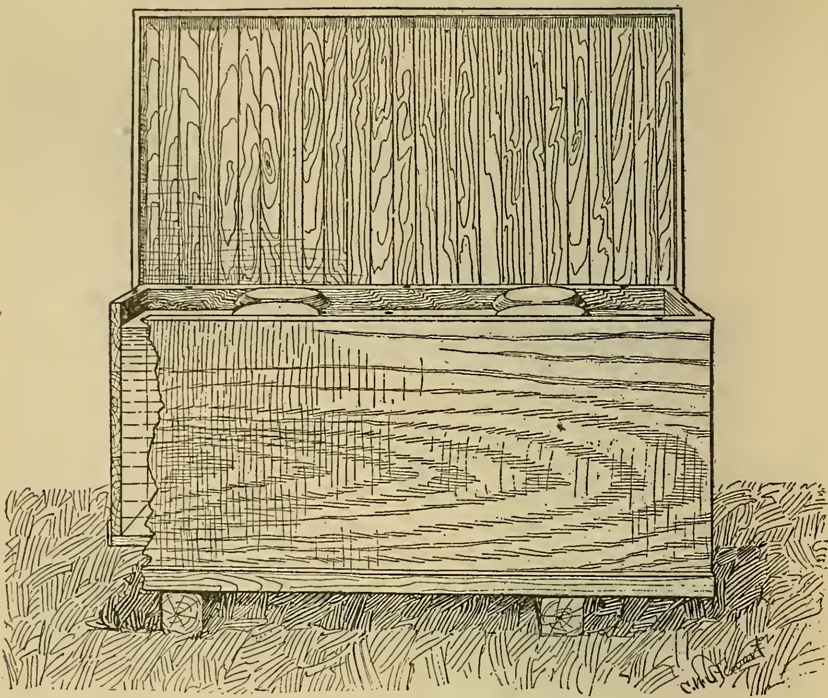

FIG. 5.—Wooden milk-cooling tank.

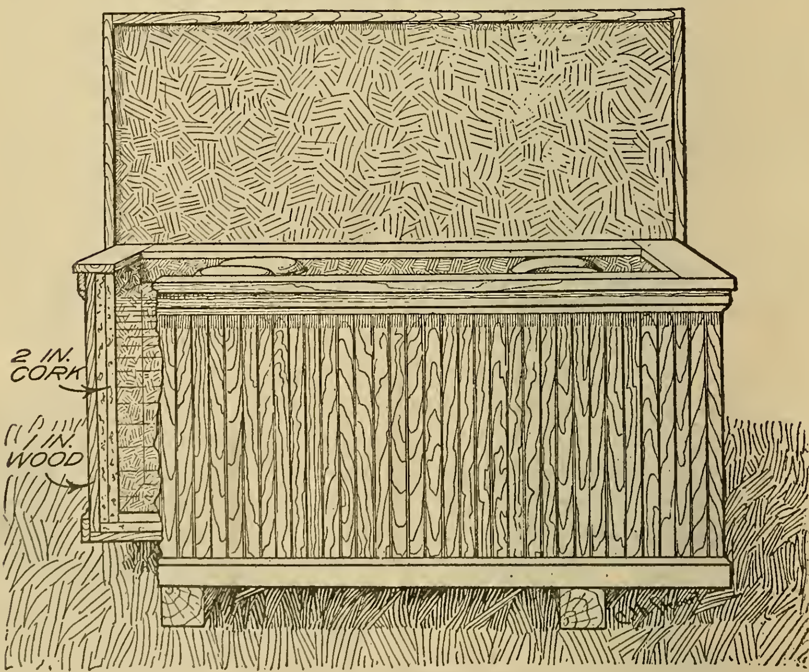

FIG. 6.—Cork-insulated milk-cooling tank.

four tests. Table 1 shows the B. t. u. absorbed under the different conditions:

TABLE 1.—*B. t. u. absorbed by water and tanks under different conditions.*

Type of tank.	Outdoors.		Indoors.	
	Uncovered.	Covered.	Uncovered.	Covered.
	B. t. u.	*B. t. u.*	*B. t. u.*	*B. t. u.*
Galvanized iron	24,200	15,950	15,400	12,100
Concrete	19,800	12,650	11,550	8,800
Wood	15,400	5,500	7,150	4,400
Insulated	11,550	1,650	4,400	1,100

Table 2 shows the relative loss of efficiency in cooling tanks of different construction compared with the insulated tank.

TABLE 2.—*Relative loss of efficiency in cooling tanks of different construction, based on the insulated tank as unity.*

Type of tank.	Outdoors.		Indoors.	
	Uncovered.	Covered.	Uncovered.	Covered.
Galvanized iron	2.1	9.7	3.5	11
Concrete	1.7	7.7	2.6	8
Wood	1.3	3.3	1.6	4
Insulated	1	1	1	1

The relative loss of cooling effect in tanks of different construction expressed in pounds of ice is shown in Table 3. This table also emphasizes the range of loss in cooling effect through radiation from cooling tanks during hot weather.

TABLE 3.—*Relative loss in cooling effect in tanks of different construction expressed in pounds of ice.*

Type of tank.	Outdoors.		Indoors.	
	Uncovered.	Covered.	Uncovered.	Covered.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Galvanized iron	168	111	107	84.0
Concrete	137	88	80	61.0
Wood	107	38	50	30.5
Insulated	80	12	30	7.6

The galvanized-iron tank, without a cover and exposed to the direct rays of the sun, lost 168 pounds of ice compared with 7.6 pounds of ice for the cork-insulated tank covered and sheltered, or a difference of 160.4 pounds of ice. A loss of this amount of ice each day for 150 days would amount to approximately 24 tons for the season. At that rate, in 150 days the loss of ice, estimated at 15 cents a hundredweight, would be $72. Frequently ice costs more than the price named, which would add to the saving effected by an insulated tank. While few dairymen would waste so large a quantity of ice, the result indicates the economy of using a covered, insulated tank.

Four other tests were conducted with the same tanks under best service conditions. All tanks were covered and sheltered. The galvanized-iron, concrete, and wooden tanks each contained 1,000 pounds

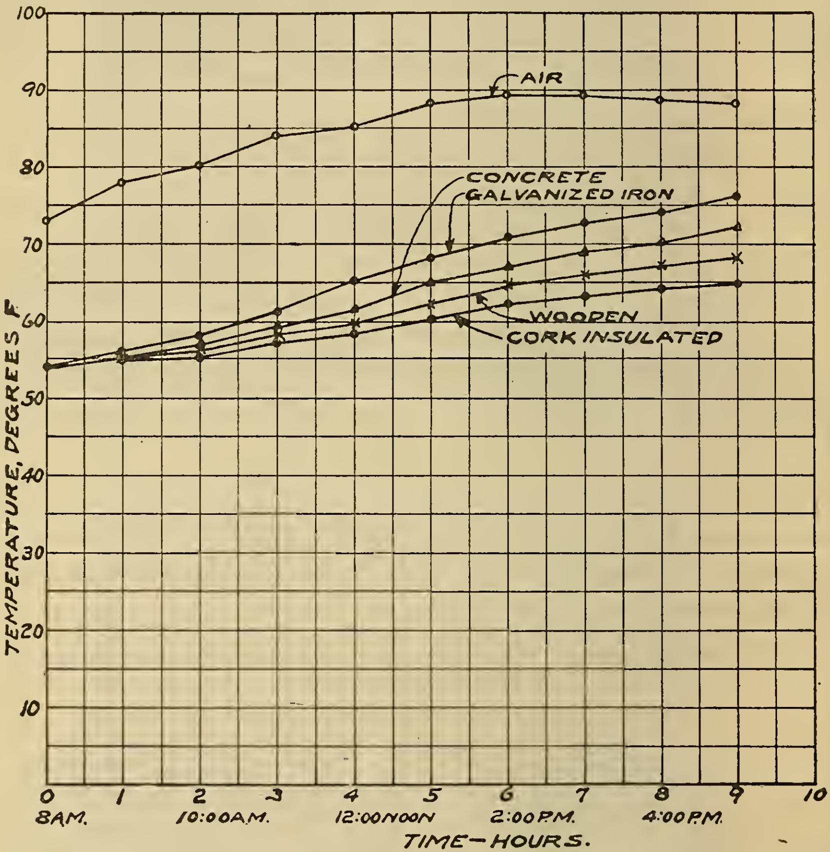

FIG. 7.—Rise in temperature of water during 9 hours in 4 types of cooling tanks. All tanks uncovered and exposed to direct rays of sun.

of water at 54° F., a 100-pound block of ice, and a 10-gallon can of warm milk; the cork-insulated tank contained the same quantity of water and ice and two 10-gallons cans of milk. In each case the block of ice was placed close to the can in order that the milk might receive its immediate cooling effect. The water in the tank was slightly stirred each hour, after which the temperature reading was taken. The milk was not stirred during any of the tests; the results of the tests are shown in figure 11.

During the test with the galvanized-iron tank the air temperature ranged from 72° to 80° F. with an average of 76° F. At the end of nine hours the temperature of the water was 58° F. and the temperature of the milk was 56.5° F. It will be noted that the minimum temperature of the water was reached three hours after the ice was added, and from that time on the temperature of the water rose slightly for the next two hours, until all the ice was melted. From this point the rise in the temperature of the water was more rapid. The temperature of the milk continued to fall until just before the sixth hour, when the curves showed that the temperature of the milk dropped below the water. This was due to the fact that about one hour before all the ice was melted the temperature of the water began to rise and rose faster than the temperature of the milk dropped. This is caused by the fact that there is a double transfer of heat, first from the air to the water, then from the water to the milk.

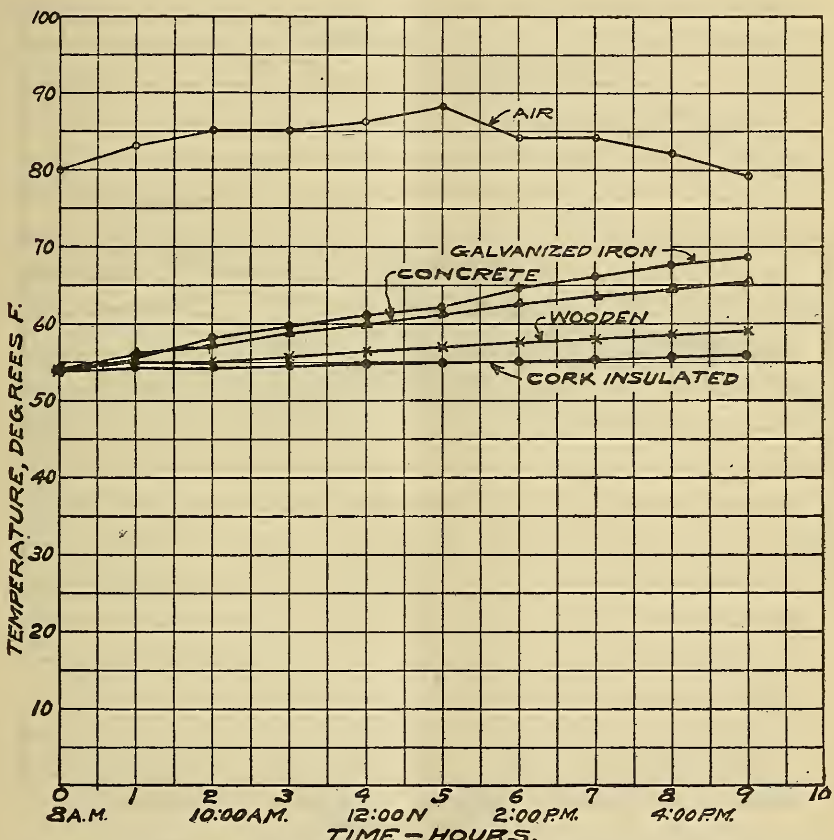

FIG. 8.—Rise in temperature of water during 9 hours in 4 types of cooling tanks. All tanks covered and exposed to direct rays of sun.

In the case of the concrete tank the air temperature ranged from 72° to 85° F. with an average of 79.4° F. or 3.4 degrees higher than in the case of the galvanized-iron tank. Notwithstanding this fact the final temperatures of the water and milk were 3 degrees lower in the concrete tank.

In the test of the wooden tank the air temperature ranged from 79° to 85° F. with an average of 81.1° F. for the 9-hour period. At the end of the test the tank-water had a temperature of 50.5° F. and the

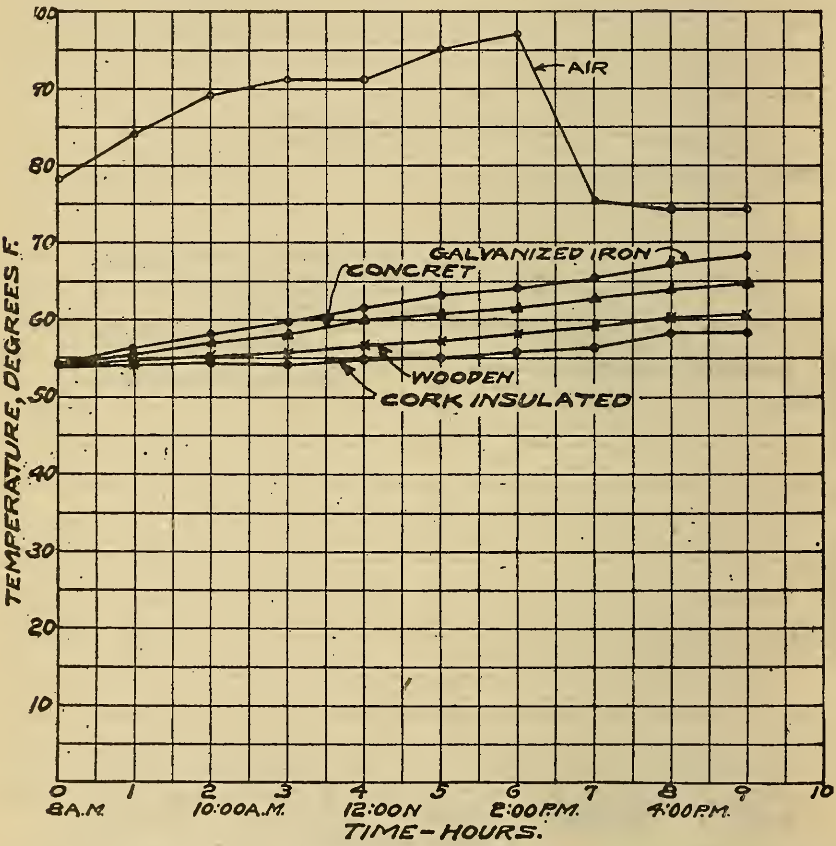

FIG. 9.—Rise in temperature of water during 9 hours in 4 types of cooling tanks. All tanks uncovered and in milk house.

milk was 49.5° F. Notwithstanding the fact that the average air temperature was 5½ degrees higher than in the case of the galvanized-iron tank and 1.7 degrees higher than in the case of the concrete tank, the temperatures of the water and milk at the end of the test were 5½ degrees lower than in the concrete tank and 8½ degrees lower than in the galvanized-iron tank. This again illustrates the superiority, from the milk-cooling standpoint, of a wooden tank over either concrete or galvanized iron.

The range of air temperature during the test of the cork-insulated tank was from 78° to 95° F. and averaged 89.3° F. Two 10-gallon cans of warm milk were placed in the tank instead of one, as in the foregoing tests. At the end of nine hours the temperatures of the tank-water and the milk were approximately the same, namely, 49° F. It will be noted, however, that at no time during the test did the temperature of the water rise above that of the milk, and it will

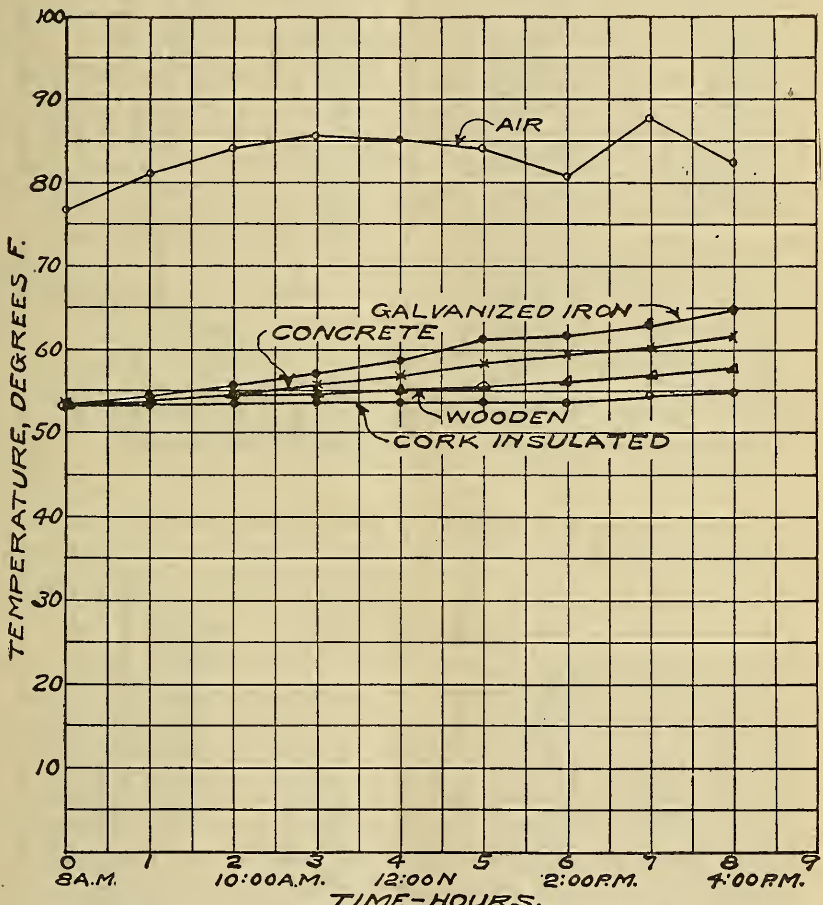

FIG. 10.—Rise in temperature of water during 9 hours in 4 types of cooling tanks. All tanks covered and in milk house.

be further noted that all the ice was not melted until the end of the sixth hour. The cork-insulated tank withstood an air temperature 13.3 degrees higher than the galvanized-iron tank, 9.9 degrees higher than the concrete tank, and 8.2 degrees higher than the wooden tank, and cooled two cans of milk instead of one to a lower temperature than any of the other tanks. The final temperature of the water in the insulated tank was 9 degrees lower than in the iron tank, 6 degrees lower than in the concrete tank, and 1½ degrees lower than in the wooden tank.

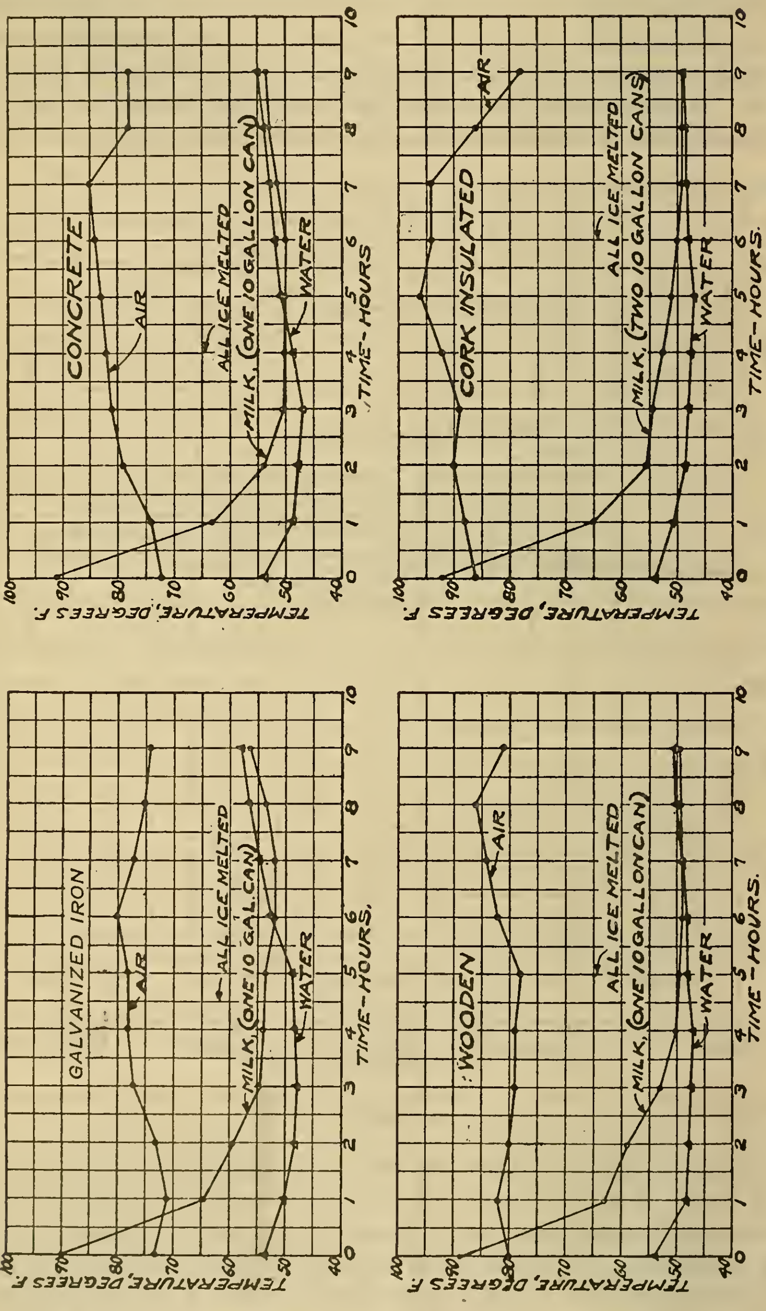

FIG. 11.—Variation in temperature of air, water, and milk in different types of tanks. All tanks covered and in milk house.

These tests illustrate the efficiency of the different tanks for cooling milk. Expressed in terms of ice melted the relative loss was 29 pounds for the insulated tank, 65 pounds for the wooden tank, 101 pounds for the concrete tank, and 126 pounds for the galvanized-iron tank.

THE CONSTRUCTION OF MILK TANKS.

Milk tanks should be so constructed as to minimize the loss in cooling effect through radiation from both water and ice. They should also be easy to construct, durable, and easy to clean. The best insulating materials are those that contain the greatest amount of entrapped air in the smallest space. Other factors, however, such as space occupied, structural strength, uniformity of insulating value, and ability to withstand moisture, should be considered in the selection of the insulating material. The material should not absorb moisture readily, because as soon as it is water-soaked its insulating value is impaired and it will rot. The insulation should be light, easy to work into place, and should occupy little space.

The height of the cooling tank depends upon the height of the cans to be used. Provision should be made so that the water on the outside of the cans will always be as high as the milk inside. An overflow pipe to regulate the height of the water, and a drainage outlet in the bottom of the tank so that the water may be emptied when it is desired to clean the tank, should be provided. Narrow strips on which to set the milk cans should be placed on the bottom of the tank in order to permit the water to flow under as well as around the cans. A frame should be made of 2 by 2 inch material, laid 2 inches apart, so that it will fit snugly in the bottom of the tank. It may be made to fit tightly by means of wooden wedges.

THE INSULATED CONCRETE TANK.

For use on the farm an insulated concrete tank will usually be found to be the most efficient and satisfactory in every respect. In building a tank of that kind the walls should have a total thickness of from 8 to 10 inches, divided into a 2 to 4 inch outer wall of concrete, next to which is placed a 2-inch layer of insulating material and an inside concrete wall of 4 inches. The concrete mix should consist of 1 part Portland cement, 2 parts clean, sharp sand, and 4 parts broken stone or gravel. Hydrated lime equal to 10 per cent by weight of the cement should be added to the mix for the purpose of making the tank waterproof. The outer wall should be constructed first, then the insulation should be set in hot asphalt or gas-house tar and its inner surface coated with the same material and allowed to dry thoroughly before the inner wall of concrete is built. The inside wall of the tank should be carefully troweled to force back all particles of stone or gravel, thus insuring a smooth inner surface.

In constructing the tank, if built partly underground as shown in figure 12, an outside form extending only from the surface of the ground to the top of tank is required. If built entirely above the ground a complete outside form is necessary. After the outside forms are in place pour 4 inches of concrete in the bottom. On this concrete set the inside form, leaving a space of from 2 to 4 inches between the forms, depending on the thickness of the outside wall. After the concrete is set remove the inside form and coat the inside walls and floor with hot asphalt or tar. The sheets of insulation should be coated also with the same material and put in place on the floor and against the walls, care being taken to make all joints tight. After the insulation is in place cut down the inside form, previously used, to a size that will provide a 4-inch space between the walls and

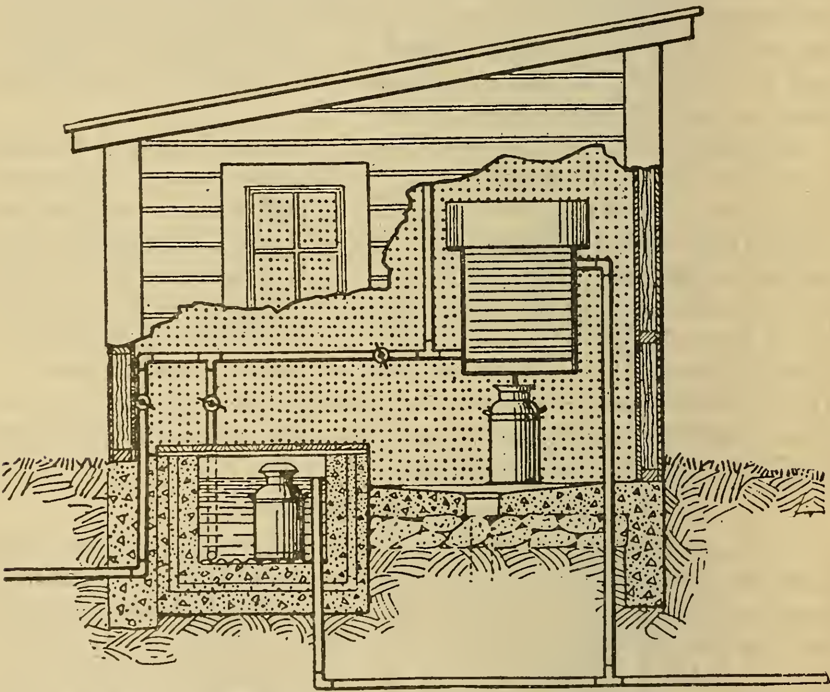

FIG. 12.—Arrangement of concrete-insulated cooling tank built partly below ground level.

forms. The form should be set in place and blocked up 4 inches above the floor, and the concrete for the inner walls and floor should be poured in one operation. The wooden curb around the top of the tank should have 20-penny spikes driven into the underside at frequent intervals and the curb set in place and pressed down so as to embed the spikes in the concrete before it sets. If the inner surface of the walls is rough upon removal of the forms, a plaster coat of cement mortar should be applied.

DIVIDING THE TANK INTO A SMALL AND A LARGE COMPARTMENT.

The size of the tank depends upon the quantity of milk to be cooled. Frequently tanks are built of such sizes as to require an ex cessive quantity of ice for cooling. Since the quantity of milk produced on a dairy farm fluctuates from season to season and from year to year, it is advisable to construct a tank of two parts, the larger being approximately twice the size of the smaller. With a tank of that kind the larger part should be large enough to cool the quantity of milk ordinarily produced. The smaller part may be used in addition for handling an increased supply. In case production is decreased the smaller part can be used alone, thus insuring more efficient cooling. Such arrangements can be made with little additional expense at the time of building, and they result in more efficient cooling.

As an example of what may be accomplished by such an arrangement a test was conducted in which a 10-gallon can of milk at 91° F. was placed in a concrete tank containing 1,000 pounds of water at 54° F. to which a 100-pound block of ice had been added. The can was left in the tank from 8 a. m. until 5 p. m. on a day when the air temperature ranged from 75° to 85° F. At 5 p. m. the milk had a temperature of 53½° F. The same tank was afterwards divided into two parts, one being two-thirds and the other one-third the size of the original tank. Into the smaller part of the tank were placed 350 pounds of water at 54° F., a 100-pound block of ice, and a 10-gallon can of milk at 90° F. The air temperature during the 9 hours, from 8 a. m. to 5 p. m., ranged from 75° to 85° F., and during that time the milk was cooled to 48° F., or 5½ degrees lower than when cooled in the larger tank.

The test was repeated with a wooden tank, a can of milk at 90° F. being left for 9 hours in a tank containing 1,000 pounds of water with an initial temperature of 54° F. and a 100-pound block of ice. At the end of the 9 hours the milk had been cooled to 50° F. The tank was then partitioned in a manner similar to the concrete tank and a 10-gallon can of milk at 90° F. was placed in the smaller part, the quantity of water and ice used being the same as in the concrete tank. At the end of 9 hours the can of milk was cooled to 41° F., or 9 degrees lower than for a similar can in the large wooden tank. It is evident that for cooling efficiency a tank holding 3 or 4 gallons of water for each gallon of milk makes for more efficient use of ice than a larger tank.

LOCATION OF TANK.

For best results the cooling tank should be covered and placed in a building where it will be sheltered from the direct rays of the sun. The best location, therefore, is in the milk house. When a milk-cooling tank is placed outdoors, exposed to the action of the weather, there is usually a rapid deterioration and a great loss in cooling efficiency. Besides keeping milk cold a properly constructed cooling tank also protects it from dust, flies, and other contaminating influences.

HOW TO COOL MILK QUICKLY.

Much of the market milk for our large cities reaches the railroad station in the country for shipment at a temperature of about 60° F., and some is as high as from 80° to 90° F. At least one of our large cities obtains milk from a territory 400 miles away. It is evident, therefore, that milk on such a journey to the city has a considerable time in which to deteriorate in quality. The higher the temperature of the milk the sooner it will deteriorate. Because of the shortness of time between milking and the time of shipping, it is usually impracticable to cool all milk to below 50° F. on the farm by the use of a milk-cooling tank alone. Some sort of surface cooler must be used in addition if the milk is to be cooled to 50° F. before shipment. A surface cooler properly used with a supply of cold running water greatly reduces the quantity of ice needed in cooling milk

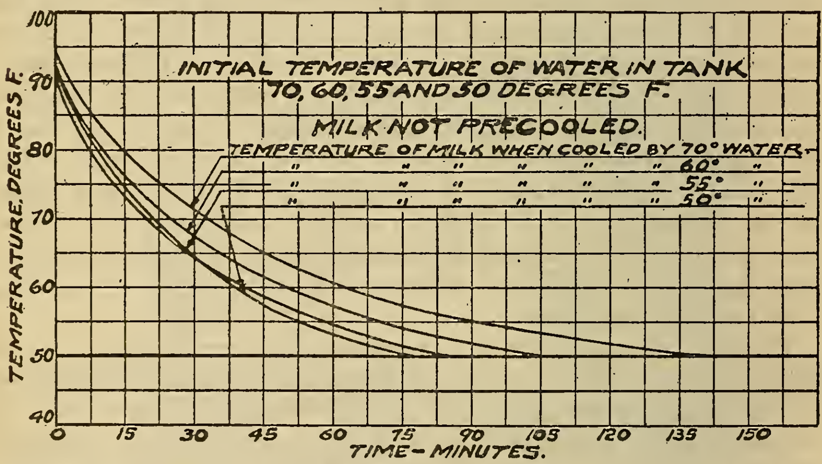

FIG. 13.—Time required to cool a 10-gallon can of milk to 50° F. under various conditions. Milk not precooled.

to a definite temperature, and also insures more rapid cooling. Unfortunately much of the running water used in surface coolers becomes warmer before use, either by allowing it to flow above the surface of the ground, as from a spring, or by taking it from a storage tank exposed to the sun.

It is possible, by using a surface cooler to best advantage, to cool the milk to within 2 or 3 degrees of the temperature of the water. The colder the water, therefore, the more effective will be the cooling. A series of tests was conducted with water at different temperatures in order to determine the length of time necessary to cool milk to 50° F. In each test a 10-gallon can of milk was used. The milk was placed in an insulated tank containing from 75 to 80 gallons of water. Tests were conducted with water at 70°, 60°, 55°, and 50° F., respectively, and in each test a 300-pound block of ice was placed in the tank. The quantity of ice used was larger than is common for tanks of the size mentioned and consequently the time required to cool a 10-gallon can of milk to 50° was shorter than under most farm conditions. In the first test the air temperature was from 70° to 75° F. and the water had a temperature of 70° F. In the second test the air temperature was from 60° to 65° F. and the water 60° F. In the third test the water had a temperature of 55° F. and the air but 1 or 2 degrees higher. In the fourth test the air and water were both at about 50° F. Figure 13 shows the time required to cool milk to 50° F. under various conditions when the milk was not precooled with a surface cooler. In none of the tests was the milk stirred. The

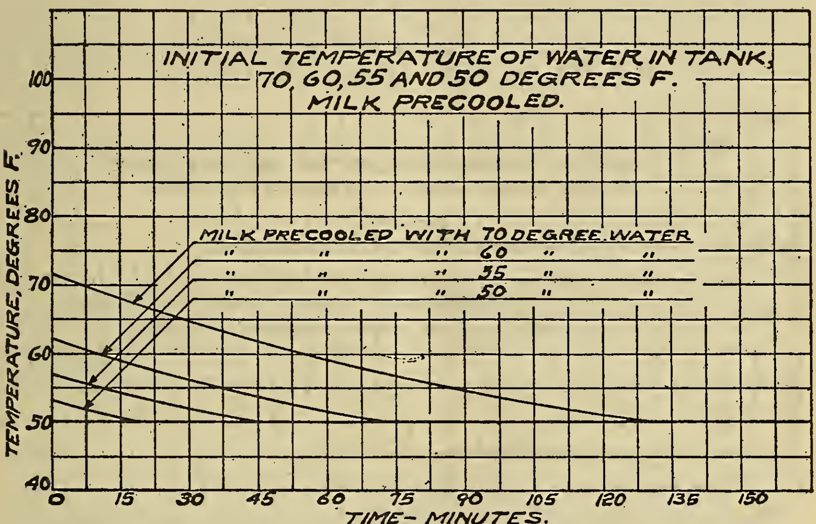

FIG. 14.—Time required to cool a 10-gallon can of milk to 50° F. under various conditions. Milk precooled.

time required to cool the milk to 50° F. when the tank water was 70°, 60°, 55°, and 50° F., respectively, was 2 hours and 25 minutes, 1 hour and 45 minutes, 1 hour and 25 minutes, and 1 hour and 20 minutes.

It is evident that the time necessary to cool milk to 50° F. by these methods is too long for satisfactory use on dairy farms where the morning's milk must be delivered to the railroad station a short time after milking. It must be remembered also that an exceptionally large quantity of ice was used.

The effect of precooling milk with a surface cooler through which water circulates at temperatures of 70°, 60°, 55°, and 50° F., respectively, upon the length of time required to reduce it below 50° F. in a cooling tank is well illustrated in figure 14. When milk was precooled by water at 70°, 60°, 55°, and 50° F. the time necessary for cooling to 50° F. under conditions similar to those mentioned in the previous experiment was, respectively, 2 hours and 10 minutes, 1 hour and 15 minutes, 43 minutes, and 20 minutes. In terms of ice melted the precooling resulted in a saving of 11, 16, 19, and 22 pounds of ice, respectively.

An efficient way of cooling milk on a dairy farm is well illustrated in figure 15. Warm milk that was not precooled was placed in a tank containing water at 37° F. and was cooled to 50° F. in about an hour. The same quantity of milk precooled with water at 55° and then placed in a tank of ice water at 37° was cooled to 50° F. in 20 minutes. This illustrates an easy and rapid method of cooling milk to 50° F. or below if ice is used.

While, from a cooling standpoint, wooden tanks give good results, an insulated concrete tank similar to the one shown in figure 1 is more satisfactory for the dairy farm. A tank of that kind is not

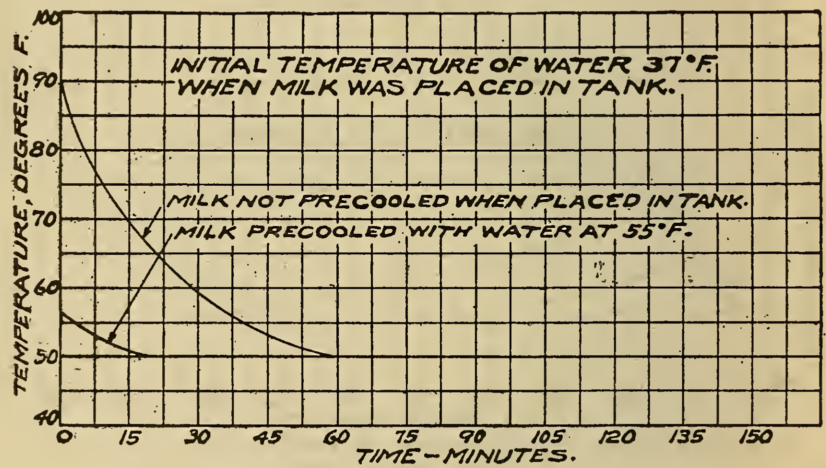

FIG. 15.—Showing quick method of cooling milk with ice water.

hard to construct, is very durable, and can be set partly in the ground, which is an advantage in that cans can be lifted in and out with less effort.

THE USE OF ICE.

For best results ice should be put into the cooling tank a sufficiently long time ahead of the cans of milk to insure that the tank water is at a low temperature when the cans of milk are set in. To insure that milk is cooled to and is held at a sufficiently low temperature, a cooling tank always should contain ice during hot weather. The quantity of ice necessary depends upon the outside temperature, the quantity of milk to be cooled, and the size, construction, and location of the cooling tank. The quantity necessary for any given set of conditions can be determined readily by putting a definite quantity of ice into the tank and using a thermometer to ascertain the temperature to which the milk is cooled. When milk is precooled by means of a surface cooler to between 52° and 62° F. and is placed in a cooling tank in which the temperature of the water is 45° F., from 1½ to 2 pounds of ice for each gallon is necessary to cool milk to and to keep it at 50° F. for a day. When precooling is not practiced and the tank water has a temperature of 45° F. about 4 pounds of ice per gallon will be necessary.

EFFICIENCY OF DIFFERENT TYPES OF CANS FOR HOLDING MILK.

In order to determine the relative value of different types of milk cans for maintaining low temperatures in milk held without agitation for a considerable period, a series of experiments was conducted. Six 10-gallon cans were used, as follows: Nos. 1 and 2 were insulated; No. 3 had an ice compartment; No. 4 was an ordinary can covered with 1-inch felt jacket; No. 5 was an ordinary can covered with a ½-inch jacket; and No. 6 was an ordinary milk can. The cans were placed in a room in which the temperature was maintained at 74½° F. The initial temperature of the milk in cans Nos. 1, 2, 3, and 4 was 35° F.; in No. 5 it was 36° F., and in No. 6 it was 37° F.—The milk was not stirred in any of the cans during the test, the temperature reading being taken by removing the top and inserting a long-stemmed thermometer into the center of the can. In each case formaldehyde enough was added to the milk to prevent premature souring.

The results of the test are shown in figure 16. It will be noted that the time required for the temperature of the milk to rise to 50° F. was as follows:

	Hours.		Hours.
Can No. 1	24	Can No. 4	22
Can No. 2	30	Can No. 5	18
Can No. 3	22	Can No. 6	11

It should be kept in mind of course that the initial temperature of the milk in can No. 5 was 36° F. and in can No. 6 37° F. Comparing the various cans with No. 6 (the bare, unprotected can) it will be noted that No. 1 took 2.18 times as long; No. 2 required 2.73 times as long; Nos. 3 and 4 required twice as long; and No. 5 required 1.63 times as long as No. 6 for the temperature of the milk to rise to 50° F. The results indicate the efficiency of the various methods of protecting cans in keeping milk at low temperatures.

In test No. 2 the conditions were similar to those in the first test except that the room temperature was 99.5° F., or 25 degrees higher, and the initial temperature of the milk in each can was 44° F. The relative time required for the milk to rise in temperature from 44° to 50° F. for the various cans was as follows:

	Hours.		Hours.
Can No. 1	8	Can No. 4	4
Can No. 2	10	Can No. 5	2
Can No. 3	3	Can No. 6	¾

While the high temperature of 99.5° F. would not be encountered frequently in practice, it serves well to illustrate the efficiency of different types of cans under extreme conditions. In curve No. 3 of

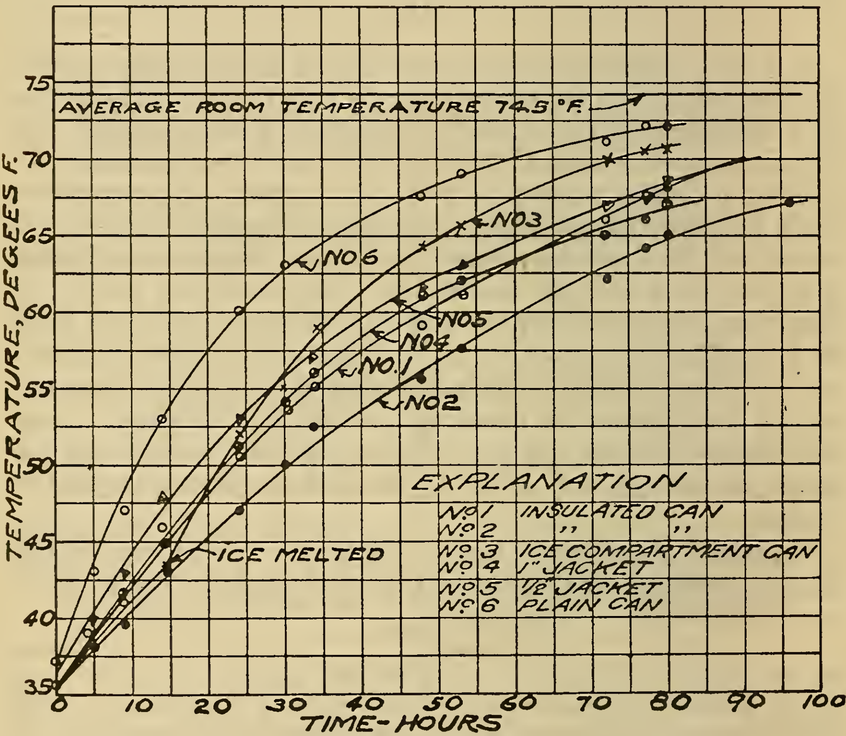

FIG. 16.—Efficiency of various types of cans for holding milk. Room temperature, 74.5° F.

figure 17, showing the rise in temperature of milk in the ice-compartment can, it will be noted that all the ice was not melted until about 8 hours after the beginning of the test. The temperature of the milk, however, rose to 50° F. within 3 hours. The rapid rise in temperature of the milk in the can, even though the ice compartment contained ice, is due to the large surface which was exposed to the warm outside air as compared to the smaller surface exposed to the ice. The absorption of heat by the milk from the air was much faster than the absorption of heat by the ice from the milk. It will be noted that after all the ice was melted the rise in temperature of the milk in the can was about the same as in the ordinary milk can, No. 6.

Comparing the time required for milk to rise in temperature from 44° to 50° F. with the ordinary can (No. 6), it will be found to be 10.7 times as long in can No. 1, 13.3 times in can No. 2, 4 times in can No. 3, 5½ times in can No. 4, and 2.7 times in can No. 5. The importance of some sort of insulation for milk cans is apparent when

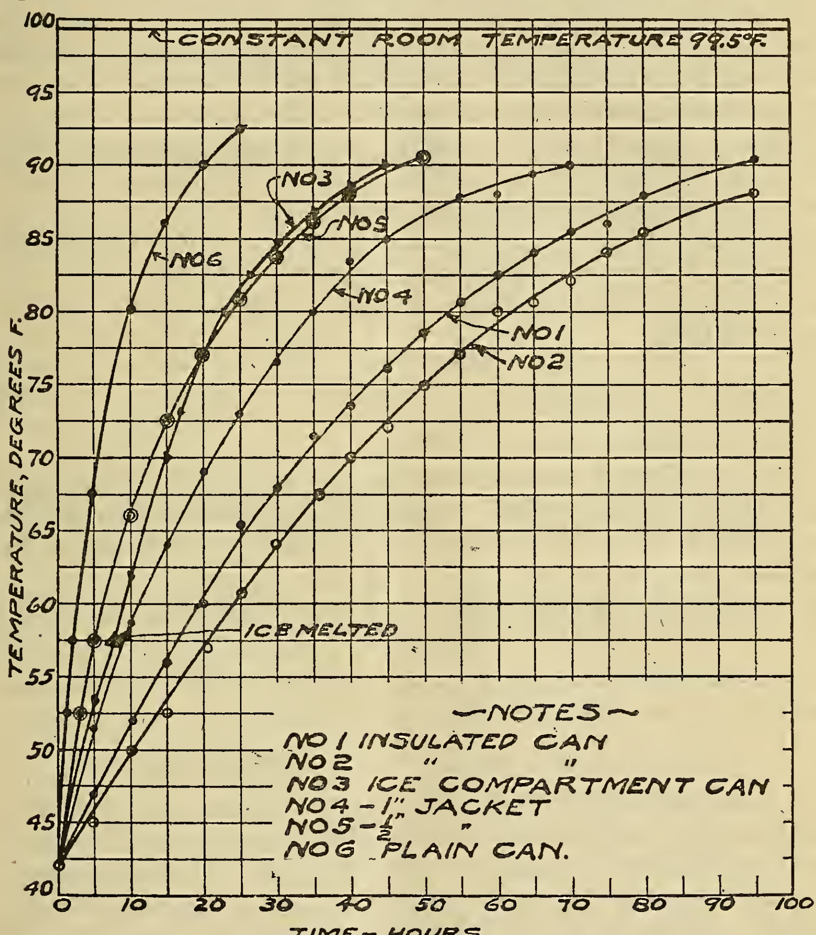

FIG. 17.—Efficiency of various types of cans for holding milk. Room temperature, 99.5° F.

milk is to be shipped considerable distances and reach its destination at a temperature below 50° F. This last experiment illustrates very well the rise in temperature which may be expected when milk is allowed to stand in the sun during very hot weather. Instances in which cans of milk are left for several hours without shelter or other protection either on the roadside or at the milk-receiving station, are too common to need comment.

In the northern section of the United States milk is frequently shipped to the city during the winter when the temperature of the air is below zero. Since milk freezes at a temperature between 31° and 29° F., it is important that some provision be made to prevent freezing in transit. A test, therefore, was conducted to determine the efficiency of the same cans used in the previous tests for preventing freezing. Because of the limited space in the refrigerator but two cans could be handled at a time. It was not possible to hold, therefore, all cans at exactly the same temperature during the test because of the difficulty in keeping the refrigerator at exactly the same temperature from day to day. The temperature of the refrigerator ranged from ¼° to 4½° F., the average temperature being about 2½ degrees above zero. The initial temperature of the milk, when the cans were placed in the refrigerator, was 77° F., and the cans were held until its temperature had reached 30° F. The drop in temperature is graphically shown in figure 18. The time required for the milk in the different types of cans to drop from 50° to 30° F. was as follows:

	Hours.		Hours.
Can No. 1	20	Can No. 5	16½
Can No. 2	21	Can No. 6	7
Can No. 4	18½		

Can No. 3, the ice-compartment can, was not used as it was not suitable for the experiment. Comparing the time necessary for the temperature of the milk to drop from 50° to 30° F. with that of the ordinary can (No. 6) we find:

Can No. 1 required 2.9 times as long.	Can No. 4 required 2.6 times as long.
Can No. 2 required 3.0 times as long.	Can No. 5 required 2.3 times as long.

The showing above indicates the efficiency of felt jackets or insulated cans for shipping milk in zero weather.

TRANSPORTING MILK AT LOW TEMPERATURES.

A large percentage of city milk supplies is delivered to the railroad station by the producers or is brought to the station by wagons or trucks which collect milk from several farms. A certain quantity of milk is hauled directly to the city by means of teams or motor trucks. Unless the milk is especially protected its temperature will rise several degrees in the journey from the farm to the station, and if afterwards in the haul of from a few hours to all day to the city it is exposed to high temperatures its temperature when it reaches the market is usually not low enough to prevent the rapid multiplication of bacteria. Much milk is transported to the city in ordinary baggage cars or in uniced milk cars. To insure its reaching the city in the best condition milk should be cooled on the farm to 50° F. or below and should be carefully protected during shipment to the city. The same precautions which prevent milk from becoming warm during shipment in summer also prevent it from freezing in the winter.

In some refrigerator cars it is possible to keep milk at a low temperature during shipment, but most of the milk is shipped in cars that frequently are opened in transit to receive new supplies, and in which the ice, if any is used, is placed on the top of the milk cans. Much of the cooling effect is lost when the cars are thus opened.

RESULTS OF EXPERIMENTAL SHIPMENTS.

To determine the relative efficiency of ordinary milk cans compared with jacketed and insulated cans in keeping milk cold during long shipments, three experiments were conducted as follows:

In the first experiment 4 of the 10-gallon cans used in the previous tests were employed, No. 1 being insulated, No. 4 having a 1-inch felt jacket, No. 5 having a ½-inch felt jacket, and No. 6 being the ordinary milk can. The cans were filled with milk cooled to 44° F. and were hauled in an open truck a distance of 13 miles from the farm to the railroad station. The air temperature during the 2½ hours' haul was about 80° F. Upon arrival at the station the cans were shipped in an ordinary baggage car which was opened in transit to receive and discharge baggage from Washington, D. C., to New Orleans, La., a distance of 1,120 miles.[1]

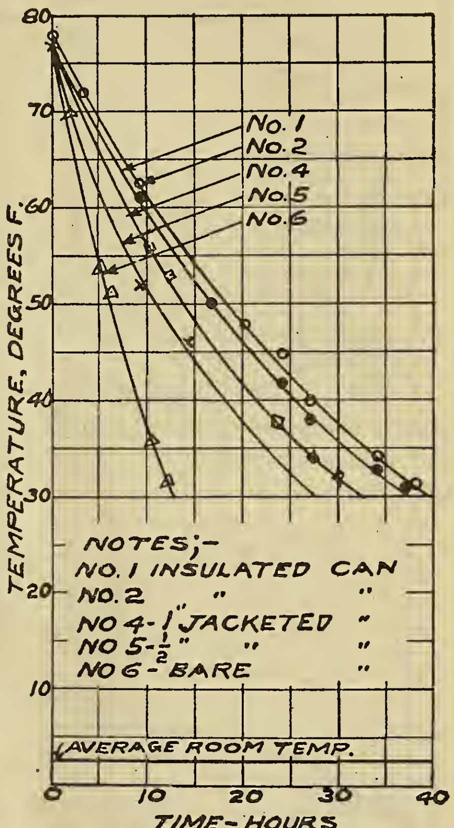

FIG. 18.—Efficiency of various types of cans for holding milk. Temperature near zero F.

The rise in the temperature of the milk and the temperature of the surrounding air during transportation was obtained by means of recording thermometers. Figure 19 shows the rise in temperature of the milk in each of the several cans, together with the air temperature during the trip. The milk in the ordinary can reached 60° F.

[1] The shipment of milk was supervised by C. S. McBride, of the Dairy Division.

after it had traveled about 10 miles from the farm; the milk in the can covered with a ½-inch felt jacket reached 60° F. after approxi-

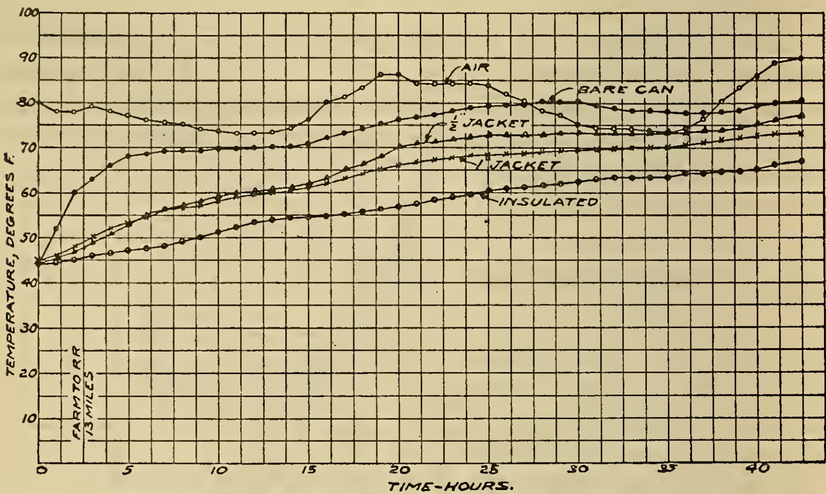

FIG. 19.—Relative efficiency of 4 types of cans in shipment of milk from Washington, D. C. to New Orleans. Milk cooled to 44° F. and hauled 13 miles in open truck to station.

mately 268 miles of travel; the milk in the can covered with a 1-inch felt jacket reached 60° F. after 332 miles, and that in the insulated can after 650 miles. The average air temperature during the journey

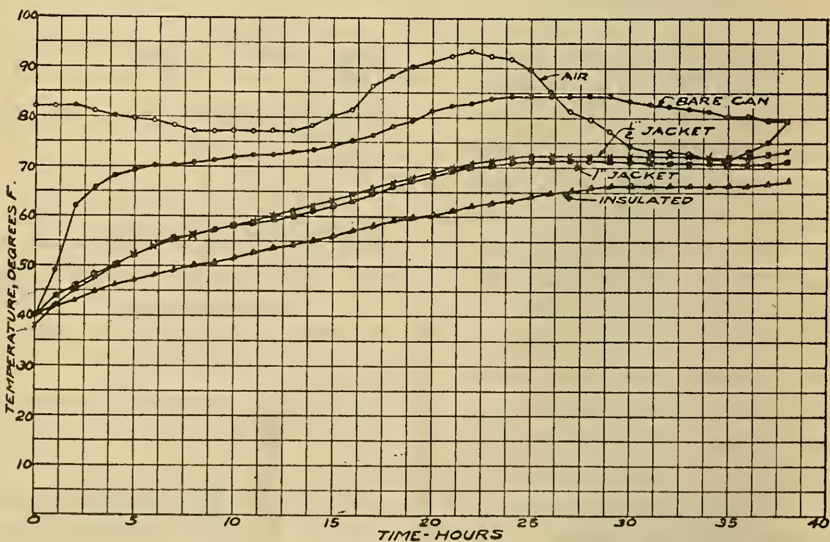

FIG. 20.—Relative efficiency of 4 types of cans in shipment of milk from New Orleans to Washington, D. C. Milk cooled to 40° F. and loaded directly at railroad station.

was 80° F. Compared with the ordinary can, the ½-inch jacketed can allowed milk to be shipped 26 times as far before it reached 60°

F.; the milk in the 1-inch felt jacketed can traveled 33 times as far; and that in the insulated can 65 times as far.

In the second experiment the same cans were used and the other conditions were the same, except that there was no country haul and the milk was cooled to 40° F. before being started on its journey. The results are shown graphically in figure 20. The milk in the ordinary can reached a temperature of 50° F. after traveling about 75 miles; that held in the ½-inch jacketed can after 355 miles; that

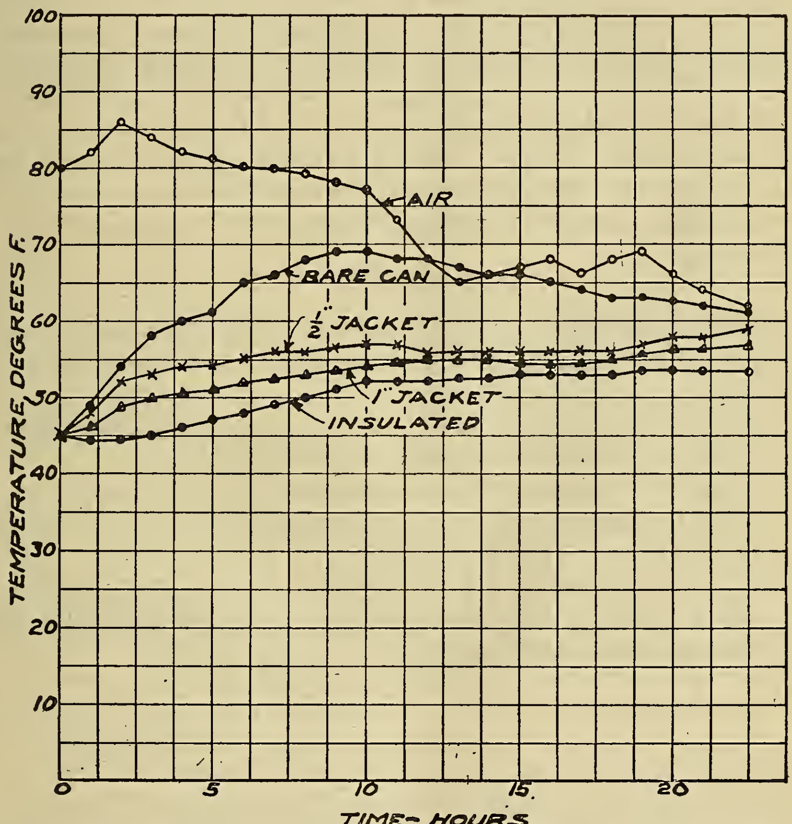

FIG. 21.—Relative efficiency of four types of cans in shipment of milk from Chicago to Washington, D. C.

in the can covered with the 1-inch felt jacket after 385 miles; and that in the insulated can after 605 miles.

In the third experiment 4 similar cans of milk were shipped from Chicago, Ill., to Washington, D. C., a distance of 787 miles,[1] in an ordinary baggage car. As in the previous experiments the doors were opened at stations to receive and deliver baggage. The data obtained in this experiment are shown graphically in figure 21.

[1] This shipment of milk was supervised by R. S. Smith, of the Dairy Division.

The milk was $22\frac{1}{2}$ hours in transit and the average air temperature of the baggage car was about 73° F. The temperature of the milk in the different cans was between 44° and 45° F. when placed in the car. This test demonstrates that the temperature of milk upon its arrival at destination is no indication of the temperatures which it has experienced in transit and that jacketed and insulated cans prevent rapid fluctuations in temperature.

When milk is cooled to between 40° and 45° F. on the farm, it may, through the use of felt jackets or insulated cans, reach the market with but a comparatively few degrees rise in temperature even in very hot weather. The use of felt jackets or insulated cans adds somewhat to the cost of shipping milk, because of the initial cost of the jackets or insulated cans and the increased transportation charges due to the greater weight. Taking all these things into consideration, however, it is believed that in many cases it is more economical for the dairyman to use some form of protection in shipping his milk to the city.

SUMMARY.

Milk must be kept at a low temperature (50° F. or below) from the time it is produced until it is consumed if its quality is to be maintained.

Prompt cooling of milk on the farm necessitates the most efficient use of water in both surface coolers and cooling tanks.

Ice is needed if milk is to be cooled quickly to low temperatures.

Cooling tanks should be covered, protected from the sun, insulated, and of such size as to use ice efficiently.

Felt jackets or insulated cans proved to be very effective in keeping milk cold during long shipments in hot weather and in preventing freezing during cold weather.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 745

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. ▼ January 29, 1919

CHOPPED SOAPWEED AS EMERGENCY FEED FOR CATTLE ON SOUTHWESTERN RANGES.

By C. L. Forsling, *Grazing Examiner.*

CONTENTS.

THE NEED OF EMERGENCY FEED.

Heavy losses of stock resulting from long periods of drought are the greatest handicap of the stock industry on the ranges of the Southwest. Such droughts have occurred at intervals of from 3 to 10 years. When these droughts continue for more than a year the situation becomes critical because of lack of range forage or other available feed.

Cottonseed products serve well as supplemental feed in times when enough range forage is available to provide the necessary roughage. During prolonged droughts like the present one, which began early in 1916 and continues unbroken at the present time (June 15, 1918), the range forage crop may be so small as to require other roughage as well as concentrated feeds.

The problem may be solved in part in some of the less arid regions by raising fodder crops by dry farming. The ranges where this is practicable at present, however, are not extensive. On a few ranges, adjacent to irrigated districts, the necessary emergency feeds might be furnished by crops from such irrigated areas; but this supply at best would be restricted to range in the immediate vicinity of the irrigated areas and would not provide emergency feed for the larger portion of the ranges of the Southwest, where losses have been heavy, and where breeding herds established through years of effort have been sacrificed.

In the hope of meeting the problem on such ranges, at least to an extent which will make it possible to maintain the breeding herd over critical periods, the Department of Agriculture for a number of years has been cooperating with a practical stockman on the Jornada Range Reserve[1] in southern New Mexico in working out a comprehensive plan of range management and supplemental feeding. For several years this plan has included investigation of the use of native vegetation as emergency feed. The results of range management with supplemental feeding, and of the initial tests to determine the value of soapweed as ensilage, were reported in Department of Agriculture Bulletin 588.[2] Later investigations, including extensive experimental feeding, have shown conclusively that soapweed, if properly utilized, is of great value as an emergency stock feed.

SOAPWEED AS RANGE FORAGE.

Soapweed (*Yucca elata*) is recognized as a valuable forage plant in its native state on the range. The green leaves are eaten during winter and spring, especially when a shortage of other forage exists. Ordinarily, the sharp points of the leaves discourage grazing, but where other forage is scarce cattle learn to chew the leaves from the center or base toward the sharp end. It is very difficult to estimate the exact food value of each plant, but where from 170 to 300 plants per acre are found no small amount of forage may be obtained from them. In the fall of 1917 a herd of cattle in southern New Mexico was maintained for at least two months on a range where the green soapweed leaves furnished 50 per cent or more of the forage. On an overgrazed pasture at a distance of 2 miles from water 47 per cent of the soapweed plants were grazed; and on closely grazed range 3 miles from water about 30 per cent were grazed. In many cases the entire leafage of soapweed plants was utilized.

The soapweed blossoms are of especially great value. The panicles of large white flowers appear on stalks commonly from 4 to 10 feet

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[1] The Jornada Range Reserve is located in Dona Ana County, N. Mex., about 50 miles north of the Mexican boundary. It includes a range unit of approximately 200,000 acres. The average rainfall is less than 9 inches and varies from 3.5 inches to 15 inches.

Mr. C. T. Turney, the cooperating stockman, originated the idea of using the soapweed as a supplemental feed on the Jornada Range Reserve and was principally responsible for getting manufacturers to develop the machines which are now used successfully in chopping the soapweed.

[2] Jardine, J. T., and Hurtt, L. C., Increased Cattle Production on Southwestern Ranges, Bulletin 588, U. S. Department of Agriculture, 1917.

tall. Both the stalks and the flowers are palatable. The stalks begin to make their appearance early in May, and the stalks and flowers are good forage until late in June. Cattle thrive on them. Besides, they are so succulent that cattle grazing on them can go several days without water. This makes possible the use, for a short period at least, of range which otherwise might not be utilized on account of its great distance from water. The value of the bloom crop is increased by the fact that it occurs during a critical season when other forage usually is scarce and the stock is in poor condition. Without it, it would be difficult in many cases to carry the stock through until the summer rains. The main drawback is the uncertainty of a full crop. Large crops occur at intervals of several years, usually in the spring following a rainy autumn. However, some of the plants bloom each year, so that a small annual supply can be depended upon.

The young leaves or growing tips of the soapweed stems also are valuable for forage immediately after growth has started in the spring. It is common to see a cow go from one plant to another biting out the center or growing tips.

The value of soapweed as stock forage in its native state on the range makes it desirable, other things being equal, to use range supporting the heaviest stands of soapweed during the winter and spring. This practice, of course, should vary so as to secure the maximum use of the most important forage plants on the area.

Close observation during the winter, spring, and early summer on closely grazed cattle ranges where soapweed occurs in any abundance will convince anyone that soapweed is valuable as a range forage plant. Even when grazed to the best advantage, however, it does not adequately meet the requirements of an emergency feed. The nourishment obtained from grazing the leaves alone is not sufficient to tide an animal over for more than a very short period, and drought may make it necessary to give additional feed to stock long before the growth of the soapweed begins.

CUT SOAPWEED AS EMERGENCY FEED.

PRELIMINARY EXPERIMENTS.

Investigations to determine the practicability of cutting and feeding soapweed were begun at the Jornada Range Reserve in 1915. In December, 1915, approximately 150 tons of the heads and leaf portions were gathered and run through an ordinary ensilage cutter into a pit silo. In March, 1916, the silo was opened and about 10 tons of the soapweed ensilage was fed to poor cows over a period of several weeks. The results of the feeding were encouraging, although the stock had difficulty in eating the ensilage (which they relished) because the cutter had not chopped the material fine enough.

The silo was opened again in January, 1918, and about 30 tons of the ensilage fed to poor cows, many of them suckling calves. About 15 pounds of a mixture of ensilage and cottonseed meal, in the ratio of 10 pounds to 1, was fed to each cow daily. The ensilage was in a good state of preservation, and the leaves had softened a good deal; but the fiber appeared to be about as tough as when the material was put into the silo in 1915. The feeding gave good results. The silo was closed again to save the remainder of the ensilage for emergency.

After the feeding of 1915–16, investigations were made to determine the food value of the stems and leaves of the soapweed plants. The following results of chemical analyses show that the material as a whole has a comparatively high food value.

Chemical analyses of soapweed (Yucca elata), compared with chemical analyses of important native range grasses of the same locality, on moisture-free basis.

	Soapweed.[1]		Black grama grass.[2]	Red three-awn grass.[2]
	Stems.	Leaves.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ash	8.4	6.7	7.4	8.2
Ether extract	2.0	3.6	1.4	1.1
Protein	4.25	8.2	4.6	4.8
Crude fiber	35.1	38.4	33.2	35.6
Nitrogen-free extract	50.25	43.1	53.4	50.3
Total	100.0	100.0	100.0	100.0

Chemical analyses of soapweed (Yucca elata), compared with chemical analyses of alfalfa, corn ensilage, and fresh green timothy, on moisture basis.

	Water.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.	Number of analyses.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Soapweed stems[3]	54.7	3.6	1.1	1.3	15.2	24.1	2
Soapweed leaves[3]	42.3	3.6	3.1	4.5	22.3	24.2	2
Fresh green alfalfa[4]	74.7	2.4	1.0	4.5	7.0	10.4	143
Immature corn ensilage[4]	73.7	1.7	.8	2.1	6.3	15.4	121
Fresh green timothy[4]	62.5	2.2	1.2	3.1	11.7	19.3	88

[1] Average of four analyses made by the Bureau of Chemistry, U. S. Department of Agriculture, from samples submitted Sept. 10, 1917, Apr. 18, May 14, and May 31, 1918.
[2] Average of 24 analyses made by the Bureau of Chemistry, U. S. Department of Agriculture, from samples submitted each month beginning April, 1916, and ending March, 1918.
[3] Average of two analyses by Bureau of Chemistry, U. S. Department of Agriculture, from samples submitted May 14 and May 31, 1918.
[4] Analyses of alfalfa, corn ensilage, and timothy taken from "Feeds and Feeding" by Henry and Morrison.

The two native grasses, black grama grass (*Bouteloua eriopoda*) and red three-awn grass (*Aristida longiseta*) are the most important grasses on the Jornada Range Reserve, and yet the comparison is slightly in favor of the soapweed. Although soapweed is considerably higher in crude fiber and ash than fresh green alfalfa, immature corn ensilage, and fresh green timothy, the comparison in the amount of ether extract (fat) protein, and nitrogen-free extract is favorable enough to indicate that the soapweed is a valuable feed so far as this is determined by chemical analysis alone.

Steps were taken also to secure a machine which would chop the plants finer, and several types of machines designed to cut the entire soapweed plant into material more suitable for feeding were put on the market early in 1918. One of these was installed at the Jornada Range Reserve January 13, 1918, and was there perfected to chop the plants satisfactorily.

SOAPWEED FEEDING ON THE JORNADA RANGE RESERVE IN 1918.

As a result of the prolonged drought the range forage crop on the Jornada Range Reserve in 1917 was far below normal. Consequently little range forage was left by January 1, 1918, and it was apparent that extensive feeding would be necessary to maintain a large percentage of the cows suckling calves and the cows heavy with calf. Accordingly, the feeding of chopped soapweed and cottonseed meal was begun January 20, 1918, with the object of preventing loss of cattle and maintaining the herd as cheaply as possible over the critical period until range forage became available. Riders were set to work gathering cows that were approaching a critical condition, and the number in the feed lot was increased daily. Soapweed feeding was still in progress June 15, 1918.

During the first 70 days of feeding an unsystematic effort was made to segregate the weaker cattle and feed them separately from the rest. Where a large number of cattle varying in condition are fed in one feed lot, the weaker ones are crowded away from the feed and will not improve in condition as they should.

Segregation was found to be important, and after the first 70 days the work was systematized so that the poorer cows were placed in a feed lot by themselves in small groups where they could receive individual attention if necessary, and were fed a slightly heavier ration than the main herd. After a short period of special attention and of feeding on the heavier ration, many of the poorer cows improved in condition and were put with the main herd on the lighter feeding.

It was found that the poorer cows when fed a daily ration of 25 pounds of the chopped soapweed and 3 pounds of cottonseed meal gained sufficiently in strength and condition in from 20 to 30 days to go into the main lot on a lighter ration. Stock in the main feed lot were fed a ration of from 15 to 20 pounds of the chopped soapweed and from 1 to 1⅓ pounds of cottonseed meal. After from 35 to 40 days on this ration about 85 per cent of the stock were put back on the range and fed 1½ pounds per day of cottonseed cake alone to supplement the dry grass and scattered browse forage available.

The number of cattle on feed varied from day to day. For the first 100 days the daily average was 340 head, varying from 500 head to 200 head for short periods following the return of stock from the feed lot to the range. More than 1,000 different individuals were in the feed lots between January 20 and June 1.

During the first 100 days approximately 306 tons of the chopped soapweed were fed, and feeding was continued at approximately the same rate up to June 1. The average period that individual animals were fed on soapweed and cottonseed meal during the first 100 days of feeding was 35 days. Some animals were fed during the entire period and others less than two weeks. After about 35 days of feeding on the soapweed and cottonseed meal the majority of the animals gained in strength and flesh sufficiently to warrant their being put back on pasture with a daily feeding of 1½ pounds of cottonseed cake.

No weights of cattle were taken to determine accurately the gains made as a result of the feeding. Under practical range conditions in time of drought, however, the measure of success in feeding is the percentage of cattle carried over the critical period without excessive cost and without the sacrifice of the breeding herd or a great reduction in the calf crop. It is estimated that without the soapweed feeding probably 50 per cent of the 1,000 head fed during approximately 150 days from January to June would have been lost. It might have been possible to save the other 50 per cent by a ration of cottonseed cake to supplement the scant range forage. As a result of the feeding the losses due to starvation from approximately 2,500 head were approximately 1 per cent for the 150-day period, and the breeding stock are in condition to produce a reasonably good calf crop provided the drought is broken by summer rains. Furthermore, the breeding stock on the reserve have been maintained at approximately the number the area will carry normally, and the efforts of years in building up the breeding herd have not been lost. Consequently, normal production of live stock will begin at once after the drought is broken.

On near-by ranges without provision for reserving pasturage or for extensive feeding, losses have been from 10 to 20 per cent during the first 150 days of 1918. In some cases where the range was overstocked the breeding stock have been sacrificed and material loss has been suffered both in the death of animals and in low market prices due to the poor condition of the stock.

The cost of feeding, as well as the success achieved in preventing losses, is influenced greatly by the ability of the riders who gather the animals. Careful riders accustomed to handling poor cattle sort out only those animals which must be fed to prevent loss, so that unnecessary feeding of the stronger animals as well as unnecessary loss through failure to feed the weaker ones is avoided. Where a range is totally denuded of forage it is necessary, of course, to maintain the entire herd on the soapweed and cottonseed meal feeding. This, however, is rarely the case. More often the stronger animals can be maintained on the range without other feed; those not exceedingly poor and weak can be maintained by feeding from 1 to 2 pounds of cottonseed products daily to supplement the range forage; and only the weaker ones have to be fed the soapweed and cottonseed products.

SOAPWEED FEEDING ON OTHER RANGES IN 1918.

Stockmen throughout the Southwest have watched with interest the development of soapweed feeding, and many of them using ranges where conditions are similar to those of the Jornada Range Reserve secured machines to chop the soapweed and began feeding operations early in 1918. It is estimated that more than 100 herds varying from a few head to 1,000 head were being fed soapweed by June 1, 1918. In a few cases at least the soapweed was tried as a feed without cottonseed products. So far as observations went, however, the results were not entirely satisfactory, and cottonseed meal was added. This method of feeding has usually given good results, and there is no doubt that by it many thousands of cattle were saved from starvation during the first five months of 1918.

THE COLLECTION OF SOAPWEED.

BURNING AWAY DEAD LEAVES.

The dry dead leaves are very low in nutritive value, as is shown by chemical analysis, and are exceptionally high in crude fiber content, which makes digestion difficult. They are very dry and harsh and extremely unpalatable. It is desirable, therefore, to remove them before chopping the soapweed. This can be accomplished best by burning the dead portions from the plants while they are standing in the field, provided the vegetation on the ground is not enough to spread the fire. The dry leaves burn readily and in a short time, leaving uninjured the succulent stem and the green foliage at the top of the plant. One man with a torch working ahead of the men doing the cutting and hauling can burn the dead portions of from 8 to 15 tons of soapweed plants per day. A simple and effective torch may be made from a dead soapweed trunk from 12 to 18 inches long carried on an iron rod 5 to 6 feet long with a small hook at one end. Such dry, dead trunks are plentiful, light, and easily handled.

Burning can be done best on days when little or no wind is blowing, as high winds often extinguish the fire before the dead leaves are completely burned. No depreciation in the food value of the plants appears to follow from standing several days after burning, and by burning several days ahead. of the cutting, it is possible to avoid days when the wind is high.

Where there is danger of fire spreading over the range, burning should be done after the plants have been hauled to the chopping machine and arranged on the ground. To avoid undue shrinkage, the plants should be placed in rows two plants wide with the butts together and the green tops to the outside. This precaution prevents fire from becoming hot enough to burn the green leaves or succulent stem, and keeps the shrinkage down to about 30 per cent of the original weight. Where the plants are scattered thickly over the ground (Pl. II, fig. 2) burning results in a shrinkage of about 40 per cent, the increase being due to the fire's becoming hot enough to burn the green leaves.

SELECTING AND CUTTING THE PLANTS IN THE FIELD.

On the Jornada Range Reserve plants 36 inches or less in height were not cut, and occasionally plants tall enough for the seed stalks to be out of the reach of cattle were left for seeding. The plants under 36 inches were left on the range partly as a protection for the soil against wind erosion, partly because they furnish considerable grazing until the growing tips, seed stalks, and flowers are beyond the reach of cattle, and partly because small plants can not be handled in the feeding operations as economically as larger ones.

The plants were cut at the surface of the ground. Investigations are under way to determine whether this procedure should be modified in order to insure the production of new growth in the minimum time. After cutting, the new leaves begin growth just below the ground surface, and it may be necessary to leave a small portion of the stem above ground.

HAULING THE PLANTS TO THE CHOPPING MACHINE.

As the plants were cut they were loaded upon a wide rack and arranged in orderly rows, so as to make the most effective use of space and facilitate unloading. Both loading and unloading are done most conveniently by hand.

Where the feeding operations are on a rather extensive scale a crew can be kept cutting and hauling continually. A crew of four men with two 4-mule teams for hauling can work to good advantage. One man acting as foreman directs the operations, selects the plants for cutting, and burns off the dead leaves, if burning is done before the plants are cut. Two men with axes cut the plants and pass them up to a third man, who arranges them on the rack and drives the team. A crew of this size can select, burn, cut, and haul four loads, approximately 8 tons, per day where the haul is not over $2\frac{1}{2}$ miles.

FIG. 1.—SOAPWEED PLANTS WHICH HAVE BEEN EXTENSIVELY GRAZED BY CATTLE ON AN OVERGRAZED RANGE.

Such general grazing of soapweed and stubby appearance of the plants are good indications that the range is overstocked.

FIG. 2.—BREEDING CATTLE BEING FED FROM 15 TO 20 POUNDS OF SOAPWEED WITH FROM 1 TO 1⅓ POUNDS OF COTTONSEED MEAL PER DAY TO MAINTAIN THEM THROUGH A DROUGHT AT THE JORNADA RANGE RESERVE.

Over 1,000 poor cows on the Reserve were fed between January 20 and June 15, 1918, and thousands of head were fed a similar ration on other stock ranches of the Southwest during the spring of 1918.

FIG. 3.—CUTTING AND LOADING SOAPWEED.

Four men with two wagons and eight mules can cut and haul 8 tons per day when the haul is not over 2½ miles.

FIG. 1.—SOAPWEED READY TO BE CUT FOR STOCK FEED.

The dead leaves have been burned off. One hundred and fifty plants, each averaging 35 pounds in weight, or more than 5,200 pounds of soapweed per acre, were cut from this area. It is probable that more careful selection in cutting should have been practiced so as to leave enough plants for protection against wind erosion. There are fewer young plants here than in the average stand over the range.

FIG. 2.—WHERE SOAPWEEDS ARE ARRANGED IN THIS MANNER AND BURNED TO REMOVE THE DEAD LEAVES, THE FIRE GETS TOO HOT AND BURNS PART OF THE GREEN LEAVES.

The loss in weight resulting from such burning on the Jornada Range Reserve was 42 per cent. Where the plants were arranged in rows two plants wide with the butts to the center, the loss in weight from burning was approximately 30 per cent. Burning on the range as shown in fig. 1 above is the most effective method where there is no danger of fire spreading and where there are but few young soapweed sprouts which may be killed by the fire.

THE PREPARATION OF SOAPWEED.

CHOPPING.

At least two types of machines have been developed to convert the stems and leaves into feed. One works on the principle of the ordinary feed chopper and cuts or slices the stems; the other works on the principle of the ordinary "wood hog" and shreds or tears the plant into particles small enough to be eaten readily by cattle.

The chopper has a heavy drumlike wheel, from 24 to 30 inches in diameter and from 12 to 14 inches wide, on the circumference of which are several heavy knives arranged to work against a cutter bar of heavy steel on the frame of the machine. The wheel makes from 250 to 300 revolutions per minute. It is mounted on a frame and is covered with a hood to prevent throwing off the cut particles of feed. The soapweed plants, after being lifted to the machine, are carried automatically over the cutter bar, and the knives chop the stem into particles somewhat resembling thin slices of pineapple. A 15 or 20 horsepower engine is required to operate successfully the larger machines first put on the market. The plants are fibrous and tough, so that power enough to maintain the cutting wheel at high speed is essential. These, when in proper order and when operated by experienced men, will chop from 25 to 30 tons of soapweed per day.

Three men are required to operate the chopper at full capacity. One man lifts the soapweed plants to the carrier of the machine, another places them in contact with the carrier, and a third clears the chopped feed away from the back of the machine.

The shredding machine consists of a heavy sheet-iron box approximately 16 inches wide, 16 inches long, and 36 inches deep, having at the bottom a small drum set with numerous tooth-edged knives. The soapweed plant is placed on end in the boxlike arrangement and with slight pressure from the hand of the feeder is forced to come in contact with the drum set full of teeth. This drum is rotated at a rate of 500 revolutions per minute, and the teeth coming in contact with the soapweed plant tear or shred it into small particles. This machine may be operated by two or three men, and requires an 8-horsepower engine. The capacity is much lower than that of the chopping machine.

Neither machine cuts the leaves of the soapweed very much, but both tear them apart enough for cattle to eat them.

MIXING SOAPWEED AND COTTONSEED MEAL.

The best way to mix cottonseed meal with soapweed is to sprinkle the meal over the chopped soapweed in successive layers as it is loaded into wagons to be hauled to the feed lot.

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FEEDING WITH SOAPWEED.

HAULING TO THE FEED LOT.

A common wagon with a bed from 14 to 24 inches deep can be used for hauling the feed from the chopper to the feed lot. When the feed is lightly trampled an ordinary wagon bed 20 inches deep will hold from 1,400 to 1,800 pounds, or approximately 20 pounds to the cubic foot. With one team and wagon two men can haul 10 loads per day, so that they would be able to feed 1,000 cattle per day at the rate of 15 pounds per head per day. The chopped feed can readily be handled with the ordinary hay or manure fork.

METHODS OF FEEDING.

The best results have been obtained by feeding the soapweed in troughs or racks. It is possible to feed on hard ground, but at best this is wasteful. The troughs are most efficient when cottonseed meal is fed with the soapweed.

Substantial troughs 16 feet long, 4 feet wide, and 1 foot deep, which gives a large enough capacity to minimize waste, were found very satisfactory in the feeding operations at the Jornada Range Reserve. They were made of 2-inch yellow pine lumber, with bottom "tongued and grooved" to retain cottonseed meal, and were set upon substantial legs placed at each end and in the middle, bolted to the sides and securely braced and long enough to leave a space of 18 inches between the trough and the ground. This is high enough from the ground to eliminate most of the danger of the stronger cows hooking the weaker ones into the trough.

To get the best results enough troughs should be provided so that there will not be more than from 12 to 16 cows for each trough.

THE COST OF SOAPWEED FEED.

The cost of operations necessary in feeding soapweed, not including cost of cottonseed meal, on the Jornada Range Reserve was approximately $2.27 per ton. This figure is the cost after the men had become familiar with the work. At first it was about $2.75 per ton. The item of wages includes board.

The cost of each step is given below:

Burning, cutting, and hauling from range to chopper:		
1 foreman and burner, at $1.66 per day	$1.66	
3 laborers, at $1.50 per day	4.50	
8 mules (feed), at $0.50 per day	4.00	
	10.16	
Capacity per day, 8 tons.		
Cost per ton		$1.27

Chopping into feed:		
1 foreman, at $2 per day	$2.00	
3 laborers, at $1.50 per day	4.50	
Fuel (gas and oil), at $4.50 per day	4.50	
Repairs, etc., at $4 per day	4.00	
	15.00	
Capacity per day, 25 tons.		
Cost per ton		$0.60
Hauling from cutter to feed lot:		
2 laborers, at $1.50 per day	$3.00	
2 mules (feed), at $0.50 per day	1.00	
	4.00	
Capacity per day, 10 tons.		
Cost per ton		.40
Total cost per ton delivered to the feed troughs		2.27

THE COST OF A MAINTENANCE RATION.

The cost of cottonseed meal used at the Jornada Range Reserve in 1918 was approximately $63.50 per ton at the reserve. The cost of the soapweed was $2.27 per ton. At this rate a daily ration of from 15 to 20 pounds of the soapweed with from 1 to $1\frac{1}{3}$ pounds of cottonseed meal cost approximately from $1.46 to $1.95 per head per month, which is a reasonable figure compared with the average cost of a maintenance ration of hay, even if hay were available.

This cost does not include the cost of machinery, nor depreciation on machinery, wagons, and equipment, nor any charge for the services of mules, nor the cost of riding to gather the poor cattle put on feed and to keep the poorest ones segregated from the rest in the feed lots. Most of these items will vary greatly and can be estimated best by the individual feeder for his intended operations. The riding will not be much greater than is ordinarily done to look after the stock in times when range is short, and most stock ranches have work horses or mules which would probably be idle if not used in the feeding operations.

A chopping machine of about 25 or 30 tons daily capacity and an engine to run it cost approximately $1,000 early in 1918.

THE TIME REQUIRED FOR CATTLE TO LEARN TO EAT SOAPWEED.

Little or no trouble has been experienced in getting poor breeding cattle to eat the chopped soapweed, and after they begin they relish it. Not a single animal among approximately 1,000 head fed on the Jornada Range Reserve seemed to dislike the feed or refuse to eat it at the first feeding. Feeding cottonseed meal with this highly palatable feed soon accustoms range cattle to the taste of cottonseed products. This is of importance because range cattle placed on feed for the first time often require from 7 to 10 days before they are eating cottonseed products to advantage if the meal or cake is fed alone.

THE AMOUNT OF SOAPWEED CATTLE WILL EAT.

In the feeding at the Jornada Range Reserve it was found that poor breeding cows will be maintained or will improve slightly in condition on from 15 to 20 pounds of the soapweed feed and from 1 to 1½ pounds of cottonseed meal per day. This is a sufficient ration to maintain breeding stock over a period of drought. A mature animal if given all it wants of a mixture of 15 pounds soapweed to 1 of meal will eat about 50 pounds daily.

ILL EFFECTS FROM EATING SOAPWEED.

There is a slight danger from overfeeding with soapweed when stock are first put on feed, and some danger of choking. If cattle unaccustomed to eating the feed are supplied all they will eat the first few days, they may be affected by bloating, sometimes resulting in death. This bloating is not very noticeable and comes on quickly after a cow has overeaten. When death results it occurs very soon after bloating begins, and the animals seem to be in great pain for a short period. Loss of two cows out of more than 1,000 fed on the Jornada Range Reserve was attributed to this cause. Choking may result from the attempt of a cow to swallow too large a piece of the soapweed. Post-mortem examination of a cow that died apparently from starvation as a result of obstruction of the food passageway revealed a large piece of soapweed lodged in the esophagus at a point approximately between the lungs.

The danger of both bloating and choking can be overcome by proper management. Poor cattle that have been on short pasturage should not be allowed to overeat soapweed during the first few days. There is less danger after stock become accustomed to the feed. The danger from choking will be slight at most, and it can be avoided by the use of proper machinery to cut the plants into smaller pieces.

No bad purging or scouring effect, such as might be expected from the plant's soaplike qualities, resulted from feeding the soapweed. Cattle fed over 100 days, extending into the time when the sap had begun to rise or growth had begun in the plants, were not affected at all. Rather than ill effect there is an apparent good effect. Normally, stock on dry feed at this time of the year are badly constipated and doubtless would do better if given more purgative. It was found on the Jornada Range Reserve that the soapweed kept the digestive tract of the animals in excellent condition. There was a slight effect of scouring on an occasional animal after the time the sap began to rise, but this was exceptional.

To determine any ill effects upon the digestive tract of the animal from feeding with soapweed, two range steers, one 4 and the other 5 years of age, were fed all the soapweed and cottonseed meal, in the proportion of 1 pound of meal to 15 of soapweed, that they would eat. One steer was fed for 65 days and the other for 87 days. The average daily consumption was slightly over 50 pounds. Both steers were butchered and carefully examined as to the effect of the feed on the digestive tract and on the meat. All the thoracic and abdominal viscera in both steers were normal. The fluidity of the viscera was marked, which may have been due in part to the ration of soapweed. The mucous membranes of the first, third, and fourth stomachs had a marked soapy appearance and touch. The fat was of good color and a firm consistency. The quality of the meat was first-class—tender and juicy. There was no evidence whatever, either in the meat or in the fat, that soapweed was the principal ration, and no impaction or other irregularity was found in the digestive tract.

FATTENING ON SOAPWEED AND COTTONSEED MEAL.

Of the two steers mentioned above, the one fed 65 days, a grade Angus, weighed 1,164 pounds on foot when butchered, having gained approximately 200 pounds in the 65-day period. The dressed carcass of this steer was 53.9 per cent of the live weight. The other, a native Mexico steer, weighed only 850 pounds and made no gain after the first 60 days of feeding. It dressed 52.9 per cent of the live weight.

The greatest value of soapweed is undoubtedly as an emergency-maintenance ration, and the available supply should be conserved for this use instead of being utilized for fattening purposes.

GROWTH HABITS OF SOAPWEED.

Soapweed (*Yucca elata*[1]), or "palmilla," as it is called by the Spanish-speaking people of the Southwest, is one of the most com-

[1] *Yucca elata* Engelm., according to Wooton and Standley (Contr. U. S. Nat. Herb. 19: 135. 1915), is distinguished from the other New Mexican yuccas (of which 8 species in all are listed) by its treelike habit, the naked woody stems in old plants attaining a height of "3 to 4 meters" (10 to 14 feet), by its narrow leaves ($\frac{3}{8}$ inch wide or less), and by its much-branched compound flower clusters.

Y. elata has long, slender, yellowish-green, flat, and fibrous-margined leaves, which readily distinguish it from the "Joshua tree" of southern California, southern Utah, and Arizona, *Yucca arborescens* Trelease (=*Clistoyucca brevifolia* (Engelm.) Rydb.). The leaves of *Y. arborescens* are short, stout, bluish green, concave above the middle, thickened, and minutely toothed; furthermore, the fruit of *Y. arborescens* is coated with a thin, dry pulp instead of being wholly devoid of flesh, the petals are much thicker, and the stigmas are not stalked.

The often treelike Mohave yucca (*Y. mohavensis* Sargent) of southern California and Arizona has leaves often about 2 feet long and 3 inches wide (much longer, wider, and mon species of the yucca group of drought-resistant plants in the Southwest. It is one of the common plants on the dry plains and mesas from western Texas throughout southern New Mexico to southern Arizona, and extends into Mexico. It occurs commonly on the sandy soil which is the favorite habitat of the black grama grass (*Bouteloua eriopoda*), on which it reaches its maximum size in southern New Mexico. The stand on such areas may vary from a few to 300 plants per acre. Soapweed grows to some extent also on the clay flats and gravelly slopes adjacent to the sandy soil but does not reach its maximum stand on such areas. It is found only occasionally on the sandhill areas, probably because the unstable soil conditions make it difficult for the soapweed to establish itself there. Wherever it has become established on the sandhill areas, however, there is often produced a heavy stand. Further study is necessary, therefore, to determine the factors limiting distribution.

As is indicated by its occurrence in different habitats, soapweed will grow in sandy, gravelly, or heavy clay soil. It is not exacting in its moisture requirements. It commonly reaches 5 or 6 feet in height and sometimes grows as high as 30 feet on the plains where the annual rainfall is less than 9 inches. On the other hand, it has been found growing on the embankments of storage tanks at stock-watering places where the soil is very moist, and the growth seemed to be little or no different from that on drier areas.

Soapweed commonly reaches a height of from 4 to 6 feet, with a stem diameter varying from 3 to 6 inches. Occasionally, specimens reach a height as great as 30 feet and a diameter slightly greater than 6 inches. *Yucca elata* is different from most palm or grasslike plants in that the stem undergoes diameter enlargement after elongation, or height growth, has begun. This permits additional increase in volume and value of the plant aside from height growth, which is very slow after the plant reaches from 4 to 6 feet.

As in many other drought-resistant plants, growth in soapweed is very slow. At best the plant requires several years to reach the average height of from 4 to 6 feet. Judging from the growth of two-year-old plants, it will take about 10 years for new plants to reach a height of 36 inches or over, which now appears necessary

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stouter than those of *Y. elata*), and, moreover, its fruit is pulpy, the flesh often being nearly ½ inch thick.

Another Southwestern yucca that usually has a treelike form is Schott's yucca (*Yucca schotti* Engelm.), of southern Arizona and Sonora. Its leaves are flat except toward their concave tips, smooth, light yellow to bluish green, 16 inches to 3 feet long, 1 to 1½ inches wide, the thickened, untoothed margins finally breaking into short brittle threads. Other distinguishing characters are the hairy-woolly inflorescence and the late (October-November) ripening fruit, with its thin, sweet, pulpy coating.

Yucca macrocarpa (Torr.) Coville, ranging from western Texas to southern California, is distinguished by its long (up to about 3 feet), spiny, concave, yellow-green leaves, very early flowers (March and April), long-stalked stigmas, and oblong, blackish, fleshy, sweet, and edible fruits, 3 to 4 inches long, terminating in an abrupt point or terminal appendage.

for profitable cutting as cattle feed. There is little information on this point, however, and it will be several years before reliable data become available from growth studies begun in 1915.

Soapweed reproduces by sprouts from the roots of the old plants and from seed. The reproduction from seed is scant in comparison with the quantity of seed produced. Flower stalks make their first appearance about May 1 to 15 in southern New Mexico, and the period of blossoming extends from the last week in May to the latter part of June. After formation of the seed, the stalk and seed begin to dry slowly, and the pod opens in the fall, dropping the light, flat seed, which may be carried a considerable distance by the wind. The seed dissemination period often extends through the winter into the following spring, since the pods do not open fully at first.

Establishment of growth from seed is very slow, perhaps because of low vitality of the seed produced or of soil-moisture conditions unfavorable to germination and to establishment of the plants after germination. Reproduction by sprouts is more rapid. The sprouts spring up from the roots of the old plants the first growing season after the old stem is cut or dies. Often also new plants spring up from the base of old plants that are still alive, indicating that when old plants mature young ones spring up to take their places. Usually one or more sprouts spring up from a single old root, and it is common to find twice as many new plants on an area as there were old plants formerly. After the first or second year the growth of sprouts is perhaps not more rapid than the growth of seedlings.

NECESSITY FOR CONSERVATIVE, SELECTIVE CUTTING.

The growth habits of the soapweed make it important to observe several precautions in cutting the plant.

While soapweed is abundant on many ranges of the Southwest at present, the plant is very slow-growing and requires possibly 10 years to reach the size for profitable cutting. Consequently, indiscriminate and unlimited cutting would result in depletion of the supply in a comparatively short time. It is advisable, at least until further information is available as to the rate of growth of soapweed, that the soapweed should be used only for emergency feed to carry stock over a time of drought or for other emergency needs, such as feeding bulls during winters of average years if this is necessary to insure satisfactory bull service. As the droughts occur at intervals of from three to ten years, it should be possible to determine a rotation system of cutting, whereby sufficient soapweed will be available at any time for a drought that may last several years.

It has been found that areas of sandy soil which have been denuded of vegetation are often reduced to a sandy waste as a result of wind erosion. The heavy stand of soapweed undoubtedly is an important factor in bringing about and maintaining stable soil conditions favorable to the establishment and growth of grama grass and other important range forage plants. It is reasonable to suppose that should the cover of soapweed be removed by cutting on sandy areas, severe wind erosion would follow and result in range depletion and difficulty in reestablishing a cover of vegetation. Some system of selection in cutting whereby a sufficient number of soapweed plants will be left to serve as protection against wind erosion is advisable. This is very simple where cutting is for feed purposes. It is not profitable to cut plants below 36 inches in height for feed, and ordinarily more than 50 per cent or more of the plants on an area are under 36 inches in height. If these plants are left uncut, they will form a reasonably effective protection.

Ordinarily stock eat all the blooms within reach in the spring of the year, leaving only the tall plants to furnish seed. In order to permit natural seeding of areas barren of soapweed it will be necessary to leave some of these taller plants uncut.

The soapweed plants in their native state on the range have a value also as a protection to stock. The tall plants furnish shade to stock during the hot summer days, besides furnishing protection, especially for young calves, during cold rains and winds, which sometimes occur in the Southwest. It may be found advisable to leave plants to furnish such protection in addition to those left for seed plants. Restricting the use of soapweed to periods of drought and feed shortage should make it possible to plan the cutting so as to leave a sufficiently large number of plants on noncut-over areas to furnish shade and shelter.

If the plants below 36 inches on areas cut over are left uncut and if no more cutting is done than is necessary for emergency feed, the amount of feed obtained from grazing the blossoms, green leaves, and new growth of the plants will not be materially reduced. Consequently this source of forage can be relied upon as much as before cutting.

The extent to which plants above 36 inches in height can be removed without endangering the permanent supply of emergency feed and without injury to the forage cover or to soil conditions must be determined by further investigation. Owing to the slow growth of the plant, it will require a period of years to determine this with accuracy. In the meantime it will probably be safe to use the soapweed for feed if the suggestions given above about cutting are observed. As new methods are developed for converting the plants into stock feed, and as more information becomes available as to the

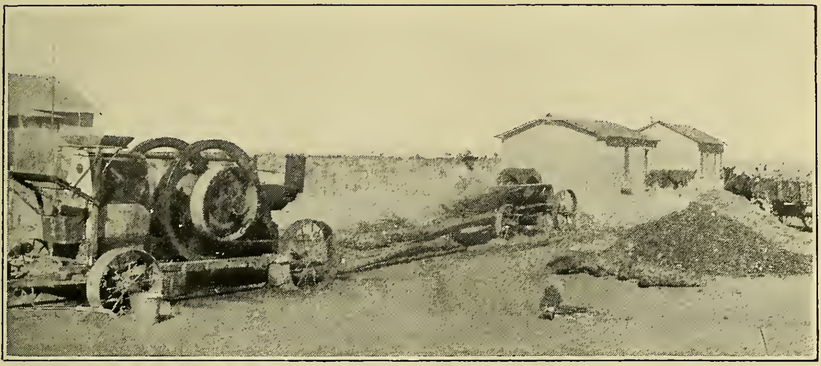

FIG. 1.—EQUIPMENT USED FOR CHOPPING SOAPWEED INTO CATTLE FEED.

Three men are required to operate this machine. The chopper cost from $300 to $550 and requires a 15 to 20 horsepower engine to operate it. Run at full capacity it will chop from 25 to 30 tons of soapweed per day.

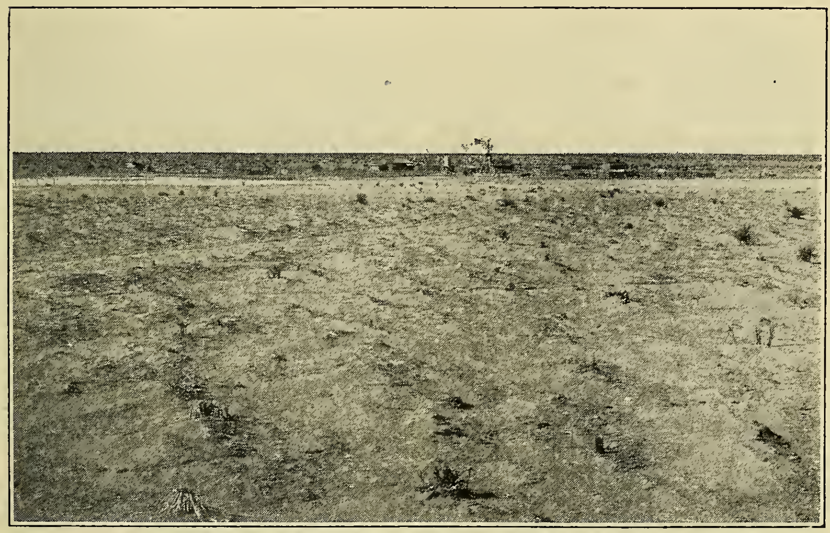

FIG. 2.—EFFECT OF WIND EROSION ON SOIL FOLLOWING THE REMOVAL OF SOAPWEED AND OTHER VEGETATION BY EXTENSIVE GRAZING AND TRAMPLING NEAR AN IMPORTANT WATERING PLACE.

The top of the root stumps was the former ground surface.

FIG. 1.—A HEAVY STAND OF SOAPWEED (YUCCA ELATA) AS IT OFTEN OCCURS ON SANDY SOIL ASSOCIATED WITH BLACK GRAMA GRASS (BOUTELOUA ERIOPODA).

Plants under 36 inches in height and occasional tall seed plants should be left when such areas are cut over. The young plants and a few older ones will serve as protection against destructive wind erosion and as protection for stock, besides insuring a second crop for cutting in perhaps 5 years.

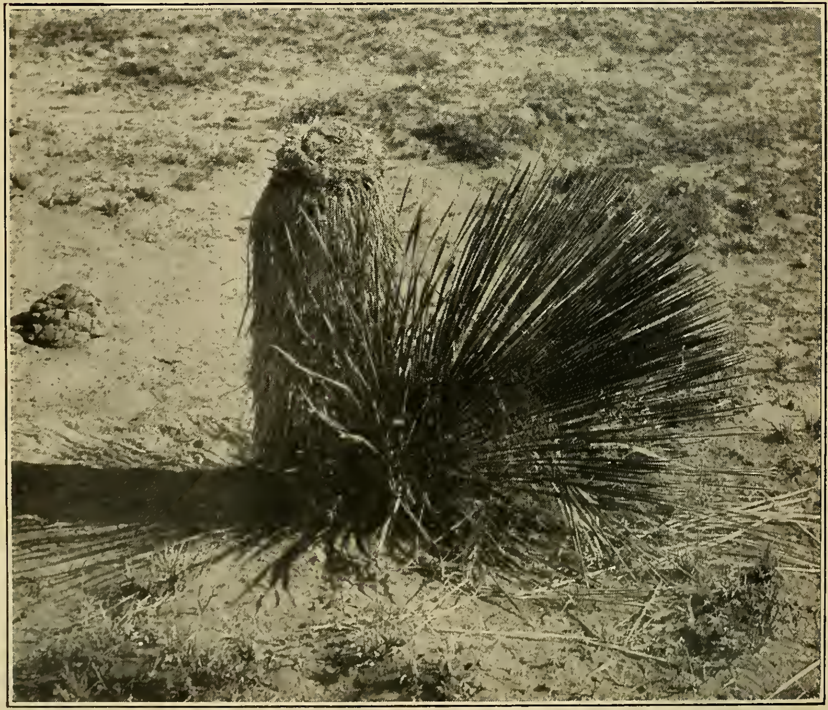

FIG. 2.—SOAPWEED SPROUT THE SECOND YEAR AFTER CUTTING OF THE OLD PLANT.

Indications are that it will require about 10 years for such young plants to reach average size for profitable second cutting.

growth habits of the plants and their value as a protection in building up and maintaining range, more extensive cutting for feed may be found practicable. On the other hand, more restricted cutting than is here recommended may be found advisable.

USE OF RELATED SPECIES.

SMALL SOAPWEED AND SACAHUISTA.

The possibility of making good feed from the leaf portions alone of plants like the soapweed suggests the use of small soapweed, or bear grass (*Yucca glauca*), which occurs north from central New Mexico, and sacahuista (*Nolina microcarpa*), which is found in southwestern New Mexico and southern Arizona, as well as *N. erumpens*, which occurs in western Texas. These often occur in considerable abundance. They do not, however, reach a height of more than 20 inches, and do not have a trunk or stem similar to that of the soapweed. They have been tried out as feed with fair success. The plants are chopped off at the ground, so that the leaves are separated from the rest. The leaves are then fed to the cattle. It is possible that this feed might be improved if made into ensilage.

SOTOL.

Sotol (*Dasylirion wheeleri*) occurs from western Texas to southern Arizona and *D. Texanum* in western Texas. Forage analyses and feeding experiments indicate that sotol is as valuable as soapweed when it is properly cut and prepared. It is more limited in quantity than the soapweed, however, since it is confined to the low mountains and foothills. Unlike the soapweed, it does not sprout again from the old root when cut. Furthermore, it is slower-growing than the soapweed, so that there will be an indefinite period after cutting before another stand is ready to cut.

SUMMARY.

Severe droughts which occur at intervals of from three to ten years have in the past caused severe setbacks to the range cattle industry in the Southwest through the greatly reduced crop of range forage during such periods and the lack of an economical feed as a substitute. A substitute, which is satisfactory to a large extent at any rate, has been found in soapweed (*Yucca elata*).

On the range soapweed is important as forage. Stock eat the leaves of the plant when other more palatable vegetation is scarce. The blooms and the growing tip in the center of the upper circle of leaves form an important part of the forage for cattle in the late spring and early summer.

Forage analysis has shown chopped soapweed to be comparable with native forage grasses and some of the poorer hay crops. The entire stem as well as the leaves can be utilized, and machines have been developed for chopping both stem and leaves into particles small enough to be eaten by cattle. As ensilage it is satisfactory, but the ensilage process is unnecessary where the soapweed is abundant. The chopped trunks or stems, which furnish the bulk of the feed, are palatable and, when fed with the chopped leaves, are readily eaten by stock without any softening process.

Results obtained on the Jornada Range Reserve, where more than 1,000 head of poor cows were fed in the spring of 1918 with very light losses, and results obtained on many other ranches in the Southwest to which the feeding practice spread rapidly, have demonstrated very clearly that the feeding of soapweed, with a supplemental ration of cottonseed meal or other similar concentrate, is practicable as a means of maintaining range cattle in time of drought.

The dead leaves should be removed before the plants are chopped. On the Jornada Range Reserve this was done by burning. If there is no danger of fire spreading, the burning can be done best while the plants are standing on the range. Otherwise, the burning should be done after the plants are hauled to the chopper. The reason for the removal of the dead leaves is that they are of low forage value and are unpalatable.

Plants over 36 inches in height should be selected for cutting. Those selected should be chopped off at the ground surface and run through a specially constructed machine which cuts or tears the entire plant into particles fine enough to be readily eaten by stock. This chopped feed mixed with a small amount of cottonseed meal or similar concentrate is fed to the stock, preferably in large troughs.

From 15 to 20 pounds of chopped soapweed with 1 to 1½ pounds of cottonseed meal daily will maintain the average breeding cow and may improve her condition slowly.

During 1918 the total operation in handling the soapweed from its native condition on the Jornada Range Reserve to the feed lot cost from $2.27 to $2.78 per ton, not taking into consideration the initial cost of machinery and equipment. With cottonseed meal at $63.50 per ton the cost of maintaining a cow on from 15 to 20 pounds of the mixed feed per day was from $1.46 to $1.95 per month, besides the cost of providing water and salt and of handling of the stock.

Where cows are very poor when placed on feed, it will probably be profitable to give them a larger ration for 20 or 30 days until they improve in condition sufficiently to be carried on the lighter ration without danger of loss. Stock that have improved on the lighter ration can probably be maintained at a slightly lower cost on a scant grass or browse pasture and $1\frac{1}{2}$ pounds of cottonseed cake per day, especially where securing labor is a difficult problem.

Poor cattle should not be fed all the soapweed feed they will eat the first few days on feed, since there is a slight danger of loss from bloating until they become accustomed to the feed.

Choking may occur as a result of a cow trying to swallow too large a particle of the soapweed. This is only occasional, however, and can be avoided by the use of a machine that cuts the feed properly.

There is no cumulative ill effect on the digestive tract of cattle fed on the soapweed over a long period. Neither is there any harmful purgative effect from the soapweed, except occasional scouring when feeding is continued after the sap begins to rise in the plant. On the contrary, the soapweed tends to keep the digestive tract of the animals in good condition. It is possible that the occasional scouring effect may be overcome by delaying the chopping of the plants into feed until they have been allowed to dry out for several days after the dry leaves are burned. This, however, is a suggestion only, as it has not been tried in practice.

The soapweed is found from western Texas to southern Arizona It reaches its average height and heaviest stands on the sandy soils usually occupied also by the black grama grass of the region. It is one of the slow-growing drought-resistant plants, and although it reproduces by sprouts from the old roots it probably requires 10 years for such sprouts to become tall enough for a profitable second cutting.

The soapweed has some value as a protection for cattle against storms and against the heat of the sun.

Soapweed is slow-growing, occupies a soil highly subject to wind erosion, and is a protection to stock, so that it is advisable to use the plant only as emergency feed. Only the larger plants should be selected for cutting, the smaller ones being left to protect the soil. Occasional plants tall enough for the blooms to be out of the reach of cattle should be left for seed plants and as a protection for stock.

Small soapweed, or bear grass (*Yucca glauca*), and sacahuista (*Nolina microcarpa* and *N. erumpens*) are somewhat similar to the soapweed, the small soapweed being found slightly farther north. It is possible that the greatest use of these plants for feed will be as ensilage.

Sotol (*Dasylirion wheeleri* and *D. texanum*) furnish feed for cattle about equal in value to soapweed when similarly chopped and prepared, but its limited distribution and slow reproduction restrict its importance as an emergency stock feed.

Methods of converting the soapweed into stock feed are not yet thoroughly developed, and will doubtless be improved upon. More data on the rate of growth, which it will take several years to acquire, will make available information upon which to base a satisfactory cutting system. Further investigations may warrant modification in the present cutting practice either by extending or by restricting cutting. Meantime, however, it is believed that the soapweed may be cut for use as an emergency feed without any great damage to the range or danger of depleting the supply for emergency feeding if the suggestions contained in this bulletin relative to selective cutting are followed.

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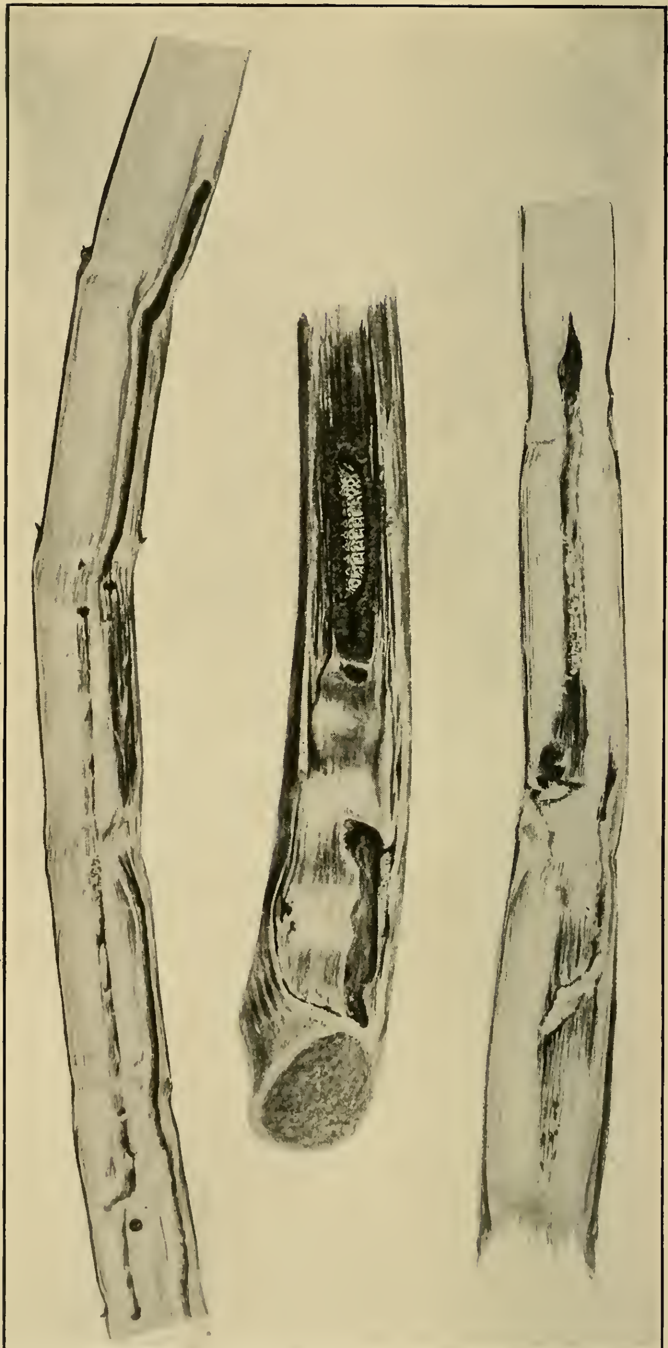

INTERIOR OF STALKS OF SUGAR CANE SHOWING HOLES MADE BY SUGAR-CANE MOTH BORER AND A BORER IN ITS TUNNEL.

The normal tissue is white or yellowish, and the reds and other colors, appearing dark in the illustration, are the results of diseases, especially "red rot," which follow the borer in the cane stalk, causing additional deterioration.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 746

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 18, 1919

THE SUGAR-CANE MOTH BORER.[1]

By T. E. Holloway and U. C. Loftin,[2]
Entomological Assistants, Southern Field-Crop Insect Investigations.

With Technical Descriptions by Carl Heinrich.

CONTENTS.

INTRODUCTION.

For the information of those who are not familiar with sugar cane, especially as grown in the United States, it may be said that the plant is a giant grass known botanically as *Saccharum officinarum*

[1] *Diatraea saccharalis crambidoides* Grote; order Lepidoptera, family Pyralidae.

[2] The writers acknowledge their indebtedness to Dr. W. D. Hunter for his interest and direction, and for the suggestions of Dr. W. Dwight Pierce and Mr. D. L. Van Dine, of the Bureau of Entomology. The tables and charts for life history were made under Dr. Pierce's supervision. The active cooperation of the Louisiana Sugar Experiment Station at Audubon Park, New Orleans, has been of the highest value, credit especially being due to Mr. W. G. Taggart, assistant director, for his suggestions concerning the practical application of methods of control. Mr. S. G. Chiquelin, the former assistant director, cooperated in the work and later made valuable suggestions concerning localities in Cuba where parasites could be obtained. Laboratory space was furnished gratis by the Louisiana Experiment Station, and the writers thank Prof. W. R. Dodson, director, for his many courtesies.

For the technical descriptions of the larva and pupa stages of the insect, the writers thank Mr. Carl Heinrich, of the Bureau of Entomology.

The writers have had the assistance in field and laboratory work of Mr. Ernest R. Barber and others. Valuable cooperation was maintained with Mr. George N. Wolcott, formerly entomologist of the Insular Experiment Station of Porto Rico and later for a short time connected with this investigation. Prof. J. T. Crawley, formerly director, and Prof. P. P. Cardin, entomologist, of the Cuba Experiment Station at Santiago de las Vegas, have been of material assistance in connection with the introduction of the parasitic flies from Cuba. Mr. Edward Foster, of the office of the State entomologist of Louisiana, has assisted with bibliographical and other information.

The drawings were made by Mr. Harry Bradford, of the Bureau of Entomology.

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Linnaeus, that it is grown from cuttings which are laid lengthwise in the rows, that it grows from late spring through the warm months of the year, and that it must be cut before it is damaged seriously by cold weather.

The plant does not produce seeds in Louisiana, though it does in tropical countries and occasionally in southern Florida and the southern tip of Texas. The stalks are cut in the fall, the leafy tops and side leaves are trimmed off and left on the fields, and the stalks are ground in the mill, this being the first step in the manufacture of sugar. The leaves and tops left on the ground usually are called the "trash," but by some "shucks," and by others "flags."

The principal insect injurious to sugar cane in the United States is a moth generally known in the larva stage as "the borer," but it is distinguished from other boring insects of sugar cane by the names "moth borer" and "lesser moth borer." It is a member of the order Lepidoptera, family Pyralidae and subfamily Crambinae, and has the scientific name *Diatraea saccharalis* Fabricius, variety *crambidoides* Grote. It is this insect which is considered in the following pages.

CHARACTER OF INJURY TO SUGAR CANE.

The work of many insects is apparent immediately, even to the untrained observer, but the injury due to the sugar-cane moth borer, familiarly known as the "borer," is the more serious for the reason that it is not noticeable except on close examination. To the casual observer one field of sugar cane is like many others. If the leaves are pulled away from a stalk, however, a few holes may be observed in the rind and perhaps a quantity of sawdustlike material may be seen clinging to the stalk. This is evidence that the moth borer has been at work. If the stalk is split lengthwise, tunnels about an eighth of an inch wide may be found running for several feet, several tunnels sometimes joining in such a way that the plant is greatly weakened and is easily blown down by a high wind.

It is evident that such injury must occasion various forms of loss, in tonnage of cane, pounds of manufactured sugar, etc. The injury is rendered even more serious by the insidious habits of the insect, since the full amount of damage is underestimated by the average planter. Only by walking through the field and examining stalk after stalk can any definite idea of the full amount of injury be obtained.

ESTIMATE OF LOSSES.

Not only are the mature canes injured greatly by the moth borer, but many young plants, especially in the early summer, are killed. (See "Effect on young cane—'dead hearts,'" p. 5.) As many as 100 plants per acre may be destroyed, but so many plants remain in the field that this loss is not great. It should be prevented, however, because it is on these young plants that the borers multiply in sufficient numbers to become a serious menace to larger canes.

Under calculable losses the injury to mature cane alone will be considered. The full amount of injury is shown only by chemical analysis. Infested and uninfested cane from Texas, not affected by red rot, a disease which often follows borer damage, was analyzed, with the following results:

Uninfested.	*Per cent.*	*Infested.*	*Per cent.*
Brix	19.5	Brix	17.55
Sucrose	17.45	Sucrose	15.1
Purity	89.5	Purity	86.0

Dr. William E. Cross, at that time of the Sugar Experiment Station, New Orleans, La., who made the analyses, stated that the loss due to the moth borer was about 20 per cent of the sugar—a greater loss than might be expected from the figures. Mr. John Allbright, chief of the laboratory at Central Chaparra, Cuba, analyzed infested and uninfested cane from a field at that central factory. The results follow:

Uninfested.	*Per cent.*	*Infested.*	*Per cent.*
Brix	21.3	Brix	18.8
Sucrose	19.9	Sucrose	16.85
Purity	93.4	Purity	89.6
Extraction	47.2	Extraction	36.4

Loss in sucrose, 3.3 per cent in cane.
Loss in sucrose, 15.3 per cent in juice.

Messrs. D. L. Van Dine (169)[1] and T. C. Barber (14) have investigated the losses due to the moth borer in considerable detail. Mr. Barber sums up the effect on sugar content in Table I.

TABLE I.—*Analysis of sugar cane (D. 74) to determine effect on sugar content of the borer injury to cane.*

No. of sample.	Nature of sample.	Weight of cane.	Weight of juice.	Per cent of juice.	Loss of juice due to borer.	Total solids in juice.	Loss in total solids due to borer.	Glucose in juice.	Solids not sugar in juice.	Glucose ratio.	Sucrose in juice.	Loss in sucrose due to borer.	Purity.	Loss in purity due to borer.
		Gms.	*Gms.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	Borer-free	9,990	6,108	61.1	.....	17.1	......	1.6	1.1	11.1	14.4	......	84.2	.....
2	Medium infested	11,081	6,735	60.8	0.3	16.1	1.0	1.7	1.2	12.9	13.2	1.2	82.0	2.2
3	Heavily infested	8,824	5,190	58.8	2.3	13.7	3.4	2.1	1.8	21.4	9.8	4.6	71.5	12.7

NOTE.—Each sample consisted of 10 canes. Each of the medium-infested canes contained from one to three infested joints, and each of the heavily infested canes five or more infested joints. Analysis made Nov. 12, 1910.

[1] Figures in parentheses refer to entries in the bibliography, pages 63–74.

TABLE I.—*Analysis of sugar cane (D. 74) to determine effect on sugar content of the borer injury to cane*—Continued.

RESULTS OF ABOVE ANALYSIS FIGURED ON A BASIS OF 1 TON OF CANE TO THE SAMPLE.

No. of sample.	Nature of sample.	Weight of cane.	Weight of juice.	Loss of juice per ton due to borer.	Total solids per ton.	Loss in total solids due to borer.	Glucose per ton.	Increase in glucose due to borer.	Solids not sugar per ton.	Increase in solids not sugar due to borer.	Sucrose per ton.	Loss in sucrose due to borer.	Actual loss in sucrose due to borer.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*
1	Borer-free	2,000	1,222	......	208.96	......	19.55	......	13.44	......	175.97	......	......
2	Medium infested	2,000	1,216	6	195.77	13.19	20.67	1.12	14.59	1.15	160.51	15.46	8.78
3	Heavily infested	2,000	1,176	46	161.11	47.85	24.69	5.14	21.17	7.73	115.25	60.72	34.51

He summarizes his results as follows:

The sugar-cane borer damages cane in the field by destroying a considerable percentage of the eyes, thus reducing the stand of plant cane; by stunting the growth of the cane, owing to the physical injury of the stem; by admitting fungous diseases through the wounds in the stem; and is the main cause of injury by the wind, owing to the weakening of the stalk due to the tunnels and burrows. These classes of injury have been appreciated by planters. It now develops that there is another and very important class of injury which has been overlooked. This is the reduction of both the quantity and quality of the juice, which is dealt with specially in this circular. It becomes evident that both the planters and the manufacturers are vitally interested in the work of the sugar-cane borer.

Mr. Van Dine states:

There is a direct loss in sugar and a decided reduction in the purity of the juice of cane infested by the moth stalkborer. This loss in Porto Rico exceeds 670 pounds of sugar per acre of cane in which the infestation was not apparent except upon examination, the yield averaging 41 tons of cane per acre and the stalks being normal and healthy in appearance. The loss increases in direct proportion to the number of joints of the cane stalks infested by the borer. There is more fiber and less juice in borer-infested cane. The actual weight of borer-infested cane is less than that of sound cane, and it is considered that the juice deteriorates more rapidly in infested cane when cane is allowed to stand without being crushed for any length of time after harvest.

In the early bulletin on the moth borer by Dr. W. C. Stubbs and Prof. H. A. Morgan (152) it is found that after the borer became established on Belle Alliance Plantation, in Louisiana, there was "a falling off of 4.98 tons per acre and about 25 pounds of sugar per ton." From the figures given in that bulletin it is calculated that an average yield of 3,455 pounds of sugar per acre accrued on Belle Alliance Plantation before the borer made its appearance, whereas the average yield thereafter was only 2,393 pounds per acre. The loss in sugar from these figures would be 1,061 pounds per acre. At 4.35 cents per pound, which is given as the average price of (white) sugar for three years, the annual money loss per acre due to the moth borer would be $46.15. At the present ruling prices the loss would be correspondingly greater.

"DEAD HEART" CAUSED BY THE SUGAR-CANE MOTH BORER.

Injury of this character results, in a few days, in the death of the young plant.

As calculated from the figures of Mr. T. C. Barber, a similarly high loss is obtained. Mr. Barber estimates a total loss of 1,078 pounds of sucrose per acre where canes are all bored, as they sometimes are. The present writers estimate the loss of 96 test sugar as 1,082.33 pounds per acre. The average price of this grade of sugar on the New Orleans market during the 14 years from 1900 to 1913, inclusive, was approximately 3.87 cents per pound. At this price the money loss where all canes are bored is $41.88 per acre.

During the six-year period from 1912 to 1917, inclusive, in which observations have been made, the average infestation has been about 58 per cent of all the canes in the infested area in Louisiana, which includes the whole sugar belt, except the parishes of Rapides and most of Avoyelles, or about 300,000 acres planted in sugar cane. Fifty-eight per cent of the maximum loss ($41.88) is $24.29 per acre. For 300,000 acres it reaches the high figure of $7,287,000. The losses in southern Florida and the lower Rio Grande Valley, in Texas, would correspond to the acreage. The infestation in Texas is always high.

These figures do not take into consideration the loss due to injury to corn, which must be considerable but is difficult to estimate.

EFFECT ON YOUNG CANE—"DEAD HEARTS."

The first injury of the moth borer to the young sugar-cane plant produces what is known as the "dead heart." This injury is illustrated in Plate I. Among plants from 6 inches to 3 feet in height some usually are to be found in which the outer leaves are a healthy green while the young inner whorl is yellow and dry. The central portion, or "heart," of the plant is dead, and the dying of the rest of the plant is only a matter of days.

This peculiar reaction to injury is rather characteristic of young cane. It is often due to the work of the borer, but it may result from various other causes. Thus some "dead hearts" are caused by a twisted growth of the inner tissues of the plant, the tissues above such a twist ultimately dying. Other "dead hearts" result from accidents of cultivation. A false step of the mule or the plowman may break the brittle inner tissues near the ground, while the outer portion of the plant, being stronger and more elastic, springs erect after the weight is removed. In a short time the heart dies, and an investigation will show that the inner tissues have been broken cleanly and have turned slightly brown at the point of separation.

Insect injury other than that of the moth borer also is responsible for "dead hearts." The work of the sugar-cane beetle (*Ligyrus*) *Euetheola rugiceps* Le Conte, and other insects produces similar injury, the inner portion of the plant being killed before the outer portion.

The "dead hearts" due to the moth borer are caused in the following manner: The adult moths emerge in the spring, when the cane plants are small, and deposit clusters of eggs on the leaves of the young plants. The eggs hatch, and the small larvæ feed here and there on the tender whorls, rolls of holes appearing on the leaves as they expand. Many of the larvæ seem to perish during this period, partly because of their cannibalistic habits. Not more than three larvæ, usually only one, seem to find their way to the interior of a young cane plant. When about half grown a larva crawls down the outside of the stem to a point near or even below the surface of the ground. Gnawing a hole through the outer layer of the stem it works its way to the interior of the plant, cutting the tender inner shoot and forming a "dead heart." The inner shoot does not dry up immediately, so that the larva has some time to work before the injury can be noticed. Tunneling within the plant the insect reaches its largest size, pupates, and finally leaves the plant as an adult moth.

During a year when few plants were killed in this way it was estimated that there were about 10 "dead hearts" per acre. In other years as many as 100 "dead hearts" have been counted per acre.

EFFECT ON MATURE CANE.

While the work of the larvæ on the small plants kills the plants, larger stalks usually do not die. In these the larvæ burrow up and down, sometimes gnawing their way out through the hard rind and reentering at another point. Frequently a mature stalk will harbor two or three larvæ which work in different parts of the cane from the top to the bottom. Three sections of infested cane are illustrated in the frontispiece.

A red coloration, showing dark in the canes illustrated in the frontispiece, usually is observed in the pith along the tunnels. This is the disease "red rot," which is caused by the fungus *Colletotrichum falcatum*. "By far the largest number of stalks become infected [with red rot] through the burrows made by the cane borer," writes Dr. C. W. Edgerton (50), who sums up the injury due to red rot as follows: "First, the loss in stand; second, the killing of the young plants; third, the injury to the leaves; fourth, the loss in per cent of sucrose with a corresponding increase of glucose." "Knowing that a large per cent of the red-rot infection in cane is by means of borer channels," Dr. Edgerton continues, "a greater effort should be made to control the insect."

The spores of other fungi, as well as bacteria,[1] also gain entrance through the borer holes. Cane badly bored is found to be hard and dry, making it more difficult to grind. The growth is checked, and

[1] Prof. Wm. L. Owen (119), formerly bacteriologist of the Sugar Experiment Station at Audubon Park, New Orleans, La., has studied and described a bacterium which he found in the tunnels made by the moth borer in sugar cane. He has given it the name of *Bacillus saccharalis*.

the bored stalks are often blown down by a strong wind. The purity of the juice is lowered, the tonnage decreased, and the sucrose content materially diminished. The eyes are destroyed in many cases, which lessens the value of the infested cane for seed.

EFFECT ON CORN.

The damage of the moth borer[1] to the corn plant has been well described by Mr. George G. Ainslie (2).

Corn is damaged by these caterpillars in two ways. First, in the early part of the season, while the plants are small, they work in the throat of the young corn, and if the tender growing tip within the protecting leaves is once damaged all chances that the plant will become a normal productive specimen are gone. In many sections of the South this is commonly known as "bud-worm" injury, and though there are several other insects which cause a similar mutilation of the leaf, a very large proportion of the so-called "bud-worm" damage may be charged to this insect. The effect of its work on the leaves of the young corn plants is similar to that resulting from attacks by the corn billbugs (*Sphenophorus* spp.) and is evidenced by the familiar rows of small circular or irregular holes across the blades of the plant.

The other form of serious damage chargeable to this pest occurs later in the season. The larvæ, having then left the leaves and descended to the lower part of the stalk, tunnel in the pith. If the larvæ are at all numerous in the stalk, their burrows so weaken the plant that any unusual strain will lay it low and destroy all chance of its maturing. While frequently ten or more larvæ may live and mature in one plant, it must be remembered that any infestation, however light, will lessen in some degree the vitality of the plant and cause a corresponding loss in the quality and quantity of the harvest.

Not only the stalks of corn, but sometimes the ears are found to contain borers.

The cornstalks, maturing about July or August, when the cane is hardly half grown, become dry and the plants are no longer attractive to the moths for the deposition of eggs. Corn and cane are grown in adjacent fields on sugar plantations, and moths from corn find cane an attractive food plant. Consequently the cane in the middle of the season is attacked not only by moths which have passed their immature stages in cane plants, but by numbers of those which have grown to maturity in corn. It is notable that the number of cane stalks infested by borers increases rapidly from the middle of the growing season until the cane is cut.

HISTORY.

Dr. L. O. Howard (77) wrote an article on the moth borer for the official entomological journal, Insect Life, in 1891, introducing his remarks with an account of the history of the species. We quote him as follows:

[1] Though this account was doubtless written with *Diatraea zeacolella* Dyar in mind, it is correct when applied to the closely allied species *D. saccharalis crambidoides,* which also attacks corn.

The attention of English-speaking people was first called, in a scientific way, to the ravages of a lepidopterous borer in sugar cane by the Rev. Lansdown Guilding in his account of the insects infesting sugar cane, in the Transactions of the Society of Arts, 1828, vol. XLVI, pp. 143–153. He described the insect as *Diatraca sacchari*, and for his paper, which comprehended also an account of the sugar-cane and palm weevils, he was awarded the gold Ceres medal of the society. His studies were made in the Island of St. Vincent in the West Indies, and from its occurrence there at this early date, and from Guilding's statement that it had been long known, there is reason to suppose that the insect may be an indigene of South America or of the West Indies, where the cultivation of sugar cane was first begun in America.

In 1856 a select committee, appointed to investigate the damage caused by the cane borer in Mauritius, reported through W. Bojer, and the insect, which is called in the report *Proceras sacchariphagus*, was treated at some length, and an account was given of its introduction into the island. In the same year Westwood reviewed this report at length in the Gardeners' Chronicle of July 5, gave a woodcut of the insect, and pointed out that it was probably identical with the species described by Guilding at St. Vincent. He also called attention to the fact that the species named many years previously by Fabricius as *Phalaena saccharalis* is probably the same thing. This insect was described by Fabricius (Entomologia systematica, vol. III, part 2, p. 238), from South America, no more definite locality being given. The probabilities are, however, that he refers to Dutch Guiana on account of the early settlement of that country and from the fact that he refers to a figure of the larva by Myhlenfels. He makes the statement that it feeds in sugar-cane, perforating and destroying the stalks and becoming a pest in plantations. He describes the larva as six-footed, of a pale hyaline color, and with the head and eight spots brown. The larval description, however, is drawn from a figure by Myhlenfels, which may have been inaccurate. As Fabricius's work was published in 1793, further evidence is thus afforded that the insect is indigenous to the western hemisphere. This insect still does similar damage in the vicinity of the original source of our information, as is indicated by two articles by Miss Ormerod in the Proceedings of the Entomological Society of London, 1879, XXXIII–XXXVI and XXXVI–XL, and by reports of Mr. Im-Thurm, curator of the British Guiana Museum at Georgetown, published some time previously, but which we have not seen.

In an added note to his Gardeners' Chronicle article, Westwood states that according to information given him by "an intelligent Jamaica cane-grower" the borer was very destructive in Jamaica some 15 years previously (1842), but that its ravages had been greatly checked by allowing the refuse to accumulate on the ground and then firing the whole plantation, the old roots subsequently throwing up more vigorous shoots.

Mr. H. Ling Roth has studied what he believes to be the same species in Queensland (Parasites of the Sugar-Cane, reprinted from the Sugar Cane, March and April, 1885. London, 1885). And in the same year M. A. Delteil (La Canne à Sucre, Paris, 1885) treats of the Mauritius borer and considers it to have been imported from Java, whereas the 1856 commission had considered that it was derived from Ceylon. In 1890 Dr. W. Kruger published in the Berichte der Versuchsstation für Zuckerrohr in West Java, Heft 1, Dresden, 1890, an account of the sugar-cane borers, and figures and describes a species determined as *Diatraea striatalis* Snell., which almost precisely resembles our species, and which he says occurs not only in Java, but also in Borneo, Sumatra, and Singapore. In this same report another similar borer is described by Snellen as *Chilo infuscatellus*.

The West Indian cane borer made its appearance in the sugar-cane plantations of Louisiana at an early date. J. B. Avequin, writing in the Journal de Pharmacie for 1857 (vol. XXXII, pp. 335–337), upon the enemies of the sugar cane in the Antilles and Louisiana, stated that during the two or three preceding years this insect had spread over some of the cane fields of Louisiana, but without having caused up to that time any great damage. He thought that the early frosts towards the end of October or November destroyed great numbers. It appears to have been first noticed in the Parish of St. John Baptist in the year 1855.

Since this time the insect must have been constantly present in the Louisiana cane fields, and has probably been reintroduced from time to time with fresh shipments of seed cane from the West Indies. In the fall of 1878 a few specimens were sent to Dr. Riley by a correspondent of Assumption Parish, Louisiana, and in the spring of 1879 Mr. E. A. Schwarz sent in a bit of cane containing larvæ from the Bahamas. In the spring of 1881, I was sent to Louisiana by Professor Comstock, then entomologist of the Department of Agriculture, to study the sugar-cane beetle (*Ligyrus rugiceps*), and had the opportunity of studying this borer upon the plantation of Dr. J. B. Wilkinson, some 40 miles south of New Orleans on the Mississippi River. Dr. Wilkinson informed me that in 1857 they were very abundant in the Lower Mississippi, and that the crop upon one plantation was utterly destroyed, the cane breaking to pieces as they attempted to cut it.

Concerning the date of the introduction of the moth borer into Louisiana, Stubbs and Morgan (152) conclude that it was introduced long before 1857. "How and when the borer was introduced is not certain," they decide, "but the separate corroborating testimony of Mr. Chamberlain and Mr. Maurin would rather fix the date at 1857, and as canes in large quantities from South America were that year introduced, it is reasonable to conclude that they came from that country as asserted by Mr. Maurin, and not from the West Indies, as Mr. Chamberlain thinks. However, if Col. Pugh and Mr. Bird are accurate in their dates, it was here in quantities before that year." In a footnote to the foregoing these investigators add: "Subsequent investigations have proven that the borer was here in quantities long before the importations of cane described above."

A little-known book by Champomier (32), who issued a series of statistical reports on the sugar industry of Louisiana about the middle of the last century, mentions the "borer worm" in his report for 1856–7. This reference was brought to the attention of the writers by Mr. Edward Foster, of New Orleans.

DISTRIBUTION.

The distribution of the sugar-cane borer (*Diatraea saccharalis crambidoides*) in the United States coincides rather closely with the area devoted on an intensive scale to sugar-cane growing. It is limited to the southern part of Louisiana, the southern tip of Texas, and the southern part of Florida. The borer does not occur in Rapides Parish of Louisiana and is present in only the southeastern part of

Avoyelles Parish. It has not been found in the cane-growing sections of Wharton, Sugarland, and Victoria, Tex.

It is noteworthy that the territory infested in the United States is mostly within the limits of an area known as the Gulf Strip of the Lower Austral Zone.[1] This strip along the coast is indicated in the accompanying map (fig. 1), which shows also the infested regions.

That the insect is found only in three such widely separated places as the southern parts of Texas, Louisiana, and Florida may be explained by the fact that it is a tropical species and probably was brought to these three cane-growing sections independently in shipments of seed cane. Where sugar cane is only an incidental crop it

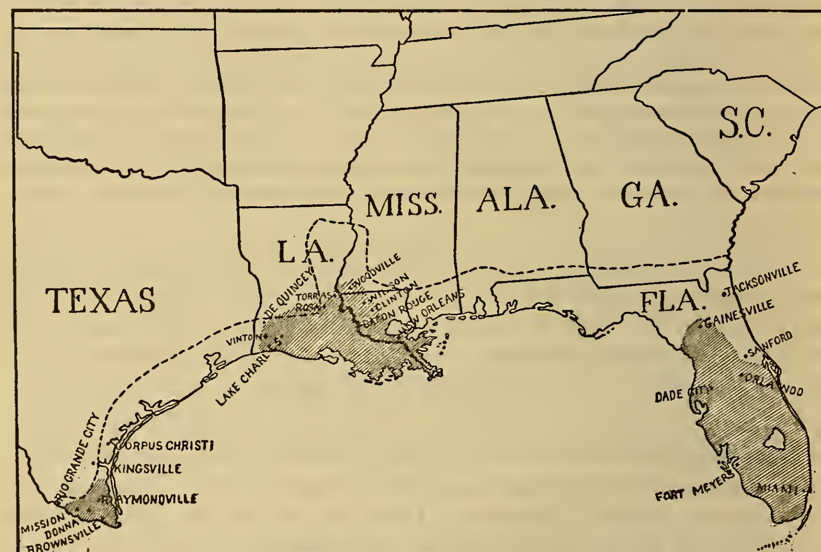


FIG. 1.—Map showing distribution of the sugar-cane moth borer (*Diatraea saccharalis crambidoides*) in the United States. The area below the line of dashes is the "Gulf Strip." Note that the territory infested is practically well within the limits of this biological zone.

does not occur, although a nearly related species attacks corn and very seldom sugar cane in Georgia, northern Florida, North Carolina, South Carolina, and Virginia (75).

SPECIES OF DIATRAEA.

Dr. Harrison G. Dyar (45) records three species of Diatraea in the United States. These are:

Diatraea saccharalis saccharalis Fabricius. French Guiana, Cuba, Trinidad, Peru. Also a female from southern Florida. Probably Santo Domingo.

Diatraea saccharalis crambidoides Grote. Mexico, numerous localities; Gulf States and lower Mississippi Valley.

Diatraea zeacolella Dyar. North Carolina, South Carolina, Virginia.

Diatraea lineolata Walker. Cuba, Trinidad, the Guianas, Venezuela, Costa Rica, Mexico, and southern Arizona.

[1] Merriam, C. Hart. Life Zones and Crop Zones of the United States. U. S. Dept. Agr. Div. Biol. Surv. Bul. 10. 79 p., 1 col. map. 1898.

Dr. Dyar has determined the species from Louisiana as *Diatraea saccharalis crambidoides.*

The authors' observations indicate that *D. zeacolella* occurs in Georgia and northern Florida, as well as in the Carolinas and Virginia. In places in these States where both corn and sugar cane are grown this species has been found to be abundant in corn while rare or absent in adjoining cane fields. Practically, it may be regarded as an enemy of corn exclusively. The larval characters which distinguish *D. zeacolella* from *D. saccharalis crambidoides* have been noted elsewhere by the senior writer (75) and have been further investigated by Mr. Carl Heinrich. (See description of larva, p. 13.)

The southern Arizona species (*D. lineolata*), observed by the authors at Phoenix, Ariz., on sugar cane and Johnson grass, has the distinctive habit of feeding on the leaves of cane until quite large before entering the stalk.

D. saccharalis crambidoides occurs in both corn and sugar cane in the area infested by this variety. It will be noted that the observations of the authors, limiting the variety to southern Louisiana with a small portion of Mississippi, southern Florida, and the lower Rio Grande Valley in Texas, are not at variance with Dr. Dyar's general statement, "Gulf States and lower Mississippi Valley."

The following species of Diatraea are recorded from various parts of the world:

TABLE II.—*Records of species of Diatraea.*

Species.	Distribution.	Authority.
amnemonella Dyar	Castro, Parana, Brazil	Dyar (45)
angustella Dyar	Castro, Parana, Brazil	Dyar (45)
bellifactella Dyar	Sao Paulo and Castro, Parana, Brazil	Dyar (45)
berthellus Schaus	Castro, Parana, Brazil	Dyar (45)
canella Hampson	Grenada; Trinidad; Guiana	Dyar (45)
	British Guiana	Bodkin (17)
continens Dyar	Castro, Parana, Brazil	Dyar (45)
culmicolella Zeller	Colombia	Dyar (45)
grandiosella Dyar	Guadalajara, Mexico	Dyar (45)
instructella Dyar	Popocatepetl Park, Mexico	Dyar (45)
lineolata Walker	Cuba; Trinidad; Guiana; Venezuela; Costa Rica; Mexico; southern Arizona	Dyar (45)
	British Guiana	Bodkin (17)
magnifactella Dyar	Various points in Mexico	Dyar (45)
mauriciella Walker	Mauritius	Hampson (65)
minimifacta Dyar	Trinidad	Dyar (45)
pallidostricta Dyar	Sao Paulo, Brazil	Dyar (45)
pedibarbata Dyar	St. Laurent, Maroni River, French Guiana	Dyar (45)
pedidocta Dyar	Cordoba, Mexico	Dyar (45)
saccharalis Fabricius	British Guiana	Bodkin (17)
	Australia	Jarvis (83)
saccharalis crambidoides Grote	Mexico; United States (Gulf States and lower Mississippi Valley).	Dyar (45)
saccharalis grenadensis Dyar	Grenada	Dyar (45)
saccharalis obliteratellus Zeller	Brazil; Paraguay	Dyar (45)
	Argentina	Rosenfeld and Barber (137)
saccharalis saccharalis Fabricius.	French Guiana; Cuba; Trinidad; Peru; Florida; probably Santo Domingo.	Dyar (45)
saccharalis tabernella Dyar	Canal Zone; Panama; Nicaragua	Dyar (45)
saccariphaga (*mauritella* Walker).	Ceylon; Mauritius	DeCharmoy (52)
strigipennella Dyar	Guiana; Brazil	Dyar (45)
venosata Walker (*striatalis* Snellen).	Java; Borneo	VanDeventer (166) Van der Goot (58), Hampson (65)
zeacolella Dyar	Southeastern United States	Dyar (45)
sp.	Philippines	On authority of Muir.

FOOD PLANTS.

Food plants other than sugar cane and corn are broom corn, Kafir corn, milo maize, sorghum (*Sorghum halepense*), Sudan grass (*Andropogon sorghum* var. *sudanensis*), Para grass, vetiver (*Andropogon muricatus*), and feather grass (*Lectochloa mucronata*). Bodkin (20) records rice as a food plant in British Guiana.

A large larva will almost fill the interior of a stalk of grass, but nevertheless will develop successfully.

The number of food plants, some of which grow wild about plantations, makes the species more difficult to control than if it were limited to corn and sugar cane, the larvæ being able to grow to maturity on wild grasses and the adults migrating to the corn and cane fields.

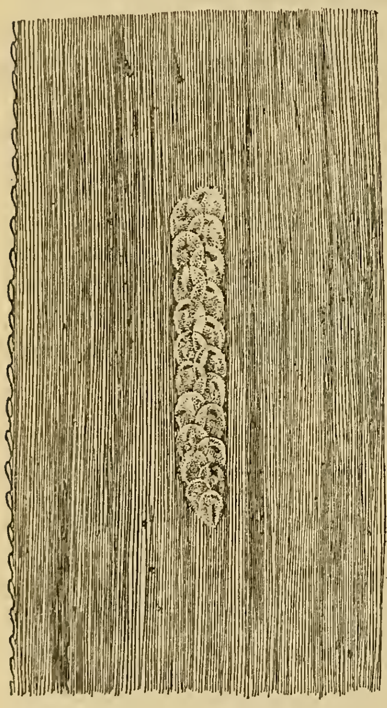


FIG. 2.—Cluster of sugar-cane moth-borer eggs nearly ready to hatch. Much enlarged.

SUMMARY OF LIFE CYCLE.

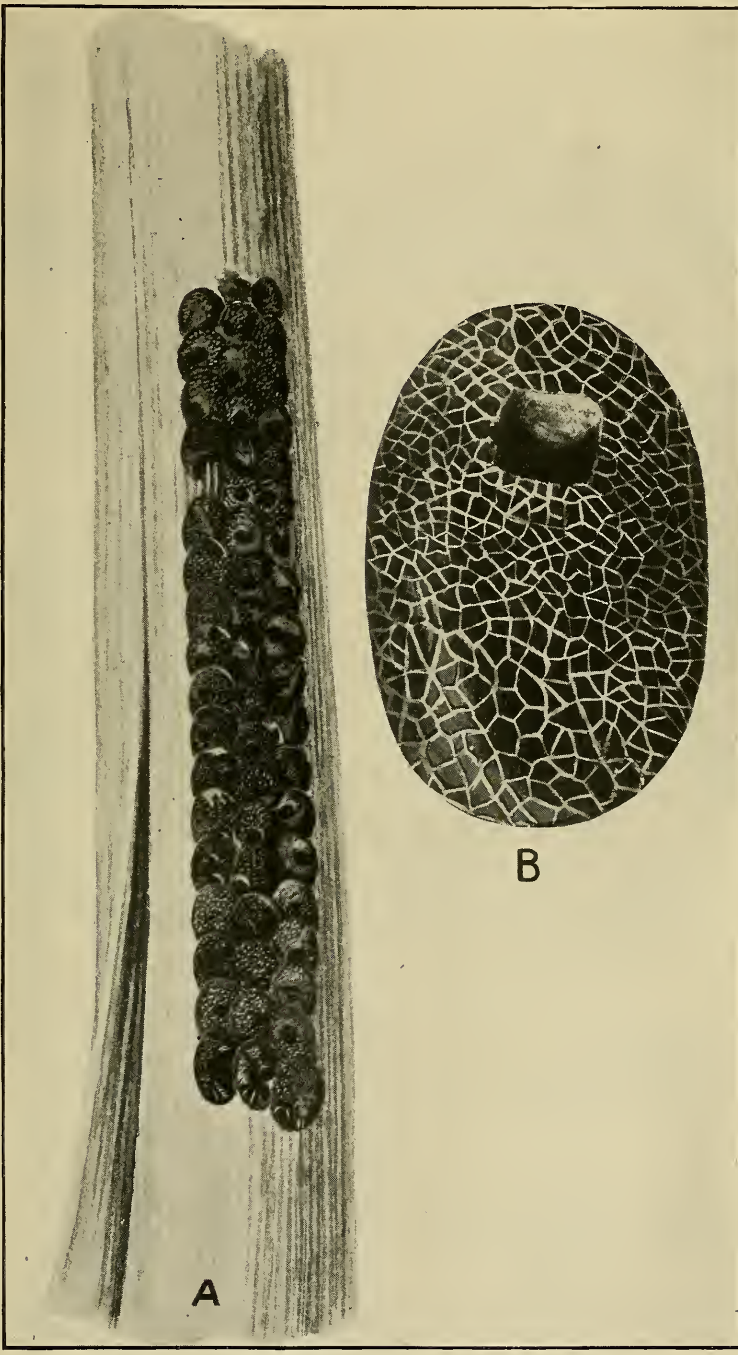
Emerging in the spring, the adult females deposit their eggs on the young plants of sugar cane, corn, etc. These eggs hatch, the young larvæ feeding here and there on the leaves for a short time and then boring into the stalks. After reaching their full development the "borers" pupate and in a few days the moths emerge. Eggs are again deposited, and the life cycle is repeated again and again until winter, during which the larval period is prolonged until spring. The overwintering larvæ then pupate, moths emerge and mate, and the cycle is repeated.

DESCRIPTIONS OF STAGES IN LIFE CYCLE.

THE EGG.

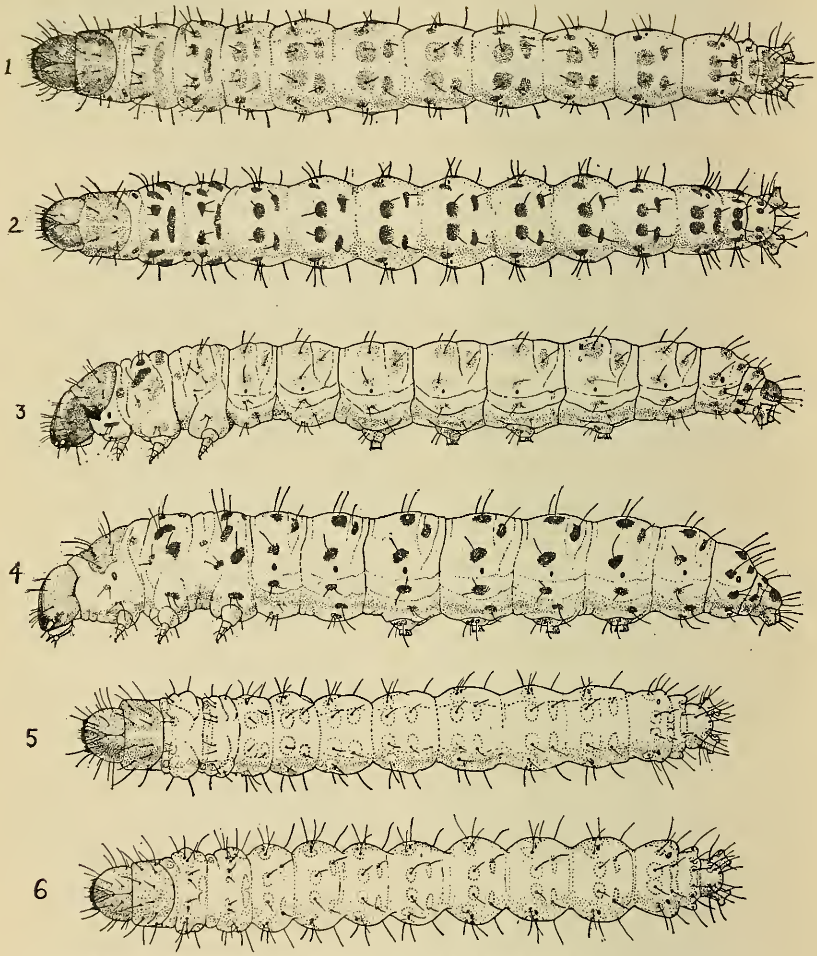
The eggs are round-oval, flattened, about 1.16 mm. long by about 0.75 mm. wide,[1] and are deposited in clusters. Beginning at the top of a cluster they overlap one another (see fig. 2), like scales on a fish. A group or cluster contains from 2 or 3 to 50 or more eggs. The clusters vary in shape as well as in size, a small one often being irregularly round, while the larger ones are much longer than wide—sometimes

[1] One millimeter is about one twenty-fifth of an inch.



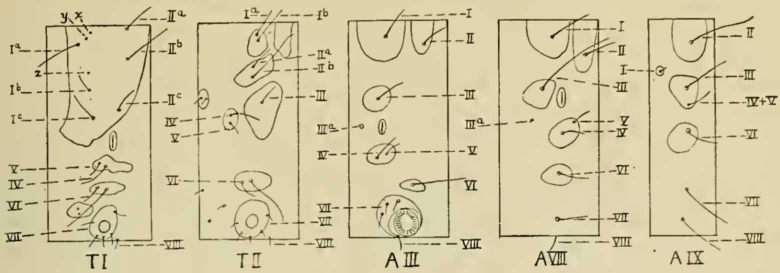
PARASITIZED EGGS OF THE SUGAR-CANE MOTH BORER.

A.—Cluster of moth-borer eggs which have been parasitized. Much enlarged. Note dark appearance and emergence holes of parasites. B.—Individual parasitized egg, showing dark appearance and emergence hole of parasite. Very greatly enlarged.



LARVAE OF THE SUGAR-CANE MOTH BORER AND THE LARGER CORN STALK-BORER.

FIG. 1.—The sugar-cane moth borer (*Diatraea saccharalis crambidoides*): Larva, summer form, dorsal view. FIG. 2.—The larger corn stalk-borer (*D. zeacolella*): Larva, summer form, dorsal view. FIG. 3.—*D. saccharalis crambidoides:* Larva, summer form, side view. FIG. 4.—*D. zeacolella:* Larva, summer form, side view. FIG. 5.—*D. saccharalis crambidoides:* Larva, winter form, dorsal view. FIG. 6.—*D. zeacolella:* Larva, winter form, dorsal view.



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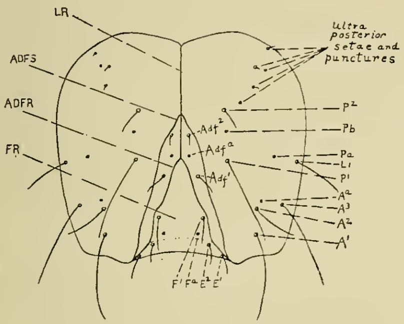

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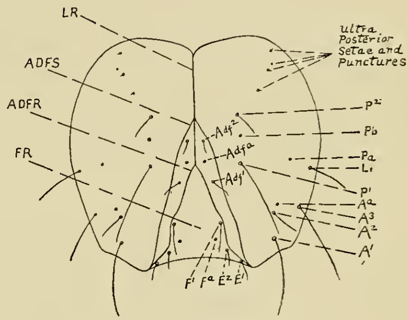

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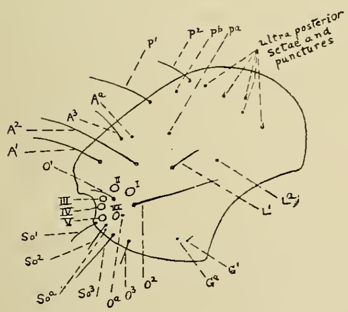

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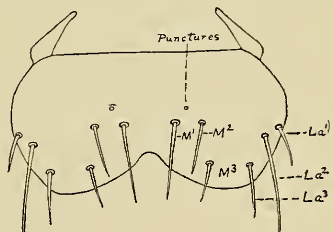

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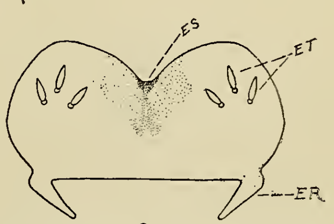

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Larval Details of the Sugar-Cane Moth Borer and the Larger Corn Stalk-Borer.

Fig. 1.—The sugar-cane moth borer (*Diatraea saccharalis crambidoides*): Larva, setal maps of body. Fig. 2.—*D. saccharalis crambidoides:* Larval head capsule, dorsal view. Fig. 3.—The larger corn stalk-borer (*D. zeacolella*): Larval head capsule, dorsal view. Fig. 4.—*D. saccharalis crambidoides:* Larval head capsule, lateral view. Fig. 5.—*D. saccharalis crambidoides:* Larval labrum. Fig. 6.—*D. saccharalis crambidoides:* Larval epipharynx.

more than 12 mm. long by 3 mm. wide. They are white at first, but later an orange hue develops. They are lightly sculptured with an irregular network of depressed lines which is visible with a microscope. This sculpturing resembles the "pebble grain" of leather. Just before hatching the black heads of the young larvæ are plainly visible through the eggshell, and the eggs assume a blackish hue.

Eggs may be deposited on either side of a leaf. The fresh ones are very difficult to find, their whiteness blending with the green of the cane or corn leaf. They are securely glued to the leaf surface and in nature are never detached before hatching. Having hatched, the empty shells become translucent white. The appearance of a cluster of eggshells from which the larvæ have emerged has been well likened to a fragment of cast snake skin.

When parasitized the eggs gradually turn jet black and remain so even with the emergence of the parasites. Because of their color, parasitized eggs are much more easily detected in the field than are the normal eggs. The holes made by the parasites in emerging are readily discernible. (Pl. II.)

THE LARVA.

The larva, which is the form of the insect most familiar to sugar planters, is about 1 inch long by one-eighth inch wide. In this form the insect commits its ravages. The head is brown and the body white with brown spots. This is the summer coloration of the larva, but in the winter it loses its spots and the body assumes a uniform dirty white.

Technical descriptions of both the winter and summer forms (full-fed larvæ) have been published elsewhere by the senior writer (75), and they have now been corrected by Mr. Carl Heinrich to conform to the latest knowledge of lepidopterous larval characters. His descriptions are given below.

General Characters.

No secondary hairs. Legs and prolegs normal. Crochets triordinal and in a complete circle. No anal fork. Prothoracic shield broad, divided. A narrow pigmented shield on mesothorax, caudad of setæ I*a* and I*b*, bearing no setæ. Spiracles elongate oval; prothoracic spiracle twice the size of those on abdominal segments 1 to 7; that on segment 8 slightly larger than prothoracic and slightly dorsad of other abdominal spiracles. (Pl. III, figs. 1, 3, 5.)

Body setæ (Pl. IV, fig. 1) moderately long; tubercles prominent, broadly chitinized; IV and V on abdominal segments 1 to 8 under the spiracle and approximate; prespiracular shield of prothorax narrow, horizontally elongate, bearing only two setæ (IV and V) situated ventro-cephalad of the spiracle, III of prothorax absent; group VI bisetose on prothorax, mesothorax, and metathorax;[1] IV and V united on abdominal segment 9 and approximate to III;

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[1] This is the Pi group of Fracker which he erroneously describes as unisetose in the Crambinae. See Fracker, S. B. The classification of lepidopterous larvæ. Illinois Biological Monographs, v. 2, No. 1. 169 p., 10 pl. 1915. (See p. 87, 91.)

III above the spiracle on abdominal segments 1 to 7, before the spiracle on abdominal segment 8; III*a* rudimentary or indistinguishable, before the spiracle on abdominal segments 1 to 7, ventro-cephalad of the spiracle on abdominal segment 8; group VII trisetose on abdominal segments 3 to 7, unisetose on abdominal segments 8 and 9; abdominal segment 9 bearing six prominent setæ in a nearly vertical line, I rudimentary or absent, when distinguishable it is latero-cephalad of II and equidistant from II and III; on the other abdominal segments II is slightly shorter than, and latero-caudad of I; setæ and punctures on prothoracic shield as follows: I*a*, *b*, *c* behind the frontal margin of the shield, distance separating I*b* and I*c* equal to that between II*a* and II*b*, II*a* dorso-caudad of I*a*, puncture *z* slightly lower than the level of II*b*, punctures *x* and *y* dorso-caudad of I*a*, distance between I*c* and II*c* slightly less than that between I*b* and I*c*.

Head capsule (Pl. IV, figs. 2, 4) spherical, slightly trapezoidal or broadly oval (nearly square) in outline viewed from above, as wide or a trifle wider than long; greatest width back of middle of head; incision of dorsal hind margin slight; distance between dorsal extremities of hind margin less than one-half the width of the head. Frons (FR) a trifle longer than wide, not quite reaching to middle of head; adfrontal ridges (ADFR) parallel from lower limit of epistomal area to point of juncture of tentorial arms, thence converging in slightly curved lines to the longitudinal ridge (LR); longitudinal ridge slightly longer than frons: adfrontal sutures (ADFS) meeting longitudinal ridge slightly behind middle of head. Projection of dorsal margin over ventral less than one-half the diameter of the head.

Ocelli six (Pl. IV, fig. 4); I larger and III smaller than the others; III and IV closer together than any of the others.

Epistoma (Pl. IV, figs. 2, 4) with the normal setæ (E^1, E^2).

Frontal punctures (Pl. IV, figs. 2, 4) (F^a) well separated; distance between punctures considerably greater than distance from puncture (F^a) to seta (F^1); distance from frontal seta (F^1) to seta Adf^1 about equal to distance separating adfrontal setæ (Adf^1 and Adf^2); Adf^2 well behind beginning of longitudinal ridge; puncture Adf^a equidistant from Adf^1 and Adf^2 and approximate to beginning of longitudinal ridge.

Epicranium (Pl. IV, figs. 2, 4) with the normal number of primary setæ and punctures and with three ultraposterior setæ and one or two ultraposterior punctures. Anterior setæ (A^1, A^2, A^3) in a right angle; A^2 equidistant from A^1 and A^3; anterior puncture posterior to A^2. Posterior setæ (P^1, P^2) and puncture (P^b) of posterior group lying parallel with longitudinal ridge; P^1 nearly on a level with beginning of longitudinal ridge; P^2 on, or nearly on a level with place of juncture of adfrontal sutures with longitudinal ridge; P^b between P^1 and P^2; P^a slightly nearer to L^1 than to any other seta, lying between L^1 and P^1. Lateral seta (L^1) remote from A^3, on a level with P^1; lateral puncture (L^a) directly posterior to the seta, remote. Ocellar setæ (O^1, O^2, O^3) well separated; O^1 equidistant from and ventrad of ocelli II and III; O^2 directly ventrad of and approximate to ocellus I; O^3 remote from and ventrad of O^2, nearer to SO^3 than to O^2; puncture O^a closely approximate to ocellus VI. Subocellar setæ (SO^1, SO^2, SO^3) triangularly placed; puncture SO^a equidistant from setæ SO^2 and SO^3. Genal puncture (G^a) anterior to seta (G^1).

Labrum (Pl. IV, fig. 5) with median incision moderately concave; setæ M^1, M^2, and M^3 triangularly placed; M^1 and M^2 nearly on a line with La^1; La^1 and La^2 closely approximate; M^3 and La^3 on a line; distance separating M^3 and La^3 about equal to that between M^2 and M^3; puncture equidistant from and slightly back of M^1 and M^2.

Epipharyngeal shield (Pl. IV, fig. 6) (ES) not sharply defined, merging in a broadly chitinized area on the central forward part of the labrum. *Epipharyngeal setæ* (ET) triangularly grouped, well behind anterior margin of epipharynx, moderately long, narrow, equidistant. *Epipharyngeal rods* (ER) indicated only by their prominent posterior projections.

Maxillulæ normal.

SPECIFIC DESCRIPTION.

Summer form (Pl. III, figs. 1, 3; Pl. IV, fig. 2): Head slightly trapezoidal in outline viewed from above; widest at the level of the posterior seta P^2; lateral and frontal margins nearly straight; posterior region broad, not constricted; ultraposterior setæ of epicranium forming a very obtuse angle, with the apex of the angle pointed to the longitudinal ridge (LR); color rich brown, varying to black at mouth parts and to orange on dorsal aspect. Prothoracic plate pale brown, tinged with black ventrally. Body white. Tubercles light brown or paler. Abdominal tubercles II oval and about twice as far apart as tubercles I. Setæ yellow to brown. Imaginary lines connecting setæ I and II of abdominal segments 3, 4, and 5 (text fig. 3, *a*) on each side, if prolonged, form angles averaging 30.2 degrees. Tubercle I on ninth abdominal segment discernible. Spiracles dark brown. Average length (10 specimens) 25.6 mm.

Winter form (Pl. III, fig. 5): Differs from the summer form in the following characters: Color yellow to rich brown, varying to black at mouth parts and to yellow on dorsal aspect. Prothoracic plate yellow. Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles dark brown, distinct and sharply contrasting with rest of body. Average length (10 specimens) 22.4 mm.

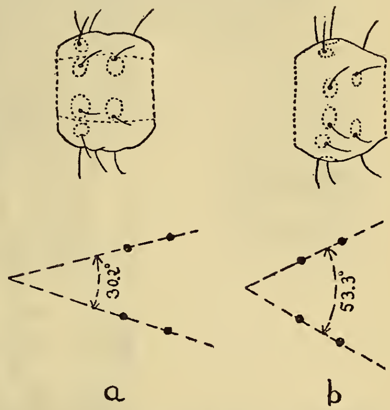


FIG. 3.—*a*, Fourth abdominal segment, dorsal view, of larva of sugar-cane moth borer (*Diatraea saccharalis crambidoides*), and diagram of angle formed by imaginary line through bases of setæ; b, same for larger corn stalk-borer (*Diatraea zeacolella*).

As the nearly related species *Diatraea zeacolella* is liable to confusion with *D. saccharalis crambidoides*, Mr. Heinrich has furnished the following descriptions:

SPECIFIC DESCRIPTION OF LARVA OF DIATRAEA ZEACOLELLA.

Summer form (Pl. III, figs. 2, 4): Head broadly oval, widest at the level of posterior puncture P^b; the lateral and frontal margins slightly but evenly rounded; posterior region slightly constricted, narrower than middle of head; ultraposterior setæ forming a very obtuse angle, with the apex of the angle pointed to the lateral margin. (Pl. IV, fig. 3.) Color yellow, varying to black at mouth parts. Prothoracic plate yellow. Body white. Tubercles dark brown, contrasting sharply with ground color of body. Abdominal tubercles II narrowed and about four times as far apart as tubercles I. Setæ yellow to brown. Imaginary lines connecting setæ I and II of abdominal segments 3, 4, and 5 (text fig. 3, *b*) on each side, if prolonged, form angles averaging 53.3 degrees. Tubercle I of ninth segment not discernible. Spiracles black. Average length (3 specimens) 25.2 mm.

Winter form (Pl. III, fig. 6): Differs from summer form in the following characters: Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles black, very distinct, and sharply contrasting with rest of body. Average length (4 specimens) 24.5 mm.

THE PUPA.

On molting for the last time the larva enters the pupa stage, the quiescent period of the insect. The pupa (fig. 4) at first is white, but soon changes to a dark brown. It is cylindrical in form and bears little resemblance to either the larva or the moth. The following technical description has been written by Mr. Carl Heinrich:

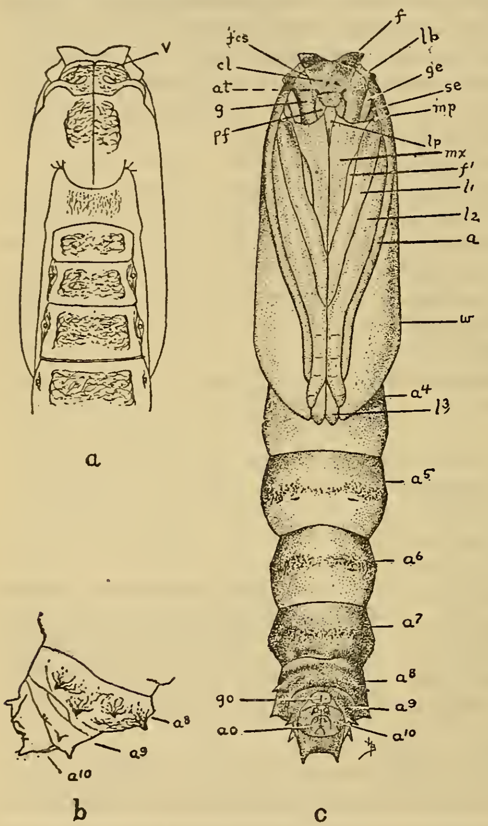


FIG. 4.—Pupa of sugar-cane moth borer: *a*, Dorsal view of anterior portions; *b*, lateral view of anal segments; *c*, ventral view of entire pupa.

GENERAL CHARACTERS.

Elongate; slender, pilifers well developed; maxillary palpi present; prothoracic and mesothoracic legs not extending cephalad between sculptured eyepiece and antenna; sculptured and glazed eyes, labrum, frontoclypeal suture, and invaginations for anterior arms of tentorium clearly indicated; front extended upward into two hornlike projections; maxillæ prominent, only half the length of the wings; wings extending to midventer of fourth abdominal segment; mesothoracic legs not extending to end of wings; metathoracic legs extending to, or a trifle beyond, tips of wings; femora of prothoracic legs clearly indicated; antennæ not reaching tips of wings; body roughened but without hooks or prominent setæ; cremaster absent; posterior end broad; tubercles of the eighth, ninth, and tenth segments developed into stout, sharp, thornlike projections; dorsum of prothorax, mesothorax and metathorax and the first nine abdominal segments rugosely scobinate; on segments 5, 6, 7, and 8 of the abdomen the scobinations form a median band encircling each segment; a deep furrow on dorsum separating ninth and tenth abdominal segments; genital opening single and slitlike in both sexes; anal opening a slit terminating in two short lines (/\); spiracles elongate, oval, moderate, easily distinguishable.

SPECIFIC DESCRIPTION.

Sixteen to 20 mm. long; yellow or yellowish brown, darkest at caudal and cephalic ends; the front, clypeus, scobinate areas, and enlarged abdominal tuber-

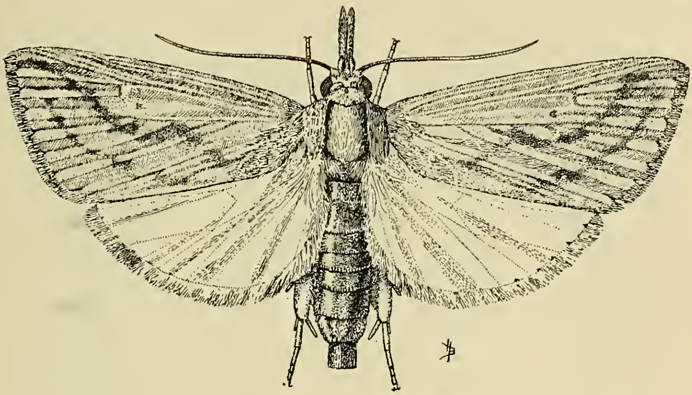


FIG. 1.—ADULT MALE.

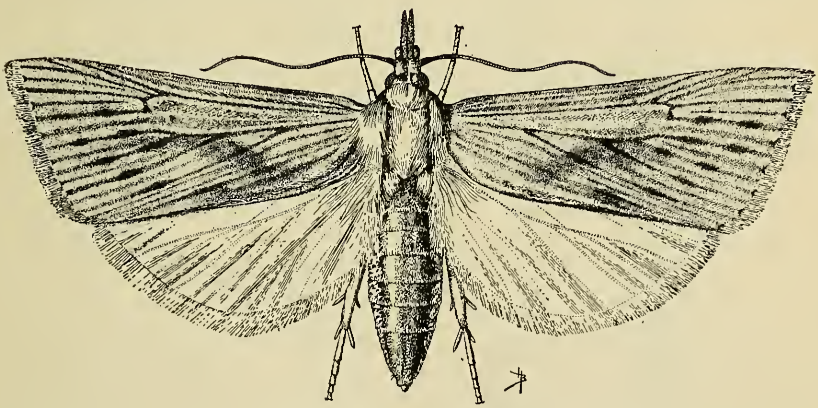
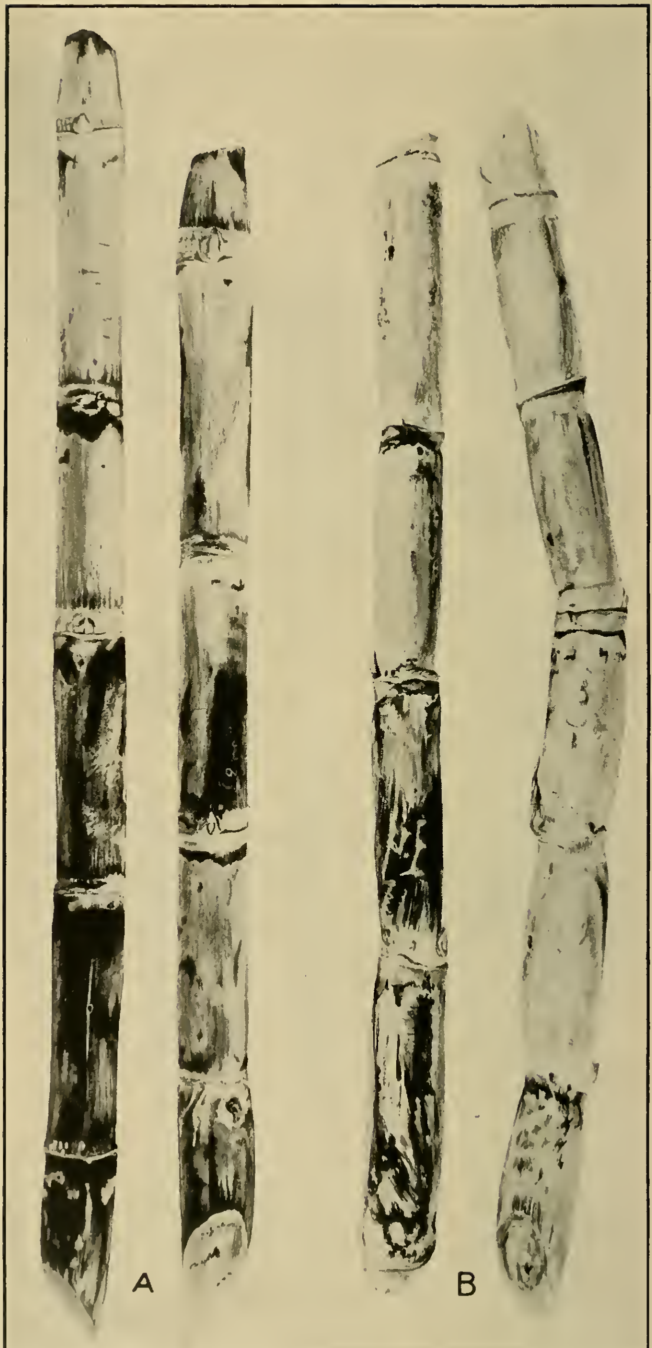


FIG. 2.—ADULT FEMALE.

THE SUGAR-CANE MOTH BORER (DIATRAEA SACCHARALIS CRAMBIDOIDES).



MATURE STALKS OF SUGAR CANE, SHOWING EMERGENCE HOLES OF MOTH BORER.

A.—Variety "Louisiana Purple." B.—Variety "D 74."

cles dark brown, in some specimens almost black; thornlike tubercles of abdominal segments 8, 9, and 10 stout and very prominent.

THE ADULT.

The adult (fig. 5; Pl. V) is a straw-colored moth, the forewings marked with darker lines. It varies in size, average specimens measuring about an inch across the wings.

FIG. 5.—The sugar-cane moth borer: Adult with wings folded.

In his article, "The American Species of Diatraea Guilding," Dr. Harrison G. Dyar (45) describes the moth as follows:

Diatraea saccharalis Fabricius.

This species is divisible into a number of well-marked geographical forms. Two of them occur in the United States. The typical *saccharalis* reaches us by the way of the West Indies and occurs in Florida. The race *crambidoides* Grote comes from Mexico and occurs in the Gulf States. . . .

Diatraea saccharalis crambidoides Grote.

Chilo crambidoides Grote, Can. Ent., XII, 15, 1880.

? Crambus lineosellus Walker, Cat. Brit. Mus., XXVII, 162, 1863.

In this form the front is roundedly prominent, slightly projecting above the eyes, but without cone or tubercle. The male has the hind wings dusky, those of the female are white. The wings are narrow, outer margin oblique, apex pointed. The male is brownish ochre in color, the female straw yellow; the two rows of brown dots are distinct in both sexes.

Range: Mexico, numerous localities, Gulf States, and lower Mississippi Valley.

Grote's *crambidoides* was described from Kansas, so there can hardly be any doubt of the application of the name. Walker's *lincosellus* was described from Honduras, whence I have no material. If the names shall be found to refer to the same form, Walker's name would have priority.

INSECTARY METHODS.

Experiments with the sugar-cane moth borer were conducted at New Orleans in a room open on all sides, wire screen taking the place of walls and allowing free access of air and moisture.

Cylindrical cages of wire screen were used for the adults. Shortly after emergence the moths were transferred to these cages, which were made by sewing together with wire the edges of pieces of ordinary window screen, these pieces being cut of such a size as to form cages about 7 inches high by 6 inches wide. Some of the horizontal strands of wire were pulled off the top and pieces of cheesecloth were stretched across so that the exposed ends of the vertical wires would extend through the cloth, thus holding it firmly in place. These cages were placed over saucers of damp sand, and the adults were supplied with young cane or corn leaves in tubes of water for oviposition. The females laid eggs readily on the leaves and also on the sand and the sides and tops of the cages.

The leaves with the masses of eggs were then transferred to specimen jars about 3½ inches wide by 12 inches high, covered with cheesecloth. On hatching, fresh food was supplied as needed, and the young larvæ were allowed to remain until after the first molt, when they were transferred to individual tubes. These were about half an inch in diameter by 7 inches long, made by breaking ordinary glass tubing. One larva, with pieces of fresh stalks of cane or other food plants, was placed in each tube, the ends of which were firmly plugged with cotton batting. A number of tubes were placed in a cigar box, the dark interior of which was somewhat similar in degree of illumination to the interior of a cane plant. The actions of the larvæ were easily observable through the glass. The tubes were very easily cleaned by forcing a wad of cotton through them from end to end with a rounded stick or plunger.

The pupæ were placed on damp sand under ordinary drinking glasses.

Temperature and humidity apparatus used in the experiments were maximum and minimum thermometers, sling psychrometer, and recording hygrothermograph.

LIFE HISTORY.

MOTH.

EMERGENCE.

The moth, or adult, emerges from the pupa, which is in a stalk of cane, corn, or other food plant, easily breaking the threads of silk spun by the larva in the tunnel, and forcing its way through the side of the stalk by breaking a thin membrane of plant tissue left by the larva for its ready emergence when it should reach the adult stage. The emergence holes are shown in Plate VI. On emerging the wings are still close to the body, and the moth rests on a convenient leaf or stalk for some time to allow them to expand.

PROTECTIVE HABITS.

An adult of the moth borer is very seldom seen, even in the fields of an infested plantation. The moths fly at night and hide among the corn or cane leaves in the daytime, moving only if disturbed. As they are small and of a light-brown color, similar to the dead leaves of cane or corn, they are not readily observed at any time.

The eggs, which are deposited on the leaves of food plants, blend with the leaves and can be found only with difficulty. The entire pupal period, with most of the larval period, is spent in the burrows formed in the stalks, and in this protected situation the borers are safe from birds and most predacious insects.

FERTILIZATION.

The mating of the moths undoubtedly occurs at night, but it has not been observed by the writers. Pairs of moths were placed in small cages made of wire screen and cheesecloth and examined during the evening and at intervals through the night, but the moths were never found in copula. Examinations were begun as early in the evening as 5.40 p. m.,[1] and were continued on one night at short intervals until 11.20 p. m., with three more observations at 2.50, 3.05, and 5.45 a. m. On another night examinations were made at 5.40, 6.40, and 9 p. m., at 11.45 p. m. to 12.30 a. m. (continuously), at 1.35 to 1.50 a. m. (continuously), and at 2.15, 3.50, and 7.15 a. m.

OVIPOSITION.

In ovipositing the female stands on a leaf with the head upward. She feels about on the leaf with the extended ovipositor and then deposits one egg, pressing it down and flattening it against the leaf with the end of her ovipositor, the egg adhering to the leaf like a tiny fish scale. Then she moves the ovipositor down or to one side,

[1]All references to clock time refer to Standard Time.

and another egg is deposited, part of it extending over a portion of the surface of the first egg. More eggs are deposited in the same way, the female gradually moving downward and backward, so that she stands over the slowly enlarging cluster. As the eggs overlap, one being deposited partly over the other, the completed cluster more than ever resembles a group of fish scales (see Pl. II).

In this action the moth is very quiet, her wings folded, antennæ back, and legs apart. She keeps the tip of her ovipositor pressed against the leaf continuously, making it difficult for an observer to ascertain the exact time any one egg is deposited. During the action she raises the body "on tiptoe," relaxing and resting against the leaf at intervals. One cluster of 6 eggs was formed in 16½ minutes, and another moth laid 34 eggs in 8 minutes. Oviposition is begun at dusk and continues throughout the night, the female flying and walking occasionally. Many clusters of different numbers of eggs may be formed in the same night. Individuals deposit eggs during one, two, three, or four nights, never longer. Oviposition is extended over several nights in cooler weather. Males in the same cage with egg-laying females are indifferent, paying no attention to their mates.

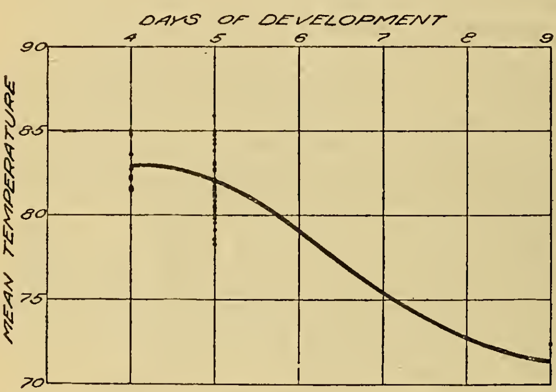


FIG. 6.—Diagram showing relationship of mean temperature to length of egg period of the sugar-cane moth borer, and indicating line of calculated means. The dots represent period means of individuals.

EGG.

DURATION OF THE EGG STAGE.

The duration of the egg stage has been found to be from 4 to 9 days, depending on the temperature, with the average for the year a trifle over 5 days. These results have been obtained from experiments in the insectary, but it is probable that greater variations between the minimum and the maximum periods occur in the field. The period of incubation has been lengthened to 12 days by placing the eggs in an ice box and it is likely that they will stand even greater retardation without being killed. The temperature in the ice box was not very low and eggs laid in the early spring or late fall would probably require as long to hatch. The average length of the egg stage at the prevailing temperatures during the different months is shown in Table III and is graphically illustrated in figure 6.

TABLE III.—*Relationship of mean temperature to the developmental period of the sugar-cane moth borer in the egg stage.*

Period.	Average mean temperature.	Number of records.	Period.	Average mean temperature.	Number of records.
Days.	° *F.*		*Days.*	° *F.*	
4	82.8	10	7	75.2	1
5	81.7	41	8	72.1	1
6	78.9	7	9	72.4	1

DEVELOPMENT.

When the eggs are first deposited they are creamy white, and in a field of cane are practically invisible against the light green of the cane leaves. They gradually darken until they are reddish brown, with the eyes of the embryo showing through as two small black spots. Later the head turns black and the eyes can not be distinguished, but the segments of the larva are discernible. The head seems to fill the whole egg cavity and gives to the egg mass a bluish-black cast. Just before hatching the larva can be seen moving within the eggshell.

HATCHING.

Hatching usually occurs in the early morning during the summer, and later in the day in cooler weather. Observations indicate that all eggs in a given cluster hatch within a few hours. The larva emerges from the egg by rupturing the upper surface, leaving it torn and ragged but without altering the arrangement or position of the egg in the cluster. The empty eggshells are papery and almost transparent, but they show a slight marking under the microscope. The cluster of eggshells adheres to the leaves for some time before being washed away by rains, and is more conspicuous at this period than it is before hatching.

While no definite record has been maintained of the percentage of eggs which hatch, it is only occasionally that one or two in a cluster from a fertilized female fail to produce larvæ. Eggs from unfertilized females do not hatch.

LARVA.

FOOD HABITS.

The larvæ are active from the time of hatching and almost immediately begin their search for food. Those from a single group of eggs congregate in the terminal buds of two or three plants in the immediate vicinity of the place where hatched and begin feeding at once. They are active and can move about and lower themselves with silken threads, but they do not seem to travel far from the place of hatching. They go well down into the "bud" or whorl of the plants, where they are protected from bright light and from possible enemies, and they suffer no harm if, as is frequently the case, the bud is full of water. Young larvæ have often been observed to crawl down into a bud which was completely submerged and feed for several hours under water without any apparent discomfort. Some of them at first eat only the epidermis from one side of the leaf, causing a yellowish blotch, but a little later they burrow through the leaves while these are still unrolled. As one leaf is thus pierced in a number of places at once a row of holes arranged horizontally will be seen when it expands. Very often the larvæ burrow into the midrib, following a zigzag course for several inches along its length. They can be seen very plainly by holding the infested leaves up to the light. The larvæ usually leave the buds or the midribs after the first molt and crawl down between the leaf sheaths and the stalk, some of them entering the stalk immediately and others feeding for a day or two, or until after the second molt. It seems that the larvæ feed longer outside the stalks on old cane than on young plants. The species of Diatraea which occurs at Phoenix, Ariz. (*D. lineolata*), has been observed to spend its entire larval and pupal periods in the midrib.

The larvæ feed either up or down from the place of entrance, but usually upward, producing a winding burrow or tunnel a foot or more up the stalk. The burrows may be branched or two or more may unite, forming a network of tunnels in a badly infested stalk. The tunnels are quite small at first, but they are enlarged as the larvæ increase in size until they are one-eighth to one-fourth inch in diameter, allowing the larvæ to move about and turn round with freedom. The frass is packed loosely behind the larvæ, seldom completely closing the passages. The burrows usually become infested with the red-rot fungus within a short time, causing the surrounding tissue to turn red, the discoloration often extending for several inches beyond the burrow (see frontispiece).

CANNIBALISM.

When larvæ are confined in cages in the insectary they are cannibalistic, especially in the smaller stages. If 200 or 300 newly hatched larvæ are left together they will be reduced to 40 or 50 within two or three days. The smaller ones are usually eaten by the larger when larvæ of different stages are confined together, though full-grown ones also are attacked. It seems that the larvæ usually are attacked when they are weak or inactive, especially just before or after molting. Three or four larvæ often are found living in the same stalk of cane, but in these cases they are more or less separated by their burrows, and it is not likely that large larvæ are eaten by others under field conditions, where they have freedom of action, whereas the habit of small larvæ of congregating in the terminal buds of the plants is very conducive to cannibalism, and many doubtless are destroyed by their companions.

GROWTH.

The rate of growth is dependent upon many external conditions, the temperature and kind of food being the most important factors,

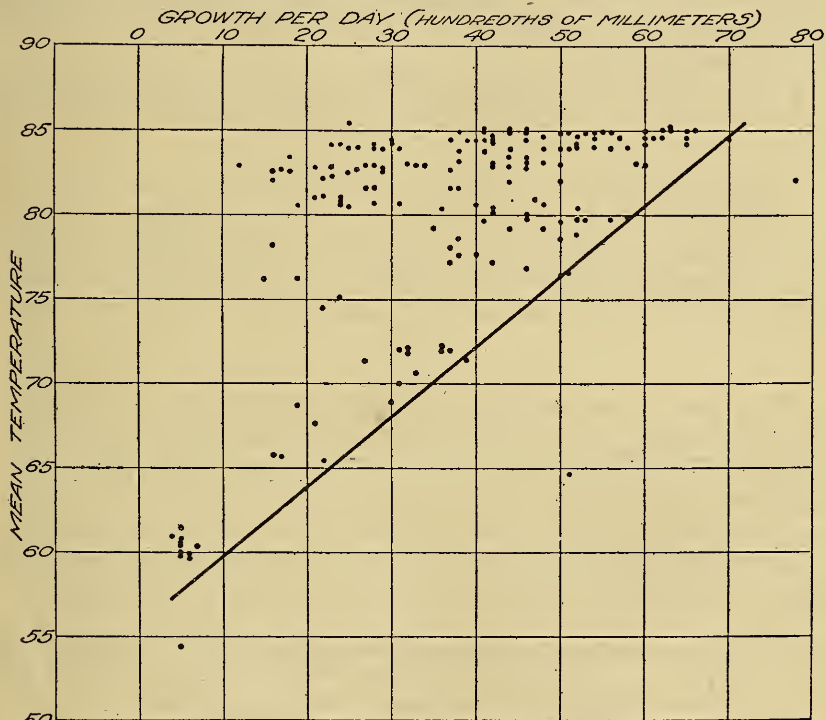


FIG. 7.—Diagram showing relationship of mean temperature to larval growth of the sugar-cane moth borer per day in hundredths of millimeters, showing line of maximum growth of normal individuals. The dots represent growth of individuals in hundredths of millimeters.

but larvæ feeding under similar conditions show a great variation in the rate of development and in the length of the larval period, as is shown by figure 7. Under favorable conditions the rate of increase in body length is about 0.75 mm. per day, but it is often much less. Larvæ are from 1.5 to 2 mm. long when hatched and from 25 to 30 mm. long when fully grown.

MOLTS.

Before molting the larvæ stop feeding for a few hours or sometimes longer and appear stiff and helpless. The skin then ruptures just back of the head, and by a series of contractions and contortions it is worked back over the body. Sometimes the head capsule is cast before the skin and at other times not until afterwards, but usually it is cast during the process of molting. The capsule is worked loose by the movements of the body and is deposited at one side.

The freshly molted larvæ are white and almost colorless, or show faintly purplish markings running the length of the body. The head is white and soft when first molted, but it turns mahogany brown in a few hours and the markings deepen. Rosenfeld and Barber (137) say that the color of the protective fluid secreted by the larvæ is determined by the color of the head and that the fluid is white in freshly molted larvæ.

The whole process of ecdysis requires about 15 minutes. The larvæ then turn, eat the discarded skin, and recommence feeding on the cane.

Ordinarily there are 5 molts, but sometimes there are only 4 in rapidly-developing larvæ. More than 5 are fairly common, as many as 14 having been observed in hibernating larvæ. When the larval period is prolonged by low temperature or other conditions, the larvæ continue molting, with little or no increase, or even a decrease, in size.

INSTARS.

The period from hatching until the first molt is called the first instar. Between the first and second molts the period is known as the second instar, and so on until the larva reaches the pupa stage. The last instar is the period between the last larval molt and the beginning of the pupal period. The number of instars has been found to be from 3 to 10, with 5 as the most common number. The number in relation to mean temperature is shown in Table IV.

TABLE IV.—*Relationship of mean temperature to the number of instars of the larva of the sugar-cane moth borer.*

Number of instars.	Average mean temperature.	Number of records.	Number of instars.	Average mean temperature.	Number of records.
	° *F.*			° *F.*	
3	74.8	14	7	78.9	18
4	80.3	65	8	69.8	11
5	81.1	102	9	68.8	8
6	82.2	50	10	65.5	4

DURATION OF LARVAL PERIOD.

The larval period is the most variable of all the stages in the life history of this insect, as it is this stage which is prolonged by hibernation or adverse conditions. The first molt takes place from 3 to 6 days after hatching, when the larvæ are from 2 to 4 mm. long. From 4 to 8 days are spent in the second instar, and during this period the larvæ attain a length of from 6 to 9 mm. The third instar is somewhat longer and requires from 6 to 9 days, the larvæ reaching 10 to 15 mm. in length, while the fourth instar lasts from 4 to 6 days, at the end of which the larvæ are 15 to 20 mm. long. From 3 to 6 days are spent in the fifth instar, and the larvæ attain a length of from 20 to 30 mm.

The usual time required for the larva stage under favorable conditions is from 25 to 30 days in summer and from 30 to 35 days in the cooler weather, but it may be much longer. Larvæ from the same mass of eggs and reared under exactly the same conditions vary a great deal, and some of them require two or three times as long as others to pupate. Under the most favorable conditions the larval period has been as short as 18 days, and has varied from this to 276 days for hibernating larvæ. The larvæ are very adaptable in this

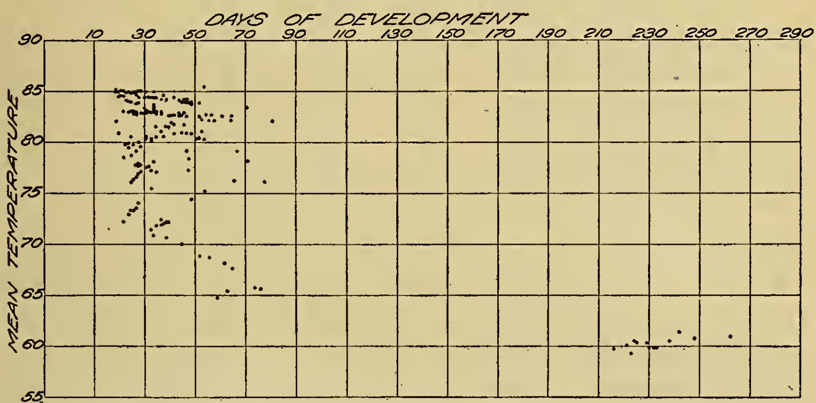


FIG. 8.—Diagram showing relationship of mean temperature to length of larval period of the sugar-cane moth borer. The dots represent period means of individuals.

way and can pass over periods of cold or food shortage without serious inconvenience. Typical life histories at different seasons of the year are shown in Table V and figure 8.

TABLE V.—*Relationship of mean temperature to developmental period in larva stage of the sugar-cane moth borer.*

Mean temperature.	Average period.	Number of records.	Mean temperature.	Average period.	Number of records.
°F.	*Days.*		*°F.*	*Days.*	
59.4	246.5	2	78.7	25	1
59.6	216	2	79.1	42	4
59.8	232.5	5	79.5	24	1
60	221	1	79.6	29	1
60.3	225	1	79.7	26	1
60.4	224	1	79.8	23.5	2
60.5	233	2	79.9	23	1
60.7	248	1	80	28	1
60.9	262	1	80.1	33	1
61.4	242	1	80.3	48.5	2
65.3	63	1	80.4	31	1
65.6	76	1	80.5	57	3
65.7	74	1	80.6	38	1
67.6	65	1	80.7	49	1
68.7	56	1	80.8	42	1
68.8	52	1	80.9	46	1

TABLE V.—*Relationship of mean temperature to developmental period in larva stage of the sugar-cane moth borer*—Continued.

Mean temperature.	Average period.	Number of records.	Mean temperature.	Average period.	Number of records.
°*F.*	*Days.*		°*F.*	*Days.*	
70	45	1	81	45	2
70.6	39	1	81.5	35.1	7
70.8	34	1	81.7	46	1
71.4	33	1	82	50	2
71.7	35	1	82.1	65	1
71.9	37	1	82.2	54.5	2
72	38	2	82.4	52	1
72.1	38.5	2	82.5	57.6	3
72.2	22	1	82.6	42.5	6
72.3	37	2	82.7	40.4	5
72.9	24	1	82.8	36	12
73.3	25.8	5	82.9	31.1	19
73.5	27	1	83	24.3	6
73.9	28	1	83.1	31	1
74	39	1	83.3	71	1
74.4	49	2	83.4	34	1
75.1	54	2	83.7	34	2
75.4	33	1	83.8	32.8	7
76.1	60.3	2	83.9	38.8	10
76.2	66	2	84	24	3
76.3	26	1	84.1	45.5	4
76.5	27	1	84.2	29.7	8
76.8	28	1	84.3	38.5	2
77.1	32	2	84.4	29.6	9
77.2	38	2	84.5	20.5	9
77.5	31	1	84.6	25.5	5
78	34	1	84.8	25.5	2
78.1	71	1	84.9	26.2	13
78.2	28	3	85	25	8
78.3	48	1	85.1	19	1
78.5	22	1	85.4	54	1

PUPAL CELLS.

When the larvæ are fully grown they construct a kind of pupal cell before pupating. The larval tunnel is cleaned, enlarged, and extended to the rind of the cane, where a small circular opening 4 to 5 mm. in diameter is made. The rind is not completely cut out, but it is eaten away from the inside until only a thin paperlike section, lightly attached at the edges, remains. This is held in place by threads of silk fastened to the inside so that the moth can easily escape, but other insects can not enter. The lower end of the cell is closed with frass and silk, and the whole cell is lightly lined with silk. In the rearing tubes in the insectary the pupal cell usually is formed on the side of the cane between it and the sides of the glass.

PREPUPA.

As the pupal cell nears completion the larva merges into the prepupa stage. No molt occurs, but the larva ceases feeding and becomes sluggish and helpless. The body contracts longitudinally, especially the thorax, while the use of the legs is lost and the insect thrashes about as do the pupæ. From 1 to 3 days are spent in the prepupa stage, but it often happens that this stage is not noticed by an observer, as it is not very distinct from the larva stage.

PUPATION.

After resting for a short time as a prepupa the pupa is disclosed by the casting of the last larval skin in the same manner as the others are cast.

PUPA.

The pupa at first is dirty white, about the same color as the hibernating larva, with faint purplish longitudinal stripes. It gradually hardens and darkens, and in an hour or two becomes mahogany brown. As the time for emergence approaches the pupa darkens more and may become almost black.

ACTIVITY.

The pupa is quite active when disturbed, being able to thrash about with its abdomen, which gives it a rolling, squirming motion. A touch or a jar will cause this action, as will also the placing of the pupa in direct sunlight in summer. Placed in the sun, a pupa squirmed about till it reached a shady place.

DURATION OF PUPAL PERIOD.

The first pupæ in the spring are formed from overwintering larvæ in April or May, and pupæ may be found from this date to December. Few larvæ pupate after the middle of November, those which have not pupated prior to this time hibernating as larvæ. Nearly 200 larvæ were collected in cane cut for the mill on December 2–4, 1915, but no pupæ were found in all the stalks cut open. Adults have emerged from pupæ in the insectary as late as December 5, but a large percentage of those which did not pupate until late and had the pupal period prolonged by cold did not emerge.

The pupal period, like that of the larva, has a wide variation, from 6 to 22 days being required for the emergence of the adult, with an average of 8½ days throughout the year. The pupæ which produced male moths required on an average 8.8 days for emergence, and those which produced females 8.4 days. Often there is a variation of 2 to 3 days among pupæ which transform on the same date. The data are presented in Table VI and figure 9.

TABLE VI.—*Relationship of mean temperature to the developmental period in the pupal stage of the sugar-cane moth borer.*

Period.	Average mean temperature.	Number of records.	Period.	Average mean temperature.	Number of records.
Days.	° *F.*		*Days.*	° *F.*	
5	77.1	3	13	71.6	1
6	82.3	27	14	79.7	7
7	81.1	153	15	73.9	5
8	81.3	92	16	77	5
9	80.9	42	17	72	1
10	76.6	19	18	69.8	1
11	76.1	12	19	84.6	3
12	74	4	22	63.7	1

DURATION OF THE LIFE CYCLE.

The length of the life cycle varies considerably with the temperature. Taking the minimum of each immature stage, the sum of 28 days is obtained, while in the same way a maximum of 293 days is secured. The sum of the periods required by most individuals in the various stages is 43.1 days, which may be regarded as an average. The maximum larval period is 262 days and only occurs in hibernating larvæ.

SEASONAL HISTORY.

SEASONAL ABUNDANCE.

NUMBER OF BROODS OR GENERATIONS.

The variation in the time required for the development of the moth borer is so great that there are no distinct broods or generations. It is found that some larvæ require three or four times as long to reach the adult stage as others hatching from eggs laid at the same time,

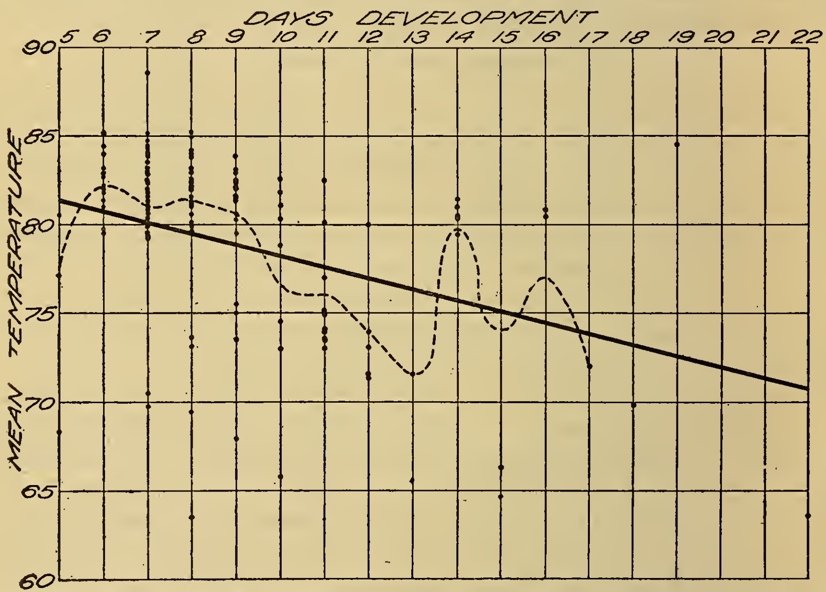


FIG. 9.—Diagram showing relationship of mean temperature to length of pupal period of the sugar-cane moth borer, showing line of calculated means (dashes) and general trend of means (solid line). The dots represent period means of individuals.

and this causes such an overlapping that the broods can not be distinguished.

The time of emergence of the moths in the spring varies from year to year, depending on the season. The earliest record is of a first-instar larva collected on cane in the field on May 5, 1914, and as the eggs require from 6 to 7 days incubation at this season the moth must have emerged during the last few days of April. The first emergence in the insectary was not until May 8, and emergence continued until May 25. Adults emerged from cane planted in boxes of soil as late as June 21. A pupa from the spring brood of borers was found in a "dead heart" on June 2, 1914. Thus adults from the hibernating larvæ and adults from the first spring generation are emerging at the same time. This overlapping continues until by midsummer the broods can not be separated.

The maximum number of generations may be computed by taking the first eggs laid by each generation and assuming that they would develop under optimum conditions, thus reaching the adult stage in the shortest time possible at the prevailing temperature:

The first eggs in the spring, laid by adults from the hibernating larvæ, would hatch by May 1 and the adults appear by June 10.

Adults of the first generation would lay eggs June 11, and these would produce adults on July 24, after 43 days.

Adults of the second generation would lay eggs on July 25, and these would produce adults on September 1, after 38 days.

Adults of the third generation would lay eggs September 2, and these would produce adults on October 8, after 36 days.

Adults of the fourth generation would lay eggs on October 9, and these would produce adults on November 18, after 40 days.

Adults of the fifth generation would lay eggs on November 18, and the larvæ would hibernate and emerge in the spring.

On the other hand, it is equally possible for two generations to span the entire year, if we take the last to emerge from hibernation and allow them the maximum time for completing their life cycle. The latest record of emergence is June 21, 1914, and a moth emerging then would not oviposit before June 22 or 23. Eggs laid in the insectary June 25, 1914, required 90 days to complete their cycle, the adults not emerging until September 23. Larvæ hatching the latter part of August or in September frequently hibernate, so it is evident that the whole year could easily be taken up by two generations.

These data are based on rearing notes in the insectary and on observations in the field. While first-instar larvæ have been found in the fields from May 5 to the middle of December, and adults have emerged in the insectary in December, it is seldom, if ever, that the maximum number of generations are produced in the field. Most of the larvæ reared in the insectary have required from one and a half to two or more times the minimum length of time necessary to complete their life cycle, and there are usually only four, seldom five, generations. If the spring is early and other conditions favorable, there may be five generations, but if the spring is late and cold, as it was in 1915, there will be only four. In the Rio Grande Valley there is no true hibernation, although the stages are prolonged somewhat in winter, and in Cuba they are more nearly the same all the year around.

POSSIBLE ANNUAL PROGENY OF ONE PAIR.

It is on account of its rapid rate of reproduction that the borer is able to inflict enormous damage. As almost all the larvæ are killed in the fall by grinding the cane, and as there is a high mortality among those which escape and hibernate, it is evident that comparatively few emerge in the spring. Yet there is always a heavy infestation by fall. The rapidity of reproduction during the warm months is the only factor which can account for this high infestation.

The record of oviposition for 56 moths at various times during the season of activity shows that each female moth deposits on an average 210 eggs. The sexes are produced in equal proportions. Allowing 200 eggs for each female and four generations a year as a conservative estimate, it is found that each pair surviving the winter is capable of producing the following numbers:

Generation.	Borers.
First	200
Second	20,000
Third	2,000,000
Fourth	200,000,000
Total	202,020,200

Of course this maximum number will never be produced, because of the numerous checks which control the insect, but something of its enormity may be realized by considering that if the offspring of one female were confined to 1 acre there would be over 10,000 borers per stalk of cane, about 20,000 stalks being the average per acre. Under average conditions about 50 per cent of the stalks are infested and about 25 to 30 per cent of the infested stalks contain borers when cut for the mill, giving from 2,500 to 3,000 borers per acre. Considering the possibilities, it is only surprising that the infestation is not much higher.

PROGRESS OF INFESTATION.

The moth borer is late in developing in the spring. The first "dead heart" at New Orleans is usually found about the 1st of May, which indicates that moths have emerged from hibernation several weeks previously. Not much injury can be found through the summer, but the numbers of borers gradually increase. When the cornstalks become dry in July and August the emerging moths undoubtedly migrate to sugar-cane fields in large numbers. The infestation increases rapidly from about this time until the cane is cut for grinding.

STATUS EXAMINATIONS.

Field examinations to determine the annual status of the moth borer and other sugar-cane insects have received considerable attention from the writers. The best and practically the only time to determine borer injury to sugar cane is during the grinding season when the cane is cut, as the infestation increases up to this time and as the examinations necessitate the removal of the leaves from the stalk—a rather undesirable proceeding when the plant has still to make considerable growth. The plan adopted has been to examine at least 100 stalks in a field, sometimes many more. The uninfested and the infested stalks in these groups have been counted, and the percentage of infestation is determined from the data thus obtained. In actual practice this procedure has been modified. The number of fields examined in one vicinity seldom has been less than four, and often many more, depending upon the amount of time at the disposal of the inspector.

The infestation by the moth borer has been rather accurately determined year by year for the six years 1912 to 1917, inclusive, but the prevalence of other insect pests, which are not so important, has been only estimated.

To facilitate the inspections a card form was devised, which is reproduced here.

Form of card for field notes.

Sugar-cane Status, 191.... State.................... Plantation..............................

Locality.................... Date.................... Parish or county........................

Group examinations.	1	2	3	4	5	Total.	Per cent.	Owner, Location of field,	
Stalks,								Year of crop,	
Clean,								Variety,	Soil,
Diatraea,								Cultivation,	
								Sugar-cane condition,	
Joints,								Stalks cut? Stalks standing?	Trash burned?
Clean,								Aphis,	Weevil,
Diatraea,								Lachnosterna,	Ligyrus,[1]
								Ants,	Pseudococcus,
Remarks:								Sugar-cane diseases,	
								Environment,	

Notes by..............

[1] *Ligyrus*= *Euctheola rugiceps* Le Conte.

AVERAGE ANNUAL INFESTATION IN LOUISIANA.

Observations have been made annually from 1912 to 1917, inclusive, on the infestation of from 6 to 13 localities in the borer-infested area of the Louisiana sugar-cane belt, with the result that the average annual infestation has been determined to be 58.2 per cent, or over half the canes infested. In 1912 the general average was 50.4 per cent, in 1913 it was 52.4 per cent, in 1914 it reached the high figure of 73.9 per cent, while in 1915 the average sank to 51.5 per cent. The average was again high in 1916, being 75.5 per cent, but in 1917 it was 48.8 per cent, the lowest during the six years. In some localities an infestation of 100 per cent is sometimes reached, or all canes infested, while in others the damage may be 30 per cent or lower.

Continuous observations have not been made in Texas, but in the lower Rio Grande Valley, to which the borer is limited at present, casual inspections usually reveal an infestation of nearly 100 per cent.

VARIATIONS IN INFESTATION.

The infestation of different fields of sugar cane in the sugar-producing region varies from a low percentage to 100 per cent, or every cane infested. Conflicting opinions are held by different planters as to the infestation of the different varieties of cane and the infestation in different years of growth. It has not been found that one common variety is more resistant to the moth borer than another, or that plant cane is more infested or less infested than first or second year stubble.[1] Another popular belief is that cane grown on sandy land is likely to be more heavily infested than cane grown on heavy soil. Examinations do not show that this is true, but the belief may have some basis, because it has been found that moths can emerge more readily from canes planted in sandy soil than from those planted in clay soil. The idea is also held that land treated with stable manure or cottonseed meal will be more heavily infested, but the data on the subject are insufficient to warrant any conclusion.

MANY LARVÆ CRUSHED IN THE MILL.

The greater number of moth borers in the larva stage in the late fall and early winter which would otherwise hibernate remain in the stalks of cane after they are cut. An examination of bored stalks at Audubon Park just before grinding yielded the information that 38 per cent of the stalks contained borers. When the stalks are ground in the mill these larvæ are crushed with the cane, leaving only such borers as may be in the stubble, seed cane, scraps of cane left about the plantations, cane tops, and Johnson grass and other grasses to start the infestation the following year.

[1] In 1918, however, 10,000 stalks of cane were examined on a group of six plantations, the examinations being well distributed and evenly divided between plant and stubble cane. It was found that the general average for plant cane on each plantation was invariably higher than for stubble, though there were wide variations among certain fields and parts of fields, both of plant and stubble cane. Examinations on a much smaller scale, made in previous years, did not indicate any difference in favor of either plant or stubble.

Because the species is so prolific, it is easily possible for a very few borers which remain alive in the spring to cause a high infestation over a whole plantation by the following grinding season.

NATURAL DISSEMINATION.

The moth borer has not been found to extend noticeably the limits of the area infested by it, as the cotton boll weevil does. The insect has never been found at Bunkie, La., though it has been observed at Melville, some 30 miles southeast, since 1914, and has probably been there for a much longer time.

ARTIFICIAL DISSEMINATION.

It is apparent that the infestation of new territory is caused principally through shipments of sugar cane, both for grinding and planting. The mature canes, if infested, contain larvæ or pupæ or both, and if left in a freight car on a railway siding, or if planted and imperfectly covered, the resulting moths can easily emerge. It is then an easy matter for the species to become established on such food plants as may be available at the time of year, and the infestation of adjacent cane fields may be expected within the next few years.

Infested seed cane was planted about 1909 above Baton Rouge on property which had previously been devoted to cotton farming and undoubtedly was not infested by the moth borer. In 1914 practically every stalk of cane was bored.

Introduction of new varieties of sugar cane should be left to experiment stations, and the cuttings should be subjected to special treatment and inspection (see "Immersion and fumigation," p. 49).

If cane is needed for planting or grinding by persons outside the infested area, great care should be taken to secure uninfested cane. Freight cars used for hauling cane may contain infested scraps which should be collected and destroyed at frequent intervals.

HIBERNATION.

STAGE OF INSECT THAT HIBERNATES.

The moth borer passes the winter in the larva stage. As fall approaches some of the larvæ go into hibernation, while others enter the pupa stage and emerge shortly as moths. There is nothing to indicate which of these two classes will hibernate and which will become moths. During the summer of 1913 some of the larvæ from eggs laid as early as August 13 went into hibernation, while others from the same mass of eggs completed their development as usual. Other larvæ from eggs laid August 18 and September 8, 22, and 27 died or hibernated, but larvæ from eggs laid September 1 and 18 completed their development and emerged in October and November.

One adult emerged in December from eggs laid as late as September 25, although the others from this mass of eggs hibernated. In general, it seems that most of the larvæ from eggs laid after the middle of September hibernate if they are not killed in the mill, but this depends somewhat on the season, as more will develop in a late fall. All instars of the larvæ hibernate. Small first and second instar larvæ have been seen as late as the middle of December crawling over the cane tops, and these would hibernate if they found suitable places. Hibernation is not what may be called complete, since the larvæ remain active on warm days and continue to feed to some extent. When infested cane is windrowed in the fall it is often badly damaged by the borers continuing their feeding throughout the winter, destroying many eyes and tunneling the stalks until they become brittle and break with handling. The well-grown larvæ continue molting at irregular intervals throughout the winter, but do not increase in size; in fact, they are even smaller and more flabby in the spring than they are in the fall. The small larvæ increase slowly in size and all hibernated larvæ are of a very uniform size in the spring.

PLACES OF HIBERNATION.

The larvæ hibernate in scraps of cane, tops of the cane plant, stalks of large grass, cane stubble, and planted and windrowed cane. Very few are to be found in stubble and grass stalks, however. No larvæ have been found in cornstalks during the winter, for these dry out and become unattractive to the moth borer long before cold weather begins. The usual place of hibernation of the closely related species *D. zeacolella*, however, is in the taproots of corn.

The favorite places of hibernation are scraps of cane left after grinding, and windrowed and planted cane. The windrow forms an ideal place for hibernation, the larvæ being well protected by the earth and the quantity of leaves covering the stalks.

EMERGENCE FROM HIBERNATION.

The hibernating larvæ pupate in the spring and emerge as moths when the cane is from a few inches to a foot or more in height. Though planted cane is covered with earth, this is often washed away by a heavy rain, exposing or partially exposing the seed cane. Moths have been found to emerge from cane under one-half inch of packed soil so that it is often possible for them to emerge from planted cane. There is of course no obstacle to their emergence from grass or cane stubble.

The times of emergence from planted cane under observation were May 7, May 21, and June 1, 1914, and the earliest emergence in the insectary was on May 8. A first-instar larva, however, was collected in the field as early as May 5, indicating that the parent moth must have emerged during the last few days of April.

SURVIVAL OF HIBERNATED LARVÆ.

Only a small proportion of the larvæ which go into hibernation survive the winter and emerge as adults. They die from time to time during the winter and those which have been in the larva stage for a long time seem to have trouble in pupating and often die in the attempt. Then, too, the mortality is higher among the pupæ from hibernated larvæ than from others, and the adults that emerge are not so vigorous.

Not more than 10 per cent of the larvæ kept under insectary conditions emerged, and as those pupating in the field often have the additional trouble of emerging through some depth of soil, it is evident that only a small percentage survives. On account of their rapid increase in numbers it requires only a few moths in the spring to produce a large number of borers during the summer and fall.

LONGEVITY OF HIBERNATED LARVÆ.

The usual larval period is greatly prolonged by cold weather or other adverse conditions, and the larvæ can survive great hardships. It is not at all uncommon for them to live for a month or two without food, and Stubbs and Morgan (152) have kept them for 75 days without food and had them pupate afterwards. Rosenfeld and Barber (137) kept a larva for 200 days without food and it pupated, while E. R. Barber records placing a larva in the photographic dark room on October 19, and finding it alive June 9, a period of 231 days, during which it did not feed on the piece of sugar cane provided. The larva stage of overwintering individuals is generally about 7 or 8 months, and during this time there are 10 or 12 molts, but in the authors' experiments some required 276 days and 14 molts to reach the pupa stage.

NATURAL CONTROL.

CLIMATIC CONTROL.

EFFECT OF RAINFALL.

Mr. George N. Wolcott, while entomologist of the Insular Experiment Station, Rio Piedras, Porto Rico, made a number of observations which tend to prove that the moth borer is adversely affected by rainfall. The following is an abstract of Mr. Wolcott's conclusions:

A large number of careful observations made in Porto Rico during the past grinding season, confirmed by the evidence from other countries, indicates that there is a constant relation between the amount of rainfall and the abundance of Diatraea. The table, which gives the percentage of infestation of cane by Diatraea in conjunction with the total annual rainfall in inches for 1914, shows that the abundance of Diatraea is in inverse proportion to the amount of rainfall. (The table mentioned shows that the infestation varies from 6 per cent, where there were 101 inches of rain, to 66 per cent, where there were only 21 inches.) . . .

It is comparatively easy to demonstrate the effect of an abundance of rainfall in lessening the numbers of Diatraea, but much more difficult satisfactorily to account for this effect. The eggs of the borer are deposited on the leaves of the cane, and when the young larvæ hatch, a considerable interval elapses while they crawl about on the cane before they enter the stalk or the midrib of the leaf. It is quite probable that this is one of the most crucial periods in its life history, and that considerable numbers of borer larvæ were killed in young cane by the more rapid growth of the central shoot of a cane plant than of the outer leaves. Also, larvæ were found which had been drowned in a mixture of water and decaying cane juices which had collected in their tunnels after rains. To avoid danger from these causes, many larvæ were found living outside the shoot, where they were exposed to the attacks of predators or parasites.

The rainfall over the sugar belt of Louisiana does not vary to any great extent, and while there are annual differences both in infestation and rainfall at various points, a careful study of the subject has failed to prove that these variations correspond as they do in Porto Rico.

Below is given the infestation by the moth borer at various places in 1916 as compared with the annual rainfall.

Infestation by the moth borer compared with annual rainfall at various places in Louisiana.

Place.	Annual rainfall. *Inches.*	Canes infested in fall. *Per cent.*
Donaldsonville	61.51	91
White Castle	50 to 60	99
Thibodeaux	50 to 60	79
Mathews	50 to 60	97
Palmetto	50 to 60	37 [1]
Franklin	58.89	53.5
New Orleans	55.37	38
Napoleonville	54.96	95
Lafayette	54.68	99
Melville	51.98	22
Abbeville	50.39	98
Morgan City	47.69	93.5

The period during which the growing cane is attacked by the borer in Louisiana is, roughly, from the month of April to the month of October, inclusive. A graphic comparison of the rainfalls during these months for the years 1912, 1913, 1914, 1915, and 1916 with the average infestations by the borer in the fall of each year is shown in figure 10. In some years the line representing infestation descends as the line representing rainfall ascends, but there were exceptions, especially in 1916, which the authors can not explain. Mr. Wolcott suggests that the small variation in the rainfall at different points

[1] Probably flooded.

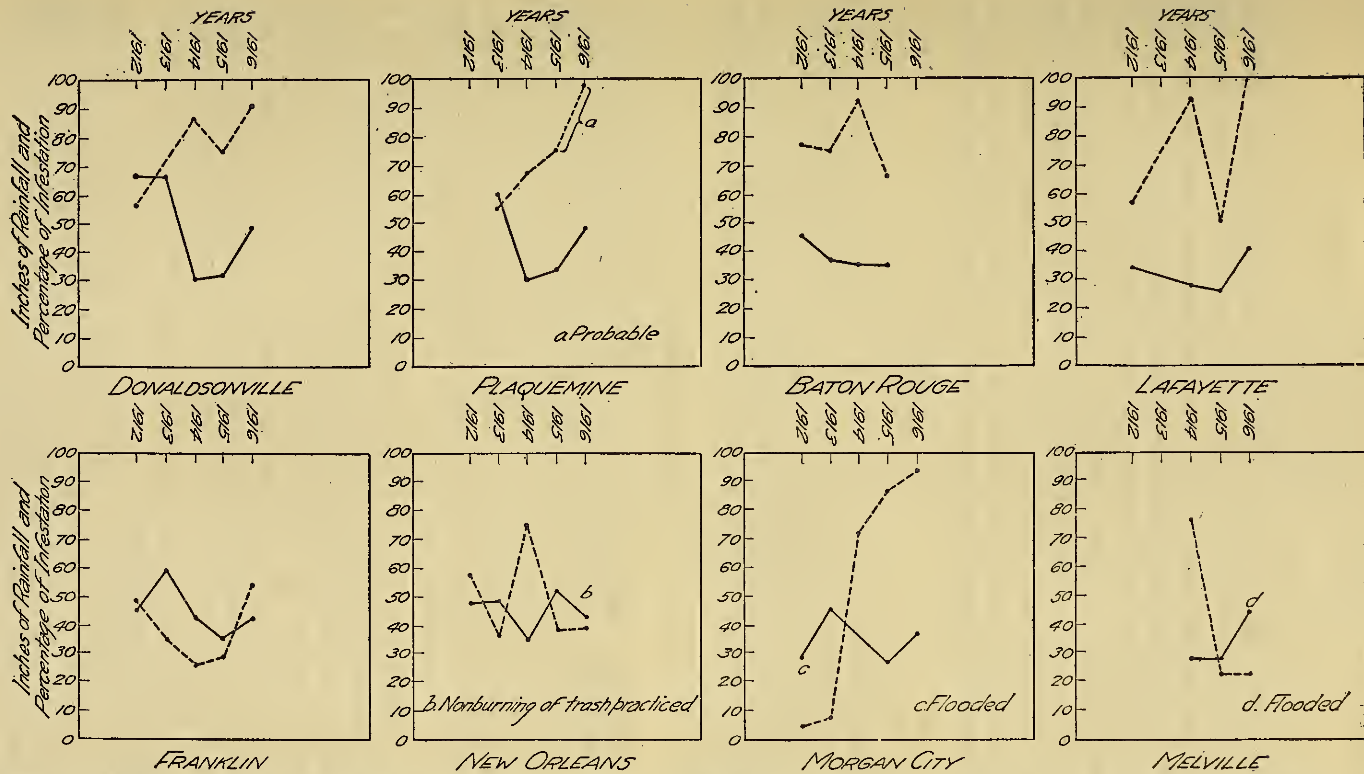


Fig. 10.—A series of graphs showing the nonrelationship of rainfall to infestation by the sugar-cane moth borer in Louisiana. Dash lines represent percentages of infestation and solid lines inches of rainfall from April to October, inclusive, the months of greatest activity.

in Louisiana as compared with Porto Rico makes it more difficult to determine its effect on the moth borer.

EFFECT OF FLOODS.

Complete flooding of cane fields for long periods seems to have a great influence on the infestation of the moth borer. For four years observations have been made on a plantation near Morgan City, which was under water for some weeks in the spring of 1912. In the fall of 1912 the infestation on this plantation was 4 per cent. In the fall of 1913 it was 6 per cent, only slightly higher than in the year of the overflow. In the fall of 1914, however, the infestation had reached 68 per cent, while in 1915 it was 87 per cent. It seems that the moth borer was much reduced in numbers by flooding, but that the numbers increased rapidly the second year after the inundation.

EFFECT OF IRRIGATION.

Though floods seem to reduce the percentage of infestation, it has not been observed that irrigation has any effect. Observations have been made on the nonirrigated plantations of Louisiana and on the irrigated properties of the lower Rio Grande Valley of Texas. No difference in the infestation which can be traced to irrigation has been noticed.

FUNGOUS DISEASES.

Although a fungous disease on the larvæ of *Diatraea saccharalis* was studied by J. R. Picard (120) at the Louisiana State University in 1903, its occurrence under natural conditions is very rare. Larvæ are sometimes attacked in the insectary, especially when kept in tin boxes, but all attempts to inoculate healthy larvæ have failed and it is probable that the fungus is only saprophytic. One such diseased larva of *D. zeacolella* sent in by Mr. A. G. Davis from Chipley, Fla., was submitted to Mr. Alden T. Speare, Mycoentomologist of the Bureau of Entomology. He reported that "the fungus seems to be very close to *Aspergillus parasiticus*, which I found to be parasitic upon the sugar-cane mealybug in Hawaii. There is no doubt that the fungus is an Aspergillus, but I would venture no specific name at present. *A. flavus* has been found to be parasitic upon sugar-cane mealybugs in Louisiana and in Porto Rico, but this is the first record to my knowledge of an Aspergillus on Diatraea, hence I can not vouch for its parasitism."

The fungus parasite *Cordyceps barberi* is recorded by Van Dine (169) from Porto Rico, and by Bodkin (17) from British Guiana on both the larva and the pupa of Diatraea. The present writers planned to experiment with this disease but they were unable to obtain cultures or diseased specimens.

PARASITES AND PREDACIOUS ENEMIES.

MOTH-BORER ENEMIES IN THE UNITED STATES.

Four parasites of species of Diatraea have been found in the United States, but three of them are extremely rare. The chalcis-fly *Trichogramma minutum* Riley is universally distributed in the sugar-cane fields of Louisiana and of the lower Rio Grande Valley of Texas, and is a very important factor in the control of the moth borer. It is a minute wasplike insect, the female of which deposits her eggs within the eggs of the borer, in the course of a few days numbers of adult parasites emerging from the moth-borer eggs.

A similar insect is the black parasite *Ufens niger* Ashmead, found near Brownsville, Tex., by the senior writer in 1912. This has not been found a second time, although Mr. George N. Wolcott made a special search for it extending over about two months in the summer of 1917. Vickery[1] records it as a common parasite of eggs of the leafhopper *Draeculacephala mollipes* Say, and it may attack Diatraea only rarely.

Parasites of the larvæ have not been found in Louisiana, but a braconid, *Microgaster* sp., has been reared from larvæ of *Diatraea zeacolella* Dyar, collected in corn by Mr. E. R. Barber at Bennettsville, S. C. A thorough search for larval parasites was afterwards made in South Carolina, Georgia, and Florida by Mr. A. G. Davis and the junior writer, but none was found.

Another braconid has been reared by Dr. A. W. Morrill, State entomologist of Arizona, from the species of Diatraea (probably *lineolata*) which occurs in that State.

Stubbs and Morgan (152) record a telephorid beetle, *Chauliognathus marginatus* Fabricius, as feeding on the larvæ. This is occasionally found in considerable numbers in sugar-cane fields in Louisiana.

During 1916 Mr. A. G. Davis found earwigs (Dermaptera) consuming larvæ of Diatraea in Florida, and in 1917 Mr. George N. Wolcott, in Texas, observed them feeding on eggs of *Diatraea saccharalis* which had previously been parasitized by *Trichogramma minutum*. It is unlikely that the work of earwigs is of any importance in control, and in feeding on parasitized eggs they would, of course, do more harm than good.

The Argentine ant (*Iridomyrmex humilis* Mayr) has been observed feeding occasionally on eggs, larvæ, and pupæ of the moth borer, but it can not be considered a factor in repression. The ants seem to attack only those eggs which have been parasitized, and while they may sometimes attack larvæ they will not ordinarily molest a

[1] Gibson, Edmund H. The sharpheaded grain leafhopper. U. S. Dept. Agr. Bul. 254. 16 p., 1 fig. 1915.

larva or a pupa unless it has been injured in some manner. The damage produced by ants in increasing the number of mealybugs, and as sugar-house and household pests, more than offsets any good which may come from their destruction of insects.

THE EGG PARASITE, TRICHOGRAMMA MINUTUM RILEY.

On account of its economic importance *Trichogramma minutum* (fig. 11) deserves more extended consideration. It is almost microscopic, and belongs to the large order of Hymenoptera, which includes the bees and wasps. Under the microscope its wings are found to be fringed with delicate hairs and to have lines of these hairs running across their surfaces.

The adults are about one-fiftieth of an inch long, with a wing expanse of a little more than the length of the body. On account of their minute size they are practically invisible in a sugar-cane field, even though they may be present in great numbers. The best way to find them is to search for a cluster of moth-borer eggs which have turned black (indicating parasitism). During the summer, and especially in the fall, an experienced person can sometimes find these clusters in considerable numbers on the leaves both of corn and of sugar cane. If the eggs are put in a small tube and observed for a few days, many light yellow Trichogramma adults may be found to emerge.

In the fields the females of these parasites search for moth-borer eggs very soon after emergence. Finding a cluster, the female inserts her own eggs into the borer eggs, and in the course of eight days or longer, depending on the season, a new generation emerges, the parasites having developed from egg to adult within the moth eggs.

The parasites are scarce at the beginning of the season, and in fact eggs destroyed by them were never found earlier than June 18 in Louisiana. As the season progresses they become more and more abundant, until at last they destroy almost every egg cluster of the moth borer.

If the parasites could be so controlled that they would start their beneficial work earlier in the year, great good would result in limiting the ravages of the moth borer. Low temperatures retard the development of insects, and in an experiment to keep them over the winter parasitized eggs were placed in a refrigerator having a uniform temperature of about 50° F. Some of the parasites emerged even at this temperature, however, and all of them died during the winter.

Under natural conditions they undoubtedly hibernate in the cane trash left on the fields of the sugar plantations, at least until the trash is burned, when many of them are probably destroyed. This practice is probably to blame for their scarcity during the following spring and early summer. To avoid the destruction of these beneficial parasites experiments have been conducted for the last five years in conserving the cane trash. The trash may be raked to the headlands or to waste land, or it may be plowed under. This subject is thoroughly discussed under the heading "Not burning cane trash," page 55.

MOTH-BORER ENEMIES IN FOREIGN COUNTRIES.

The minute egg parasite *Trichogramma minutum* occurs almost universally, having been recorded from Cuba, Porto Rico, Trinidad, British Guiana, Barbados, and elsewhere, as noted below. Another egg parasite, *Telenomus* sp., is recorded from British Guiana by Bodkin (17), who also records a braconid, a tachinid fly,[1] and a large chalcidid, *Heptasmicra curvilineata* Cameron. Two species of ants are mentioned by Bodkin as destroying the eggs. Predators in British Guiana are an elaterid and the histerid *Lioderma quadridentatum* Fabricius. From the same country Moore (104) lists *Iphiaulax medianus* Cameron, *Iphiaulax* sp., *Cremnops parvifasciatus* Cameron, and *Cremnops* sp. (all braconids), and the ichneumonid *Mesostenoideus* sp. From Trinidad Urich (164) records a sarcophagid fly[2] (probably parasitic) and a hymenopteron, *Cyanopterus* sp. The tachinid *Euzenilliopsis diatraeae* Townsend was found in Cuba by the junior author, as well as a species of Apanteles. *Tachinophyto* sp.[1] is recorded by Van Dine (170) from Porto Rico. Rosenfeld and Barber (137) record an intestinal worm, the braconid *Microdus* sp., and a dipteron[2] from Argentina. Van der Goot (58) states that in Java Diatraea is parasitized by *Phanurus beneficiens* Zehntner, *Trichogramma minutum* Riley, *T. nanum* Zehntner, *T. australicum* Girault, in the egg stage, and by a braconid and a tachinid[3] in the larva stage. He also records two species of ants attacking the pupæ and the eggs, and a small carabid feeding on the larva. De Charmoy (51) notes *Telenomus* sp., (*Ophion*) *Stauropodoctonus mauritii* Saussure, *Trichogramma australicum* Girault, *Ophion*

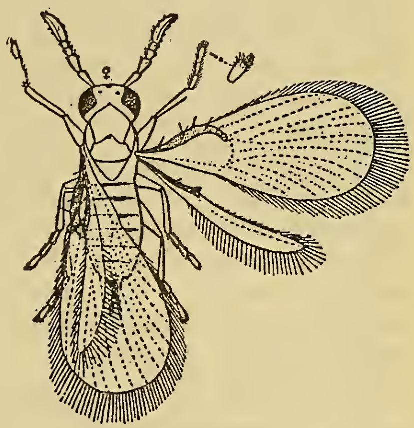


FIG. 11.—*Trichogramma minutum*, an egg parasite of the sugar-cane moth borer. Highly magnified. (Riley.)

[1] These flies are thought by Dr. C. H. T. Townsend to be probably his *Euzenilliopsis diatraeae*.

[2] According to Dr. Townsend Rosenfeld and Barber's "dipteron," and probably Urich's "sarcophagid fly," are *Oxysarcodexia peltata* Aldrich.

[3] According to Dr. Townsend this is *Diatraeophaga striatalis* Townsend.

(*Henicospilus*) *antankarus* Saussure, *Apanteles simplicis* Viereck, and a tachinid fly from Mauritius. Jarvis (83) states that *Diatraea saccharalis* "appears to be under effective natural control in Queensland," while Mr. Frederick Muir has told the writers that this is the case in the Philippine Islands also.

REPRESSION.

EXPERIMENTS AND OBSERVATIONS IN ARTIFICIAL CONTROL.

DESTRUCTION OF SCRAPS OF CANE LEFT AFTER GRINDING.

One of the chief places of hibernation of the moth borer is in scraps of cane left about the plantation. The wise manager will therefore collect such scraps as soon as possible after the grinding season and destroy them. On a plantation on which many scraps had been left about the mill and the derricks from one season to the next the infestation was practically 100 per cent over the whole plantation.

After the scraps are collected they may be disposed of by a very thorough burning with oil or some dry material. Throwing the scraps into a lake or other body of water is not to be recommended, as some of the moths may emerge from the floating stalks or from those which are washed ashore. Passing the scraps between the rollers of the mill has been recommended, but this would hardly be practicable on the ordinary plantation.

CUTTING OUT "DEAD HEARTS."

The dead plants, or "dead hearts," which follow the work of the moth borer in the spring, contain for a few weeks the larvæ which have killed them. A familiar recommendation has been to cut out these dead plants and burn them, care being taken to cut to or even below the surface of the ground so as to secure the larvæ.

The writers had an opportunity of observing this work in progress on a large scale at the State penitentiary farm at Angola, La., in the spring of 1917. The cutting of the "dead hearts" was being done very efficiently by convicts. They collected the dead plants in bags and burned them on the headlands. It was the opinion among the foremen that the "dead hearts" should be cut out of each field three times during the early growing season. One man was said to cover 4 acres per day.

The writers made a point of revisiting the penitentiary farm in the fall to ascertain the results of the work. It was found that the average infestation of the whole plantation was 31.5 per cent, which for 1917 was not extraordinarily low. Around Port Allen, La., for instance, the average infestation was 30.7 per cent, and the "dead hearts" had not been cut out at that place. Individual fields at Angola ran from 6 to 85 per cent, and at Port Allen from 9 to 94 per cent.

It is possible that the different fields at Angola did not all receive exactly the same treatment as to cutting out the "dead hearts," especially as the plantation is divided into a number of farms or sections, each of which has its separate manager. As far as the authors could ascertain, however, the treatment had been uniform over the whole plantation.

It was the opinion of several of the farm managers that cutting out the "dead hearts" would not be practicable on a plantation where free convict labor is not available.

Moore (104) records the collection of 15,285,960 larvæ and pupæ of the moth borer on 17 estates in Demerara, British Guiana, in 1912, and 13,632,655 in 1911. He then remarks:

> The effect upon the pest of all this terrific slaughter has not as yet been very marked, but will increase more and more rapidly if the destruction be kept on persistently, systematically, and relentlessly. The insect propagates at such a very rapid pace, in spite of the counter-activity of a variety of natural enemies, and in spite of whatever may be the weather conditions, when its seasons come round, that to overtake it and bring it under proper control must needs be a rather long undertaking.

POISONING YOUNG PLANTS.

By covering the young plants with an arsenical in powdered form, which was suggested by the junior author, it was hoped to present a poisoned leaf surface to the first young borers of the year. Before gnawing into the plants the newly emerged larvæ feed among the leaf whorls for a limited time. It was thought that if they could then be poisoned much damage later on could be prevented.

A small preliminary experiment gave what seemed to be promising results, and in 1916 a large plantation experiment was planned. Fields on a typical plantation were poisoned one, two, and three times, powdered arsenate of lead being used, and the applications being made at many different dates in the spring. After nearly every application, however, there was a heavy rain, and the following fall no benefit could be observed. About 2 pounds of poison per acre were applied, a special horse machine being used.

The experience gained in 1916 had proved that the machine, which was designed for cotton, was not well adapted to sugar-cane fields. In 1917 the framework was strengthened and a gasoline engine added. This gave a much more uniform distribution of the poison, and an application of 2 pounds per acre covered the plants rather thoroughly. One man and a 2-horse team with this machine could cover 35 acres per day at a total cost for labor and material of

64 cents per acre. The apparatus used in the test is illustrated in Plate VII.

A 125-acre field at Belle Alliance Plantation near Donaldsonville, La., which was naturally divided into approximately 5-acre plats by drainage ditches, was selected for the experiment. One plat was poisoned once a week during the nine weeks from April 19 to June 14 while other plats received from one to four applications of 2 pounds per acre at weekly and fortnightly intervals, beginning at different dates during the nine weeks' period. The season was rather dry and rain did not interfere with the work any more than might be expected under Louisiana conditions.

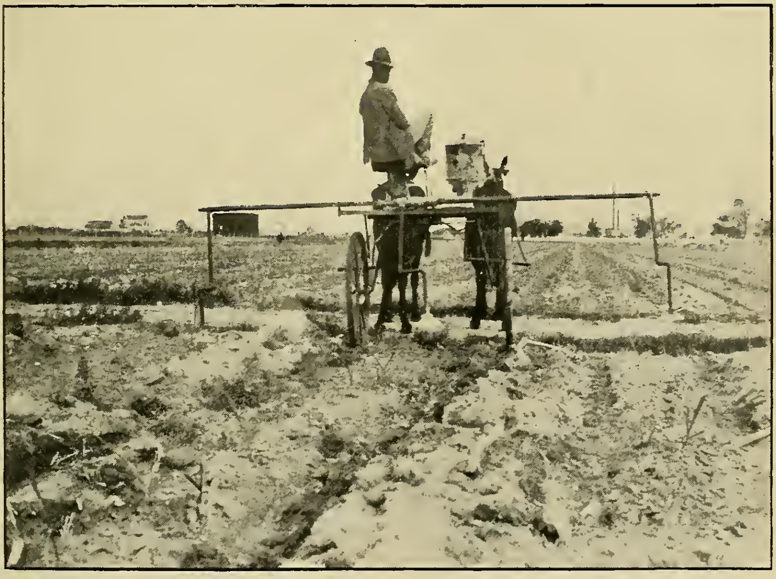
Borer eggs and "dead hearts" were observed throughout the spring and summer in the various plats, and in October, when status examinations were made, considerable variation was found in the different plats, but no relationship between the poisoning and borer infestation could be established, the treatment evidently having no effect whatever. This is probably due to the fact that the poison did not enter the central whorl or "throat" of the plants, where the young larvæ were feeding.

These experiments will indicate to the reader just how difficult is the control of the sugar-cane borer, and how inefficient are the usual methods of repression when used against it. For a long time the application of poison to sugar cane was regarded as hardly practicable, but when tried it was found to be not prohibitive as to cost or labor, although of absolutely no benefit.

REACTION OF ADULTS TO HONEY AND OTHER BAITS.

In the control of certain pests of vineyards in Europe, baits composed of fermenting molasses and other substances have been reported as successful in attracting the adults. In fact the use of these baits appears to be a well-established practice in some communities. It is also well known that collectors often make use of a mixture of stale beer or rum and brown sugar for attracting certain night-flying moths. It was thought worth while, therefore, to test the attraction of various chemicals and mixtures to borer moths.

Five modified flytraps were hung in cane and corn fields known to be infested. All the traps were baited with the same substance at a time, and were left in the fields for at least 24 hours. The following mixtures and chemical compounds were experimented with: (1) Honey; (2) honey, water, and alcohol; (3) 1 part honey dissolved in 3 parts alcohol; (4) stale beer, low-grade sugar, and alcohol; (5) stale beer and sugar; (6) oil of anise; (7) imitation strawberry sirup; (8) orange-flower sirup; (9) cedar oil; (10) solution of citric acid; (11) pyridin; (12) xylene; (13) vanilla extract; (14) oil of



POISONING YOUNG CANE PLANTS WITH POWDERED ARSENATE OF LEAD.

Poison was found to be unsuccessful in controlling the moth borer.

citronella; (15) oil of wintergreen; (16) oil of cinnamon; (17) formaldehyde solution; (18) pennyroyal; (19) fluid extract of valerian. No borer moths and very few other insects were captured.

REACTION OF ADULTS TO LIGHTS.

Attracting the adults to lights has been proposed occasionally as a means of controlling the moth borer. It seems evident, however, that lights can exercise little attraction for them. The moths avoid the sunlight and remain concealed during the day in dark places, such as between the leaves and the stalk of a sugar-cane plant. If disturbed they fly for a short distance, seeking another place of concealment. As dusk approaches, however, they become very active, but daylight finds them motionless again.

Experiments have been conducted with insect light traps, which are so constructed that insects which fly to the light will be killed by a poisonous gas and fall into a jar, from which they may be removed at the convenience of the collector. A commercial moth trap was used. Some of the traps were fitted with glasses of various colors, so that they would throw colored lights, and they were equipped with electric lights of high candlepower in addition to the kerosene lamps with which they were furnished by the manufacturers.

In September, 1914, a light trap was placed about 20 feet from a plat of young corn which was heavily infested by the moth borer. A clear light of about 60 candlepower was used. The trap was run on 16 nights between September 16 and October 13. The catch of borer moths was as follows:

Sept. 16	4 males, 1 female.
Sept. 17	13 males.
Sept. 18	18 to 20 males, 4 females.
Oct. 6	1 male.
Oct. 9	4 males.
Oct. 10	1 male.
Total males	41 to 43.
Total females	5

Borer moths were caught on only about one-third of the nights during which the trap was operated, and practically no females were secured. The few females caught apparently had deposited their eggs already.

A much more elaborate series of experiments was conducted in 1915. From May 12 to June 18 five traps were operated with kerosene-oil lamps, the traps being fitted to throw lights of the following colors: Green, yellow, clear (uncolored), red, blue. As no borer moths were caught, the traps were provided with carbon-filament incandescent electric lights, 100 watts, 120 volts, candlepower about 80. A mottled brown and yellow glass was substituted for the yellow, which had been broken. The traps were operated during July, August, and September, with the following results:

Clear glass	58 males, 2 females.
Mottled	26 males.
Green	18 males.
Blue	15 males.
Red	0
Total males	117
Total females	2

Neither of the females which were attracted to the clear light contained eggs.

The lights were arranged so that they were about 6 feet from a field of sugar cane. Observations were made to determine whether the number of canes infested by the moth borer had been lowered by the proximity of the lights, but this was not found to be the case, the infestation being as high as usual.

In 1916 more experiments were conducted, larger traps made on the same principle as those previously employed being fitted with glasses of standardized colors prepared for railroad semaphore lights. The colors used were purple, blue, red, green, brown, and clear. The electric globes were of the same type as those used in 1915. The lights were operated on 54 days from May 9 to September 4, the results being as follows:

Purple	5 males, 4 females.
Blue	5 males.
Red	0
Green	6 males.
Brown	1 male.
Clear	44 males, 2 females.
Total males	61
Total females	6

Experiments were conducted also on three nights in September with a 750-watt light taken into a cane field and operated by means of a long extension wire. This was suggested by Mr. E. R. Barber. It was observed that the moths would rise and then settle on the plants again, not continuing to fly around the light. Two males and five females were caught. There was some doubt as to whether two of the females had deposited their eggs, but the remaining three were certainly gravid.

The operation of lights was also observed on a certain Louisiana plantation on a much larger scale, gasoline torches being pulled about over the plantation. One was equipped with a gasoline engine and other apparatus which caused a powerful suction of air back of the light, the insects being sucked into an inner chamber. The other arrangement was a train drawn on the plantation railway, consisting of a locomotive pulling a tank car filled with gasoline and a flat car bearing two huge gasoline burners, which produced flames 5 or 6 feet high. The lower parts of the flames were about 10 feet above the ground. The plantation management makes a practice of operating the train on favorable nights during the summer, and the expense in 1916 was said to be about $7 per night. On the night of August 25 the senior author saw both machines in operation and caught a total of 21 borer moths, of which 5 were males and 17 were gravid females. The moths would fly near the flame, their wings would be singed, and they would drop to the ground, or, in the case of the suction or vacuum outfit, they would be drawn with great force into the inner chamber. The fact that these machines were drawn through the midst of the cane fields may account for the variance of the results with those obtained with the light traps. As the lights were moved from one spot to another, group after group of insects was observed to rise. As soon as the insects had either settled or been captured or burned at one point the machines were moved a few yards farther on and a new group would start up.

It was expected that this plantation would have a low infestation in the fall. Fields were examined near which the lights had been operated and compared with other fields which had not been reached by them. The average infestation of canes was 96.7 per cent for the treated fields, while it was 97.3 per cent for the untreated fields, a difference of less than 1 per cent. The average infestation of all the fields examined as compared with the average infestation of other plantations in that part of the State not using the lights was higher rather than lower.

Even with the high percentage of females taken at the plantation lights it is apparent that with regard to percentage of canes infested the lights have no effect on the moth borer.

FALL PLANTING.

Windrowing seed cane for spring planting is a practice which affords the borer an ideal place to spend the winter. The insects can crawl from one stalk of cane to another in the windrow, killing many eyes which otherwise would germinate. The covering of earth and leaves protects the borer as well as the cane from the severities of winter.

Planting the cane in the fall instead of in the spring does away with the necessity for a windrow altogether, and is to be preferred. This is one of the recommendations of Stubbs and Morgan (152). Fall planting is practiced as far as labor and time will permit on most Louisiana plantations.

DEEP PLANTING OF SEED CANE.

To determine whether moths would emerge from planted seed cane, infested stalks were buried under various depths of soil in boxes which had been raised from the ground and isolated from ants. The soil used the first year was ordinary black soil found at the Sugar Experiment Station, Audubon Park, New Orleans, technically called "Yazoo clay." The cane was buried at the following depths: One-half inch, 1 inch, 2 inches, 3 inches, 4 inches, 5 inches, 6 inches. The soil was packed on the cane and the depths of earth were accurately determined. By covering the boxes with wire screen the capture of any emerging insects was assured. One female moth emerged from the cane buried under one-half inch of soil, while no moths emerged from cane buried at other depths.

This experiment was repeated the following year, using river sand as well as black soil (Yazoo clay) as before. The cane was buried at depths of one-half inch, 1 inch, 2 inches, and 3 inches. Three moths emerged from cane buried under one-half inch of river sand, while no moths emerged from cane buried at other depths. No moths emerged from any of the cane buried in the black soil.

The experiment indicates that the moths can emerge from cane under one-half inch of either clay soil or sand, more moths emerging from sand. Planters would, therefore, do well to keep the planted cane well covered with soil, especially in sandy land.

PLANTING BORER-FREE SEED CANE.

The old recommendation to plant borer-free seed cane is a very good one, providing borer-free seed cane can be obtaind. Ordinarily, however, it is not possible or practicable to obtain uninfested seed cane. The tendency among planters, too, is to grind the best cane and to plant the cane that is not too greatly injured, more cane being planted to a given area if it is somewhat inferior.

Planting borer-free cane has been found to give a better stand as compared to planting infested cane, but at least on a small area the subsequent infestation can not be expected to be reduced.

To determine the effect of planting selected cane, four rows were planted with borer-free cane and the adjoining four rows were planted with infested cane. The details of the experiment are shown in Table VII.

TABLE VII.—*Results from planting borer-free seed cane.*

Kind of seed cane.	Number of eyes at planting.	Plants on June 19.	"Dead hearts" on Sept. 1.
Borer-free	2,125	1,720	8
About 38.5 per cent infested	2,004	1,343	6

The senior writer was told by a reliable plantation manager of the planting of borer-free cane at Pharr, Tex., in 1916. Although there were no borers in the seed cane, which had been procured from a section known to have none, the cane was badly infested at the grinding season.

A field of cane planted with borer-free seed somewhat resembles a field of corn in its relation to borers. Undoubtedly there are often no borers in the cornfield when the seed is planted, yet there may be a heavy infestation later. The borer moths evidently fly into the cornfield during the early spring, and they can as easily fly into a field planted with borer-free seed cane.

SHAVING CANE STUBBLE.

Some sugar planters believe that "shaving" the cane stubble in the spring reduces the subsequent infestation by the moth borer. This operation is done with a "stubble shaver," a wheeled instrument having a straight or disk blade set horizontally, which cuts away the upper inch or so of the stubble. Borers are supposed to be in the upper portion, and when it is removed they are believed to be killed.

The authors' observations show, however, that few borers can be found in the stubble. Many stubble shavings have been examined, and no borers have been found in any of them.

It is apparent, therefore, that shaving the stubble can not be regarded as an effective measure for the control of the moth borer.

IMMERSION AND FUMIGATION OF INFESTED SEED CANE.

Various entomologists who have made a special study of insects injurious to sugar cane have experimented with hydrocyanic-acid gas and various liquids in attempts to disinfect seed cane before planting. In these experiments, the seed cane has been subjected to the gas in various strengths, and has been soaked in different solutions from one minute or less to at least three hours. The consensus of opinion at present seems to be that treatment of infested stalks is neither practicable on a large scale nor efficient as a means of controlling insects on an infested plantation.

At the Sugar Experiment Station at Audubon Park, New Orleans, all cane cuttings sent out are subjected to a rigid inspection and washing in fish-oil soap solution ($\frac{1}{2}$ pound soap to 1 gallon of water). Only cane not bored by the moth borer is sent out, and this is thoroughly washed in fish-oil soap solution to kill the mealybugs (*Pseudococcus calceolariae* Maskell), and afterwards is inspected to ascertain whether any mealybugs have escaped. This procedure results in the distribution of absolutely insect-free seed cane, which is highly desirable, as otherwise the experiment station would become a center of insect distribution.

On a plantation scale, however, such a treatment, even in a modified form, would be impossible. Experiments have shown that treatment of cane cuttings on a plantation already infested with the moth borer and the mealybug has little or no effect in reducing the subsequent infestation. In the season of 1911–12, a very great effort was made to eliminate sugar-cane insects from a small property in Louisiana. The trash on the fields was burned in the fall, the entire farm was given over to plant cane, no cane was windrowed, all cane was planted in the fall after having been dipped in a fish-oil soap solution (to kill the mealybugs), nearly all the stubble was removed from the fields (according to the plans *all* the stubble was to be removed, but the work was so difficult and expensive that some of the stubble was plowed under to a depth of 4 or 5 inches), and, finally, the planting of corn was delayed in the spring of 1912 so that any possible hibernated moths of the borer would not find corn as an early food plant. While the work may not have been done in an absolutely ideal way, the experiment was much more thorough than ordinarily would have been possible.

Even the weather seemed to cooperate to render the experiment a success. The winter of 1911–12 was cold, and the cane was late in sprouting in the spring, so that it seemed that there was no cane during the winter to serve as a food plant for the borers. Small borers were found, however, as early as May 24, 1912, and by October 17 the infestation ran as high as 75 per cent, with an average of 59 per cent. As to the mealybug, practically all the plants were infested. The experiment was evidently entirely negative in its results.

More exact experiments have been conducted to indicate the actual effect of fumigation and immersion on both the insects and the sugar-cane cuttings. Table VIII gives the results of dipping cuttings in various insecticides and fungicides and also of soaking the cuttings in the solutions for one hour, the borers afterwards being cut out to ascertain whether they were yet alive. The borers were kept and fed for about two weeks after the treatments.

TABLE VIII.—*Effect on moth-borer larvæ of immersion of infested cane cuttings.*

Solution.	Exposure.	Number of larvæ.	Condition of larvæ immediately after treatment.	Penetration of solution in cane cutting.	Condition of larvæ two weeks after treatment.
Bordeaux mixture 6–4–50	Dip	9	All alive	Penetrated, and was deposited on sides of holes.	7 alive.
	1 hour.	6	do	Some of the stalks were evidently full of the solution.	All dead.
Fish-oil soap, ½ pound per gallon water.	Dip	9	do	Evidently penetrated the stalks.	8 alive.
	1 hour.	11	All alive, 4 had emerged from cane and were in the solution.	do	9 alive.

TABLE VIII.—*Effect on moth-borer larvæ of immersion of infested cane cuttings*—Continued.

Solution.	Exposure.	Number of larvæ.	Condition of larvæ immediately after treatment.	Penetration of solution in cane cutting.	Condition of larvæ two weeks after treatment.
Nicotine sulphate (40 per cent nicotine), 1 part to 500 parts water.	Dip...	10	9 alive, 1 small one dead between stalk and leaf sheath.	Probably penetrated the stalks.	4 alive.
	1 hour.	7	6 alive, 1 dead	do	All dead.
Potassium sulphid, 3 pounds per gallon water.	Dip...	7	All alive	do	4 alive.
	1 hour.	10	do	do	1 alive.
Potassium sulphid 1½ pounds per 10 gallons water.	do	10	All alive, 1 emerged from cane and in the solution.	do	4 alive.

Soaking the cuttings for 1 hour in either Bordeaux mixture or nicotine sulphate solution was found to kill all the larvæ within 2 weeks. Only 1 larva was killed immediately, however, even after an immersion of 1 hour.

Eggs, larvæ, and pupæ were next subjected to immersions of 1 minute and 1 hour in the various solutions, with results as shown in Table IX. The larvæ and pupæ had previously been removed from the stalks of cane. A cluster of eggs, 5 larvæ, or 5 pupæ were used in each exposure.

TABLE IX.—*Immersion of eggs, larvæ, and pupæ of the moth borer in various solutions.*

Solution used and stage of insect.	Exposure.	Effect within 2 days.	Effect within 10 days.
Bordeaux mixture:			
Eggs	1 hour	Did not kill	All hatched.
Larvæ	1 minute	do	2 dead out of 5.
Do	1 hour	do	None dead.
Pupæ	do	do	All emerged.
Fish-oil soap:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	1 dead out of 5.
Do	1 hour	do	2 dead out of 5.
Pupæ	do	All killed	
Nicotine sulphate (40 per cent nicotine):			
Eggs	do	None hatched	All dead.
Larvæ	1 minute	Did not kill	1 dead out of 5.
Do	1 hour	do	Do.
Pupæ	do	do	All emerged.
Potassium sulphid, 3–100:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	None dead.
Do	1 hour	do	1 dead out of 5.
Pupæ	do	do	All emerged.
Potassium sulphid, 1½–100:			
Eggs	do	do	All hatched.
Larvæ	1 minute	do	1 dead out of 5.
Do	1 hour	do	All healthy.
Pupæ	do	do	All emerged.

Untreated eggs used as a check hatched as usual. Of 5 untreated larvæ, 1 died within 10 days. All of the 5 untreated pupæ were alive at the end of 10 days.

It will be noted that pupæ immersed for one hour in fish-oil soap solution were killed, while eggs immersed for one hour in nicotine-sulphate solution did not hatch. The other solutions were ineffective. It is evident that larvæ and pupæ are more seriously affected by these two dips when in the cane stalks than when they are first taken out and then immersed. The reason for this is that a certain amount of fluid remains in the tunnels after the stalks are removed from the solution, and continues to affect the insects.

To test the effect of immersion and fumigation on the germination of cane cuttings, a number of tops and bottoms of the varieties D74 and Louisiana purple were treated in the fall and planted in the experimental fields. Table X shows the number of healthy plants on May 13 and at the grinding season. The "dip" was a very thorough immersion of the cuttings. Fish-oil soap solution apparently increased the percentage of germination, while no treatment can be regarded as injurious. Table XI shows the weight of cane in pounds of cane from the treated seed at grinding. The fish-oil soap solution appears to have increased the tonnage, though this result is doubtful.

TABLE X.—*Germination of treated seed cane.*

Treatment.	D74.		Louisiana purple.	
	Tops.	Bottoms.	Tops.	Bottoms.
Check (not treated)	[1] 18–73	20–79	44–89	36–71
Bordeaux mixture, dip (6–4–50 formula)	21–81	22–82	45–88	42–87
Bordeaux mixture, 1 hour immersion (6–4–50 formula)	26–94	28–88	46–86	29–81
Fish-oil soap, dip (one-half pound per gallon of water)	34–94	26–91	37–95	39–72
Fish-oil soap, 1 hour immersion	44–119	31–89	49–94	38–91
Check (not treated)	14–85	21–90	45–93	51–79
Tobacco extract (40 per cent nicotine as sulphate), dip (1 part to 500)	26–73	21–74	36–95	53–86
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion (1 part to 500)	39–100	31–86	55–88	48–85
Potassium sulphid, 3 pounds to 100 gallons of water, dip	d2=100	29–91	46–123	51–90
Potassium sulphid, 3 pounds to 100 gallons of water, 1 hour immersion	43–108	34–87	53–108	37–70
Potassium sulphid, 1½ pounds to 100 gallons of water, 1 hour	35–118	26–91	45–112	42–94
Hydrocyanic-acid gas, 1 hour fumigation (1 ounce, 20 cubic feet, 1–2–4 formula)	39–103	(2)	53–96	41–77

[1] Number of healthy plants on May 13 (first figure) and number of stalks at the grinding season (second figure), the seed cane having been subjected to various treatments before planting.
[2] Seed cane taken by unknown person.

TABLE XI.—*Weight of cane grown from treated seed cane.*

Treatment.	D74.		Louisiana purple.	
	Tops.	Bottoms.	Tops.	Bottoms.
Check (not treated)	[1] 160	192	230	160
Bordeaux mixture, dip	154	208	208	194
Bordeaux mixture, 1 hour immersion	188	164	214	184
Fish-oil soap, dip	224	204	226	176
Fish-oil soap, 1 hour immersion	238	220	212	214
Check (not treated)	158	238	214	188
Tobacco extract (40 per cent nicotine as sulphate), dip	142	138	168	158
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion	168	158	178	138
Potassim sulphid, 3 pounds to 100 gallons of water, dip	158	158	228	148
Potassium sulphid, 3 pounds to 100 gallons of water, 1 hour immersion	178	164	188	134
Potassium sulphid, 1½ pounds to 100 gallons of water, dip, 1 hour immersion	166	164	154	184
Hydrocyanic-acid gas, 1 hour fumigation	204	(2)	212	156

[1] Weight of cane in pounds at the grinding season is indicated by the numbers, the seed cane having been subjected to various treatments before planting.
[2] Seed cane taken by unknown person.

After the development of vacuum fumigation by Mr. E. R. Sasscer, of the Bureau of Entomology, a method which has proved highly efficient in the destruction of insects in seed and cotton bales, it was planned to fumigate cane by this system. It was a matter of general surprise that larvæ of the moth borer came out uninjured, even when subjected to a strong fumigation (6 ounces sodium cyanid, 9 ounces sulphuric acid, and 18 ounces of water to 100 cubic feet) for 1 hour, a vacuum of 25 inches being applied for 15 minutes and a normal air pressure for the succeeding 45 minutes, the combination of reduced air pressure followed by normal pressure having been found very satisfactory for most species.

DESTROYING OLD CORNSTALKS.

Some sugar planters believe that if it were not for the growing of corn on the plantations there might be little damage from the moth borer in sugar cane. They reason that the borer finds an acceptable food plant in corn before the sugar-cane plants are large, and that if corn were eliminated the emerging moths in the spring presumably would die.

Careful observations, however, show that the young cane plants are attacked as early as corn in the spring, if not before. In fact, the authors have always found borers in cane before they have observed them in corn. It is true that the moths emerge from the cornstalks in summer and fly to cane fields to deposit their eggs, the dry corn plants no longer being attractive. But if there were no corn the borers could, and many of them do, reach maturity just as easily in sugar cane.

Corn is not grown in Porto Rico, except in one isolated locality, according to Mr. George N. Wolcott, formerly entomologist of the Insular Experiment Station of Porto Rico. Yet a very high infestation is often found in sugar cane.

It is probable that the elimination of cornfields from Louisiana sugar plantations could have little or no effect on the numbers of borers, but if the cornstalks could be destroyed before the borer moths leave them a large number might be killed and the subsequent infestation reduced. Borers have not been found in the dry stalks at harvest, however, and the destruction of the stalks earlier than midsummer would be impracticable, unless a specially early-maturing variety of corn should be developed. The suggestion has been made that the cornstalks be destroyed during the winter; but the moths leave them many months before cold weather.

In this connection it is worth noting that very late corn is often ruined by the ravages of the larvæ, the moths from the earlier corn and from cane depositing their eggs on the young corn plants as well as on the cane.

BURNING CANE TRASH.

In the process of harvesting sugar cane the tops of the plants and the lateral leaves are cut off and left in the fields, forming a quantity of fibrous vegetable matter almost universally called "the trash." (Pl. VIII, fig. 1.) A common recommendation has been to burn this débris as soon as it is dry enough, which is within a few weeks after the cane has been cut. Apparently burning would tend to decrease the subsequent infestation by the moth borer, but this has not been found to be the case. Examinations of the trash indicate that comparatively few borers are usually to be found in it, most of them being in the stalks of the cane, which are carted from the field and ground in the mill, thus disposing of the greater number. On the other hand, the trash is a favorable hibernating place for numbers of dipterous and hymenopterous insects, many probably of beneficial species. The eggs of the moth borer are deposited on the leaves of the cane plants, and these are attacked by the egg parasite *Trichogramma minutum*. It is probable that these minute beneficial insects are destroyed in great numbers when the trash is burned.

Louisiana sugar-cane planters have been burning over their sugar-cane fields for many years (Pl. IX, fig. 2), and it has not been found that any reduction in the number of canes infested by the moth borer results. Trash burning and other methods of control formerly recommended were thoroughly tried out on a plantation in Louisiana some years ago (see "Immersion and fumigation of infested seed cane," p. 49), but without beneficial effect. It is the opinion of the authors, after having made many field observations, that trash burning can not be expected to diminish the number of canes infested, while it may increase the infestation by destroying beneficial insects. An objection to trash burning, admitted even by its advocates, is that ordinarily it is not thoroughly done. The dry leaves which burn readily are consumed, and in the fields are left short scraps of cane, which sometimes contain living borers, even though they have been considerably heated and charred by the fire. It is evident that trash burning, while unquestionably destroying many beneficial insects, frequently fails to destroy the few borers left in the field, because of their protected situation in scraps of cane which do not burn readily.

When it is remembered that there are four or five generations of borers per year, that about half of the adults are females, and that each female lays an average of 200 eggs, it will be realized that a very few borers passing the winter successfully are sufficient to infest a whole plantation, especially if their parasites have been destroyed.

NOT BURNING CANE TRASH.

To protect the egg parasite the senior author some years ago began experimenting in disposing of cane trash by plowing it under and by raking it to the headland.

On one plat at the Sugar Experiment Station, Audubon Park, New Orleans, the cane trash was burned in the fall of 1912 as usual, while on another plat of about the same size the trash was raked to the headlands in the spring before cultivation. Through the growing season of 1913 careful examinations were made to ascertain the infestation in the two plats, and even in the spring and early summer the results were promising. For a long time no borers were found in the unburned plat, whereas borers and "dead hearts" were found in the burned-over plat, but when the cane was cut in October, the difference was most striking. In the burned-over plat 67.5 per cent of the canes were infested by the borer, while in the unburned plat only 15.5 per cent were infested.

On a plantation in the lower Rio Grande Valley of Texas no cane trash was burned in the fall and winter of 1912–13, while on neighboring plantations under the same management the trash was burned in the fall as usual. When examinations were made in the fall of 1913 the difference in infestation was easily discernible. The average infestation of the unburned fields was 30.6 per cent, while the average infestation of the burned-over fields was 76 per cent. In 1912 the average infestation of these plantations was 50.5 per cent and in a field a few miles away it was 86 per cent.

In 1914 various experiments were conducted at Audubon Park. Trash was burned in the fall, burned in the spring, raked to the headland in the spring, and plowed under in the spring. The results of these experiments are recorded in Table XII.

TABLE XII.—*Nonburning experiments, Audubon Park, New Orleans, La., 1914.*

Kind of treatment.	Number of plants infested by borer, May 29 to June 2, 1914.	Number of plants killed by borer, Oct. 28 to Nov. 2, 1914.	Per cent of canes infested by borer, Nov. 2 to 5, 1914.
Trash left on field in winter and plowed under in spring	3	3	45.73
Trash left on field in winter and raked to headland in spring	6	12	63.31
Trash burned in fall as usual in Louisiana	5	38	83.79
Trash left on field in winter and burned as soon as possible in spring	20	6	69.44

NOTE.—The plants infested May 29 to June 2 ("dead hearts") were cut out and destroyed about June 10, so that the plants killed by October 28 to November 2 were different plants which had been infested later in the season. The dates refer to the times examinations were made.

In each of these plats there were about 20 rows of cane. Three plats were in one field, not separated in any way, while the plat on which the trash was burned in the spring was separated from the plat on which it was burned in the fall by a plantation roadway about 20 feet wide. Needless to state, these conditions were not of the best for the experiments. It would have been better if each plat had been comparatively isolated from other plats of cane so that there would have been no danger of the insects going from one plat to another.

It will be noted that the infestation at the end of May was almost negligible in all plats, but even then the least injury was in the plat where trash was plowed under in the spring. By October 28 the most conspicuous injury ("dead hearts" and large plants killed) was small, but the difference between the plats subjected to different treatments is notable. Again, the smallest number of killed plants (3) was found in the plat where trash was left on the field in the winter and plowed under in the spring. Fall burning gave as many as 38 plants killed. In the plats where the trash was raked to the headland in the spring, and where it was burned in the spring, there were 12 and 6 dead plants, respectively—several times more than where the trash was plowed under in the spring. A few days later, when the cane was cut, a careful examination was made of over 600 canes in each plat. Where the trash was burned in the fall the infestation was nearly 84 per cent, but where the trash was plowed under in the spring it was only about 46 per cent. The experiments in raking the trash to the headland, and in burning it in the spring, gave about 65 and 69 per cent, respectively. From these experiments spring burning seems to be better than fall burning, and plowing the trash under in the spring better than either. (Pl. VIII, fig. 2.) Raking the trash to the headland, for some unknown reason, did not give as good results in 1914 as it did in 1913.

Extensive experiments on plantations in Louisiana were carried on in 1915, 1916, and 1917. During 1915 and 1916 the results were negative, the infestation being about the same on fields where trash was not burned as where it was burned. The fields not burned were usually in the midst of other fields which had been burned over. Yet in 1916, when the trash was not burned except on one field at Audubon Park, the infestation was much lower there than anywhere else in the State, with the exception of two places which had been flooded. The average infestation in Louisiana for 1916 was 75.5 per cent, while the infestation at Audubon Park was only 38.3 per cent.

The reason for the difference between the results on plantations and those at Audubon Park was not understood until it was suggested in 1917 by Mr. W. G. Taggart that the relative isolation of the fields at Audubon Park had prevented the reinfestation of the unburned fields by moths flying from other plantations. This explanation seems to be correct, and the latest results tend to confirm it. The average infestation in Louisiana in 1917 was 45.8 per cent,

FIG. 1.—SUGAR-CANE FIELD AFTER THE CANE HAS BEEN CUT AND REMOVED, SHOWING HEAVY COVERING OF LEAVES OR "TRASH."

FIG. 2.—SUGAR-CANE FIELD SHOWING LEAVES OR "TRASH" PLOWED IN. THE STUBBLE WAS PLOWED UP IN THE SAME OPERATION.

CONTROL OF THE SUGAR-CANE MOTH BORER.

FIG. 1.—PARTIALLY COVERING CANE TRASH WITH TWO FURROWS TO A ROW TO HASTEN DECOMPOSITION DURING WINTER.

FIG. 2.—BURNING CANE TRASH.

CONTROL OF THE SUGAR-CANE MOTH BORER.

as compared with 20.3 per cent at Audubon Park, where the trash was not burned on any of the fields but one. Comparing this burned-over field with an average of the other stubble fields, we have an infestation of 38 per cent for the burned-over field, while the average infestation of eight unburned stubble fields was 20.2 per cent, with 36 per cent as the highest infestation on an unburned field.

The plantation results in 1917 are in accord with the theory that isolation of fields influences the results of nonburning, using the term "isolation" to mean not only a situation detached from other cane plantings, but one separated from plantations where the trash is burned. In a locality in the midst of the sugar parishes, a typical plantation (designated *A* on the diagram, fig. 12), fronting on the Mississippi River and running back to swamp land was not burned over, the trash being plowed under in the fall. This plantation was bordered on the north by a burned-over plantation (*B*), and on the south by a much smaller plantation (*BB*), a long and narrow strip of land which had also been burned over. But bordering these plantations was one on the north (*C*) in which only part of the trash had been burned, the rest having been plowed under, and one on the south (*CC*) treated in the same way. Plantation *A*, where the trash had not been burned, while bordered on each side by burned-over areas, was yet the center of a district where much of the trash had been saved. The infestation at *A* was 22.5 per cent, and at *C* and *CC* it was 56.9 per cent and 53.6 per cent, respectively. At *B*—burned over, but between *A* and *C* and undoubtedly influenced by the trash saved at those places—it was 49.5 per cent. Plantation *BB* was over-

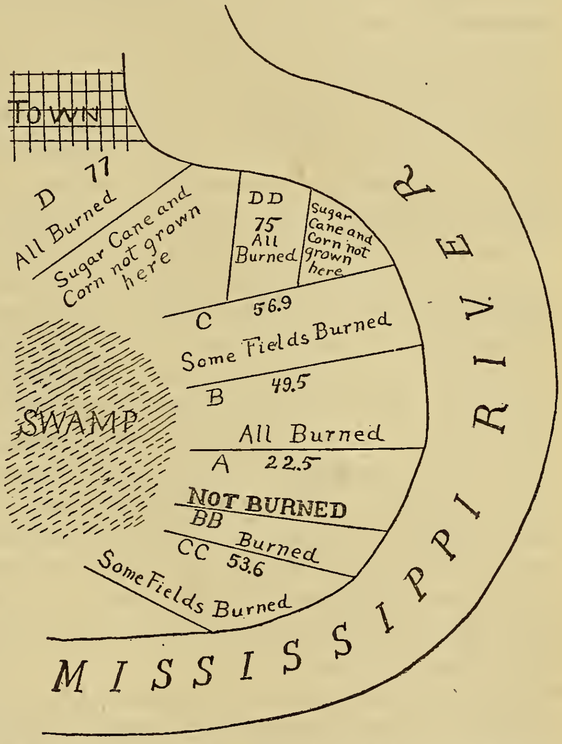


FIG. 12.—Diagram of plantations showing percentages of infestation by the sugar-cane moth borer in relation to nonburning of cane trash.

looked and the infestation is not known, but at two places in the vicinity, *D* and *DD*, both burned over, the infestation was 77 per cent and 75 per cent, respectively. The map will convey a more accurate idea of the situation than any further explanation, but the following points should be noted: At the two burned-over plantations, *D* and *DD*, farthest away from unburned fields, the infestation was high, about 75 per cent. At the two partly burned plantations, *C* and *CC*, it was medium, about 55 per cent. At the burned-over plantation *B*, bordered on each side by unburned or partly burned fields, it was also medium, 49.5 per cent. At plantation *A*, not burned and the center of a nonburning region, the infestation was the lowest of all, only 22.5 per cent.

It is evident that a plantation must be considered as a unit in determining the infestation. The former custom was to consider a field as a unit, to which there is the objection that the moths of the borer can fly readily and doubtless reinfest areas in which the parasites have gained the ascendency. Although a comparison of fields at Audubon Park is not unsatisfactory, it is true that the fields there are small, and they are not surrounded by vast stretches of cane and cornfields which are typical of the sugar parishes.

The results in 1917 indicate that nonburning will be effective on isolated areas of any size and on nonisolated areas so large that the bordering burned-over fields will have little effect on the general infestation. An illustration of nonburning on a single narrow plantation surrounded by burned-over areas was obtained in 1917. In this case nonburning was apparently of no benefit, the infestation being slightly, if any, lower than at a neighboring place. Yet the benefit to the land of plowing under the trash is considerable, and as it is only by degrees that the new practice will become established no planter should hesitate to practice nonburning because his neighbor refuses to do so.

A planter who has plowed under his trash tells us that it maintains the tilth of the soil from year to year, and the difference between the condition of the soil where trash has been plowed under and where it has been burned is immediately perceptible. Where the trash is plowed under the soil is left open and porous and is enriched by the nitrogen and other fertilizing elements of the decaying vegetation. (See Pl. IX, fig. 1.)

The work of plowing out the trash in the spring is regarded by some planters as so great that they refuse to leave it on the fields unburned. At the Sugar Experiment Station the process of caring for the trash, quoting Mr. W. T. Taggart, assistant director, is as follows:

In plowing under cane tops, especially on land where stubble is to be held for the following year, the work must be done in such a manner as not to injure the ratoons, and at the same time to hasten decomposition of the trash. The last object can be best attained by covering the tops with two furrows by the turning plow, before the green material has dried out. If the labor and teams are not available at the time, it is next best to do the plowing when the tops are as wet as can be handled without danger of damaging the mechanical condition of the soil. We find that two furrows, run as far away as possible from the old ratoon, and at the same time just deep enough to cover the trash lightly, are satisfactory. This practice practically allows all trash to be held continuously in a moist condition with free access to air, thereby hastening oxidation and decomposition. The partially decomposed vegetable matter is thoroughly and deeply buried at the usual time in early spring when cane is off-barred. Under average conditions of tonnage and winter rainfall we have found that cane trash treated according to this method will decompose sufficiently to allow cultivation of the middles without undue cost or inconvenience. However, when a heavy crop of tops has been turned under considerable difficulty may be experienced in throwing out the middles, unless the job is undertaken in two operations. First, whatever implement is assigned to this task should be run in such manner as to skim over the main layer of trash; the second furrow can then go deep enough to undermine any trash which has not been decomposed, and divide it along the side of the two rows where the following cultivation, preferably with a disc cultivator, will completely mix all this organic matter, with its humus and nitrogen, into the seed bed.

Practically the same method is used on the large plantations where the trash was left in 1916 and 1917. The labor of the first cultivation was said by one plantation manager to be about doubled and to cost about $1 more per acre than cultivation after burning. A plantation owner estimates an additional cost of $1.50 per acre. This is a very small amount to spend for the possible control of the moth borer, and is slight as compared with a maximum loss of nearly $50 per acre. Stubbs (151) calculates that for every ton of cane there are left in the trash 1.9 pounds of nitrogen, equal to the nitrogen in 27 pounds of cottonseed meal, while Mr. Taggart has told the writers that there are 556 pounds of organic matter in the trash per ton of cane. All this nitrogen and organic matter is lost in the burning of the trash, but preserved when it is buried. Considering the chemical and mechanical benefit to the soil, the possible insect control really costs nothing at all.

On the subject of nonburning, Prof. F. S. Earle (46), formerly director of the Cuba Experiment Station, writes as follows in the *Cuba Magazine:*

To the general burning of the trash in the fields after cutting there are, however, many valid objections under conditions existing in Cuba and Porto Rico. On many soils this trash is badly needed to keep up the supply of humus, but more particularly it is needed as a mulch to protect the soil from excessive drying out during our long periods of winter drought. Aside from this, the universal burning of the trash would involve an amount of summer cultivation to keep down weeds and grass that would be entirely beyond the present equipment and labor supply of most of our plantations. In other words, it is impracticable. The best we can hope in the direction of ratoon cultivation is to move the trash and cultivate alternate middles. Nor is there any reason to suppose that burning the trash would give us any real protection from the borer. Cultural conditions in Louisiana are so different from ours that the burning of the trash is practically a necessity and it is universally practiced.[1] We do not, however, find that this gives them any immunity from the borer. On the contrary, they suffer fully as much as we do. This very likely may be due to the fact that burning destroys borer parasites as well as borers. There is good reason to believe that here in the West Indies borer parasites of one kind or another are sufficiently abundant to play an important part in holding this pest in check. There is no point more urgently in need of careful investigation. Until it is fully determined it will be impossible to outline a really satisfactory campaign against the cane borer. * * * On certain fields it becomes advisable to burn the trash in order to be able by thorough cultivation to kill out pernicious grasses that would otherwise ruin the fields. When and where and how much to burn are questions that must always tax the best judgment of the administrator. If judiciously done on a small scale it is often an advantage, but if universal burning of the trash should be adopted on the advice of our scientific friends it would surely result in the financial ruin of the majority of the plantations in Cuba and of many in Porto Rico.

It is believed that Prof. Earle will be proved correct in concluding that burning or not burning trash is a matter for the mature judgment of the plantation manager, in Louisiana as well as in other countries.

EXPERIMENT WITH THE HAWAIIAN BEETLE BORER PARASITE.

The work of the entomologists of the Hawaiian Sugar Planters' Association Experiment Station is too well known to need any extended description. Suffice it to say that under the auspices of the very progressive sugar planters of Hawaii the world was searched for parasites of insects destructive to sugar cane; that they found many parasites; and that they succeeded in establishing many of them in the cane fields of Hawaii. The injury from insects has been greatly reduced and millions of dollars' worth of sugar is being saved annually.

The parasite which contributed largely to the control of the weevil borer (*Rhabdocnemis* [*Sphenophorus*] *obscurus* Boisduval) was a tachinid fly (*Ceromasia sphenophori* Villeneuve) which was brought from New Guinea. As the habits of this beetle borer in boring through the cane stalks are much the same as those of the moth borer in Louisiana, the junior author suggested that Ceromasia be tried against the moth borer. The same suggestion was made later by Dr. L. O. Howard and Dr. W. D. Hunter, of the Bureau of Entomology. Mr. Frederick Muir, of the Hawaiian Sugar Planters' Experiment Station, who had discovered the parasite and introduced it into Hawaii, was consulted, and gave his opinion that it would not attack the moth borer. He stated that he had seen the moth borer (*Diatraea* sp.) and the beetle borer working together, and that Ceromasia confined itself to its beetle host.

[1] Prof. Earle is writing of conditions in Porto Rico and Cuba, with which he is more familiar, and takes it for granted that burning the trash in Louisiana, at that time universally recommended, is a necessity.

The writers were prevented from introducing parasites known to attack the moth borer in Cuba, however, and it seemed worth while to give Ceromasia a trial. A cage isolated from ants was arranged, and in 2 feet of soil at the bottom of this cage a number of cane plants were set. Later nearly 200 stalks of cane containing tunnels of the moth borer and probably many borers were secured and put into the cage, one end of each stalk being pushed into the ground. Mr. Otto H. Swezey, entomologist of the Hawaiian Sugar Planters' Experiment Station, in September, 1917, kindly gave directions for the preparation of this cage and caused puparia of Ceromasia collected in Hawaii to be sent to the writers, who placed the adults in the cage as soon as they emerged. Eighty-seven puparia were received, from which 23 flies emerged. About half of the adults were small, but many were of normal size. Mr. Swezey's instructions were followed closely, ants were kept out of the cage, the plants were sprinkled daily, and honey and overripe fruit were provided as food for the flies.

It was found that the infestation by the moth borer in the cage was far higher than that usually found in the field. The growing plants were so heavily infested that they did not make any appreciable growth throughout the remainder of the season. Though provided with possible hosts in such numbers, the parasites did not attack the borer. Some of the cane stalks were cut open at the end of six weeks, the length of a generation of the parasite in Hawaii, but no evidence was found that they had parasitized any borers, although many live borers were found. More cane was examined later with the same negative result.

EXPERIMENT WITH A PARASITE FROM CUBA.

In 1915 the junior author went to Cuba to obtain, if possible, a tachinid parasite of the moth borer which had been reported by Mr. George N. Wolcott. It was found that while the moth borer was present, it was by no means as injurious as in Louisiana, and that the tachinid parasite *Euzenilliopsis diatraeae* Townsend evidently had much to do with its comparative control.

Living puparia of the tachinid parasite were obtained and forwarded to the senior author in New Orleans from time to time during the summer of 1915. Cages of many kinds were utilized, although none of the type which had been found satisfactory in Hawaii with tachinids was used. In every experiment the parasites died without attacking the host larvæ provided for them. Finally it was decided to release the adults in the fields at Audubon Park as soon as they emerged from the puparia. Following this action, during the next grinding season one puparium was recovered in a stalk of cane, and an adult of the species introduced from Cuba emerged from it.

No other parasites were found during the succeeding two years, and it would appear that they have died out, but the discovery of the single puparium proves that they will successfully parasitize the sugar-cane moth borer in Louisiana. It is believed by the writers that the parasite might be of much benefit in controlling the borer if it were introduced in larger numbers. If this had been possible, much might have been accomplished, but conditions in 1916 and 1917 prevented further experimental work.[1]

If the introduction of beneficial parasites can be undertaken later, it would seem advisable to station two men in Cuba to collect the parasites and one in Louisiana to receive them and ultimately to release them on the plantations. In 1915 investigations were conducted from February to September, but it appears that the most favorable season is from April to September, inclusive.

RECOMMENDATIONS.

1. Scraps of cane left about the factories and derricks after the grinding season should be destroyed by burning or otherwise. Cars in which cane is shipped, especially if they go into noninfested territory, should be kept free of such scraps.

2. Seed cane should be planted in the fall, if possible, and kept as deeply covered as practicable. Extraordinarily deep planting is not advocated, but as borer moths fail to emerge from cane under more than one-half inch of compact soil care should be taken to keep the seed cane well covered to that depth as a minimum. A heavy rain will sometimes wash the earth from the seed cane from one end of a row to the other, and in this case it is important to cover the cane again as soon as possible, especially in the spring, when the moths are emerging.

3. Cane for shipment to points beyond the infested area should be selected so as to obtain it sound and free of borers, or if this is impossible it should be soaked, previous to shipment, for at least an hour in Bordeaux mixture[2] or a solution of nicotine sulphate.[3]

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[1] Since the manuscript for this bulletin was submitted a number of sugar planters in Louisiana have agreed to contribute a small amount each to enable work in Cuba to be done. This action made it possible for the senior author to spend some time in Cuba in 1918. He collected and sent to New Orleans about 650 puparia of the tachinid *Euzenilliopsis diatraeae,* which were received and cared for by Messrs. E. R. Barber and W. G. Taggart. Several generations were reared during 1918, and it seems that the parasites will become established if they can stand the Louisiana winter.

The junior author, who was in Cuba in 1915, is no longer connected with the investigation, having accepted a position under the Federal Horticultural Board.

[2] The formula for Bordeaux mixture is as follows:

Sulphate of copper	pounds	6
Quicklime	do	4
Water	gallons	50

Dissolve the sulphate of copper in 1 gallon of hot water and slake the lime in another vessel with an equal quantity; reduce the latter to a creamy milk of lime and add slowly to the copper solution, stirring constantly. Finally, add water to make up the 50 gallons.

[3] One part nicotine sulphate (40 per cent nicotine) to 500 parts water.

4. The "trash," leaves, or "shucks" left on the fields after cutting should not be burned, but should be lightly covered with earth in the fall and plowed out in the spring. This practice has never been found to increase the borer infestation, and it has often diminished it. The soil is fertilized by the buried trash and its mechanical condition is greatly improved.

5. Cutting out "dead hearts" or dead plants and destroying them is theoretically sound, and with an abundance of cheap labor it might be recommended.

6. The introduction of parasites of the moth borer from Cuba and other tropical countries is recommended.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 747

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. | January 9, 1919

THE ECONOMICAL USE OF FUEL IN MILK PLANTS AND CREAMERIES.

By John T. Bowen, *Technologist, Dairy Division.*

CONTENTS.

IMPORTANCE OF REDUCING WASTE.

The rapid increase in the cost of fuel and the probability that the present high price will continue makes the efficient use of fuel in commercial plants a question of the greatest importance. In the production of steam power, even in the most up-to-date plants, fuel is by far the largest item of expense. The boiler room, consequently, is the most important part of the plant so far as the cost of production of power is concerned and therefore should receive careful attention.

It should be the aim of every person in charge of a power plant to obtain the greatest efficiency possible, which means the elimination of waste—waste of fuel and material, waste of energy, and waste of time and effort. In order to determine the source and the amount of loss it is necessary to keep records and make tests, and then one must devise means to eliminate the losses or reduce them to a minimum. After determining the total of the various losses the question is whether or not it will pay to correct them. The limit to the capital and labor that should be expended in making changes and repairs is the point where the interest on the money invested in material, labor, repairs, and depreciation balances the saving in operation expense. Beyond that point it is commercially not good policy to go.

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COMPARISON OF FUEL CONSUMPTION IN DIFFERENT CREAMERIES.

Although several hundred creameries were reporting regularly to the Dairy Division, it was considered advisable to make a personal inspection of many of them to observe the condition of the machinery and the method of operation and also, so far as possible, to verify the reports submitted. Visits were made, therefore, to 360 creameries and special reports were made on the quantity of butter made, the kind and amount of fuel, the size and type of boiler and its condition and method of firing, the size and condition of the engine, the condition of the piping as well as of all the apparatus using steam, and the operation of the plant in general.[1]

Only 206 of the plants inspected used steam exclusively for both power and heating. Some used combinations of steam and electricity or of steam and internal-combustion engines, while a considerable number were operating mechanical refrigerating equipment. Many of the creameries also carried on various side lines which necessitated the use of power and fuel, and it was found impossible to determine how much was used for buttermaking and how much for other purposes. Consequently only the 206 plants which used steam exclusively for both power and heating are considered.

The creameries visited represent all sizes from the smallest to the largest and in order to compare the fuel consumed for the different-sized plants they were grouped as indicated in Table 1.

Before deciding, however, to use only those creameries covered by special reports in averaging the fuel consumption of different-sized plants, the items of the fuel consumption of a large number of other creameries reporting regularly were tabulated and studied. As the averages thus obtained were very close to those shown in the special reports, it was decided to use only the latter as representative of the creameries throughout the United States.

Table 1 shows a comparison of the fuel consumed per 1,000 pounds of butter made for different-sized creameries.

TABLE 1.—*Comparison of fuel used per 1,000 pounds of butter made in creameries grouped according to size.*

Quantity of butter made annually.	Creameries reporting.	Average quantity of coal used.	Coal consumed per 1,000 pounds of butter made.
	Number.	*Tons.*	*Pounds.*
45,000 to 100,000 pounds	39	55	1,540
100,000 to 200,000 pounds	82	81	1,120
200,000 to 300,000 pounds	48	100	800
300,000 to 400,000 pounds	19	123	740
400,000 to 1,000,000 pounds	18	145	520

[1] The creameries were visited and the data collected by O. A. Storvick and the tabulations were made by T. R. Pirtle, both of the Dairy Division.

The results shown in Table 1 have been plotted in the form of curves in figure 1. Curve No. 1 represents the average number of pounds of coal consumed per 1,000 pounds of butter made in 206 plants whose outputs vary from 45,000 to 1,000,000 pounds of butter. Curve No. 2 represents the average of the number of pounds of coal of 72 of the best equipped and managed plants, and curve No. 3 the average of 37 of the poorest equipped and managed plants. These curves are plotted from the average fuel consumption of the total number of plants.

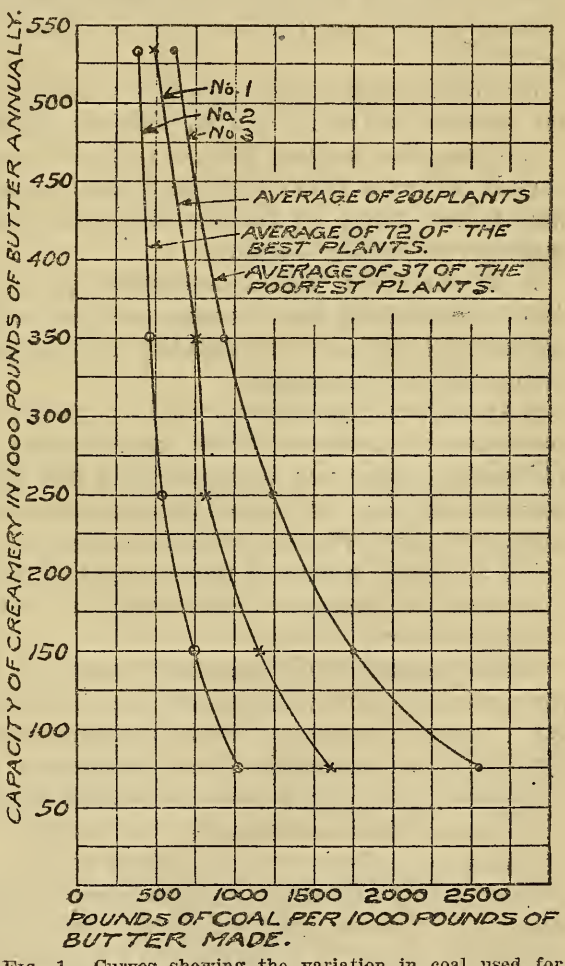

Fig. 1.—Curves showing the variation in coal used for 1,000 pounds of butter made in steam-driven plants of different sizes—(nonpasteurizing plants).

Attention is called to the fact that in curves 1 and 2 very little difference is shown between the groups of creameries making 250,000 pounds and those making 350,000 pounds of butter annually. Curve 2, representing the best practice, is practically vertical between 250,000 and 350,000 pounds of butter made, showing that between those limits the fuel consumed in the better plants is practically the same per 1,000 pounds of butter made. Curve 1, which shows the average full consumption of all the creameries, gives only a slight increase in the quantity of fuel between creameries of those sizes. The poorer equipped and managed plants, as illustrated in curve 3, however, show a decided increase in fuel used per 1,000 pounds of butter made in the plants making between 250,000 and 350,000 pounds, the increase averaging about 300 pounds of coal per 1,000 pounds of butter. In other words, the average of all plants, both good and bad, between these limits shows a variation of about 87 pounds of coal per 1,000 pounds of butter, while the poorer plants show a variation of about 261 pounds. The better plants, however, show practically no variation in the fuel used per 1,000 pounds between plants of that size.

The same condition appears in similar curves plotted from data obtained on fuel consumption in other years; hence there must be a definite reason for the variation in fuel cost in the creameries mentioned.

A careful study of the reports was made to determine, if possible, the reasons for the differences, with the following conclusions:

1. When the annual output was between 250,000 and 350,000 pounds of butter the size of the boiler and engine was increased, as well as the length of time of firing the boiler, compared with a creamery of smaller output.

2. At about the annual production shown above, the size of the creamery building was increased and the ratio of the coal required to heat the building to the quantity used for making butter is greater than in the smaller plants.

3. Often when the capacity of the creamery had reached an annual production of between 250,000 and 350,000 pounds of butter an additional helper was employed and the firing of the boiler was intrusted to him. It is probable, however, that he was not so economical in the use of fuel as the buttermaker.

4. Frequently when the annual capacity reaches 250,000 pounds it is necessary to make two churnings daily, thus increasing the time of using power.

While probably there are other reasons why the fuel consumption per 1,000 pounds of butter made does not decrease in proportion to the increase in the capacity of the plant, those mentioned are sufficient to account for much of the discrepancy.

The curves of figure 2 show the average sizes of engines and boilers for plants of different capacity, and of figure 3 the average number of hours the boilers are fired. That portion of the curves between 250,000 and 350,000 pounds of butter made annually should be noted especially. Between these points the average time of firing the boiler is increased from 7.3 to 8.5 hours, or 1.2 hours daily. There is practically no difference in the size of the boiler or the engine, or in the length of time the boiler is fired, between plants where 150,000 and 250,000 pounds of butter was made. In creameries below 150,000 pounds' capacity, however, both the size of the equipment and the time of firing decrease. Above 350,000 pounds' capacity the size of the equipment and the total time of firing increases, but at a less rate than in the smaller plants.

DEFECTS NOTED.

It is impossible to operate a creamery with any degree of economy if the equipment is not in good order. Some of the creameries had new engines and boilers and were keeping them in fairly good condition, but in by far the greater number the equipment was in very bad condition. For example, in one plant all the water leaked out of the boiler overnight, while in another the water level in the boiler was lowered 30 inches overnight by leakage. Most of the boiler settings were poorly designed and built. In most cases the side walls were only about 13 inches thick, and the result was that the settings were

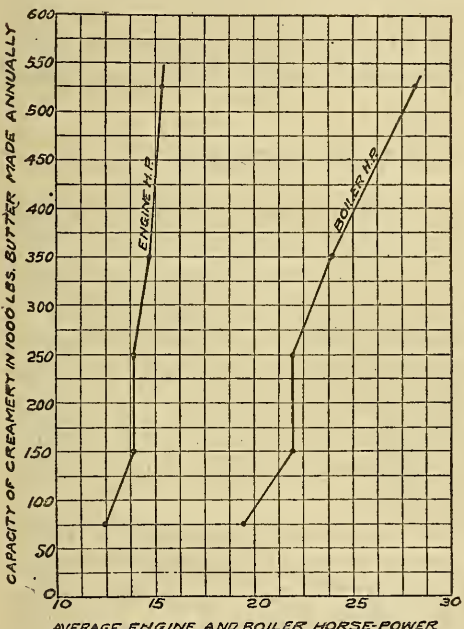

FIG. 2.—Curves showing variation in size of engines and boilers in creameries of different capacities.

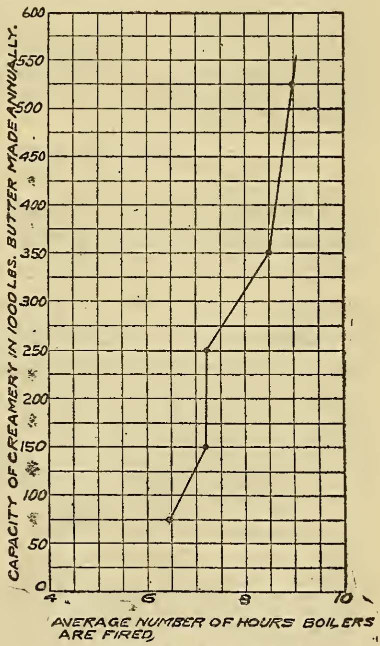

FIG. 3.—Curves showing average number of hours boilers are fired in creameries of different capacities.

full of cracks. In many cases the fire doors, ash-pit doors, and clean-out doors were warped and broken, as were the boiler fronts, and the return-tubular boilers were practically all set too low over the grates. The breechings in many instances were not tight, were too small, and often had right-angle bends. In more than one instance the breeching where it entered the stack was lower than the first bend above the boiler.

One of the greatest losses in fuel was caused by careless firing. The boiler in most cases was fired by the buttermaker or one of his assistants, and in order to lose as little time as possible from other work the fire box was filled with coal and left for from a half to three-quarters of an hour, with the result that the combustible gases in the coal were distilled and escaped unconsumed up the chimney. Finally, holes were burned in the fire bed so that too much air was allowed to pass through, which cooled the boiler and setting and also carried a large part of the heat up the stack.

The average quantity of coal per 1,000 pounds of butter made of all creameries studied was 1,140 pounds, though many of them produced 1,000 pounds of butter with a fuel consumption considerably less than 400 pounds.

The total quantity of factory-made butter in the United States, as reported by the Thirteenth Census (1910), was 627,145,865 pounds. If the quantity of coal were reduced to, say, 400 pounds per 1,000 pounds of butter, the saving would approximate 232,000 tons annually in the creameries throughout the country, which at $5 a ton would amount to $1,160,000.

CONSTRUCTION OF BOILER SETTINGS.

In comparing and studying the itemized expense reports of a large number of creameries it was noted that in most cases the fuel item was excessive. It was extremely variable even in creameries which made practically the same quantity of butter annually. Further investigations showed that this wide variation in the fuel consumed was due largely to one or more of the following causes: (1) Poor installation and maintenance of boilers and settings; (2) careless firing; (3) bad condition of engine and other steam-driven machinery; (4) failure to utilize the heat in the exhaust steam; and (5) lack of system in operating the plant.

A common cause of fuel loss in the average creamery is faulty boiler setting. Most creamery boilers in use at the present time are of the horizontal return-tubular type and require an external setting which is generally constructed of brick. The settings are usually built by local workmen who have had little or no experience in boiler work; hence the construction is nearly always too light and flimsy to withstand the heat and the weight of the boiler and contained water. As a result the settings crack from the heat and weight and thus allow too much air to enter the furnace. This reduces the draft and also causes a direct heat loss, due to the heating of excess air.

Warped and cracked firing doors also contribute to the heat loss by admitting more air into the furnace than is required for complete combustion. The economical burning of fuel requires not only the proper arrangement and proportioning of the furnace, combustion chamber, uptakes, breeching, and chimney, but also that they be practically air-tight. To burn fuel completely a definite quantity of air is required, which must be admitted at the proper place and time and be mixed thoroughly with the combustible gases.

LOCATION OF SETTING.

In placing the boiler it is very important to leave ample space between the sides and ends of the setting and the walls of the room in order that expansion, contraction, or the possible settling of the foundations may not affect the building, and to allow room for inspection, painting, and repairs. In order to avoid long lengths of pipe the boiler should be placed as near the engine as possible, but it is not advisable to have both in the same room, as the dust from the coal and ashes will get into and injure the engine bearings.

FOUNDATIONS.

The foundation of a boiler setting should receive careful consideration, for upon it depends to a great extent the structural strength of the setting. Should the foundation settle it is very probable that the setting will crack. On account of the great variation in the character of the soil it is not practicable to set a standard of proportions for foundations; consequently in planning the foundation it becomes to a great extent a matter of judgment as to its depth and area. It is far better, however, to be on the safe side and have it too strong than too weak.

In determining the proportions for foundations the weight or load to be sustained and the bearing value of the soil are the principal factors to be considered. The weight of the boiler can be obtained from the manufacturer, and the weight of water that the boiler will contain in normal working condition is about two-thirds of the weight of the boiler. By doubling the shipping weight of the boiler a safe approximation of its weight under working conditions will be obtained.

The weight of the masonry will average about 145 pounds per cubic foot, which should be added to the weight of the boiler and contained water to get the total weight per square foot of surface to be sustained by the soil.

The foundation should be so proportioned as to distribute the weight over a surface so great that the bearing values will not exceed a safe load for the particular soil in question, and to provide a suitable table to take the load. The foundation may be of concrete, brick, or stone. When of concrete the mixture should be in the proportion of 1 part Portland cement to 3 parts clean, sharp sand and 5 parts broken stone or clean, coarse gravel, all to be thoroughly mixed and well tamped into place. When of brick, only the best hard brick should be used, laid in Portland-cement mortar with the joints entirely filled. The bottom course should be laid in a bed of cement mortar.

If a stone foundation is used it should consist of hard, durable stone solidly imbedded in cement mortar. If practicable, the stones should be of a length equal to the width of the foundation trenches, but if stones of that size can not be obtained, two stones may be used, with the joints under the walls.

ERECTION.

After the foundation has been laid and allowed to set thoroughly the boiler should be placed in position and raised to the proper height by means of jackscrews and held by cribbing built up of short pieces of timber. The cribbing should be placed in the spaces that are afterwards to be the furnace and combustion chamber, care being used to clear the location of the bridge wall and blow-off pipe. If the boiler is to be supported by columns and overhead beams, they should be put into place and the slings adjusted. The rear of the boiler should be 1 inch lower than the front so as to drain properly to the blow-off pipe. The boiler front should be placed in position and propped up until the walls have been carried to a height sufficient to enable bolts or anchor rods to be inserted to hold the front in position. The walls should then be built up to their proper height, allowing pockets for the supporting brackets.

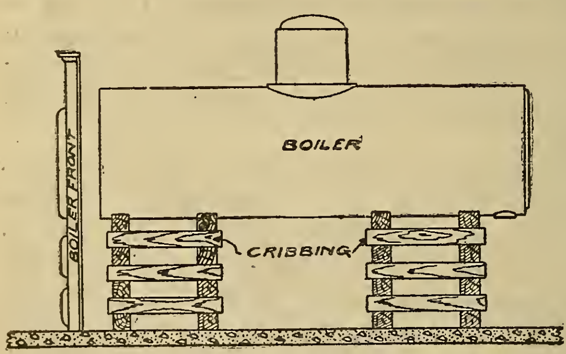

FIG. 4.—Boiler blocked up ready for setting.

The side stays should then be put into place and drawn tight. The boiler and setting should rest on the cribbing (see figure 4) until the brickwork has thoroughly dried out, when the cribbing may be removed and the weight of the boiler allowed to rest on the walls. Care should be taken to see that the brackets rest squarely on the soleplates in the walls; otherwise there will be a racking strain on the boiler during expansion and contraction. Then the setting should be closed and finished.

There is a general belief that because air is a poor conductor of heat, an air space built in the walls of a furnace will prevent or reduce the dissipation of heat through the walls. Experiments by the United States Bureau of Mines,[1] however, have shown that, so far as loss of heat is concerned, a solid wall of brick or any other

[1] Bulletin of the Bureau of Mines No. 8, "The Flow of Heat Through Furnace Walls."

ordinary material is preferable to a hollow wall of the same total thickness, especially if the air space in the hollow wall is near the furnace side.

While the solid-wall construction for boiler settings may be better from an insulating standpoint than a wall of the same total thickness containing an air space, in practice it is advisable to build the walls in two parts in order to assist in preventing the formation of cracks by the expansion and contraction of the brickwork on the furnace side of the wall. The space between the walls, however, should be filled with some solid insulating material, such as mineral wool, crushed brick, ash, or sand, as that kind of filling offers a higher resistance to the flow of heat through the walls than an air space and, furthermore, reduces air leakage into the furnace, which is a very important feature affecting its operation. The air space, however, should be kept so far as practicable from the furnace side.

The construction of boiler settings differs widely in details, depending on the type of boiler used and the local conditions, but the principles governing it remain the same. The brickwork should be substantial, so that it will not crack and crumble, conditions which always produce air leaks and cause extensive repairs. The exterior walls of the setting should be built of hard-burned brick, laid in cement mortar, while the inside lining of the furnace and combustion chamber should be of fire brick laid with fire-clay mortar, care being taken in both cases to use no more mortar than is absolutely necessary. The fire brick should be thoroughly bonded into the outer walls, but in such way as to allow replacing if occasion demands. The side walls of the furnace and combustion chamber may be either vertical or tapered. In either case from 2 to 4 inches should be allowed on the sides of the boiler just below the water line, so that the hot gases can circulate up to the point where the setting meets the boiler, which is usually just below the water line. The upper half of the boiler may be covered with a brick arch or some nonconducting insulating material. When a brick arch is used it is advisable to lay it over strips of wood about three-quarters of an inch thick. When the boiler is fired these wooden strips are burned out, leaving an open space between the boiler shell and the arch through which the hot gases may circulate. Sand should be spread over the arch to close any small crack that may occur and also to act as an insulator.

METHODS OF SUPPORT.

Two principal methods of supporting horizontal return-tubular boilers are employed. The one more commonly used, especially with comparatively small return-tubular boilers, is to support the weight on the walls of the setting by means of brackets bolted to the boiler

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shell. Soleplates are placed on the brick walls to receive the brackets, the endwise expansion being taken care of by rollers between the brackets and soleplates. It is important to have the brackets completely covered by the brickwork; otherwise they will be burned by the hot gases.

The other and better method is to suspend the boiler from a frame made up of channel bars or angle iron supported by columns, the setting being built around the framework. By this method the weight of the boiler and contained water is carried on the piers supporting the columns. With this method the walls of the setting have to support only their own weight; hence the expansion and contraction of the boiler are more easily provided for and the walls of the setting are not so liable to crack. As before stated the back end of the boiler should always be set about 1 inch lower than the front in order to drain the boiler toward the blow-off pipe, which is usually at the back of the boiler. The blow-off pipe should be carefully protected from direct contact with the hot gases by covering with a sleeve or by building a baffle of fire brick on the side next the furnace.

CLEAN-OUT DOORS.

With large boilers two clean-out doors should be provided for the combustion chamber in order to facilitate cleaning, but with small boilers one is usually sufficient. It should be placed in the center of the back wall of the setting and the bottom of the door should be on a level with the bottom of the combustion chamber. Great care should be used in making the clean-out doors air-tight, as air leaking into the combustion chamber at this point seriously affects the draft.

CONSTRUCTION OF FURNACES.

The functions of the boiler and of the furnace are diametrically opposed to each other, that of the furnace being to develop a maximum of heat from the combustion of the fuel on the grates, while that of the boiler is to absorb as much heat as possible of that produced in the furnace. In order that the furnace may develop the maximum quantity of heat from the fuel complete combustion of all material is necessary. The volatile gases which are driven off from the coal must be allowed to ignite before their temperature is lowered to a point at which they will not burn. Even a comparatively slight reduction in temperature will prevent some of the gases from igniting, with the result that quantities of combustible gases are driven off without being consumed and fine particles of carbon are forced up the chimney without combining with the oxygen to produce heat in the combustion chambers. As hot gases and vapors rise at a rate proportional to their temperature, there must be a

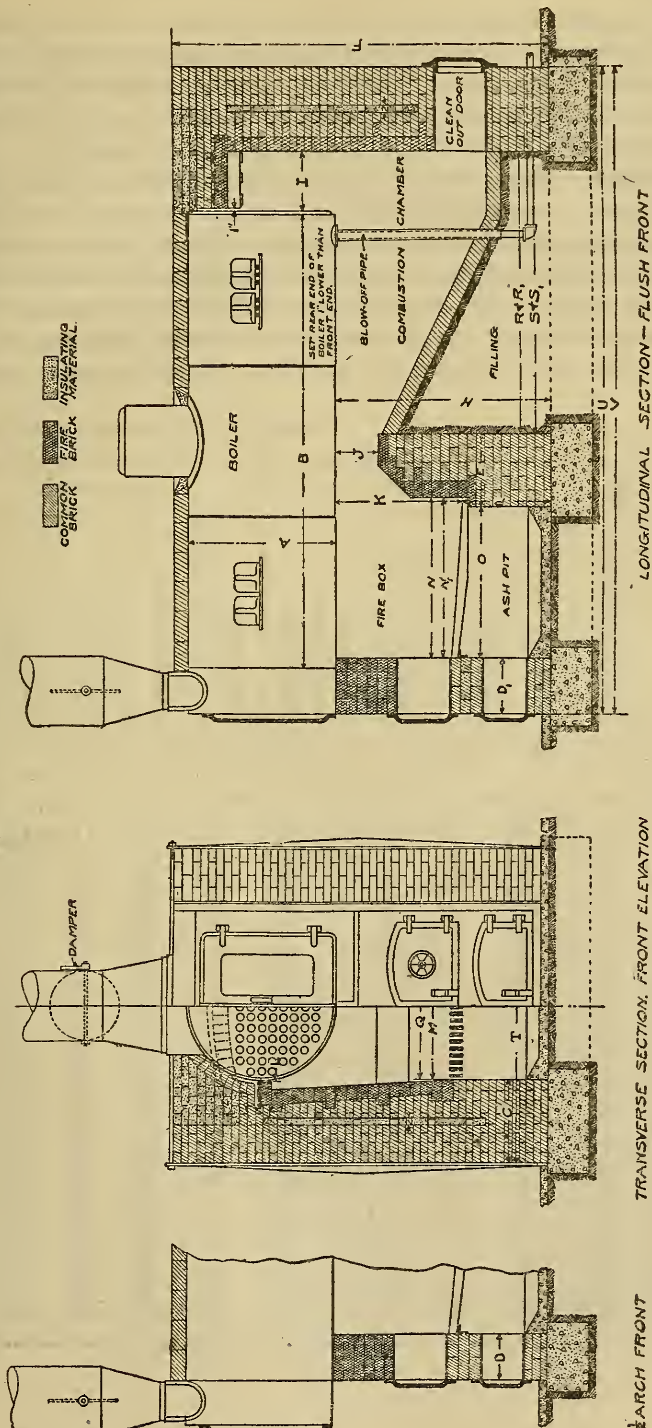

Fig. 5.—Setting for horizontal return-tubular boilers.

sufficient distance between the fuel bed and the boiler shell to allow for their complete expansion and ignition before coming into contact with the boiler shell. Soft coal usually contains a large proportion of volatile matter; consequently it needs considerably more space between the fuel bed and the boiler than anthracite.

The radiation losses from the sides of the furnace and combustion chamber are comparatively small in any well-set boiler and as the combustible gases rise a considerable distance before losing any appreciable heat the distance between the grate bars and the boiler shell should be increased over that generally used in setting boilers. This dimension depends on the kind of coal burned, the rate of burning, and upon other factors, all of which should be known in order

TABLE 2.—*Dimensions of settings for*

Diameter (inches).	Length (feet).	Horsepower based on 12 square feet heating surface.	Walls.					Spacing shell to—				
			Back and side (inches).	Front.		Bridge (inches).	Height (inches).	Ground (inches).	Back wall (inches).	Bridge wall (inches).	Grate rear (inches).	Side wall (inches).
				One-half arch (inches).	Full front (inches).							
A	B		C	D	D_1	E	F	H	I	J	K	L
30	8	12.2	21	9	13	13	84	50	16	9	28	2
32	8	12.5	21	9	13	13	86	50	16	9	28	2
32	10	15.6	21	9	13	13	86	50	16	9	28	2
36	8	15.9	21	9	13	17	94	54	16	9	30	3
36	10	19.8	21	9	13	17	94	54	16	9	30	3
36	12	23.7	21	9	13	17	94	54	16	9	30	3
36	14	27.6	21	9	13	17	94	54	16	9	30	3
36	16	31.5	21	9	13	17	94	54	16	9	30	3
40	10	26.6	25	9	17	17	100	56	18	10	32	3
40	12	32.1	25	9	17	17	100	56	18	10	32	3
40	14	37.4	25	9	17	17	100	56	18	10	32	3
40	16	42.5	25	9	17	17	100	56	18	10	32	3
42	12	33.4	25	9	17	17	102	56	18	10	32	3
42	14	39.2	25	9	17	17	102	56	18	10	32	3
42	16	44.6	25	9	17	17	102	56	18	10	32	3
44	12	36.7	25	13	17	21	106	58	18	10	32	4
44	14	43.0	25	13	17	21	106	58	18	10	32	4
44	16	49.0	25	13	17	21	106	58	18	10	32	4
44	18	55.0	25	13	17	21	106	58	18	10	32	4
48	12	43.0	25	17	21	21	112	60	18	10	34	4
48	14	50.2	25	17	21	21	112	60	18	10	34	4
48	16	57.3	25	17	21	21	112	60	18	10	34	4
48	18	64.8	25	17	21	21	112	60	18	10	34	4
54	12	52.7	29	17	21	25	122	64	20	12	36	4
54	14	61.8	29	17	21	25	122	64	20	12	36	4
54	16	70.5	29	17	21	25	122	64	20	12	36	4
54	18	79.3	29	17	21	25	122	64	20	12	36	4
60	12	62.7	29	21	25	25	128	64	24	12	36	4
60	14	73.0	29	21	25	25	126	62	24	12	36	4
60	16	83.3	29	21	25	25	126	62	24	12	36	4
60	18	93.6	29	21	25	25	126	62	24	12	36	4
60	20	104.8	29	21	25	25	126	62	24	12	36	4

to design a boiler setting that will meet exactly the requirements of a given set of conditions. With the type of setting shown in figure 5 and dimensions in Table 2, however, it is believed that satisfactory results will be obtained when using an average grade of soft coal. The dimensions of the distance between grates and boiler are to be considered as only approximate minimum limitations. If the height of the boiler room will permit, this dimension should be at least the diameter of the boiler, but in most milk plants and creameries to build the boiler-room ceiling higher would necessitate an increased expense in the construction; hence to a certain extent the height given is a compromise between the cost of building and the better combustion of fuel.

horizontal return tubular boilers.

Grate.					Ash pit.		Combustion chamber.					Outside walls.		
	Coal.		Wood.					Length.					Length.	
								Coal.		Wood.				
Width (inches).	Length (inches).	Area (square feet).	Length (inches).	Area (square feet).	Length (inches).	Depth (inches).	Width (inches).	One-half arch (inches).	Full front (inches).	One-half arch (inches).	Full front (inches).	Width (feet and inches).	One-half arch (feet and inches).	Full front (feet and inches).
M	N		N_1		O	P	Q	R	S	R_1	S_1	T	U	V
30	36	7.5	60	12.5	......	22	30	56	65	32	41	6 0	11 0	12 0
32	36	8.1	60	13.3	......	22	32	56	65	32	41	6 2	11 0	12 0
32	36	8.1	60	13.3	......	22	32	80	89	56	65	6 2	13 0	14 0
32	36	8.1	60	13.3	......	24	32	52	73	28	49	6 2	11 0	13 0
32	36	8.1	60	13.3	......	24	32	76	85	52	61	6 2	13 0	14 0
36	36	9.0	60	15.0	......	24	36	100	109	76	85	6 6	15 0	16 0
36	48	12.1	60	15.0	......	24	36	112	121	100	109	6 6	17 0	18 0
36	48	12.1	60	15.0	......	24	36	136	145	124	133	6 6	19 0	20 0
36	42	10.5	60	15.0	......	24	36	72	81	54	63	7 2	13 6	14 10
36	42	10.5	60	15.0	......	24	36	96	105	78	87	7 2	15 6	16 10
36	48	12.1	60	15.0	......	24	36	114	123	102	111	7 2	17 6	18 10
48	48	16.0	60	20.0	......	24	48	138	147	126	135	8 2	19 6	20 10
42	42	12.4	60	16.5	......	24	42	96	105	78	87	7 8	15 6	16 10
42	48	14.1	60	16.5	......	24	42	114	123	102	111	7 8	17 6	18 10
48	48	16.0	60	20.0	......	24	48	138	147	126	135	8 2	19 6	20 10
42	46	13.5	60	16.5	......	26	42	85	98	71	84	7 8	15 6	16 10
42	48	16.0	60	16.5	......	26	42	107	120	95	108	7 8	17 6	18 10
42	54	15.9	72	21.0	......	26	42	125	138	107	120	7 8	19 6	20 10
44	54	16.5	72	22.0	......	26	44	149	162	131	144	7 10	21 6	22 10
42	48	14.1	72	21.0	......	26	42	78	96	54	72	7 8	15 6	17 0
44	48	14.8	72	22.0	......	26	44	102	120	78	96	7 10	17 6	19 0
44	54	16.5	72	22.0	......	26	44	120	138	102	120	7 10	19 6	21 0
46	54	17.4	72	23.0	......	26	46	144	162	126	144	8 0	21 6	23 0
48	48	16.0	72	24.0	......	28	48	77	95	53	71	8 10	15 10	17 4
54	48	18.1	72	27.0	......	28	54	101	119	77	95	9 4	17 10	19 4
54	54	20.3	72	27.0	......	28	54	119	137	101	119	9 4	19 10	21 4
54	54	20.3	72	27.0	......	28	54	143	161	125	143	9 4	21 10	23 4
54	48	18.1	72	27.0	......	28	54	79	99	55	75	9 4	16 2	17 10
54	54	20.3	72	27.0	......	26	54	97	117	79	99	9 4	18 2	19 10
60	54	22.5	72	36.0	......	26	60	121	141	103	123	9 10	20 2	21 10
60	54	22.5	72	36.0	......	26	60	145	165	127	147	9 10	22 2	23 10
60	54	25.0	72	36.0	......	26	60	163	183	145	165	9 10	24 2	25 10

While the designs of furnaces may vary widely in the details of construction, they all require the following necessary parts: A grate for supporting the fuel and on which the fixed carbon is burned; means for supplying and controlling the air required for combustion and for removing the incombustible gases; and an ash pit for catching the refuse from the fuel.

GRATES.

The object of the grates is not only to support the fuel but to admit the proper proportion of air to get the best combustion with the particular kind of fuel used. The area of openings between the bars is usually from 30 to 50 per cent of the total grate area. The individual openings between bars vary from one-eighth inch to 1 inch, depending on the kind of fuel used. For fine sizes of anthracite the openings vary from one-eighth to three-eighths of an inch. For large sizes of anthracite and for ordinary soft coal the openings are often as wide as 1 inch. With coal that forms clinkers narrow air spaces are objectionable since they are liable to become clogged, causing the bars to burn, and, furthermore, it is difficult to keep the openings clear for the free passage of air. For ordinary conditions when soft coal is used the straight bar is preferable to other types. The bars are usually made in lengths not exceeding 3 feet and if a greater length of grate is required two sections of the proper length are used. For hand-fired furnaces 6 feet is about the limit to which it is practicable to fire, on account of cleaning the rear portion of the grate. It is very important that the surface of the grate bars be regular and even. An uneven and inadequate grate surface tends to a rapid deterioration of the bars, which is caused by the heat of the fire and contact with the firing tools combined.

Grate bars are usually supported by strips made fast to the front of the setting and to the bridge wall. They should have a pitch of about 1 inch per foot toward the bridge wall. It is obvious that there must be some intimate relation between the amount of grate surface on which the fuel is burned to produce heat and the amount of heating surface in the boiler required to take up the heat. This ratio of grate surface to heating surface, however, varies widely because it depends upon the type of boiler, the method of setting, the draft conditions, and the kind of fuel used. Under ordinary conditions, with anthracite coal, the ratio of grate surface to heating surface is from 1 to 30 or 40, with an average of from 1 to 36. If bituminous coal is used for fuel this ratio should be increased by from 25 to 40 per cent, giving a ratio of from 1 to 45 or 50 of grate to heating surface. For wood burning the ratio should be about 1 to 65 or 70.

Grates that can be shaken, because of smaller opening of the fire doors, are generally more economical in the use of fuel than the ordinary grates, provided they are handled carefully and fuel is not shaken through into the ash pit.

Grates are usually furnished by the boiler manufacturer as an integral part of the boiler, without reference to the kind of fuel to be burned. It is, of course, impossible to get the best results in all cases with a standard type of grate bars which may not be suited to the particular grade of fuel used. The purchaser, therefore, when buying the boiler, should specify the kind of bar and the size of openings desired.

FIRE BOX.

The space immediately above the grates constitutes the fire box. The combustion of a considerable part of the gases driven off from the coal takes place in the fire box, the remainder being consumed in the combustion chamber proper. The horizontal dimensions of the fire box are fixed by the size of grate required for the given conditions, but with tubular boilers the height from the grate bars to the underside of the boiler is determined by the kind of fuel.

It was formerly believed that the grate bars should be set close to the shell of the boiler, the idea being that there is a loss of radiant heat, which increases with the distance. From 12 to 18 inches, therefore, was the ordinary distance in externally fired tubular boilers, and most of the boilers used at present in milk plants, creameries, and dairies are set with the grate bars approximately from 18 to 20 inches from the shell. With dry anthracite coal satisfactory results may be obtained with a grate setting of this kind, but with bituminous coal it is hard to imagine a more unsatisfactory fire box, and practically all the creameries burn soft coal or wood.

It is impossible to get good results when burning soft coal in a furnace designed for burning anthracite. With dry anthracite coal, which burns with very little flame, almost any kind of furnace will give good results, but with bituminous coal, which burns with a long flame, the distance from the grate to the underside of the boiler shell must be such that the flame will not strike against the comparatively cold boiler shell and be extinguished before the gases are completely consumed. In order to burn fuel completely it is necessary to maintain a high temperature. With steam at a gauge pressure of 100 pounds the temperature of the boiler shell will be approximately 338° F., which is about the temperature of the water in the boiler. If the flame is allowed to strike against the comparatively cool shell, it will be extinguished, soot will be deposited on the heating surface, and the unconsumed gases and smoke will be carried up the chimney.

The functions of the fire box are to provide means for burning the fixed carbon in the fuel, for the distillation of the gases, and for the thorough mixing of air at a high temperature with the unburned gases.

COMBUSTION CHAMBER.

The combustion chamber is really an extension of the fire box in which the burning of the volatile gases takes place and where the heat thus produced is absorbed by the water through the heating surfaces of the boiler. With horizontal return-tubular-boiler settings the term "combustion chamber" is applied to the space between the bridge wall and the ends of the boiler tubes. The horizontal dimensions of the combustion chamber are fixed to a great extent by the type of boiler setting. The depth seems to have little effect on the efficiency of the setting; consequently, the depth of the combustion chamber may be as great as the form of setting will permit. The common practice of sloping the floor of the combustion chamber downward from the bridge wall to the clean-out door seems to have little value other than facilitating the removal of ashes.

ASH PIT.

The ash pit beneath the grates is to catch the ashes and refuse from the fire above and to provide an air reservoir for supplying air to the burning fuel. The depth of the ash pit should be sufficient to provide plenty of air for the burning of the fuel and to hold a considerable accumulation of ashes and clinkers without choking the air supply and burning the grate bars. The bottom of the ash pit should be made wedge-shaped, of cement, to facilitate cleaning and to allow water to be placed under the grates to prevent them from being burned. It should not be necessary to keep water in the ash pit except when the boiler is being forced.

ASH-PIT AND FLUE DOORS.

The ash-pit door, usually called the "ash-pit damper," is an opening to the ash pit for the removal of ashes, and it also serves to control the air supply through the fuel bed. It is very important to have this door tight fitting in order to control effectually the air supply through the grates.

The flue doors provide an opening to the smoke box at the front ends of the flues. These doors, unless they fit tightly, are a source of air leaks.

CHIMNEY.

The function of a chimney is to provide a draft to effect combustion of fuel on the grate and to carry off the resulting obnoxious gases. The chimney should be built carefully to prevent cracks where leakage of air through the walls may occur and to give as smooth a surface inside as possible so as to lessen the resistance to the flow of escaping gases.

The area of the chimney should be approximately 20 per cent greater than the combined flue area of the boiler or boilers which it is to serve. Table 3 gives the size of chimney for steam boilers.

TABLE 3.—*Size of chimney for steam boilers.*

[Calculated from Kent's formula assuming 5 pounds of coal per horsepower-hour.]

Area (square feet).	Diameter (inches.)	Height in feet.													Equivalent square chimney side of square.
		30	40	50	60	70	80	90	100	110	125	150	175	200	
		Commercial horsepower.													
1.23	15	10	12	13	14	16	......	......	......	......	......	......	......	......	13
1.77	18	18	20	23	25	27	29	......	......	......	......	......	......	......	16
2.41	21	....	31	25	38	41	44	......	......	......	......	......	......	......	19
3.14	24	....	44	49	54	58	62	66	......	......	......	......	......	......	22
3.98	27	....	....	65	72	78	83	88	......	......	......	......	......	......	24
4.91	30	....	....	84	92	100	107	113	119	......	......	......	......	......	27
5.94	33	....	....	....	115	125	133	141	149	156	......	......	......	......	30
7.07	36	....	....	....	141	152	163	173	182	191	204	......	......	......	32
8.30	39	....	....	....	......	183	196	208	219	229	245	268	......	......	35
9.62	42	....	....	....	......	216	231	245	258	271	289	316	342	......	38
12.57	48	....	....	....	......	......	311	330	348	365	389	426	460	492	42
15.90	54	....	....	....	......	......	......	427	449	472	503	551	595	636	48
19.64	60	....	....	....	......	......	......	536	565	593	632	692	748	800	54

For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

DAMPERS.

Each boiler should be provided with a damper in the uptake or breeching which should have an effective opening of at least 25 per cent greater area than that of the combined area of the tubes. It should be arranged for convenient manipulation by the fireman; otherwise there will be a tendency to neglect its use. The control of the draft should be done through the manipulation of this damper rather than by the ash-pit doors.

BRIDGE WALL.

The wall just back of the grates is known as the bridge wall and extends across the entire width of the furnace to a height somewhat above the level of the bars. It has for its object the directing of the hot furnace flames and gases, forcing them to rise toward the shell of the boiler, and also to hold the fuel at the rear of the grates. The distance between the top of the bridge wall and the boiler shell depends on the kind of fuel used. With anthracite, or hard coal, the distance should be less than if soft coal or wood is used. As the bridge wall above the grate bars is in the direct path of the flames and hence is subjected to a very high temperature, it should be faced with fire brick, as ordinary brick soon fuses or crumbles.

FIRE DOORS.

The fire doors should be of substantial construction and should fit tight in order to prevent cold air from entering the furnace over the top of the fuel bed. An adjustable opening having a clear area of about 4 square inches per square foot of grate area should be provided in the door through which air may be supplied above the fuel bed. The admission of air through these openings also tends to keep the door from overheating and warping.

UPTAKES.

The smoke connections between the boiler and breeching are called uptakes. These connections should be as straight as possible, with ample cross-section area in order not to hinder the draft. The cross-section area should be from 20 to 25 per cent greater than the combined tube area, or approximately 25 per cent of the grate area. If it is impossible to run the uptake connections straight to the breeching, large, easy bends should be employed. Abrupt bends materially reduce the draft. Uptakes are often fitted loosely to the smoke outlet of boiler and to breeching, thus allowing cold air to enter and cut down the draft. Care should be taken to see that these connections as well as all others are made tight.

BREECHINGS.

Breechings are the connections between the uptake and the chimney. They should be run as straight as possible and bends, if unavoidable, should be large and sweeping. Breechings may be horizontal, but it is much better to have them rise from the uptake to the chimney. Under no consideration, however, should they drop below the horizontal. They should have a cross-sectional area of at least 25 per cent greater than the combined tube area, or one-fourth of the grate area. Round or square breechings are preferable to broad, flat ones, as the resistance offered to the flow of gases is not so great in the former as in the latter. In no case should a breeching be used in which one dimension is twice that of the other. Both uptakes and breeching should be tight and carefully covered with a good quality of heat-insulating material.

HAND FIRING OF BOILER FURNACES.

Boilers employed in the dairy industry are generally small, although ranging from the smallest size which is used on the dairy farm to several hundred horsepower in the largest milk plants. The great majority, however, range from 10 to 50 horsepower. The conditions and methods of operation used in these small plants are entirely different from those plants employed solely for the generation of power; consequently the economical firing of the boiler presents problems different from those in plants that operate under practically constant load throughout the day. In many large power plants instruments are used to measure the temperature and composition of the flue gases, which greatly aids the fireman in maintaining the fire bed in the best condition. In the smaller plants, where the load is intermittent and the boilers are fired for only a few hours during the day, it is impracticable to use flue-gas instruments; consequently the fireman is forced to depend entirely on his judgment as to the condition of the fire.

The chemical action that goes on in the furnace during the combustion of the fuel is an exceedingly complicated one and is not very well understood. While important, it is not absolutely necessary, in order to get good results, for the fireman to understand in general the chemical changes that take place during the combustion of the fuel. Hand firing of a boiler furnace is a combination of science and skill which is generally acquired through long experience and by careful observation of the conditions of the fire.

To get the best results definite proportions of fuel and air must be used, and the air must be evenly distributed throughout the fuel bed so that all parts will get the proportion of air necessary to effect complete combustion. Too much air absorbs heat from the fire and furnace walls, and the heat is carried up the chimney, while too little air causes the fire to smoulder, with the result that the combustible gases from the fuel are carried off without being consumed. The fireman must learn from the appearance of the fire whether the required proportion of air is being admitted, and if it is properly distributed. He must be able also to recognize any defects in the fuel bed, due to clinkers, ashes, holes, too thick or too thin fires, etc. With an even fuel bed clinkers or ashes on the grate are indicated by dark spots on the fuel bed or by shadows cast on the floor of the ash pit. In order better to observe the condition of the fuel bed through the casting of shadows in the ash pit the floor of the pit should be kept clean. Holes or thin spots may be noted by the white color of the burning fuel, indicating that too much air is being admitted at that point. The color of the fire bed indicates whether it is too thin or too thick. If too thin, the fire shows a uniformly white color, but if too thick it is more of a red color. An uneven fire bed shows dark and bright spots.

Different kinds of coal require different treatment in firing to obtain the best results. For instance, with soft coal the best results are obtained when the fires are kept level and relatively thin, from 6 to 8 inches, under average conditions of draft. Coal should be added often and in small quantities, and carefully spread evenly over the thin spots in the fuel bed. The fuel bed as a whole should be kept level. In small milk plants and creameries where a regular fireman is not employed it is customary to shovel into the furnace a large quantity of coal, expecting it to last for a considerable length of time, thus giving the employee more time to attend to other work around the factory. It is hard to conceive of a more wasteful method of firing, for when the fire box is freshly filled with coal the draft is throttled, the temperature of the furnace is lowered, the fire smoulders and smokes, and the volatile gases are driven off without being burned. In time holes burn in the fuel bed, allowing too much air to enter the furnace, which finally chills the furnace by absorbing heat from the fire and furnace walls. Such a method of firing combines the two features most detrimental to the economical burning of fuel, namely, an insufficient supply of air for complete combustion when fuel is first added, and later, when the coal is partially burned, there is too much air, which chills the fire and furnace.

For the complete combustion of fuel a definite quantity of air must be admitted to the furnace and brought into close contact with the fuel, and the temperature in the furnace must be kept above the ignition point. The exact quantity of air necessary to burn 1 pound of coal completely depends on the kind of coal used. The grade or quality of coal generally used in milk plants and creameries requires about 12 pounds, or approximately 161 cubic feet of air, to burn 1 pound of coal completely, provided that it were possible to supply the air uniformly to all parts of the fuel bed, so that each particle of coal would receive enough for its complete and thorough combustion. This is, of course, impossible of accomplishment in actual practice; hence it is necessary to supply about twice the theoretical quantity of air in order to burn the fuel satisfactorily. The rate of supplying the air must be varied according to the requirements. For instance, when fresh coal is thrown into the furnace, large quantities of gas are immediately given off; consequently more air must be supplied at this time to obtain satisfactory combustion. After the distillation and burning of the gases from the fresh fuel is completed, the air necessary for burning the solid matter is only a fraction of that required just after charging with fresh fuel. The quantity of air needed at any particular time depends on the quantity of fresh fuel added and the condition of the fuel bed. It is impracticable to supply the theoretical quantity of air necessary to burn the fuel completely under service conditions, and it is necessary, therefore, to add fuel often and in small quantities. Just after firing, air should be admitted over the fuel bed through the openings in the fire door. When the fuel has burned down the supply of air over the fuel bed is greater than is needed for the complete combustion, and consequently it must be reduced. Thus it is seen that by small and frequent firing it is possible to regulate more nearly the air supply to the demand of the burning fuel. The leakage of air through the walls of the boiler setting and through warped and broken furnace doors is practically constant.

The loss of heat due to the admission of an excessive supply of air through or over the fuel bed is the greatest single loss in a boiler plant.

In good practice there is a loss of about 23 per cent in the stack, due to heating air. This loss, however, is necessary in order to maintain draft through the furnace, and hence can not be avoided.

In the average creamery the heat loss due to heating an excessive amount of air is 40 or 45 per cent on account of air leaks in the setting. At least half of the loss can be eliminated by stopping the cracks in the boiler setting.

The tools necessary for firing should be provided and the floor from which the coal is to be shoveled should be hard and smooth. If the coal is shoveled directly from a wheelbarrow or specially designed coal car, the inside surfaces should be made smooth by dressing off all rivet heads or other obstructions against which the edge of the shovel may strike. The coal should be placed near the furnace door in such position that it may be shoveled quickly and easily into the furnace, thus making it necessary to keep the furnace doors open only a short time. Dampers should be provided in the uptake with means for operating from the fireman's position in front or at the side of the furnace doors. It is important that damper connections be conveniently placed so that the dampers can be easily and accurately adjusted; otherwise there will be a tendency to neglect their use and, instead, control the draft by means of the ash-pit door. Under no circumstances should the ash-pit door be used to control the draft in a furnace; with the ash-pit door closed or partly closed there is little or no air admitted through the grates and combustion is incomplete, and valuable fuel in the form of combustible gases which have been driven off from the green fuel is wasted by being carried off unconsumed up the stack.

Ordinarily the firing tools consist of a shovel, rake, hoe, and slice bar, which should be of the proper size to suit the particular furnace and should be kept in good condition. The front or cutting edge of the shovel should be kept straight and never be allowed to become bent or gapped. The tines of the rake and the blade of the hoe should not be bent or otherwise distorted. The slice bar should be bent to an angle suited to the particular furnace with which it is to be used.

The floor surrounding the boiler from which the coal is to be shoveled should be of concrete, with a smooth and hard surface, or better still, some form of car or truck should be used and the coal shoveled directly from the car into the furnace. By using a car the dust and dirt from the coal are kept down to a minimum and the inconvenience and unsightly appearance of coal scattered over the floor is prevented to a great extent.

Ample room for working should be allowed the fireman. In many small plants the space for firing is often so limited that it is difficult to fire effectively. The fireman is forced to stand so close to the firing door and the heat from the furnace is so great that to avoid the heat as much as possible he stands to one side so far that he can not see where coal is needed, thus making it necessary to level the fuel bed frequently by the use of the rake.

In firing bituminous coal the large lumps should be broken up into pieces about the size of a man's fist or smaller. Adding large lumps of coal makes it impracticable to regulate the draft so as to get an even flow of air through the fuel bed; especially is this true in small boiler plants which are fired at a slow rate and in which a comparatively thin fuel bed is maintained.

METHODS OF FIRING.

There are three methods of hand-firing boiler furnaces, known as the spreading, alternate, and coking methods.

The spreading system, which is the simplest and perhaps the one most commonly used, consists in spreading the coal in a thin and even layer over the entire fuel bed. With this system it is harder to prevent smoking than with the other systems, especially if too much coal is added at a time. Consequently, the firing should be done often and only a small quantity of coal fired at a time, thus providing for better combustion. When the coal is spread in a thin layer over the entire fuel bed the volatile gases are quickly driven off and burned. This system of firing is particularly applicable to small boilers that have only one firing door, since the entire surface of the fuel bed can be easily seen. A difficulty experienced with the spreading system is that, unless specially guarded against, holes are liable to be formed in the fuel bed near the bridge wall. A modification of the spreading system is sometimes used which consists in keeping the fuel bed much thicker at the bridge wall than at the front, thus preventing it from burning out so quickly. Except for the fact that the fuel bed is kept wedge-shaped, the firing is the same as previously described. In firing hard coal the spreading system is used almost entirely, as coal of that kind contains very little volatile matter.

In order to prevent smoke a system of firing has been devised known as the alternating method. It consists in alternately adding coal to the front and back of the furnace or to the right and left sides. The object is to burn the volatile gases which are driven off in large volumes when soft coal is heated. By placing fresh coal on one side of the furnace while the other side is partly burned the fresh coal upon being heated discharges large quantities of volatile gases which require a great deal of air for combustion. The air needed for burning the volatile gases is supplied to a great extent by the excess air which comes through the fuel bed on the opposite side of the furnace. As soon as the combustible gases from the charge of fresh coal have been distilled off and burned the opposite side of the grate is fired, with the same result. Instead of firing the sides of the furnace alternately some prefer to alternate in charging the front and back of the furnace. The principle, however, is the same in each case, and it is simply a matter of personal preference. When firing in this manner comparatively small quantities of coal are used at frequent intervals.

The coking method of firing soft coal has for its object the lessening of the smoke nuisance as well as the economical burning of a highly volatile coal. The method consists in shoveling just inside the furnace door a moderate quantity of coal, which is gradually heated, thus distilling off slowly the volatile gases which pass over the fuel bed in the rear and are burned by mixing with the excess air coming through the fuel bed. After the coking process has been completed the mass is broken up and pushed back over the fuel bed, taking care that all holes and thin spots are covered, and a fresh supply of coal added as before. Coke is the solid substance which remains after all the volatile gases have been driven off from coal through the application of heat. When pure it consists almost entirely of carbon and burns without smoke and with very little flame. The frequency of firing by the coking method depends upon the draft and rate at which steam is used, but under ordinary conditions it should be from 10 to 15 minutes. It is believed that this method of firing is the best for creameries, where the fireman has duties to perform in addition to firing the boiler, as the time between firings is somewhat longer than in either the spreading or alternate methods. The fireman should determine for himself how much coal should be fired at a time and the length of time between firings. This can be easily determined by noting the condition of the fuel bed as to holes, the thickness and color of the fuel bed, the quantity of coke required, and the degree of coking for different lengths of time.

AIR LEAKS.

In order to burn fuel economically, all air leaks into the boiler setting must be found and stopped. One way to find the points at which air leaks into a boiler setting is to have the boiler under steam and the fire burning rapidly. When the fuel bed is a glowing heap of coals cover the fire with a layer of fuel and close the dampers tight. The fresh fuel will liberate large quantities of gases which on account of lack of air to burn them will cause smoke. The smoke thus formed will issue from all cracks and openings in the setting and boiler doors, which should be marked for repairs.

Another method is to go over with a lighted candle the outside surface of the setting around the boiler front, flue doors, clean-out doors, and other points where air leaks are liable to occur. Where leaks occur the flame of the candle will be drawn in, due to the inrush of air. In order to make the flame more sensitive, the candle may be placed in a box having both ends open, one end of the box being moved over the surface of the setting.

After finding the leaks the openings should be packed with asbestos rope saturated with fire-clay mortar. The rope should be forced well into the crack and the latter pointed up with the mortar. After all the leaks have been stopped several coats of a good quality of heat-proof paint should be applied to the entire setting. The paint effectually seals all small cracks that may have escaped detection and also prevents the absorption of air through the walls, due to the porosity of the bricks.

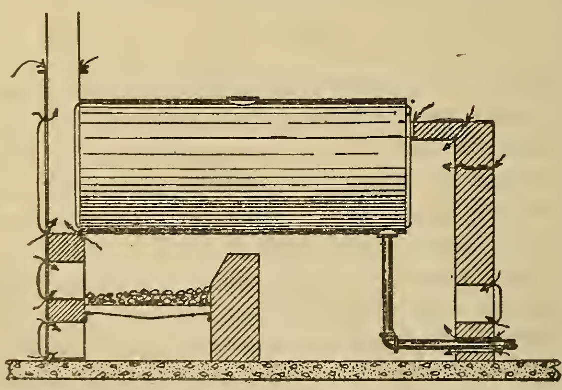

Fig. 6.—Common sources of air leaks in horizontal return-tubular boiler settings.

A large part of the excess air which enters through cracks in the walls of the setting does little or no good in completing the combustion of the fuel. Air entering at the rear of the setting or into the uptake, breeching, or chimney not only has no effect on the combustion of the fuel but cuts down the draft at those points and makes it difficult to get the necessary volume of air through and over the fuel bed. It is very important, therefore, that all parts of the setting, uptakes, breeching, and chimney be made tight.

Figure 6 shows the points where air leaks are most commonly found in a horizontal return-tubular boiler and its setting.

The cast-iron boiler front is a frequent source of air leaks, as it is frequently warped or broken, due to the heat from the furnace, and often it is not placed in position properly, cracks through which the air passes being left between the front and the brickwork. When installed the space between the front and the brickwork should be carefully filled with cement mortar. Should a crack develop after the setting has been in operation it can be stopped easily with asbestos rope and fire-clay mortar, as previously described. When the front is broken it is difficult to repair and when badly broken should be replaced with a new one. Care should be taken to construct the masonry so as not to allow the intense heat of the furnace to be conducted to the cast-iron front.

Fire and ash-pit doors are often badly fitted, warped, or broken, allowing too much cold air to enter the furnace. While it is necessary for air to be admitted at those points, the doors should fit tightly, and the volume of air admitted should be under the control of the fireman.

Flue doors seldom close tight, or if they are capable of being closed tight the fireman often neglects to do so. As the hot gases leaving the tubes impinge directly upon these doors, they are often warped and broken from excessive heat, thus allowing the entrance of air at that point.

With the horizontal return-tubular boiler it is very common to find that the weight of the boiler has caused the settling of the brick arch, thus leaving an opening between the end of the boiler and the top of the brickwork, through which the hot gases from the furnace pass directly to the stack instead of taking the path from the furnace through the combustion chamber and the boiler tubes, resulting in a high stack temperature. This short circuiting of the flue gases causes a large loss of heat in the stack with a corresponding decrease in furnace efficiency.

Almost invariably the opening through the wall of the setting through which the blow-off pipe passes is made larger than necessary, thus allowing cold air to enter the combustion chamber and lower the temperature of the gases and consequently reducing the effective draft. The door and frame of the clean-out door are more often than not found to be cracked or badly fitted. The back arch is forced back, due to the expansion of the boiler, until there is a permanent opening between the end of the boiler and the arch, through which large quantities of air pass directly to the boiler tubes. The back wall of the setting is very often cracked from the expansion of the boiler at the points indicated in figure 5.

While the foregoing are the places in the setting of a horizontal return-tubular boiler where air leaks occur most frequently, there are other points through which outside air finds its way into the furnace and combustion chamber. The side walls of the setting frequently develop cracks, and the entire brickwork is more or less porous and allows air to "soak" through even though there are no visible openings. It is obvious that in order to obtain reasonable economy in a boiler plant the air leaks must be stopped.

BELT-DRIVEN PUMPS.

The ordinary steam-driven pump requires from 100 to 200 pounds of steam per horsepower hour; therefore it is more economical to use a belt-driven pump which can be driven directly from the line shaft. By this means the power for pumping is furnished by the engine, which will develop a horsepower hour on from 40 to 70 pounds of steam, depending on the type of engine, steam pressure, the conditions of its valves, etc. One disadvantage of the belt-driven pump is that it becomes necessary to run the engine when it is desired to pump water into the boiler, but that is not a serious objection, as the engine is usually in operation during the time steam is kept on the boiler and can be easily run for the purpose. The belt-driven pump can be easily adjusted to feed the boiler continuously at just about the rate required. It is usually provided with a tight and loose pulley or some form of clutch so that the pump can be started and stopped at will when the machinery is in operation.

It may be well to state here that in order to pump hot water satisfactorily the pump should be placed always below the source of supply. If this is not done the pump will either fail entirely or operate very unsatisfactorily, depending on the temperature of the water. In pumping cold water there is an atmospheric pressure of 14.7 pounds per square inch on the surface of the water, which will support a column of water approximately 30 feet high. Allowing for frictional resistance in the suction pipe and valves, if the pump is within 20 feet above the supply it will operate satisfactorily, provided the piston speed of the pump is not too great to allow the water to follow the piston. The vapor pressure of water at 50° F. is only about one-quarter of a pound per square inch, and therefore is negligible as compared with atmospheric pressure. With water at 212° F. the vapor pressure is just 14.7 pounds per square inch, or just equal to the atmospheric pressure, and if we try to lift water at that temperature by suction the body of water will not rise at all, but the steam vapor will rise from the surface of the water and follow the piston. With water at 200° F. there will be about 3.3 pounds' pressure by the atmosphere in excess of the vapor pressure, which is sufficient to raise the water approximately 7.9 feet, but with no excess pressure to overcome the frictional resistance of the pipe and to lift the valves, to say nothing of giving velocity to the water. The pump, therefore, should be placed at least 3 feet below the supply when pumping hot water in order to have head enough to force it through the supply pipe at the required velocity and to lift the valves in the pump chamber. The pump should be placed near the water supply, and the supply pipe should be as straight and free from bends as possible. The springs of the pump valves should be made as light as practicable in order to insure proper operation.

If, however, the pump is at such a distance from the supply tank, or the supply pipe has so many abrupt bends that the head of 3 feet is not sufficient to force the required quantity of water through the supply pipe close to the pump, the standpipe may be vented to the air or back to the top of the supply tank. In either case the benefit of the full head will be obtained at the pump. To pump hot water successfully it is necessary to keep a solid body of water at all times against the pump plunger, otherwise the pump will not operate successfully. The packing for a pump required to pump hot water, of course, should be adapted to the temperature it will have to withstand.

STEAM LEAKS.

But few realize the enormous indirect fuel loss caused by leaks in the piping system. A single leak in itself does not appear to be serious, but a number of leaks around valve stems, blow-off cocks, pipe flanges and unions, safety valves, and at other points throughout the system will reduce the available horsepower of the boiler very greatly and indirectly increase the quantity of fuel burned. For instance, if the sum of the openings through which steam escapes to the atmosphere should equal one hundredth (0.01) of a square inch and the steam pressure in the piping is 75 pounds' gauge, or 89.7 absolute, the amount of steam that will escape in one hour will be approximately: $\frac{89.7\times0.01}{70}\times60\times60=46$ pounds, or 1.3 boiler horsepower. Should these leaks continue to exist and the plant be operated 10 hours a day for 310 days in a year, the annual loss in steam would be $46\times10\times310=142{,}600$ pounds. This would require the burning of 21,283 pounds, or 10.6 short tons, of average coal to produce the amount of steam mentioned, if we assume a boiler and furnace efficiency of 50 per cent, which is greater than is found in most creameries and milk plants. If the coal costs $5 a ton the money loss will amount to $53 annually, to say nothing of the inconvenience, unsightly appearance, and deterioration of valves and fittings due to the escaping steam. It is obvious therefore that all leaks should be stopped as soon as they appear.

HEAT LOSSES FROM BARE PIPE.

But few creamerymen insulate their steam piping. They are either not aware or are negligent of the serious loss in heat that goes on continuously when pipes or apparatus carrying steam are left bare. A square foot of bare piping inside a building will radiate about 3 B. t. u.[1] per hour for each degree difference in temperature between

[1] B. t. u.=British thermal unit, the amount of heat required to raise 1 pound of pure water 1 degree Fahrenheit.

the inside and outside of pipe. Suppose there is an equivalent of 50 square feet of steam piping in the average creamery and the steam pressure carried in the piping is 70 pounds' gauge, and the average room temperature is 70° F. (The temperature of the steam inside the pipe when at a pressure of 70 pounds' gauge is 316° F.); then the loss per hour is $50\times3(316-70)=36,900$ B. t. u. If the plant is operated 8 hours a day for 300 days in a year the loss will be $36,900\times8\times300=88,560,000$ B. t. u. With a boiler and furnace efficiency of 50 per cent and coal containing 12,500 B. t. u. per pound it would require the burning of $\frac{88,560,000}{12,500\times.50}=14,009$ pounds, or about 7 short tons, which at $5 a ton would amount to $35 annually. Good insulation will reduce this loss about 85 per cent, in which case the loss would be only $5.25, which would mean an annual saving of $29.75. The cost of the insulation put on the pipes should not exceed 50 cents a square foot, making the cost of insulating the piping $50\times.50=\$25$. The insulation, therefore, will more than pay for itself through the saving of fuel in one year.

SELECTION OF POWER.

The accepted boiler horsepower is the evaporating of 34.5 pounds of water an hour from a feed-water temperature of 212° F. into steam at the same temperature, corresponding to atmospheric pressure. This is equivalent to the absorption of $34.5\times970.4=33,478.8$ B. t. u. There is, therefore, no direct connection between the horsepower rating of a boiler and that of a steam engine or other steam-driven machine. For instance, the latest and most improved triple-expansion engines condensing with high-pressure steam have produced a horsepower hour on about 9 pounds of steam, whereas the ordinary small slide-valve engine commonly employed in the smaller dairy establishments will use anywhere from 40 to 80 pounds of steam per horsepower hour. One boiler horsepower when used in connection with the most improved engines will furnish sufficient steam to produce nearly four horsepower hours, but if used in the smaller engines may produce only about one-half of a horsepower hour. Consequently, in estimating the size of boiler necessary the steam consumption of the engine and auxiliaries must be taken into consideration. For example, a 12-horsepower engine of the type generally used in the smaller creameries requires at full load about 60 pounds of steam per horsepower per hour at a gauge pressure of 70 pounds, or $12\times60=720$ pounds. The horsepower capacity of the boiler to supply steam will be $\frac{720}{34.5}=20.8$. But this is assuming that the feed water is fed to the boiler at a temperature of 212° F., or at the boiling point, and that steam is generated at atmospheric pressure. If the water is fed to the boiler at a temperature other than 212° F., or if steam is generated at a pressure other than atmospheric, it is obvious that a correction factor must be employed in order to reduce the results to an equivalent evaporation from and at 212° F. This factor is known as the "factor of evaporation." The heat actually required to evaporate a pound of water into steam is the total heat at the boiler pressure less the sensible heat at feed-water temperature. Since 970.4 B. t. u. are required to evaporate a pound of water from a temperature of 212° F. into steam at atmospheric pressure the factor of evaporation is $F=\frac{Th-Sh}{970.4}$, in which Th is the total heat in steam at boiler pressure and Sh the sensible heat in the feed water.

If the boiler feed water is at a temperature of 60° F. and steam is generated in the boiler at a gauge pressure of 70 pounds, the factor of evaporation, $F=\frac{1183.3-28.08}{970.4}=1.191$. Therefore, if the 720 pounds of steam required per hour by the 12-horsepower engine were generated from a feed-water temperature of 60° F. into steam at 70 pounds' gauge pressure, the equivalent evaporation from and at 212° F. would be $720\times1.191=857.5$ pounds and the boiler capacity would be $\frac{875.5}{34.5}=24.8$ boiler horsepower.

With a pasteurizer efficiency of 80 per cent it requires 382,500 B. t. u. to heat 4,000 pounds of milk from 60° F. to a final temperature of 145° F. If the heating is done in 30 minutes by using live steam directly from the boiler, it will require $\frac{382.500}{33,479}\times2=22.8$ boiler horsepower. This added to the boiler horsepower required for furnishing steam to the engine makes the total capacity of the boiler, $24.8+22.8=47.6$ horsepower. In practice about 25 horsepower is used and it is forced during pasteurization. Before beginning to pasteurize a full head of water is fed to the boiler and the fires crowded. As pasteurization proceeds the water level in the boiler falls until at the end of the operation the water level has fallen perhaps to the bottom of the gauge. This method of operation puts a severe strain on the boiler and is attended with more or less danger.

On the other hand, if the heat in the exhaust steam is used for pasteurizing, the necessity of forcing the boiler during pasteurization is avoided, for there are $720\times800=576,000$ B. t. u. per hour, or 288,000 B. t. u. per half hour available in the exhaust steam. By storing this heat in a specially designed tank it becomes unnecessary to draw live steam from the boiler and the boiler capacity can be reduced practically one-half with a corresponding reduction in fuel, to say nothing of the lessened strain placed on the boiler through forcing and the extra labor required in firing. By feeding the boiler with water heated by exhaust steam, expansion and contraction strains are greatly lessened, the fuel consumption is reduced as well as the work of firing, and the capacity of the boiler is increased in proportion to the temperature to which the feed water is heated. Where there is use for the heat in the exhaust steam from the engine, pumps, and other steam-driven machinery the power developed becomes a by-product of the heating system, and hence costs but little. In a milk plant or creamery in which pasteurization is practiced steam power is, generally speaking, the cheapest, for it is necessary to provide a boiler to furnish steam for the pasteurizing and as there is about 85 per cent of the heat in live steam at 70 pounds' gauge pressure remaining in the exhaust steam from the engine, it is economy to use the steam first in the engine to produce the required power for operating the machinery and then for the purpose of pasteurizing, heating water, and heating the building.

The size of boiler will be approximately the same whether it is used for pasteurizing only or for furnishing steam first to the engine and then employing the exhaust steam in the pasteurizer. Especially is this true if the engine is operated only a few hours daily, as it is necessary to raise steam for pasteurizing and after the boiler is once fired up but little additional fuel is required to furnish steam for power purposes for, say, three or four hours.

There are certain conditions, however, in which it is more economical to install a boiler for heating and a gas engine or electric motor for power. For instance, in nonpasteurizing plants where only a comparatively small quantity of heat is required for heating the wash water, a small boiler may be used for generating low-pressure steam for heating, and a gas engine or electric motor for running the machinery. The advantages in employing a gas engine or electric motor are that it is ready for instant use and that power costs cease with the stopping of the machine. With a steam-engine, however, time is required to raise steam in the boiler and firing must be continued while the engine is in use. Furthermore, it requires about 10 pounds of coal per horsepower capacity of the boiler for raising steam. That is, a 20-horsepower boiler requires about 200 pounds of coal for heating the walls of the setting and raising steam to a pressure of 70 pounds' gauge pressure. In some cases the apparatus requiring power is operated intermittently throughout the day, in which case it may not be advisable to use a steam engine, as a greater economy may be obtained by using a gas engine or an electric motor that can be put into or out of service as required.

The relative cost of coal, gasoline, or electricity delivered at the factory must also be taken into account in selecting the kind of power best suited for any particular plant. In some cases the factory is a considerable distance from the railroad, and the inconvenience and expense of getting coal to the plant may be such as to prohibit the use of a steam engine. In other cases the cost of electricity may be so small as to make its use profitable. By utilizing the heat in the jacket water and exhaust gases of internal-combustion engines it is possible in some plants to produce the necessary quantity of hot water for heating, or the heat may be used to supplement that of a steam boiler, thus reducing the size of the boiler. A typical arrangement of such an equipment is illustrated in figure 9. In short, there is such a wide variation in the operating conditions of creameries throughout the country that it is impracticable to state in general just which form of power is the most economical, as each case requires a special study.

UTILIZING THE EXHAUST STEAM.

It should be the aim of any one in charge of a steam plant to utilize as much of the heat energy contained in the fuel as practicable, and there are few classes of steam plants that offer more varied opportunities for the utilization of exhaust steam from the engine, pumps, and other steam-driven machinery than those used in the dairy industry. In plants in which steam is generated for power purposes only, even with the best possible apparatus and arrangement, only a small portion of the heat in the coal is utilized. In the dairy industry, however, where much low-temperature heating is required which can be accomplished through the use of exhaust steam, even the smallest plants with little or no extra expense can be made much more efficient than the most modern steam plant when used only for the generation of power. There are dairy plants, however, that are taking advantage of their opportunities to use the heat available in the exhaust steam.

In the dairy industry large quantities of hot water are required for washing apparatus and utensils, pasteurizing, boiler feed water, and other purposes around the plant. The heating is done at present for the most part by live steam from the boiler, whereas the large amount of exhaust steam going to waste might be used for the purpose.

Exhaust steam at atmospheric pressure contains between 85 and 90 per cent of the heat of the live steam at 70 pounds' gauge pressure.

Consequently, if used for heating below the temperature of 212° F. exhaust steam is practically as good as live steam. As the exhaust steam when not used for heating is entirely lost, it is obvious that by its use the efficiency of the plant will be greatly increased.

Allowing for radiation from pipes, pasteurizers, hot-water tanks, etc., it is safe to assume that 800 B. t. u. are available for useful heating in each pound of exhaust steam.

The exhaust steam available from the engine, pumps, and other steam-driven equipment in milk plants, creameries, and dairies is, in general, not quite sufficient to take care of the maximum heating load which comes when pasteurizing is being done. But as the engine and pumps are operated for some time before pasteurization commences, it is perfectly feasible to store up the heat contained in the exhaust steam and draw on it when needed.

Pasteurization is now done almost entirely by the use of hot water, the water being heated either in the jacket space included in the construction of the pasteurizer or in a separate tank heater designed for the purpose and pumped from the heater through the pasteurizer and back into the heater.

The ordinary feed-water heater found on the market is not suited for use in milk plants except when it is used for heating the boiler feed water only, as it has little or no storage capacity and the heating surface is entirely inadequate. As hot water in dairy plants is used intermittently it becomes necessary to provide a large storage capacity in order to have a large quantity ready without delay when needed. Storage heaters especially designed for creameries and milk plants can be obtained from a number of manufacturers.

In designing water heating and storage tanks for use in the dairy industry the size should be based on the quantity and temperature of the water required or on the quantity of exhaust steam available for heating. In other words, the heat-transmitting surface should be proportioned so that approximately all the heat available in the exhaust steam will be transmitted to the water, provided, of course, there is use for the hot water.

Table 4 gives the capacity of water heating and storage tanks for different-sized creameries, with the amount of heating surface necessary to heat the water in each instance by exhaust steam at atmospheric pressure and temperature, from an initial temperature of 50° F. to a final temperature of 200° F. in one hour. The heating surface is supposed to be made up of steel or brass pipe.

TABLE 4. *Capacities of storage heaters for different-sized creameries, and the amount of coil surface necessary with brass and iron pipe, respectively, to heat water from 50° to 200° F., in one hour with steam at a temperature of 212° F.*

BRASS PIPE.

Annual capacity of creamery.	Size of heater.			Coil surface.	Piping.				
	Diameter.	Length.	Capacity.		1¼-inch.	1½-inch.	2-inch.	2½-inch.	3-inch.
Pounds of butter:	*Inches.*	*Inches.*	*Gallons.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
100,000 to 150,000	30	72	220	24	55	48	38	32	26
150,000 to 200,000	36	72	315	34	78	68	54	45	37
200,000 to 300,000	36	96	420	45	104	90	72	60	50
300,000 to 400,000	42	96	575	60	138	120	96	80	66
400,000 to 600,000	48	96	750	81	186	162	129	108	89

IRON PIPE.

Pounds of butter:									
100,000 to 150,000	30	72	220	40	92	80	64	53	44
150,000 to 200,000	36	72	315	58	133	116	93	77	64
200,000 to 300,000	36	96	420	76	175	152	122	101	84
300,000 to 400,000	42	96	575	105	242	210	168	140	116
400,000 to 600,000	48	96	750	137	315	274	219	182	150

It is estimated by a number of creameries which have recently installed a water heating and storage tank similar to those shown in figures 7 and 8 that a saving in fuel of from 15 to 25 per cent has been effected, and it is believed that in most cases an even greater saving in fuel can be made if sufficient care and attention are given

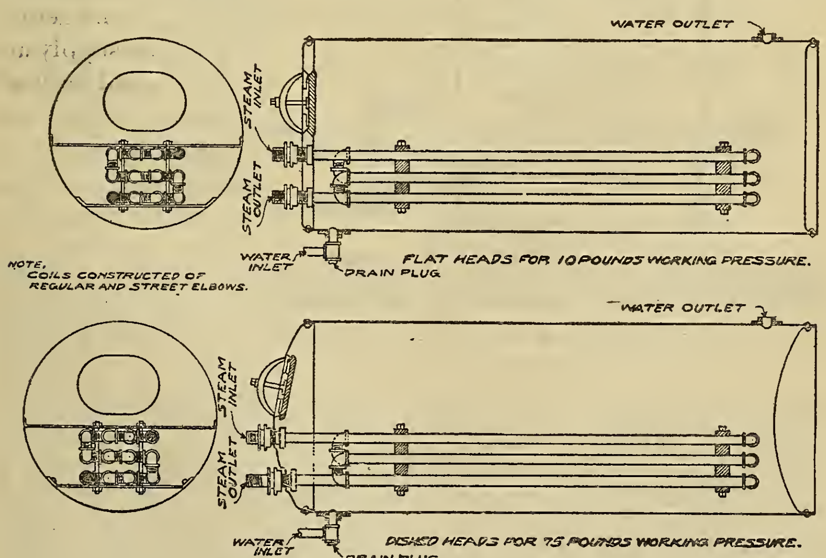

FIG. 7.—Horizontal exhaust-steam water heater and storage tank.

to the utilization of all the heat in the exhaust steam, or as much as can be used profitably in the factory.

The importance of effectively insulating hot-water tanks and piping is not appreciated by most dairymen. A good quality of heat insulation properly installed will pay for itself in fuel saved in from six months to a year. Not only will the insulation prove to be a good investment from the standpoint of fuel saved, but it will maintain the water at higher temperature, thus preventing the possibility of the water freezing over night and bursting the tank.

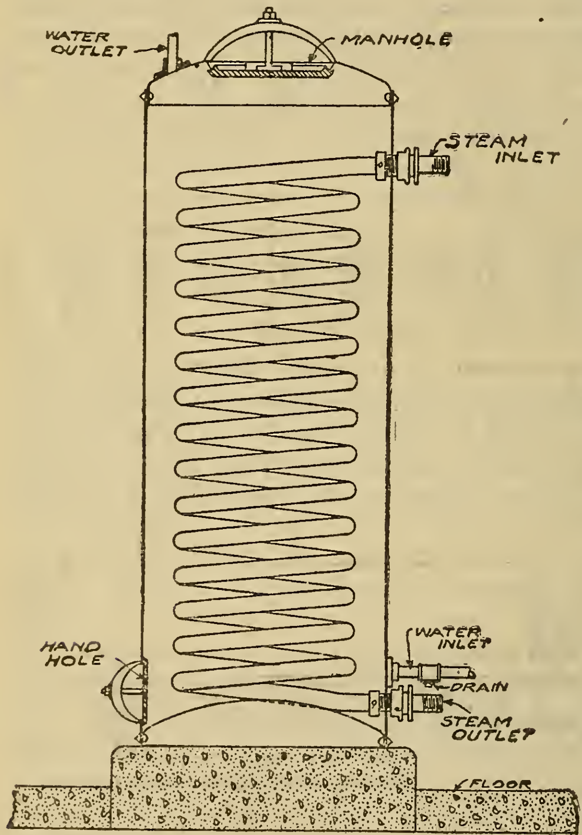

FIG. 8.—Vertical exhaust-steam water heater and storage tank.

The water-heating and storage tank should be placed in the boiler or engine room, where the temperature of the surrounding air will assist in maintaining a high temperature inside the tank. The tank should be used for a general supply of hot water for all purposes around the creamery, such as boiler feed, wash water, pasteurizing, etc. When practicable it is advisable to place the tank high enough to allow the hot water to flow by gravity for washing floors, utensils, etc., but for pasteurizing it is necessary to install a circulating pump in the pipe line, preferably in the return line between the pasteurizer and the tank, so that a forced circulation of hot water will be maintained. It is also necessary to provide a boiler-feed pump, designed for handling hot water, as an injector will not handle satisfactorily water of high temperature.

SAVING IN FUEL THROUGH HEATING BOILER-FEED WATER BY EXHAUST STEAM.

It is the common practice in creameries to feed the boiler with low-temperature water; that is, water of the temperature at which it comes from the well or other source of supply. The temperature is generally about 60° F., and in some instances, as when the water is drawn from a stream or from a storage tank, it is near the freezing point. The contraction strains which are set up in the boiler plates and seams, due to feeding cold water, are enormous and are liable to weaken the plates and open up the riveted joints. In addition to causing deterioration in the boiler itself, the feeding of cold water in large quantities reduces the temperature and consequent pressure inside the boiler and makes it difficult if not impossible to keep a

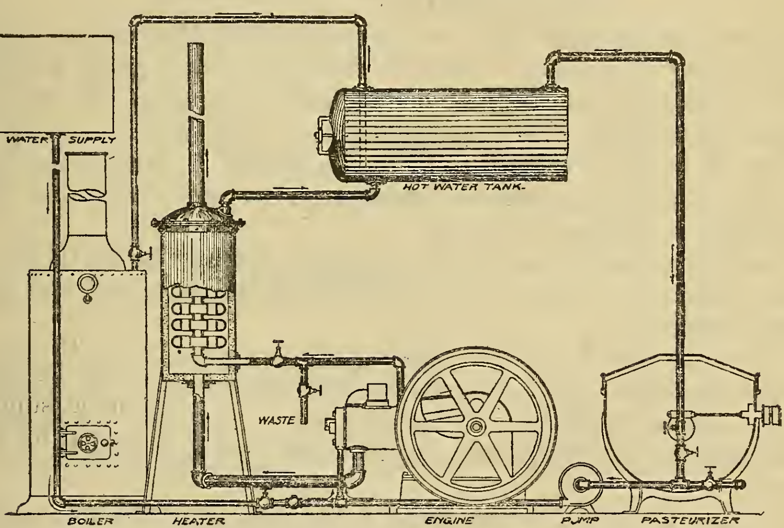

FIG. 9.—General arrangement for utilizing heat in exhaust gases and jacket water from internal-combustion engine.

uniform pressure. It also reduces the output of the boiler, for it is obvious that the boiler must furnish the heat required to raise the temperature of the feed water from its initial temperature to that corresponding to the steam pressure carried in the boiler.

It is advantageous to "preheat" the boiler-feed water, even though it is necessary to take live steam direct from the boiler to accomplish it, for by so doing the life of the boiler is prolonged, its output is increased, and there is a direct fuel saving due to the more even temperature maintained in the boiler. But by utilizing the heat in the exhaust steam which is otherwise wasted, not only are the contraction and expansion strains avoided to a great extent but there is a saving in fuel and the boiler output is materially increased.

The possible saving in fuel due to the "preheating" of the boiler-feed water may be readily found by the use of the following formula:

$$\text{Per cent of saving} = \frac{(T-t)}{(H-t)} \times 100$$

where T=B. t. u. in water above 32° F. after passing through heater.
t=B. t. u. in water above 32° F. before passing through heater.
H=B. t. u. in steam above 32° F. at boiler pressure.

As an illustration of the formula shown above, suppose the steam pressure in the boiler is 70 pounds' gauge and the initial temperature of the feed water is 60° F. If the water is heated to 200° F. by exhaust steam before entering the boiler, the per cent of saving in fuel will be

$$\frac{(167.94-28.08)}{(1,183.3-28.08)} \times 100 = 12.11 \text{ per cent.}$$

The maximum gain that can be realized by using exhaust steam for heating feed water in an open heater is, with a gauge pressure of 70 pounds per square inch on the boiler, approximately 15.2 per cent, this being the case when taking water at an initial temperature of 32° F. and delivering it to the boiler at 212° F., the highest temperature that it is possible to heat water at sea level in an open vessel under atmospheric pressure.

Table 5 gives the per cent of saving in fuel by "preheating" the boiler feed water from various initial temperatures to different final temperatures.

For every 11° F. that the feed water is heated before entering the boiler approximately 1 per cent less fuel is required to generate the same amount of steam, and for each 11° F. increase in feed-water temperature, the boiler capacity is increased approximately 1 per cent.

Besides the direct saving in fuel due to heating the feed water, the injurious effects of unequal expansion in the boiler, caused by having feed water at a low temperature, are diminished, and the life of the boiler is prolonged. It is easier also to keep a constant pressure on the boiler. There will be a further gain because of the smaller quantity of fuel consumed, due to the even firing, for when a fire is crowded to take care of a temporary overload a considerable amount of heat in the coal is lost by admitting an excess of air into the furnace and by a portion of the combustible matter being carried up the stack unconsumed.

To reduce the per cent of saving in fuel, as shown in Table 5, to their equivalents in dollars and cents, let us assume that the boiler has a capacity of 40 horsepower and that it is operated 8 hours a day for 310 days in the year. With a combined boiler and furnace efficiency of 50 per cent, about 6½ pounds of coal per boiler horsepower hour will be consumed, or 2,080 pounds per day of 8 hours, when the feed water is admitted to the boiler at 40° F. If the feed water,

TABLE 5.—*Per cent of saving in fuel by heating feed water. Steam at 70 pounds' pressure.*

Initial temperature of feed water.	Temperature to which feed water is heated.														
	100° F.	110° F.	120° F.	130° F.	140° F.	150° F.	160° F.	170° F.	180° F.	190° F.	200° F.	210° F.	220° F.	250° F.	300° F.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
35° F.	5.50	6.35	7.19	8.04	8.89	9.73	10.57	11.42	12.28	13.13	13.97	14.83	15.68	18.26	22.59
40° F.	5.10	5.95	6.80	7.65	8.49	9.34	10.20	11.05	11.90	12.75	13.61	14.46	15.32	17.91	22.26
45° F.	4.69	5.54	6.40	7.25	8.11	8.96	9.81	10.67	11.52	12.38	13.24	14.10	14.96	17.56	21.93
50° F.	4.28	5.14	5.99	6.85	7.71	8.57	8.42	10.28	11.14	12.00	12.86	13.73	14.59	17.21	21.59
55° F.	3.87	4.73	5.59	6.45	7.38	8.17	9.03	9.90	10.76	11.62	12.49	13.35	14.22	16.85	21.25
60° F.	3.45	4.31	5.18	6.04	6.91	7.77	8.64	9.51	10.37	11.24	12.11	12.97	13.85	16.49	20.91
65° F.	3.03	3.90	4.77	5.64	6.50	7.37	8.24	9.11	9.98	10.86	11.73	12.60	13.48	16.12	20.57
70° F.	2.60	3.48	4.35	5.23	6.10	6.97	7.84	8.72	9.57	10.46	11.35	12.22	13.10	15.76	20.22
75° F.	2.18	3.06	3.94	4.82	5.69	6.56	7.44	8.32	9.19	10.08	10.96	11.83	12.72	15.39	19.87
80° F.	1.76	2.64	3.51	4.39	5.27	6.15	7.03	7.91	8.80	9.68	10.56	11.45	12.34	15.02	19.52
85° F.	1.32	2.21	3.09	3.97	4.85	5.74	6.62	7.51	8.39	9.28	10.17	11.06	11.95	14.64	19.17
90° F.	.88	1.77	2.66	3.55	4.43	5.32	6.21	7.10	7.99	8.88	9.77	10.67	11.56	14.26	18.81
95° F.	.44	1.34	2.23	3.12	4.01	4.90	5.79	6.68	7.58	8.47	9.37	10.27	11.17	13.89	18.45
100° F.	.00	.89	1.79	2.68	3.58	4.47	5.37	6.27	7.17	8.06	8.97	9.87	10.77	13.50	18.08

however, is admitted to the boiler at 200° F., there would be a saving of 13.61 per cent—that is, the quantity of coal consumed per day would be reduced to 1,797 pounds. The saving in coal would be therefore 283 pounds a day, or 43.86 tons a year. If the coal cost $5 a ton delivered in the bunkers, the annual saving in fuel would be

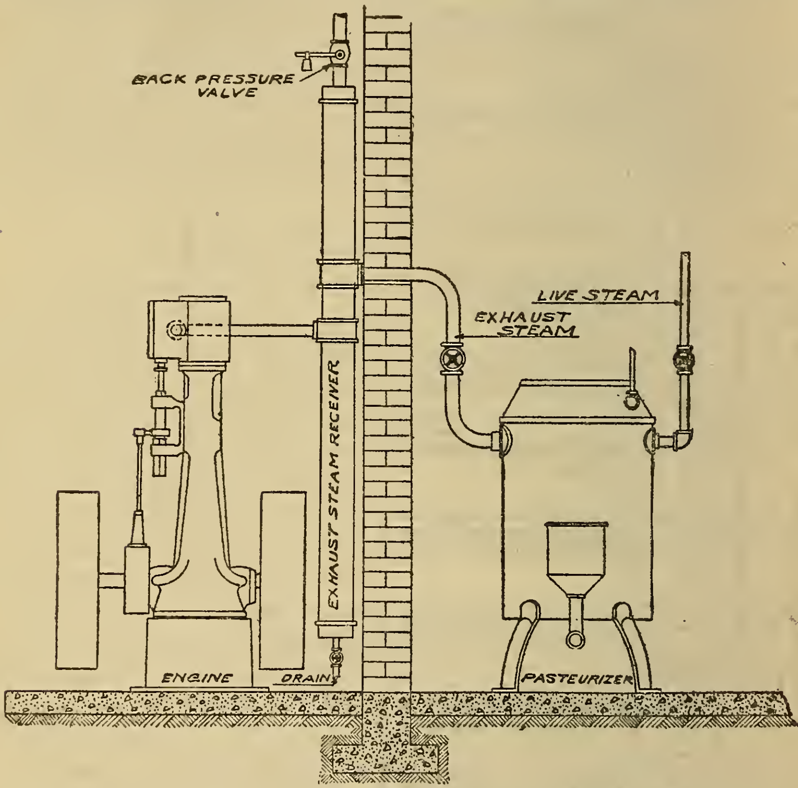

FIG. 10.—Connections for using exhaust steam in continuous pasteurizer.

$219.30. Table 6 shows the sums annually saved under various conditions of feed-water temperature and cost of coal:

TABLE 6.—*Amounts annually saved by heating feed water to 200° F. from various initial temperatures with coal at stated prices per ton. (Assuming a 40-horsepower boiler working 310 days of 8 hours and 6.5 pounds of coal burned per horsepower hour.)*

Cost of coal per ton (2,000 pounds) in bunker.	Initial temperature of feed water.							
	40° F.	60° F.	80° F.	100° F.	120° F.	140° F.	160° F.	180° F.
$2	$87.72	$78.12	$68.00	$54.70	$47.40	$36.10	$24.60	$12.24
$2.50	109.65	97.65	85.00	68.37	59.25	45.12	30.75	15.30
$3	131.58	11.18	102.00	82.05	71.10	54.15	36.90	18.36
$3.50	153.51	136.71	119.00	95.73	82.95	63.17	43.05	21.42
$4	175.44	156.24	136.00	109.40	94.80	72.20	49.20	24.48
$4.50	197.37	175.77	153.00	123.07	106.65	81.22	55.35	27.54
$5	219.30	195.30	170.00	136.75	118.50	90.25	61.50	30.60
$5.50	241.23	214.83	187.00	150.42	130.35	99.27	67.65	33.66
$6	263.16	234.36	204.00	164.10	142.20	108.30	73.80	36.72
$6.50	285.09	253.89	221.00	177.77	154.05	117.72	79.95	39.78
$7	307.02	273.42	238.00	191.45	165.90	126.35	86.10	42.84

Figures 10 and 11 illustrate methods of utilizing the exhaust steam in a continuous and in a vat pasteurizer, respectively. Figure 12 shows certain arrangements of machinery, not all intended for use at the same time, but rather to illustrate the general principles involved in utilizing the heat in the exhaust steam; they are easily adapted to almost any ordinary condition which is liable to occur in the average creamery. All pipes and devices necessary or desirable for utilizing the heat in the exhaust steam are shown shaded in order to distinguish them more readily from the other piping and apparatus. The exhaust steam from all steam-driven machines is piped into a common exhaust pipe. This pipe just before entering the ex-

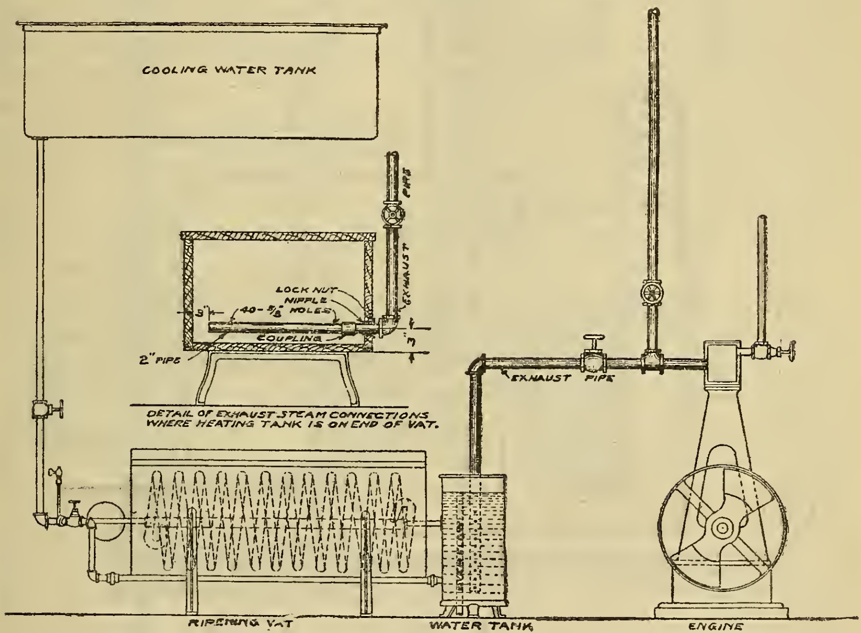

FIG. 11.—Connections for using exhaust steam in batch pasteurizer.

haust receiver is provided with an oil separator for the elimination of any oil that may be in the exhaust steam from the various machines. By having the exhaust from all steam-driven units exhaust into a common exhaust main, only one oil separator is necessary.

The object of the exhaust receiver is to prevent fluctuation in the back pressure of the different machines, as would be the case if they were allowed to exhaust directly into the smaller pipes. From the exhaust receiver the steam is piped under practically a steady pressure to the different creamery machines requiring heat. The receiver is fitted with a back-pressure valve so that in case the pressure in the system should build up above that at which the valve is set it will open and allow the excess steam to flow to the atmosphere. On the other hand should the supply of exhaust steam be insufficient for the requirements of the creamery live steam is taken from the boiler

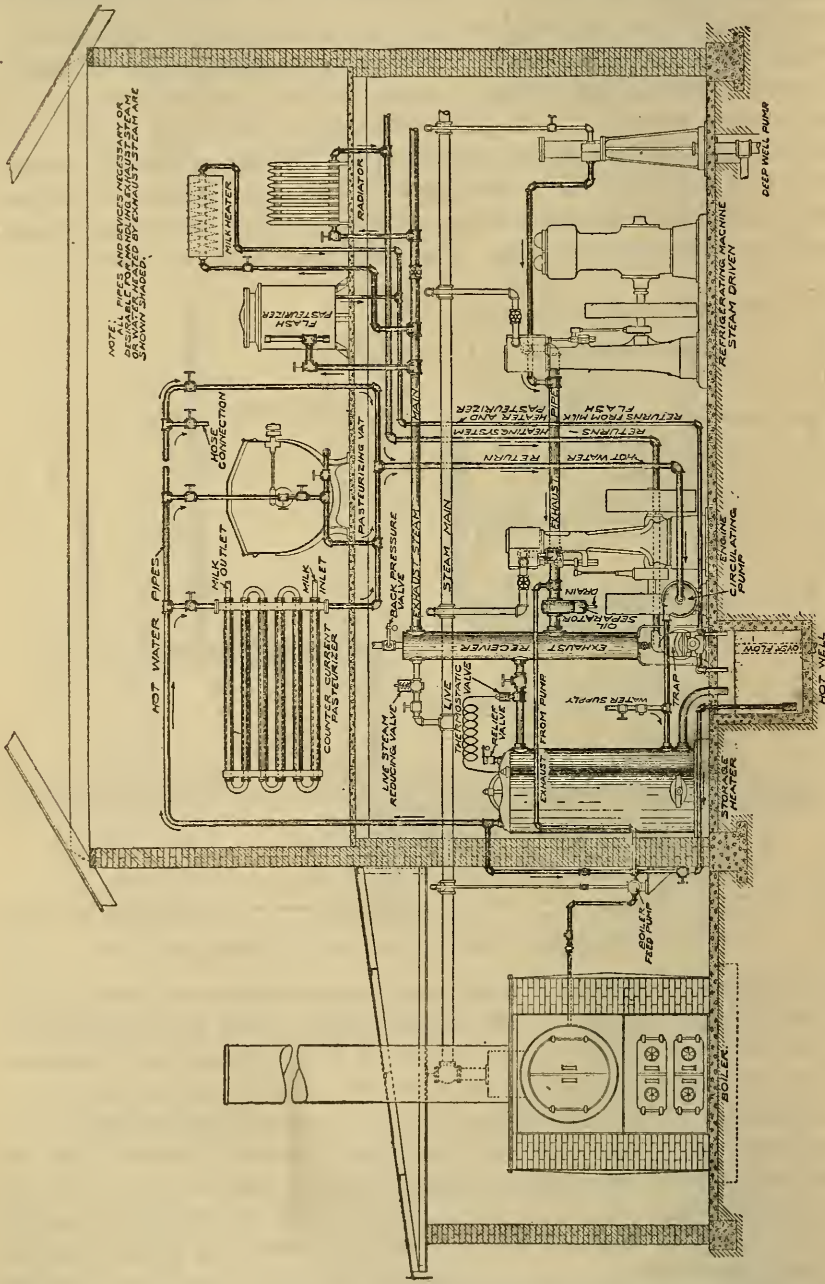

FIG. 12.—Diagrammatic arrangement for utilizing exhaust steam in creameries.

through a reducing valve to make up the shortage, thus insuring automatically a constant pressure in the system at all times. Should the engine and other steam-driven units be shut down the reducing valve will open up and supply the full amount of steam required and at the pressure desired.

In figure 12 there are shown, connected to the exhaust-steam main, a flash pasteurizer, a milk heater, and one radiator of the heating system. The steam pressure on these units is maintained constant automatically by the use of the back pressure and reducing valves as previously explained. The steam is delivered under water in the jacketed space surrounding the pasteurizer and is all condensed. The steam delivered to the disk milk heater is also condensed in the heater. The condensation from these two units is piped direct to the hot well, from which it is pumped by the boiler-feed pump to the boiler, thus utilizing a large portion of the heat in the water. The condensation is returned to a low-pressure steam trap, which also discharges to the hot well. The boiler-feed pump, however, should be placed within about 3 feet of the surface of the water in the hot well in order to handle the hot water satisfactorily. The temperature of the water in the hot well will be cooled down to a point at which the pump will handle it satisfactorily if placed 3 feet above its surface.

The storage-water heater is connected to the exhaust receiver, as shown. A stop valve is placed in the pipe connecting the two so that the supply of exhaust steam may be entirely cut off if desired. Just after the stop valve a thermostatic valve is placed in the pipe supplying steam to the heater. The function of this valve is to maintain automatically a fixed temperature of the water in the heater. If the temperature of the water in the heater falls through supplying cold water the thermostatic valve will open and admit steam to the heater coils; if on the other hand the temperature of the water rises to the point at which the thermostatic valve is set it will immediately cut off the steam supply. The capacity of the storage heater should be sufficient to keep on hand a large volume of hot water ready for instant use. A large volume of water also has the advantage of allowing the heat in the exhaust steam to be stored at a time when but little or no use is being made of it. The boiler-feed pump is so connected that it can draw from either the hot well or the storage heater as desired.

In many creameries it is desirable to pasteurize milk and cream by the use of hot water instead of steam. Piping connections from the storage heater to a counter-current heater and pasteurizing vat are shown in the diagram, as well as hose connection for drawing off hot water for washing purposes. A circulating pump is shown connected to the pipe line in order to force the hot water through the system at a high velocity. When not using hot water for pasteurizing the circulating pump may be stopped. As the hot-water piping system is a closed one a circulation will be maintained due to the difference in temperature of the water in the heater and that in the piping, thus making it possible at any time to draw off hot water through the hose connections. The clearance through the pump is sufficient to allow the water to pass through when the pump is not in operation. The water supply required to make up for that used in feeding the boiler for washing and for leakage is to be furnished from a pressure system, either from the city supply lines or from an overhead tank. The connection should be made through a check and stop valve, as shown. Stop valves are shown at the different units for controlling the supply of steam or hot water.

DISTRIBUTION OF HEAT ENERGY FROM COMBUSTION OF COAL.

Table 7 shows the distribution of the heat energy obtained from the combustion of the coal in the boiler furnace in an average gath-

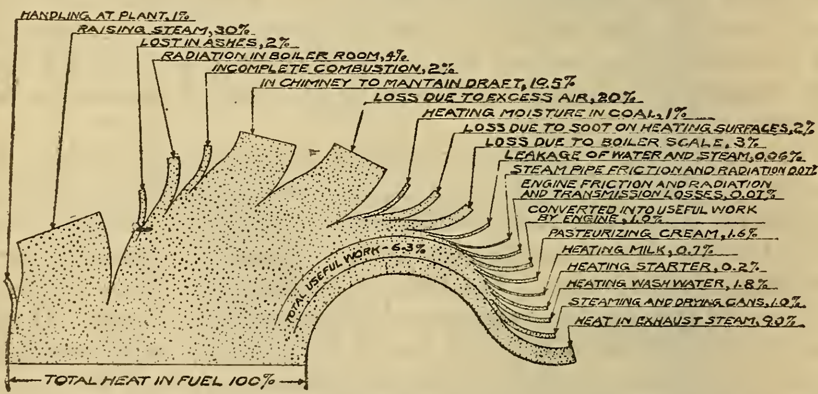

FIG. 13.—Graphic illustration of the distribution of heat energy between the coal pile and machinery in an average creamery making 500,000 pounds of butter annually from pasteurized cream, live steam being used for all purposes.

ered-cream plant making approximately 500,000 pounds of butter annually. The results are illustrated graphically in figure 13. The figures are based on actual tests and on careful estimates. The type of creamery selected is one in which all heating is done by live steam direct from the boiler. The distribution of heat energy covers a full day's operation, starting with raising steam in the boiler and ending when the fire in the furnace is burned out.

By studying the following table of the heat losses it will be noted that many items are excessive and can either be eliminated entirely or be greatly reduced. The loss of coal at the plant is one that can be entirely eliminated by exercising care in handling. It is often the case that the coal is stored some distance from the boiler room, necessitating its transfer from the bunker to the boiler by means of a wheelbarrow or a specially designed coal truck. The barrow or truck is often overloaded and the coal falls off and is trampled into the dirt. This loss is one due entirely to slovenliness or carelessness, and not only results in a direct loss of coal but causes the plant to present an untidy and unkempt appearance. A little care and the use of a broom will eliminate this loss and also improve the appearance of the plant.

TABLE 7.—*Distribution of heat energy between the coal pile and machinery in an average creamery making 500,000 pounds of butter annually from pasteurized cream, live steam being used for all purposes.*

Total B. t. u. in coal 1,000×13,500,000=100 per cent.

	B. t. u.	Per cent.
Heat distribution in boiler room:		
Lost in handling at plant	135,000	1.00
Lost in raising steam	4,050,000	30.00
Lost in ashes	270,000	2.00
Lost by radiation in boiler room	540,000	4.00
Lost by incomplete combustion	270,000	2.00
Lost in chimney to maintain draft	2,632,500	19.50
Lost due to excess air driven through grates and leaks in boiler setting	2,700,000	20.00
Lost through heating moisture in coal	135,000	1.00
Lost due to soot on heating surfaces	270,000	2.00
Lost due to scale in boiler	405,000	3.00
Lost due to leakage of water and steam	8,100	.06
Heat distribution in engine room:		
Lost due to friction and radiation from steam pipes	9,450	.07
Lost due to engine friction, radiation, etc., and loss in transmission from engine to machinery	9,450	.07
Amount consumed in engine as useful work	135,000	1.00
Amount used in pasteurizing cream	216,000	1.60
Heating milk for separating	94,500	.70
Heating starter milk	27,000	.20
Heating wash water	243,000	1.80
Steaming and drying cans	135,000	1.00
Lost in exhaust steam	1,215,000	9.00
	13,500,000	100.00

In the great majority of creameries the boilers are kept fired only a few hours a day, the fires being allowed to burn out entirely or just fire enough maintained to keep the boiler warm overnight. It is necessary, therefore, to build a fire in the furnace each morning. The average boiler requires about 10 pounds of coal per horsepower capacity of boiler for heating up the boiler and the brickwork of the setting and for raising steam. A large portion of this heat which is stored in the brickwork of the setting, in the boiler shell, and in the water contained in the boiler is dissipated over night and must be supplied again the next morning. On account of the comparatively short time the boiler is operated each day this loss is one of the largest and one that can be reduced only slightly by careful firing and by stopping all air leaks in the setting, firing doors, doorframes, and other places. Even in the case of a well constructed and maintained boiler setting, 10 pounds of coal per horsepower capacity of boiler will be required for raising steam. With poorly constructed and maintained settings this quantity of coal will be exceeded.

The loss of small particles of unburned coal which fall through the openings in the grate bars and are removed with the ashes may be reduced by more careful firing. The coal is broken up and falls through into the ash pit on account of stirring the fuel bed with the firing tools. If proper attention is given to the fire it is not necessary to stir up the fuel bed, and the percentage of unburned coal in the ashes will thus be reduced. While it is impracticable to eliminate this loss entirely, careful firing will greatly reduce it.

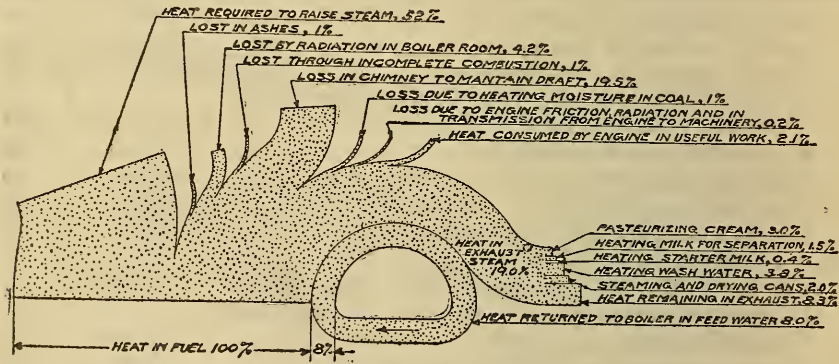

FIG. 14.—Graphic illustration of the possible distribution of heat energy in a creamery making 500,000 pounds of butter annually from pasteurized cream.

The quantity of heat radiated from the setting, uptakes, breeching, and from the exposed positions of the boiler itself depends, of course, on the arrangement of the particular plant, and while it is given in the table at 4 per cent, it is often considerably more. While some loss by radiation is unavoidable, the greater portion can be prevented through insulating the exposed surfaces. Efficient insulation not only conserves the heat but reduces the temperature in the boiler room, increases the draft, and when applied to iron surfaces prolongs their life. The insulation of the uptake and breeching may be effected by applying asbestos or magnesia blocks held in position and covered with a half-inch coat of asbestos or magnesia plaster. The walls of the boiler setting should be made amply thick to begin with, and should have a 2-inch space constructed in the wall. The United States Bureau of Mines, through exhaustive experiments, has proved that a wall with an air space will lose more heat than one of the same thickness constructed of solid masonry. The air space, however, is valuable in reducing the liability to crack. It should be filled with ashes or sand or some similar material, thus reducing heat losses, and should cracks form in the walls, this fine material will run into and fill them and prevent the air from leaking into the furnace or combustion chamber. The exposed top of the boiler should also be covered with a layer of sand or ashes, or a layer of asbestos blocks or insulating brick may be substituted. By properly insulating the boiler setting, uptakes, and breeching the heat loss can be easily reduced one-half or more.

The heat loss through incomplete combustion is an extremely variable quantity in creameries where the firing of the boiler is done at irregular intervals. In most of the smaller plants no regular fireman is employed, but some one engaged in other work around the plant is depended upon to fire the boiler; consequently the firing is not given the proper attention. In the larger and better-managed plants, however, this loss is not more than about 2 per cent, which can be practically eliminated through careful firing.

There is a certain amount of heat loss in the stack that is necessary to maintain the draft for burning the fuel, and hence can not be eliminated. In practice it is found that twice the theoretical amount of air is necessary for complete combustion of the fuel. Assuming that twice the theoretical amount of air is supplied and that the coal used has a heat value of 13,500 B. t. u. per pound, then the necessary heat lost in the stack, as given in the table, is 19.15 per cent. It is impracticable to reduce this loss to any appreciable extent.

The greatest operating loss is that due to excess air which is allowed to leak into the furnace and combustion chamber through cracks in the walls of the setting, firing doors, doorframes, and other points. This is a loss that can be entirely eliminated if all cracks are carefully stopped and the air supply through the openings in the ash pit and firing doors is properly controlled.

The loss due to heating the moisture in the coal is one that is impracticable to eliminate or reduce. The loss depends, of course, upon the amount of moisture contained in the coal, but seldom exceeds 2 or 3 per cent.

Soot is one of the best-known insulators. Consequently if allowed to collect on the heating surfaces of the boiler it will reduce materially the amount of heat passing through the heating surfaces to the water inside the boiler. The loss from this source may be entirely prevented. The remedy lies in keeping all heating surfaces clean.

Nearly all boiler-feed water contains scale-forming impurities. Rain water, while not containing scale-forming material, always contains carbonic and often sulphuric acid, and hence should never be used as boiler-feed water on account of pitting and corroding the boiler plates. The heat loss from scale deposit depends, of course, on the thickness and nature of the scale formed. While in the foregoing table it is estimated as averaging only 3 per cent, it often amounts to several times as much. In addition to cutting down the passage of heat it causes the plates to become overheated and is often the direct cause of explosions. Creamery boilers as a rule are not cleaned internally at regular intervals, and the scale is allowed to form until it greatly reduces the efficiency of the boiler and in extreme cases is liable to cause an explosion. The remedy lies in keeping the internal parts of the boiler thoroughly clean, either by treating the feed water with chemicals before admitting it to the boiler, or by cleaning mechanically at regular intervals. It is possible to eliminate entirely the heat loss through scale formation.

Leaky pipe joints, valve stems, blow-off valves, etc., are the rule instead of the exception in many small plants. This is due entirely to carelessness. It is an easy matter to stop leaks in pipe joints, pack valve stems, and regrind the blow-off valve, and thereby stop leakage losses entirely.

Heat losses through radiation from steam piping can easily be reduced 85 per cent by covering the bare pipes with a good grade of pipe covering, thus reducing the loss to a negligible quantity.

The losses due to engine friction and bearing, belt, and shaft friction may be reduced by better lubrication, proper size and tension in the belts, and careful alignment of the shafting. Small plants in particular often suffer power loss through an unnecessarily large amount and from poorly installed and maintained shafting. With care these losses can be reduced at least one-half in the average creamery.

We now come to the heat consumed in the useful work. The heat actually used in the engine for pasteurizing cream, heating milk before separation, heating starter and wash water, and steaming and drying cans amounts to only 6.3 per cent of the total heat units contained in the coal consumed in a day's operation. The heat lost in the exhaust steam amounts to 9 per cent of the total in the fuel. Exclusive of the heat energy consumed in useful work in the steam engine only 5.3 per cent of the heat in the fuel is used for other purposes. The 9 per cent of the total heat in the fuel lost in the exhaust steam, therefore, is more than sufficient to perform all the heating required in the creamery, and also to heat the boiler-feed water.

Table 8 is based on the same plant as that covered by Table 7, and shows the possible distribution of heat energy through improvements in the plant. Table 7 is based on 1,000 pounds of coal burned to produce a certain amount of work. Table 8 shows that after stopping leaks, utilizing the exhaust steam, and otherwise improving the operation of the plant the quantity of coal consumed in performing the same amount of work was only 470 pounds, or less than one-half the former amount.

TABLE 8.—*Possible distribution of heat energy in same plant as in Table 7.*

	B. t. u.	Per cent.
Total B. t. u. in coal 470×13,500=6,400,000=100 per cent.		
Heat distribution in boiler room:		
Lost in raising steam	3, 334, 550	52. 0
Lost in ashes	64, 000	1. 0
Lost by radiation in boiler room	266, 000	4. 2
Lost by incomplete combustion	64, 000	1. 0
Lost in chimney to maintain draft	1, 248, 000	19. 5
Lost through heating moisture in coal	64, 000	1. 0
Heat distribution in engine room:		
Loss due to engine friction, radiation, and in transmission from engine to machinery	9, 450	. 15
Heat consumed by engine in the production of useful work	135, 000	2. 1
Heat in exhaust steam	1, 215, 000	19. 0
	6, 400,000	100. 0
Heat returned to boiler through heating feed water	512, 000	8. 0
Distribution of heat contained in exhaust steam:		
Pasteurizing cream	216, 000	3. 4
Heating milk for separating	94, 500	1. 5
Heating starter milk	27, 000	. 4
Heating wash water	243, 000	3. 8
Steaming and drying cans	135, 000	2. 0
	715, 500	11. 1

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 748

Office of the Secretary
Contribution from the Office of Farm Management
E. H. THOMSON, Acting Chief
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WM. A. TAYLOR, Chief

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FARM PRACTICE IN GROWING SUGAR BEETS IN MICHIGAN AND OHIO.

By R. S. Washburn, *Scientific Assistant*, L. A. Moorhouse, *Agriculturist*, and T. H. Summers, *Scientific Assistant, Office of Farm Management*, and C. O. Townsend, *Pathologist in Charge, Sugar-Plant Investigations, Bureau of Plant Industry*.

CONTENTS.

This study was made in order to ascertain the field practices that are employed in the production of sugar beets under typical humid conditions and to determine the relationship of these operations to the cost of growing this crop.

The data presented are based upon 320 farm records obtained from operators in Michigan and Ohio. The farmers who reported on their methods of producing sugar beets lived in the vicinity of Caro, Alma, and Grand Rapids, Mich., and in northwestern Ohio (fig. 1). The records discussed outline the work and show the returns for these farms during the crop seasons 1914 and 1915. The labor rates that prevailed throughout this period were not nearly so high as those for 1916 and 1917, which were greatly advanced by war conditions.

Note.—This is the third of a series of bulletins published by the Department of Agriculture giving the results of an investigation relative to the practice and cost of growing sugar beets in four of the most important areas in the United States. One of these bulletins gave the results obtained from a study of this enterprise in Utah and Idaho. Another contained a review of records that were taken in three Colorado districts. A subsequent publication will discuss the practice and distribution of costs in connection with the production of beets in three California regions.

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The hours of man labor and horse labor do not vary greatly from one period to another. Moreover, the quantity of seed planted per acre will not change perceptibly throughout a given period, and the applications of manure or fertilizer are not likely to increase or

FIG. 1.—Map showing the districts in which records were obtained, also indicating the location of the beet-sugar factories in Michigan and Ohio.

decrease to any marked extent. Other necessary supplies will remain fairly constant. In presenting accompanying tables these facts have been kept in view, so that if the reader wishes to figure the cost of production on the basis of prices other than those prevailing when this study was made all that need be done is to apply any prevailing scale of prices to the more or less constant factors which have been determined in this study.[1]

SUMMARY OF RESULTS.

A fairly definite rotation system was found in each district visited. In the Caro, Alma, and Grand Rapids areas sugar beets followed corn or beans in the rotation, while in northwestern Ohio sugar beets or corn were planted on clover sod. On 39 per cent of the Ohio farms visited the sugar beet succeeded clover in the cropping system.

Manure was applied at an average rate of approximately 13 tons per acre on 201 out of a total of 320 farms.

Commercial fertilizers were applied on 68 per cent of the farms visited in the Caro district, 47 per cent at Alma, 78 per cent at Grand Rapids, and 39 per cent in northwestern Ohio. The rate of application ranged from 130 to 170 pounds per acre.

The dates of planting varied from April 5 to June 1. The seed was drilled in at a rate of 15 pounds per acre, and it cost 15 cents per pound.

The greater part of handwork on sugar beets was performed at a contract rate of $18 per acre for 22-inch rows, $16 for 24-inch rows, and $15 for 28-inch rows. Fifteen per cent of the farmers did their own blocking and thinning, 17 per cent hoed, and 10 per cent did their own topping. On the remaining farms this work was done on a contract basis.

Beets were hauled an average distance of 2.47 miles to loading station or sugar-factory dump.

Beet growers in the Caro district produced an average yield of 9.72 tons per acre, at a cost of $47.65, or $5.62 per ton; at Alma the average yield was 11.4 tons, and the cost amounted to $57.42 per acre, or $5.04 per ton. Grand Rapids growers reported an average yield of 10.16 tons, and the cost per acre averaged $53.05, or $5.21 per ton. Northwestern Ohio operators had an average yield of 13.17 tons per acre, costing $56.04, or $4.26 per ton.

Twenty-two men produced a yield of 8 tons or less per acre, at a cost of $49 per acre, or $7.05 per ton. Twenty-five men produced 14 tons and over per acre, at a cost of $58.18 per acre, or $3.92 per ton. Although the cost per acre increases as the yield increases the cost per ton decreases.

The labor cost was approximately 64 per cent of the total cost of producing sugar beets in the area visited. Materials, including manure, fertilizer, and seed, constituted about 11 per cent, and other

[1] Mr. James W. Jones, Agriculturist, Office of Sugar Plant Investigations, and Mr. M. R. Cooper, Scientific Assistant, Office of Farm Management, assisted in collecting the records discussed in this bulletin.

costs, such as insurance and taxes, interest and rent, machinery use cost, and other miscellaneous expenses, amounted to about 25 per cent of the total cost of production.

Approximately 96 per cent of the farmers in Michigan fed the beet tops to stock. In northwestern Ohio about half the producers fed and half plowed under the tops. Beet tops were valued at from $1.50 to $3.40 per acre.

METHOD OF TAKING RECORDS.

An investigation of this character involves an inquiry as to the man and horse labor required in the preparation of land for sugar beets as well as in regard to the subsequent care of the crop until the final product is delivered to the manufacturer. It also calls for definite information with reference to use of land, manure, fertilizer, and seed, and the apportionment or distribution of certain general costs to the various enterprises of the farm.

In order to secure the desired data on the practice and cost of growing sugar beets a suitable blank report form was printed; with this schedule in hand, trained enumerators visited the beet growers of the regions selected for these observations. Each operator consulted gave a complete description of the methods employed in growing sugar beets on his farm and furnished additional facts concerning the other important enterprises forming a part of his business. As far as possible, the acreage in beets and the yields obtained from each farm were checked with the sugar-factory reports. Inasmuch as some growers delivered sugar beets to more than one factory, it was not possible to make comparisons for all farms. (See Table I.)

TABLE I.—*A comparison of growers' estimates with factory records—Average acreage, yield, and return per acre, 1914–1915.*

District.	Number of farms.	Acres in beets per farm		Yield per acre.		Cash return per acre.	
		Estimated.	Factory.	Estimated.	Factory.	Estimated.	Factory.
				Tons.	*Tons.*		
Caro	73	14.33	14.22	8.82	7.56	$52.89	$46.32
Alma	49	9.57	9.36	11.65	10.43	69.91	61.90
Grand Rapids	36	6.40	6.32	10.16	9.67	61.32	58.45
Northwestern Ohio	57	15.19	14.63	13.15	12.68	72.74	69.39

In this investigation the Office of Farm Management had the cooperation of the Office of Sugar Plant Investigations of the Bureau of Plant Industry. The latter office was not only interested in the farm-management data that would be made available by this survey but was desirous of obtaining a detailed account of the field practice in typical regions. It was felt that these data would be exceedingly valuable in indicating some of the urgent needs of the farmer and would in turn assist in devising remedies or suggesting means of combating some of the enemies of this crop. Acknowledgement is due the farmers of these districts for their hearty cooperation. The questions that were asked were answered promptly and courteously, and the department is under obligation to them for this service.

DEVELOPMENT OF SUGAR-BEET INDUSTRY IN MICHIGAN AND OHIO.

The first four beet-sugar factories in Michigan were built during the year 1899 (fig. 2), and were located at Alma, Bay City, Caro, and Holland, respectively. Two additional factories were constructed in 1900. Other factories were built at the rate of three per year up to and including 1903. During the five-year period of 1899 to 1903 the

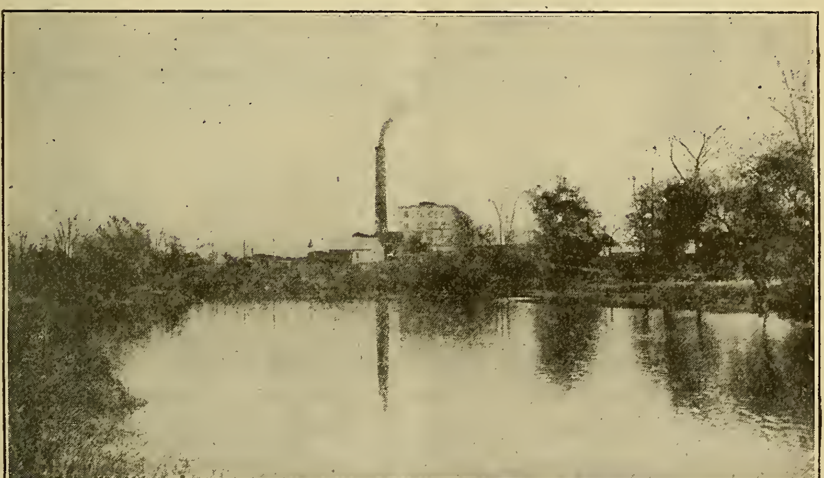

FIG. 2.—One of the first beet-sugar factories erected in Michigan.

beet-sugar industry became well established in this State. Sixteen factories are now available for the manufacture of beet sugar in Michigan; 15 of these were in operation during the period of this survey.

In Ohio the first factory was built during the year 1900. No other factories were constructed until the period 1910–12, at which time four factories were erected and put in operation, making a total of five for this State; three of these contracted sugar beets and conducted active campaigns during the period of this survey. One factory was idle in 1914, but operated in 1915.

According to census figures for 1909, sugar beets were grown extensively in Tuscola, Bay, Huron, Gratiot, and Saginaw Counties, Mich. Paulding was the leading sugar-beet growing county in Ohio that year.

SIZE OF FARMS.

The size of the farm is one measure of the operator's business. It is of interest to know something about the common farm sizes in a region that has developed one or more special enterprises. In making a study of the sugar beet, this feature received some attention in the reports prepared on the Utah-Idaho and Colorado areas. Similar figures, obtained by the Census Bureau in 1909, are available for the Michigan and Ohio region. While some changes have undoubtedly taken place since then, sizes that were common at that time constitute some of the important groups at present. (See Table II.) Side by side with the census figures is shown the distribution of the farms visited in this survey:

TABLE II.—*Size and number of farms, and number of records obtained, in Tuscola, Gratiot and Allegan Counties, Mich., and Paulding County, Ohio.*

Acres	Tuscola Co., Michigan.		Gratiot Co., Michigan.		Allegan Co., Michigan.		Paulding Co., Ohio.	
	Number of farms (census).	Number of farm records.	Number of farms (census).	Number of farm records.	Number of farms (census).	Number of farm records.	Number of farms (census).	Number of farm records.
9 and under	91	....	103	....	200	....	124	....
10 to 49	1,486	9	1,327	10	2,233	3	681	1
50 to 99	2,085	63	1,740	19	2,299	10	1,082	40
100 to 174	1,290	49	841	17	1,161	16	701	35
175 to 259	213	9	133	7	233	6	189	14
260 to 499	66	3	54	....	78	1	58	7
500 to 999	10	1	6	....	8	....	4	....
1,000 and above	3	....	1	....	5	5	1	....
		134		53		36		97

According to the census figures of 1909 more than one-third of all Michigan farms were classified in the group size 50 to 99 acres. Nearly one-fourth were placed in the group size 10 to 49 acres, and approximately one-fourth were 100 to 174 acres in size. These three groups include the 40, 80, and 160 acre farms and, together, they constitute about five-sixths of the farms of the State. It will be seen that there is some correspondence throughout in the number of farms that were classified in the group-size 50 to 99 acres. The records obtained from farmers in these regions are representative of the farms found in these areas, so far as size is concerned.

RAINFALL.

The normal rainfall in this region is distributed quite uniformly throughout the year. Table III gives the average monthly and annual precipitation for three districts in Michigan and one district in Ohio. In two of these districts the total annual rainfall for the years 1914 and 1915 is given for a comparison with the averages that are reported. The 1915 annual rainfall for the Paulding area is also given in this connection.

TABLE III.—*Mean annual rainfall for three districts in Michigan and one in northwestern Ohio.*

Month.	Caro District, Arbela, 1887–1908.	Alma District, Alma 1887–1908.	Grand Rapids District, Grand Rapids, 1870–1908.	Ohio District, Paulding, 1883–1908.
	Mean.	*Mean.*	*Mean.*	*Mean.*
January	2.29	2.53	2.69	2.44
February	2.03	1.95	2.33	2.07
March	2.63	2.49	2.65	3.08
April	2.71	2.39	2.49	2.76
May	4.14	3.56	3.25	3.32
June	3.20	3.07	3.92	3.18
July	3.13	3.11	3.17	3.49
August	2.79	2.73	2.67	2.74
September	2.80	3.28	3.42	2.27
October	2.70	2.61	2.76	2.23
November	2.63	2.66	2.85	2.47
December	2.33	2.34	2.65	2.71
Average annual precipitation	33.38	32.74	34.85	32.76
Average annual precipitation, 1914	....	37.63	29.83	....
Average annual precipitation, 1915	....	30.26	28.93	32.78
Elevation	728 feet	730 feet	707 feet	725 feet

There is only a slight variation in normal rainfall in these four districts, the average annual precipitation for the entire area being not far from 33 inches. In the Alma district the rainfall for 1914 was about 5 inches above the average, while in 1915 it was 2.5 inches below normal. In the Grand Rapids region the precipitation was considerably below the average for the two seasons 1914 and 1915.

A study of the prevailing summer temperature for the sugar-beet regions of the United States has shown that an average of 70° F. during the growing period is conducive to the development of a satisfactory sugar content. This condition obtains in the Michigan and Ohio sugar-beet areas.

SOILS.

In Tuscola and Gratiot Counties the soil type that is best adapted to sugar beets, and the one that produces the major portion of this crop, is known as Clyde loam. It is the most extensive type in this region.[1] Clyde loam has been described as a soil that is easily tilled, if cultivated at the proper time, but if worked when too wet or too dry it breaks up into lumps and is apt to remain in a rough condition during the entire season. It is especially well suited to the production of sugar beets, beans, corn, oats, wheat, and hay. In the Grand Rapids area Allegan black clay appeared to be the type upon which the sugar beet was grown most extensively. Clyde clay was the most significant type in the Ohio survey.

[1] Bureau of Soils report, Saginaw area, 1904; Bureau of Soils report, Allegan County, 1901; Bureau of Soils report, Paulding County, 1904.

CROP ROTATION.

A fairly definite rotation of crops was found in each district visited, depending on local conditions and the crops best adapted to the region. Following is an outline of the typical rotations followed:

Caro and Alma areas:	Grand Rapids area:	Northwestern Ohio area:
Clover and timothy 1 to 3 years.	Clover and timothy 1 to 3 years.	Clover and timothy 1 to 2 years.
Corn 1 year or beans 1 year.	Corn 1 year.	Sugar beets or corn 1 year.
Sugar beets 1 year.	Sugar beets 1 year.	Grain 1 year.
Grain 1 year.	Grain 1 year.	Reseed to clover and timothy.
Reseed to clover and timothy.	Reseed to clover and timothy.	

The Caro and Alma records were combined in the study of crop rotation, because the conditions in these two districts were very similar. The chief difference noted was that in the Alma district the general practice was to follow timothy and clover with corn, while in the Caro district beets or beans are often substituted for corn as the crop to follow timothy and clover.

In the Caro district sugar beets and beans are the two most important competing cash crops. For the year 1915 the sugar-beet and bean acreage was about equally divided. An average of about 15 acres per farm was devoted to each crop. Approximately 9 acres per farm was planted to corn. On 30 per cent of the farms in this district beans followed clover and timothy and preceded sugar beets. On 17 per cent, corn followed clover and timothy and preceded the sugar beet. On 10 per cent, beans were planted after corn and were followed by sugar beets.

Beans did not occupy so prominent a place in the cropping system of the Alma district. However, on those farms where beans were grown the average acreage per farm was 13, while that of sugar beets was 10. An average of 13 acres per farm was devoted to corn. The sugar beet followed corn on 57 per cent of the farms visited; on 25 per cent sugar beets followed beans.

In the Grand Rapids area, where 36 farms were visited, beans were reported on 19 farms and corn on all farms, the average corn acreage being 17. Sugar beets followed corn on 24 farms and beans on 2 farms. The average acreage per farm of beans was 9, while that of sugar beets was 6.

In northwestern Ohio beans were not included in any of the rotations mentioned. Corn appeared in the rotation on every farm and preceded sugar beets on 28 per cent of the farms in this district. (See fig. 3.) The average acreage of corn per farm was 33. The average acreage devoted to sugar beets was 16. On 39 per cent of these farms, the sugar beet followed a crop of clover. Occasionally sugar beets follow a crop of alfalfa. (See fig. 4.)

FIG. 3.—Sugar beets followed corn in the rotation in northwestern Ohio.

There was a striking similarity in the general arrangement of the cropping systems in all of these districts. It was the general practice to grow beets once in the rotation; this intertilled crop was then

FIG. 4.—Sugar-beet growing on land that was in alfalfa during the preceding year. Occasionally sugar beets follow a crop of alfalfa.

changed to another field. Clover was utilized in every district to add nitrogen to the soil and keep up the humus content. Timothy was usually grown with the clover. The major differences noted were the absence of beans in the rotation in Ohio, and the tendency of farmers there to follow a crop of clover with sugar beets. This latter practice seems to be a commendable one.

MAN AND HORSE LABOR.

In calculating the 1915 costs reported for the various operations discussed here, a rate of 20 cents per hour was used for the man labor and 10 cents per hour for the horse labor. A few enterprise records secured in the Caro district for the crop year 1914 were worked out with a rate of 16 cents per hour for the man labor. The horse rate was the same as that for the year 1915. In view of the fact that a limited number of records entered into the 1914 determination, the lower man-hour rate that obtained did not appreciably influence the average rate. The latter was about 19 cents per hour. The prevailing rates for regular and extra labor were used in working out the standard rates that have been indicated. Contract labor will be treated under a separate paragraph.

FARM PRACTICES IN GROWING SUGAR BEETS.

THE USE OF MANURE.

Sugar-beet operators in these areas appreciate the value of farm manure. They know that it is essential, not only to keep up the soil fertility, but also to add humus and thereby maintain a good physical condition. Three hundred and twenty farmers were interviewed in these districts. The sugar beets on 201 farms received a benefit from an application of manure. Of this number, 45 per cent applied manure directly to sugar-beet land, 30 per cent to corn land, 14 per cent to bean land, and 2 per cent to meadow land. In northwestern Ohio, where 97 farmers were visited, only 32 per cent applied manure. However, 36 per cent plowed under either a crop of clover or clover sod. The latter practice did not prevail in any of the other districts visited. In each of the three other districts approximately 75 per cent applied manure. Where manure was applied directly, 50 per cent of the estimated value was charged to the sugar beet; if applied to a crop immediately preceding, 30 per cent was charged, and if two other crops preceded the beet, 20 per cent was charged.

Most of the manure hauling was done during the late fall and early spring months, at a season of the year when there was little field work requiring the attention of the farmer. Fifty-one per cent of the manure was applied with a crew consisting of one man and two horses. Twelve per cent of the farmers used a 1-man and 3-horse crew; on 16 per cent of the farms a 2-man and 2-horse crew was used.

The average amount of manure applied per acre was fairly uniform for all districts studied, but the amount applied per acre on individual farms showed considerable variation (Table IV). The latter ranged from 4 tons to 30 tons per acre.

The average labor requirements and cost per acre of hauling were also quite uniform. However, the amount of labor and the cost per acre on individual farms showed considerable variation. This variation may be explained largely by the amount of manure applied per acre and the kind of implement used in hauling. The lowest labor cost per acre was found in the Caro district, where a charge of 90 cents was made for a 4-ton application. The highest labor cost, $9.50 for a 30-ton application, was reported in northwestern Ohio.

TABLE IV.—*Use of manure, average by districts.*

District.	Per cent of all records	Acres in beets.		Tons per acre.	Hours of labor per acre.		Labor cost per acre.
		Total.	Manured.		Man.	Horse.	
Caro	75	15.46	8.00	12.87	9.03	16.58	$3.33
Alma	75	9.74	6.23	14.30	11.19	19.91	4.23
Grand Rapids	72	6.27	4.41	13.13	7.94	18.30	3.42
Northwestern Ohio	32	15.24	6.55	13.94	10.20	20.69	4.11

The manure spreader was used on 135 farms and the wagon on 56 farms. On 10 farms the implement used was not indicated. The capacity of the manure spreader ranged from 50 to 100 bushels, with an average of about 75 bushels.

An examination of the estimates reveals the fact that the farms using wagons to haul manure average 20 per cent smaller than those using spreaders. In many instances farms using wagons exclusively are too small and the amount of manure to be hauled too limited to warrant the purchase of a manure spreader. It has been demonstrated that the application of manure by means of a manure spreader is the best method, not only in time required to do the work, but also in respect to the quality of the work done. It would seem that two or more farmers on adjacent small farms might purchase a manure spreader to be used jointly to the advantage of each.

Undoubtedly stable manure is the best fertilizer for general use with sugar beets, but on most farms the supply is limited, making it advisable to supplement the barn-yard manure with an application of commercial fertilizer to the beet land. Sixty-eight per cent of the farmers in the Caro, 47 per cent in the Alma, 78 per cent in the Grand Rapids district, and 39 per cent in northwestern Ohio applied commercial fertilizer. It will be noted that the use of fertilizer and stable manure in northwestern Ohio was not so extensive as in the other districts visited. The general practice in northwestern Ohio is to depend to a greater extent for the maintenance of soil fertility on sugar-beet land on the practice of systematically plowing under a clover crop. Twenty-nine per cent of the men in the Caro, 32 per cent in the Alma, and 56 per cent in the Grand Rapids district, and only 5 per cent in northwestern Ohio applied both manure and commercial fertilizer. With very few exceptions, the growers who applied commercial fertilizers covered their entire beet acreage, even though a portion of the acreage had received an application of manure.

Beet drills with fertilizer attachments were used to apply the fertilizer in the drill row at the time of seeding, so that the labor requirements for fertilizing are included under planting practice.

A majority of the men interviewed reported a special trip to town after fertilizer. The labor cost for hauling amounted to about 20 cents per acre. The rate of application ranged from 130 pounds to 170 pounds per acre and consisted in most cases of a prepared mixture containing about 2 per cent nitrogen, 8 per cent phosphoric acid, and 3 per cent potash. The cost per acre for the above application ranged from $1.75 to $2.

PLOWING.

Sugar beets require a well-prepared, deep, firm seed bed. To obtain this the land should be in good condition at the time of breaking and the depth of plowing should be sufficient to allow the long taproot of the sugar beet to penetrate some distance into the soil. The depth of plowing varied from 6 inches to 9 inches, with an average depth of about 7.5 inches for all districts studied. (Table V.)

It is generally conceded that fall plowing of sugar-beet land is to be preferred, and this was found to be the practice on a considerable number of the farms visited.

In the Caro district 56 per cent of the men reported fall plowing, 20 per cent spring plowing, and 24 per cent did a portion of the work in the fall and the remainder in the spring. A small proportion practiced fall plowing in the other districts, but this was mainly because of lack of time to do the work before cold weather set in. The spring plowing was all done early in April, or as early as the land was in condition to work.

Table V.—*Plowing.*

District.	Per cent of all records.	Acres in beets per farm.		Hours of labor per acre.		Labor cost per acre.
		Total.	Plowed.	Man.	Horse.	
Caro	96	14.94	14.54	5.77	14.34	$2.50
Alma	92	9.44	9.21	4.85	11.87	2.16
Grand Rapids	100	6.40	6.40	5.19	13.52	2.39
Northwestern Ohio	100	15.64	15.29	5.69	14.58	2.60

Six men in the Caro and four in the Alma district reported on the practice of planting beets after beans without plowing. In the cases where the plowing was omitted the disk and spring-tooth harrow were substituted for the plow in the preparation of the seed bed. Very good results, where the land was free from weeds, were reported by this method.

Two common types of plows were observed, the common moldboard walking plow (fig. 5) and the one-way sulky plow. Two hundred and twenty-five walking, 76 riding, and 7 two-furrow gang plows were reported. The walking plows ranged in width from 12 to 14 inches, and the sulky plows were practically all 14 inches in width. Three-horse teams were used almost exclusively with sulky plows (fig. 6), while with the walking plow not only the 2-horse but also the 3-horse team was used. Forty-eight per cent of the men used

FIG. 5.—A crew of one man and two horses breaking land with a walking plow. This was a common type in these districts.

a 1–3 crew and were able to cover an acre of ground in an average of 5.2 hours, while the 47 per cent who used a 1–2 crew required 6.1 hours per acre. The width of implement ranged from an average of 12.7 inches for the 1–2 crew to 13.2 inches for the 1–3 crew. Five per cent used a 1–4 crew and plowed an acre in an average of 3.4 hours. Mainly two-bottom 12 to 14 inch gang plows were used with the latter crew.

One grower in the Alma district used a two-bottom 12-inch gang plow drawn by a tractor. With one man to operate this outfit, plowing was done at the rate of 1 acre in about 3½ hours.

DISKING.

The disk harrow, or pulverizer, as it is commonly called, is often used in preparing a seed bed for the sugar beet. Disking destroys weeds which may be present on fall-plowed land and breaks up surface clods. The seed bed should also be compact and free from hard lumps. The disk harrow by means of its sharp blades pulverizes and

FIG. 6.—Plowing with a sulky. Three-horse teams were used almost exclusively with sulky plows.

fines the lower portion of the seed bed, which allows free circulation of air and enables the delicate rootlets of the sugar beet to penetrate all portions of the soil in search of plant food. Disking is especially

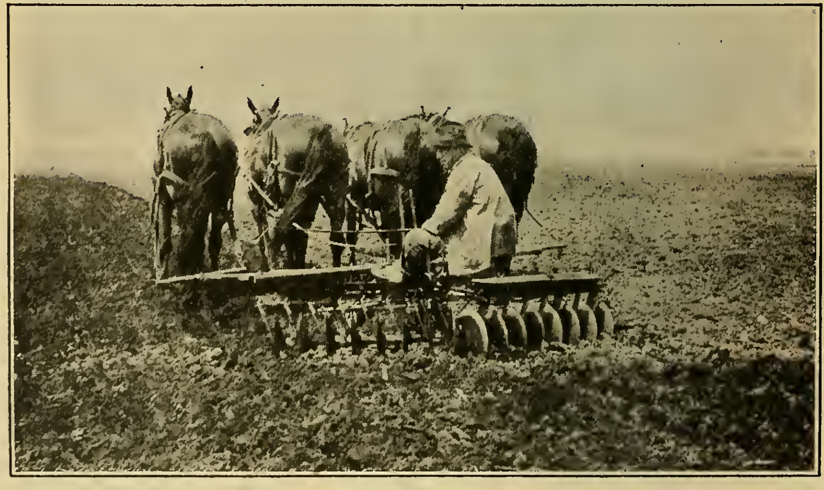

FIG. 7.—Disking is an important factor in breaking up clods and firming the soil.

desirable on spring-plowed land which has not had the advantage of the freezing and thawing action of the preceding winter. It is an important factor in breaking up clods and firming the soil (fig. 7).

The disk harrow was not used to so great an extent in the Alma and Grand Rapids districts. In these two areas the work of pulverizing the soil was done largely by means of the spring-tooth harrow.

Disking in all districts was done early in April. Few double-action disks were recorded in any section except northwestern Ohio, where 23 were found. This type has two sets of disks, one in front of the other, and is so adjusted that the front set throws the dirt out while the rear set throws it in, leaving the ground practically level. Because of the double row of disks the land is disked twice each time that the ground is gone over.

A crew of 1 man and 4 horses was used with the double-action disk. A 1-man and 3-horse crew was typical for the single-action disk. However, a 1-man and 2-horse crew was reported on several farms. The width of the implement varied from 5 to 8 feet. The average width for all districts was about 6 feet.

The average cost per acre was fairly uniform, with the exception of the Grand Rapids area, where the cost was slightly higher than that of the other districts (Table VI).

Table VI.—*Disking.*

District.	Per cent of all records.	Acres in beets per farm.		Times disked.	Hours of labor per acre.		Labor cost per acre.
		Total.	Disked.		Man.	Horse.	
Caro	56	16.50	15.70	2.85	3.48	8.88	$1.51
Alma	36	10.55	10.32	1.88	2.18	5.64	1.00
Grand Rapids	28	8.58	8.48	2.60	3.50	12.21	1.92
Northwestern Ohio	68	15.35	14.68	2.39	2.45	7.71	1.26

DRAGGING.

The principal object to be attained in the use of a planker or drag is to break up surface lumps. This is a homemade implement constructed from planks which are lapped one upon the other forming a ridged undersurface. When this surface comes in contact with the soil it creates a grinding, pulverizing action which smooths and slightly compacts the soil and fills in depressions. The records indicate that it was used principally just ahead of the drill. The width varied from 6 to 10 feet, with an average width of approximately 8 feet. It is a common practice to place a piece of railroad iron or other heavy weight on the float. Sometimes the operator rides to give it additional weight.

A typical crew for this operation consisted of one man and two horses. Eighty-one per cent of the farmers used a crew of this size, 16 per cent used a 1-man and 3-horse crew, and 3 per cent a 1-man and 4-horse crew. The average cost per acre for one operation was fairly uniform. On individual farms for one operation the lowest cost was 20 cents and the highest 68 cents per acre. (See Table VII.)

TABLE VII.—*Dragging.*

District.	Per cent of all records.	Acres in beets per farm.		Times dragged.	Hours of labor per acre.		Labor cost per acre.
		Total.	Dragged.		Man.	Horse.	
Caro	45	13.01	12.74	1.09	0.97	2.06	$0.39
Alma	74	9.56	9.17	1.51	1.56	3.42	.65
Grand Rapids	33	6.27	6.02	1.25	1.22	3.18	.56
Northwestern Ohio	45	14.73	13.95	1.16	1.06	2.50	.46

HARROWING.

Two types of harrow were used in each district, viz, the spike-tooth and the spring-tooth. The spike-tooth harrow stirs the soil to a moderate depth and is the implement commonly used to create a smooth, even surface. Seventy-nine per cent of the growers interviewed used this type of harrow.

FIG. 8.—Harrowing with a spike tooth. This implement stirs the soil to a moderate depth and is commonly used to create a smooth, even surface.

The width of the implement varied from 8 feet to 16 feet, with an average of about 9 feet. Fifty-nine per cent used a 1-man and 2-horse crew. This crew size predominated in all sections except northwestern Ohio. In this area the width of harrow averaged about 10 feet, and 40 per cent of the men used a crew of one man and three horses. (See Table VIII.)

TABLE VIII.—*Harrowing (spike-tooth).*

District.	Per cent of all records	Acres in beets per farm.		Times harrowed.	Hours of labor per acre.		Labor cost per acre.
		Total.	Harrowed.		Man.	Horse.	
Caro	70	15.92	15.56	1.49	1.09	2.33	$0.43
Alma	87	9.80	9.31	1.76	1.23	2.77	.53
Grand Rapids	67	7.20	6.95	1.33	1.09	2.69	.49
Northwestern Ohio	91	16.40	16.30	1.87	1.49	3.74	.67

The average labor requirements and cost per acre were fairly uniform, but there was considerable variation on individual farms.

The spring-tooth harrow stirs the soil to a greater depth than the spike-tooth, brings clods to the surface (see figs. 9 and 10), and was

FIG. 9.—One man and three horses harrowing with a spring tooth. This was a common crew in the regions or districts visited.

used extensively in all districts, although not to so large an extent in northwestern Ohio as in the other three sections. This operation was performed on 252 farms. (See Table IX.)

TABLE IX.—*Harrowing (spring-tooth).*

District.	Per cent of all records.	Acres in beets per farm.		Times harrowed.	Average crew.		Hours of labor per acre.		Labor cost per acre.
		Total.	Harrowed.		Man.	Horse.	Man.	Horse.	
Caro	90	14.06	14.06	3.07	1.0	2.5	3.44	8.65	$1.51
Alma	96	9.58	9.50	3.15	1.0	2.6	3.66	9.05	1.63
Grand Rapids	94	5.75	5.75	3.50	1.0	2.9	3.64	10.34	1.76
Northwestern Ohio	47	15.98	14.72	1.58	1.0	2.9	1.82	5.01	.86

The average width of implement was approximately 6½ feet. Forty-four per cent of the men interviewed used a crew of one man and two horses. On 43 per cent of the farms a 1-man and 3-horse crew was used. The crew of one man and two horses predominated in

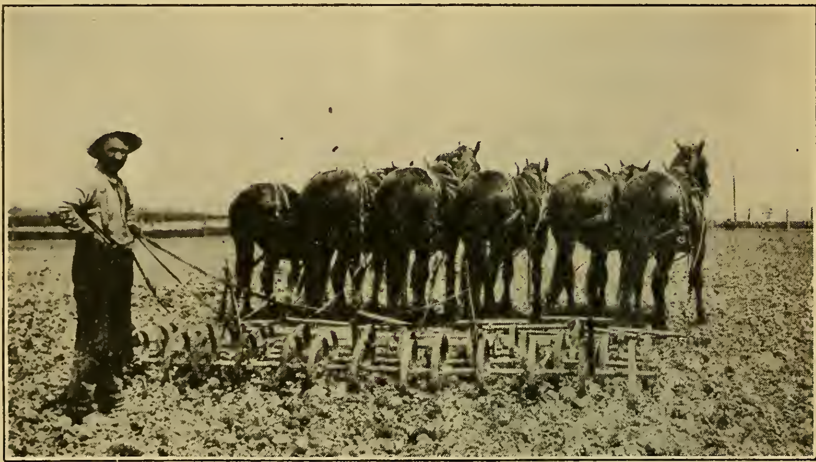

FIG. 10.—A crew of one man and six horses operating a spring-tooth harrow. More horses are used here than in the average crew. (See Table IX.)

the Caro and Alma districts, while the 1-man and 3-horse crew was in the majority in the Grand Rapids and Ohio districts.

ROLLING PRACTICE.

Two general types of rollers were found in these districts; the solid smooth drum roller (fig. 11), either steel or wood, and the bar

FIG. 11.—Rolling with a smooth drum roller. This type crushes clods and leaves a smooth surface.

roller or pulverizer. (fig. 12). Two hundred and thirty-one smooth iron, 37 bar, and 18 wood rollers were reported. The average width of these implements was about 8 feet. (See Table X.)

TABLE X.—*Rolling.*

District.	Per cent of all records.	Acres in beets per farm.		Times rolled.	Hours of labor per acre.		Labor cost per acre.
		Total.	Rolled.		Man.	Horse.	
Caro	93	15.15	15.06	2.17	1.63	3.26	$0.63
Alma	98	9.53	8.95	2.36	1.87	3.74	.74
Grand Rapids	78	5.92	5.92	1.91	1.48	2.96	.60
Northwestern Ohio	85	16.69	15.71	1.84	1.40	2.80	.56

Sixty-six per cent of the men in the Caro district, 87 per cent in the Alma, 78 per cent in the Grand Rapids district, and 44 per cent in northwestern Ohio rolled prior to or immediately after planting. The average number of times the land was rolled ranged from 1.4 to 1.9.

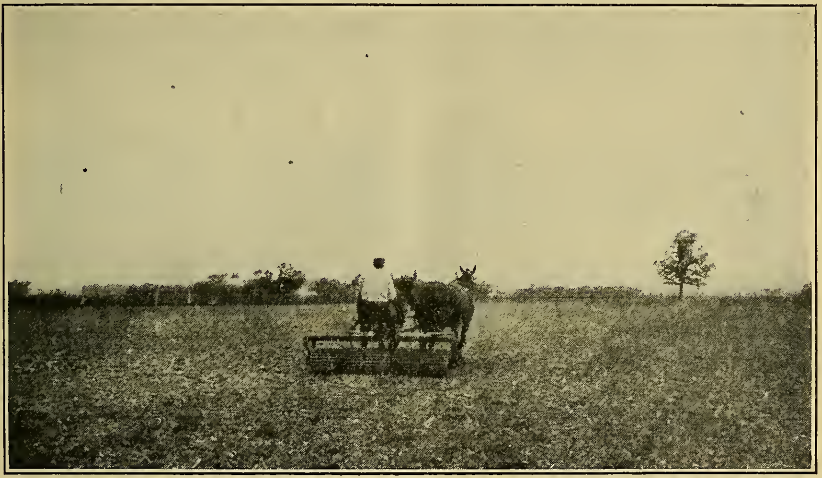

FIG. 12.—Rolling with a bar roller. This implement firms and also pulverizes the soil.

The majority of the men rolled immediately before planting, some after planting, and a few rolled both before and after seeding. The object of rolling before seeding was to create a smooth even surface for the drill rows. Still other men used the roller along with the harrow and disk in the general work of preparing a suitable seed bed.

Fifty-four per cent of the men in the Caro district, 64 per cent in the Alma, 19 per cent in the Grand Rapids district, and 63 per cent in northwestern Ohio rolled at about the time the beets were pushing through the ground, or soon after. Rolling at this time, called "rolling beets," may be done for several reasons. If the rain has caused a crust to form at a period when the seed is germinating, it is customary to employ a bar roller to break the crust, thus allowing the young plants to push through to the surface. This condition often prevails on the heavier soil types. Again, after blocking and thinning it is often advisable to use a roller to smooth the surface and to firm the soil around the young and tender plants.

The average labor requirements and cost per acre were practically the same, regardless of whether the work was done before or after planting.

The cost per acre for one time over on individual farms ranged from 20 cents to 50 cents per acre. The use of a 1-man and 2-horse crew was universal in all districts studied.

PLANTING.

Planting covered a period from April 5 to June 1. Most of the work, however, was done during a period extending from April 20 to May 20. In a few instances, where the seed was planted on sandy soil, wind storms blew it out and it was necessary to replant a fractional part of the acreage. These areas were so small, however, that no charge has been included for seed used in replanting. (See Table XI.)

TABLE XI.—*Planting.*

	Per cent of all records.	Acres planted per farm.	Hours of labor per acre.		Labor cost per acre.
			Man.	Horse.	
Caro	100	15.13	1.10	2.13	$0.41
Alma	100	9.54	1.12	1.92	.41
Grand Rapids	89	6.80	1.19	1.98	.44
Northwestern Ohio	99	15.77	1.02	2.04	.40

The seed was purchased from the sugar companies, at a cost of 15 cents per pound. The average rate for seeding for all areas was 15 pounds per acre. A few men used a little less, a few more. The lowest amount reported was 9 pounds and the highest 22 pounds per acre. On four farms in the Grand Rapids district the seed was sown with a hand drill at a cost of 73 cents per acre. One farmer in northwestern Ohio hired another operator to do the planting. These farms are not included in the table.

The seed is planted in continuous, solid rows to insure a good stand. Later, when the seed has germinated and the young plants have pushed through the ground, they are thinned out to a suitable distance. This operation will be discussed under a separate heading. Seed was planted at a depth of from one-half to 1 inch.

Ordinary grain drills and special beet drills (fig. 13) were used to do the planting. Where grain drills are used all the hoes are removed except the ones distributing the seed, and they may or may not be equipped with press wheels. The special beet drills are of two sizes; the 2-row and the 4-row drill, each of which has press-wheel attachments which exert a uniform pressure on the drill row. This firms the soil and aids in retaining sufficient moisture to insure a quick germination of the seed. The use of grain drills for seeding was common in three sections. Forty-four drills were reported at Caro, 5 at Alma, and 11 in the Grand Rapids area. In northwestern Ohio special 4-row beet drills were used exclusively. The custom in this area has been for the sugar companies to rent beet drills to the farmers at a nominal charge of 15 cents per acre.

In northwestern Ohio 20-inch rows were found on all farms with the exception of four, where 24-inch rows were reported. In all other districts the width of row varied from 20 inches to 28 inches.

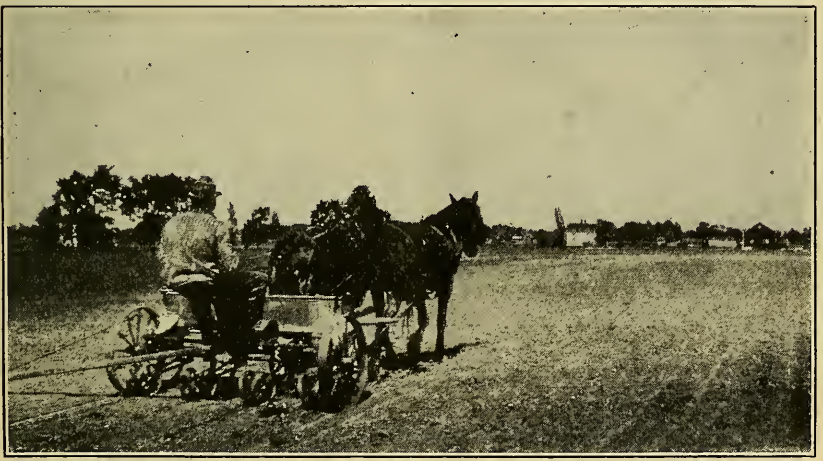

FIG. 13.—Planting seed with a special beet drill.

One-horse 2-row drills were used only in the Grand Rapids and Alma areas. Nine men in the Alma district and 7 at Grand Rapids used this type of drill. The labor charge for seeding on these farms was 55 cents per acre, while the men in the same areas who used a 2-horse, 4-row drill performed the work at a labor cost of about 40 cents per acre.

CULTIVATING.

Sugar beets in these areas were cultivated an average of about five times. The first cultivation occurs as soon as the rows can be seen plainly. The cultivator is equipped with knives or crowfeet for killing weeds. Blocking and thinning usually follow the first cultivation. All subsequent cultivations are usually made with bull-tongue attachments, which stir the soil to a greater depth and create a dust mulch. If weather conditions permit, it is customary to run the cultivator at frequent intervals until the beets are so large that it is impossible to follow the rows. (See Table XII.)

In the Ohio district either the 2-row walking or the 4-row riding cultivator was used. In other districts the 1-row or 2-row riding or

FIG. 14.—Cultivating sugar beets with a 2-row walking cultivator.

walking cultivator was used (figs. 14 and 15). It has been the custom of the Ohio sugar companies to rent 2-row walking cultivators at a charge of 25 cents per acre for the season to sugar-beet farmers desiring them.[1]

TABLE XII.—*Cultivating.*

District.	Per cent of all records.	Acres per farm cultivated.	Times cultivated.	Hours of labor per acre.		Labor cost per acre.
				Man.	Horse.	
Caro	69	13.20	4.58	9.05	9.05	$2.56
Alma	89	9.30	6.20	11.55	11.55	3.47
Grand Rapids	83	6.09	4.88	11.92	11.92	3.57
Northwestern Ohio	81	13.21	4.00	7.56	7.56	2.27

[1] The type of cultivator used was a factor that caused the comparatively high labor requirement for cultivation in these districts, as may be seen by reference to the following table, which gives a record of the work by a 1–1 crew with a 2-row cultivator in comparison with work done by a 1–2 crew operating a 4-row cultivator.

Labor requirements for cultivating in northwestern Ohio.

Crew.	Records.	Row.	Times over.	Hours per acre.		Labor cost per acre.
				Man.	Horse.	
1 man-1 horse	79	2	4.0	7.56	7.56	$2.27
1 man-2 horses	20	4	4.1	3.86	7.72	1.54

It will be seen that there was a difference here of 3.7 hours of man labor in favor of the 4-row cultivator. The difference in cost amounted to 73 cents per acre.

In addition to the records indicated in Table XII, 82 men were visited who used a 1-man, 2-horse crew. The average beet acreage per farm in this group in the Caro and Ohio districts was from 29 per cent to 49 per cent larger than in the same areas where a 1-man, 1-horse crew was used.

FIG. 15.—Cultivating sugar beets with a 2-row riding cultivator.

HAND WORK ON SUGAR BEETS.

This labor consists of blocking, thinning, usually hoeing twice, pulling, topping, and throwing into piles. Very few farmers have sufficient farm labor to do the hand work, and therefore in most cases it is done by special beet workers at a stipulated contract rate per acre. In addition, the farmer agrees to furnish the beet workers a house to live in (fig. 16), haul fuel, and furnish transportation to and from the railroad station. The beet workers furnish all necessary hoes and knives.

Common contract rates for hand labor in Michigan and Ohio.

Kind of work.	22-inch rows.	24-inch rows.	28-inch rows.
Blocking and thinning	$6.00	$5.00	$5.00
Hoeing, 2 times	3.00	3.00	3.00
Topping and piling	9.00	8.00	7.00
Total	18.00	16.00	15.00

In the Alma area the rates for hand labor were slightly greater than the above. The rate for beets planted in rows 18 inches to 22 inches apart was $20. For beets 24 inches apart the rate was $18 per acre, and for beets 28 inches apart, $16 per acre.

BLOCKING AND THINNING.

As pointed out under planting practice, the beet seed is drilled in solid rows to insure a good stand. Therefore the young beets

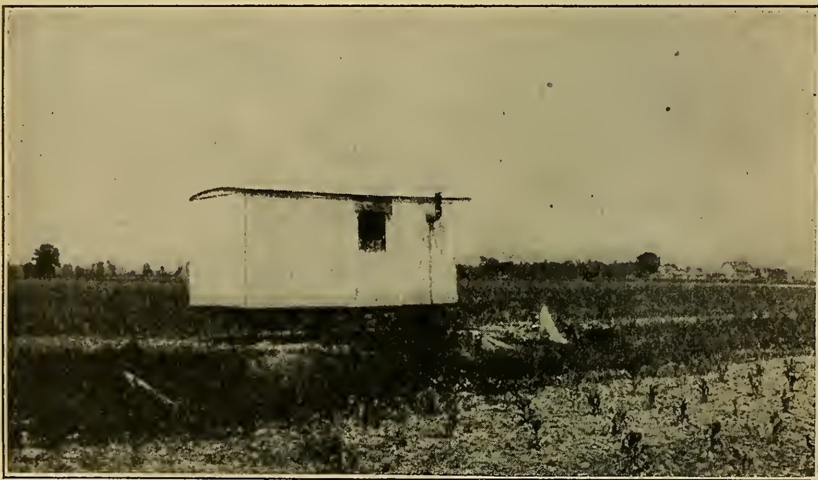

FIG. 16.—Temporary movable quarters provided for labor doing the handwork on the beet crop.

must be thinned in order to provide sufficient space for the growth and development of the plants allowed to remain. The proper time

FIG. 17.—Sugar beets that were not thinned at the proper time. This work should be done as soon as the young plants are up and the rows can be seen plainly.

to block and thin is just as soon as possible after the young plants are up and the rows can be plainly seen. (See fig. 17.)

The blocking consists of hoeing out all of the surplus plants and leaving a small bunch of beets at regular intervals in the row. The thinning should be carefully performed so that only one plant is left in a place and in a manner which will result in retaining the strongest plants evenly distributed throughout the length of the row. For the men who gave estimates on this operation, the spacing was from 9 to 12 inches apart in the row.

Fifteen per cent of the farmers did the blocking and thinning with their own farm labor. The average labor requirements per acre varied from 25 to 36 hours and cost from $5 to $7.50 per acre.

Fig. 18.—Hoeing sugar beets after the crop has made considerable growth.

HOEING.

The agreement for contract hand labor stipulates that the beets shall be hoed twice and shall be kept free from weeds in the row and for a distance of 3 inches on each side of the row. (See fig. 18.)

Table XIII.—*Hoeing.*

Districts.	Number of records.	Acres in beets per farm.		Times hoed.	Man hours per acre.	Labor cost per acre.
		Total.	Hoed.			
Caro	13	8.82	8.59	1.48	17.17	$3.13
Alma	21	7.65	7.65	1.09	17.80	3.56
Grand Rapids	25	4.36	4.36	1.22	27.67	5.53
Northwestern Ohio	16	16.49	10.89	1.00	9.60	1.92

The contract rate for two hoeings was $3 per acre. It will be noticed (Table XIII) that the cost per acre in three districts where the hoeing was done by the farm labor was more than the contract rate, while in the Ohio district it was considerably less. The amount of work that can be accomplished in a given time is exceedingly variable, since so much depends on the number of weeds present.

Again, in Ohio the farmers did a portion of the hand labor and contracted the remainder. Hence the number of acres hoed per farm was less than the acreage planted to beets.

Seventeen per cent of the farmers did the work of hoeing with their own labor. The average number of times hoed per farm varied from one to one and one-half times.

LIFTING.

The beets are ready to be lifted or to be "plowed out" just as soon as they are mature. The time is determined by a sugar test made by the sugar-factory representative. The lifting period extends from about the middle of September until December 1. (See Table XIV.)

TABLE XIV.—*Lifting.*

District.	Per cent of all records.	Acres in beets per farm.		Hours of labor per acre.		Labor cost per acre.
		Total.	Lifted.	Man.	Horse.	
Caro	100	15.06	15.03	4.60	10.61	$1.91
Alma	100	9.54	9.54	4.14	8.35	1.66
Grand Rapids	100	6.40	6.14	4.44	8.88	1.78
Northwestern Ohio	100	15.82	15.77	4.49	9.06	1.80

Two types of implements are used in doing the work, the crotch lifter (fig. 19) and the side lifter. The crotch lifter consists of two bowed standards, each of which is equipped with a sharp projecting point, while the side lifter has only one point on the end of a long, thin cutting-blade. The points of the crotch lifter run on either side of the row, while that of the side lifter runs on one side only. The beets are loosened and slightly raised, from which position they are easily pulled and thrown into piles. The side lifter has a lighter draft and is the type usually found in these regions. The crotch lifter was found on only 49 farms.

The typical crew for all sections except the Caro district consisted of 1 man and 2 horses. There were 43 men in the latter district who used a 1-man and 3-horse crew. Slightly less than 2 acres constituted a day's work. However, it was customary to lift only enough beets at one time to keep the hand labor busy.

TOPPING.

This operation goes hand in hand with lifting and hauling. After being loosened with a lifter the beets are then removed by hand (fig. 20) and the tops cut off squarely with a heavy beet knife, just under the lowest leaf scar. It is essential that all green portions of the crown be removed in the field. The crown contains salts which in-

FIG. 19.—Harvesting beets with a lifter. The points of the crotch lifter run on either side of the row.

terfere with sugar extraction, so that if the beets are not properly topped a deduction for such beets is made on delivery to the factory or loading station. When topped they are placed in piles consisting

FIG. 20.—Beets that have been removed by hand, and toppers at work in field.

of the beets from 16 to 18 rows. The piles must be at least 2 rods apart and must be covered with tops each night.

On 10 per cent of the farms in the Caro, Alma, and Grand Rapids areas, the topping was done by the farmers' own labor. On 12 per cent of the farms in Ohio the farmer did a portion of the work and had the remainder done by contract labor. The labor requirements on farms when the topping was not contracted ranged from about 23 to 28 hours per acre and the labor cost varied from $4.65 to $5.60 per acre. It will be seen that the farmer performed the labor of topping at an appreciably lower cost per acre than the contract rate.

HAULING.

The sugar beets are forked into large beet boxes from piles in the field. From the field they are either hauled to a loading station (see fig. 21), where they are loaded into cars, or directly to the sugar-factory beet dump. Upon arrival at the loading station or factory, as the case may be, a representative sample is taken and weighed as it comes from the load. All dirt is removed. The sample of beets is retopped when necessary and the clean sample is weighed a second time. The difference in weight represents the tare. In all sections, with the exception of northwestern Ohio, the loading of beets into cars was done by hand. At one place in northwestern Ohio several mechanical loading devices were observed. (See Table XV.)

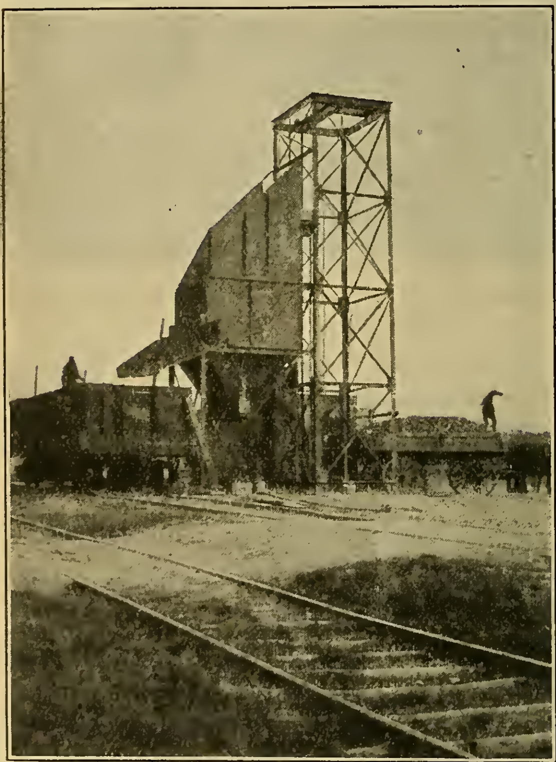

FIG. 21.—A typical loading station in northwestern Ohio. Here the beets are placed in cars and are then transported to the factory.

In northwestern Ohio five men hired the hauling done at a contract rate of from 65 cents to 80 cents per ton, depending on the distance hauled. In all other districts the hauling was done by the farmers' own labor. The weight of load ranged from 1½ to 2½ tons.

The size of the load is an important factor in determining the hauling cost per ton. By comparing the records which were obtained in the Alma district with the records which were secured in the Grand Rapids area it is found that the average load in the former area was seven-tenths of a ton greater than the average load in the latter area. In other words, the Alma operators hauled an average load of 3.1 tons, whereas the Grand Rapids growers took in only 2.4 tons per load.

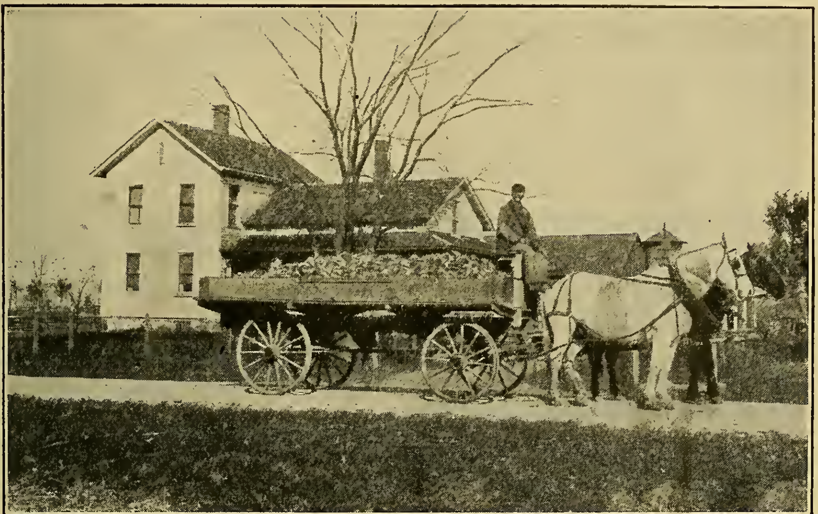

FIG. 22.—Hauling sugar beets with a crew of 1 man and 2 horses. This illustrates the common crew for these regions.

The hauling season extended from about September 15 to early in December. A 1-man, 2-horse crew (fig. 22) was used in all districts except Grand Rapids, when five men used a 1-man, 3-horse crew.

TABLE XV.—*Hauling.*

District.	Per cent of all records.	Acres in beets per farm.		Tons hauled per acre.	Miles hauled.	Hours of labor per acre.		Labor cost per acre.	Labor cost per ton.
		Total.	Hauled.			Man.	Horse.		
Caro	100	15.06	15.00	9.73	1.59	12.09	24.18	$4.62	$0.48
Alma	100	9.54	9.47	11.63	4.21	20.50	41.46	8.25	.70
Grand Rapids	100	6.40	6.14	10.40	2.90	17.72	37.14	7.25	.73
Northwestern Ohio	95	15.29	14.46	13.30	2.57	19.10	37.55	7.58	.56

The average distance to loading station or sugar-factory beet dump is 2.47 miles. Of 315 men reporting on hauling, 62 per cent hauled less than the average distance, and 38 per cent more than the average. Thirty-eight per cent hauled an average of 1.91 miles. Seven per cent hauled an average of 6.82 miles. Those men who hauled an average of 1.91 miles did so at a cost of 48 cents per ton less than the men who hauled over 5½ miles, or an average of 6.82 miles. (See Table XVI.)

TABLE XVI.—*Relation of distance from loading station to cost of delivering sugar beets.*

Distance (miles).	Average distance.	Per cent of all records.	Labor cost per ton.
	Miles.		
1 or less	0.63	25	$0.39
1 to 2½	1.91	38	.53
2½ to 4	3.33	24	.65
4 to 5½	4.79	6	.77
Over 5½	6.82	7	1.01

VARIATIONS IN FIELD PRACTICE.

Certain field methods in growing and handling sugar beets are common to all areas. On the other hand the desired results are often accomplished in a number of different ways. Variations in field practice may be due to the condition of the soil at the time the work is done. Some fields may have to be disked more than once and the soil may require extra treatment with the spring-tooth harrow. Perhaps in other cases it may be possible to put the field in good condition for seeding merely by using the spike-tooth harrow. Climatic conditions usually govern the methods that must be employed in handling the growing crop. The handwork, such as blocking and thinning, hoeing, and topping, is usually done on a contract basis, though a part of this work may in some instances be done by the owner or renter. Occasionally all of the handwork may be done by the farmer, his family, and hired hands. A few of these features are illustrated in Tables XVII to XX, which were prepared in order to show variations in farm practice for 10 representative farms in each of the 4 districts included in this survey.[1]

[1] Under the operations "removing trash" and "manuring" the fractional numbers indicate the portions or parts of the total beet acreage on which it was necessary to do some cleaning up after the preceding crop, or they indicate the part of the total area that received a treatment of barnyard manure. Referring to the table for the Caro district, it will be observed that Farm No. 1 manured one-tenth of the beet acreage; Farm No. 2 covered two-tenths or one-fifth of the beet land with manure, while Farm No. 5 treated one-half of the beet acreage with an application of manure. The manuring was done chiefly in the late fall and the early spring months.

TABLE XVII.—*Variations in farm practice in production of sugar beets, Caro, Mich.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Plowing	1	1	1	1	1	1	1	......	1	1
Disking	1	4	4	......	......	......	1	2	2	1.1
Floating	1	1	1	......	1	2	1	1	......	......
Harrow (spike)	2	......	......	2	......	1	1	2	1	1
Harrow (spring)	1	2	2	4	4	3	2	4	2	3
Rolling	......	......	......	2	1	......	1	2	2	1
Hauling fertilizer	......	1	1	1	......	1	1	1	......	1
Planting [a]	1	1	1	1	1	1	1	1	1	1
Rolling beets	1	......	2	......	1	2	2	1	......	......
Cultivating	3	5	4	4	4	5	4	4	4	3.6
Blocking and thinning	(b)	(b)	(b)	(b)	(b)	1	(b)	(b)	(b)	(b)
Hoeing, first	(b)	(b)	(b)	(b)	(b)	1	(b)	(b)	(b)	(b)
Hoeing, second	(b)	(b)	(b)	(b)	(b)	......	(b)	(b)	(b)	(b)
Topping	(b)	(b)	(b)	(b)	(b)	1	(b)	(b)	(b)	(b)
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Removing trash	......	......	.5	......	......	......	......	......	......	......
Manuring	.1	.2	......	.2	.5	.1	......	.2	.1	......
Man hours per acre	26	35	40	42	42	123	38	34	30	40
Horse hours per acre	48	72	92	94	74	65	74	71	63	77
Yield per acre (tons)	4.0	12.0	10.0	9.8	7.1	9.0	9.0	10.0	6.0	6.1
Total cost per acre	$45.56	$47.73	$46.78	$50.91	$49.50	$48.33	$47.64	$49.05	$45.68	$45.90

[a] Applying fertilizer is included in the planting operation. [b] Contract.

TABLE XVIII.—*Variations in farm practice in production of sugar beets, Alma, Mich.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Plowing	1	1	1	1	1	1	1	1	1	1
Disking	......	1	1	......	......	1	3	4	......	......
Floating	1	1	......	2.1	2	1	1	1	1	1
Harrow (spike)	......	1	3	1	2	1	4	2	2	1
Harrow (spring)	3	2	1	5.1	2	2	......	1	3	4
Rolling	2	1	2	.5	3	1	2	2	1	1
Hauling fertilizer and seed	.5	......	1	......	1	1	......	......	......	......
Planting [a]	1	1	1	1	1	1	1	1	1	1
Rolling beets	......	2	1	......	1	1	......	.1	......	......
Cultivating	9.2	4	6	6	6	6	5	5	6	8
Blocking and thinning	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Hoeing, first	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Hoeing, second	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Topping	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Removing trash	......	......	......	......	......	......	......	......	......	......
Manuring	.2	.2	.2	.1	.3	......	.1	.1	.1	.3
Man hours per acre	49	140	42	46	52	42	56	44	40	53
Horse hours per acre	82	77	79	82	110	83	102	95	76	98
Yield per acre (tons)	15.1	7.0	11.0	11.0	14.5	14.0	13.2	10.0	13.0	12.0
Cost per acre	$52.42	$46.37	$53.85	$50.28	$60.37	$68.54	$55.92	$67.48	$54.39	$55.49

[a] Applying fertilizer is included in the planting operation. [b] Contract.

TABLE XIX.—*Variations in farm practice in production of sugar beets, Paulding, Ohio.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Dragging	......	......	......	......	......	......	......	......	......	1
Manuring	......	......	0.2	......	......	......	0.1	0.3	0.1	......
Plowing	1	1	1	1	1	1	1	1	1	1
Disking	......	2	2	......	2	1.5	2.3	......	......	......
Floating	......	......	1	......	......	......	.7	2	......	2
Harrow (spike)	1	2	3	1	1	2.2	2	6	3	2
Harrow (spring)	1	......	2	1.5	......	......	......	......	......	......
Rolling	......	1	1	......	1	2	.3	2	2	......
Hauling fertilizer [a]	......	......	......	......	1	......	1	1	1	1
Fertilizing	......	......	......	......	......	......	......	......	......	1
Planting	1	1	1.	1	1	1	1	1	1	1
Rolling beets	......	......	2	.2	......	......	2	1	2	......
Cultivating	2	5	8	3	4	3	4	4	2.5	4
Blocking and thinning	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Hoeing, first	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Hoeing, second	(b)	......	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Topping	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Man hours per acre	48	101	57	34	48	19	50	40	25	39
Horse hours per acre	90	82	128	72	100	55	100	73	53	74
Yield per acre (tons)	13.2	11.0	13.8	15.0	17.0	14.0	14.0	13.8	11.0	11.8
Cost per acre	$53.87	$44.30	$61.21	$51.02	$56.76	$54.00	$59.34	$57.37	$51.86	$51.25

[a] Fertilizer is usually applied in the planting operation. [b] Contract.

TABLE XX.—*Variations in farm practice in production of sugar beets, Grand Rapids, Mich.*

Operations.	Farm No. 1.	Farm No. 2.	Farm No. 3.	Farm No. 4.	Farm No. 5.	Farm No. 6.	Farm No. 7.	Farm No. 8.	Farm No. 9.	Farm No. 10.
	Times over.	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*	*Times over.*
Dragging corn stubble	......	......	......	......	1	......	......	......	......	......
Manuring	......	......	0.5	0.1	.3	......	0.2	......	0.1	0.4
Plowing	1	1	1	1	1	1	1	1	1	1
Disking	......	4	......	......	......	2	4	......	......	......
Floating	......	2	......	......	1	......	......	......	1	......
Harrow (spike)	1	1	1	......	......	4	1	2	1	1
Harrow (spring)	3	2	3	4	4	......	......	3	4	3
Rolling	1	2	......	2	......	2	......	2	1	1
Hauling fertilizer	......	......	1	1	1	......	1	1	1	1
Planting [a]	1	1	1	1	1	1.1	1	1	1.2	1
Rolling beets	1	2	......	......	......	......	......	......	......	......
Cultivating	5	6	5	5	5	4	4	5	5	8
Blocking and thinning	(b)	1	(b)	(b)	(b)	(b)	(b)	(b)	1	1
Hoeing, first	(b)	1	1	(b)	(b)	(b)	(b)	(b)	1	1
Hoeing, second	(b)	......	......	(b)	(b)	(b)	(b)	(b)	1	......
Topping and pulling	(b)	1	1	(b)	(b)	(b)	(b)	(b)	1	1
Lifting	1	1	1	1	1	1	1	1	1	1
Hauling	1	1	1	1	1	1	1	1	1	1
Man hours per acre	45	102	75	42	28	52	29	54	153	113
Horse hours per acre	88	112	77	76	60	95	80	107	122	80
Yield per acre (tons)	8.0	10.2	10.5	18.0	12.0	13.2	10.8	9.5	8.0	4.0
Cost per acre	$50.47	$44.75	$46.96	$49.22	$45.09	$49.24	$60.50	$50.86	$59.08	$47.97

[a] Applying fertilizer is included in the planting operation. [b] Contract.

By consulting these tables it will be seen that there is considerable variation in the number of times certain operations were performed. Differences will also be noted in the method of procedure on these farms. Taking the Caro district as an illustration, plowing was a common operation on all farms except one, in which case sugar beets were planted upon bean ground. Some of the land was disked four times; the disking was done twice on a few farms, and in other cases but once; there were a few cases in which the disk was not used at all. Floating was practiced quite generally, but was not common to all farms. The spring-tooth harrow was used much more extensively than the spike-tooth in the preparation of the seed bed.

Rolling was done on some farms both before and after planting. A few men rolled prior to planting the seed and did not repeat the operation after the beets were up. On other farms this work was confined solely to "rolling beets."

The 10 Caro growers did not replant any seed, but in some of the other districts a fractional part of the acreage had to be reseeded. The number of cultivations varied from three to five in the Caro district. Only one operator in this group performed the handwork with the regular farm labor; the remaining growers contracted the blocking, thinning, hoeing, and topping.

COST OF PRODUCING SUGAR BEETS.

The cost of the various items of expense has advanced appreciably since 1915, and likewise the receipts have increased considerably. However, by substituting prevailing costs for the items of man labor, horse labor, pounds of seed, etc., the cost of producing sugar beets under present conditions can be closely approximated.

By a study of the data presented it is hoped that the beet grower will be able not only to measure his own beet enterprise, but also to judge the relative importance of each item that enters into the cost of producing sugar beets.

To find the cost of producing an acre of sugar beets in a given region the total cost of production was divided by the total beet acreage. Similarly the cost of producing a ton of sugar beets was found by dividing the total cost of production by the total number of tons of beets produced. All items of cost are computed on this basis. The final figures give the average cost of producing an acre or a ton of sugar beets on 2,018 acres of beets at Caro, Mich., 230 acres in the Grand Rapids, Mich., district, 506 acres at Alma, and 1,525 acres in northwestern Ohio, or a total acreage of 4,279 for all districts.

LABOR COSTS.

The labor required in producing sugar beets can be divided into three classes, man, horse, and contract. The last item consists mainly of man labor and is paid at a certain rate per acre or per ton. However, in a few cases where plowing or hauling was hired by the acre or by the ton, this item is classified under contract labor. The sum of the three items of labor gave the total labor cost for the four areas. Table XXI shows the labor cost of producing sugar beets in three areas in Michigan and one in northwestern Ohio.

TABLE XXI.—*Labor costs.*

District.	Number of farm records.	Total acres in beets	Labor cost per acre.	Yield per acre	Labor cost per ton.
				Tons.	
Caro	134	2,017.65	$31.40	9.73	$3.23
Alma	53	505.79	35.21	11.40	3.09
Grand Rapids	36	230.53	34.19	10.16	3.36
Northwestern Ohio	97	1,524.65	34.02	13.17	2.58

The labor cost is by far the largest item of expense, constituting over 60 per cent of the total cost of production. This item was practically the same in the Grand Rapids and northwestern Ohio areas. It will be noticed, however, that the labor cost was about $4 less per acre in the Caro area than in the Alma district. This variation is probably due to the variation in beet acreage per farm. At Alma an average of 9.54 acres of beets per farm was grown; at Caro 14.51 acres. The labor cost per acre is usually less on a large acreage than on a small one, on account of the more efficient employment of labor. In some cases the preparation for a given operation consumed as much time as the work itself. This is especially true on a very small acreage, since the time required to get the team ready and go to the field is as great for a small field as for a larger field of beets.

At Caro 15.1 acres were grown per farm, and in northwestern Ohio 15.72 acres. The average yield in the former district was considerably smaller than in the latter, where it was necessary to handle more beets, and consequently more labor was required to do the work. Not only was the beet acreage per farm smaller at both Alma and Grand Rapids than at Caro, but the yields per acre were higher. These two factors influenced the labor cost per acre in the Alma and Grand Rapids areas.

COST OF MATERIALS.

The cost of materials includes the items of manure, fertilizer, and seed. The estimated value of the manure in the yard and the actual expenditure for seed and fertilizer are charged against the beets. Table XXII shows the cost per acre for each of these three items and the total cost of materials per acre and per ton.

TABLE XXII.—*Cost of materials.*

District.	Number of farm records.	Total acres in beets.	Cost per acre.				Cost per ton.
			Manure.	Fertilizer.	Seed.	Total.	
Caro	134	2,017.65	$1.90	$1.19	$2.34	$5.43	$0.56
Alma	53	505.79	2.92	.81	2.30	6.03	.53
Grand Rapids	36	230.53	2.68	1.22	2.13	6.03	.59
Northwestern Ohio	97	1,524.65	.74	.73	2.28	3.75	.29

The cost per acre for materials was the same at Alma and Grand Rapids, but was very much lower in northwestern Ohio. The small amounts of manure and fertilizer applied result in this low total charge per acre. Reduced to a ton basis the costs do not vary appreciably except in northwestern Ohio, where this item is approximately 50 per cent of the charge in the other groups.

MANURE.

From 6 to 22 per cent of the beet acreage received an application of manure. The smallest percentage manured occurred in northwestern Ohio and the largest at Grand Rapids. In the former area a number of growers turned under a clover sod, thus adding green manure to the land; consequently the cash charge in this district for farm manure is smaller. At Grand Rapids the dairy farms supply an adequate amount of farm manure. Comparing the acres in beets manured per farm, there is not a wide variation. At Grand Rapids 1.41 acres per farm received an application, and in northwestern Ohio 0.89.

The greatest cost per acre for manure was in the Alma area. Here, too, the application was the largest (14.3 tons), and the highest estimated value per ton ($1.10) was recorded. The rate of application and the estimated value per ton were essentially the same at Caro and Grand Rapids. However, since the acreage per farm was greater in the former than in the latter, the cost at Grand Rapids was 78 cents higher than in the Caro region.

Northwestern Ohio had the largest acreage in beets and the smallest area receiving an application of manure. Consequently the lowest charge for manure occurs in this district.

FERTILIZER.

In order to insure the beet plant a rapid and luxuriant growth it is the general practice in the areas studied to apply commercial fertilizers. The northwestern Ohio growers put on more fertilizer per acre than any of the other groups, averaging 171 pounds, but they paid about $3 less per ton than the Caro or Alma farmers, and $2 less than the Grand Rapids growers. However, only one-third of the beet acreage in the former area received an application of fertilizer, while 80 per cent of the Caro, 48 per cent of the Alma, and 73 per cent of the Grand Rapids acreage was so treated.

SEED.

Beet seed was purchased from the sugar factory at a cost of 15 cents per pound. The factory advises the farmer to sow 15 pounds per acre, thus making the cost of the seed $2.25 per acre. The seed is advanced to the farmer and its value is deducted from the money due the grower when the beets are delivered. No interest is charged the farmer for the money invested in the seed.

Some growers seeded their fields at a higher, some at a lower rate than 15 pounds to the acre, while others sowed the stipulated amount. Caro farmers averaged 15.3 pounds, Alma growers 15.5, Grand Rapids 14, while the northwestern Ohio group drilled in 15.1 pounds of seed per acre. This variation accounts for the difference in the acre cost of seed. The lowest rate of seeding and the lowest cost were found at Grand Rapids.

OTHER COST ITEMS.

Other cost items include insurance and taxes, use of land, machinery, and miscellaneous expenses. These are charges against the farm as a unit and must be prorated so that each enterprise will bear a just portion of the total expense. Table XXIII gives the cost per acre of these different items, together with the total cost per acre and per ton.

There was a wide variation in the acre charge for these costs. Northwestern Ohio had the highest cost, $18.27, while in the Caro district the cost was but $10.82. A glance at the table will show that the charge for the use of land causes most of this difference. Reduced to a ton basis, this variation becomes considerably less.

TABLE XXIII.—*The use of land and other cost items.*

District.	Number of farm records.	Total acres in beets.	Cost per acre.					Total cost per ton.
			Insurance and taxes.	Use of land and interest on cash.	Machinery.	Miscellaneous expenses.	Total.	
Caro	134	2,017.65	$1.00	$6.65	$2.07	$1.10	$10.82	$1.11
Alma	53	505.79	.80	11.69	2.45	1.24	16.18	1.42
Grand Rapids	36	230.53	.92	8.25	2.45	1.21	12.83	1.26
Northwestern Ohio	97	1,524.65	.91	13.79	2.45	1.12	18.27	1.39

INSURANCE AND TAXES.

Where the operator owned the land the insurance and taxes were greater than where the beets were grown by a tenant, since the man who rented had only his personal taxes to pay and usually carried no insurance. This charge is very small on tenant farms.

On farms operated by the owner of the land the percentage of the total real-estate investment covering the beet land was used in determining the proportion of the insurance and taxes chargeable against the beet crop. This item was about the same in Grand Rapids and northwestern Ohio and slightly greater at Caro. The lower charge of 80 cents at Alma is due to the high percentage of tenant farmers in this group. About 50 per cent of the growers in this area grew beets on rented land, while only about 10 per cent of the farmers at Caro and Grand Rapids rented the land.

USE OF LAND AND INTEREST ON CASH.

The largest item in the group comes under use of land and interest on cash. If the owner grows beets, the money invested in land should pay interest to the farmer. The current rate on first-mortgage notes in the locality was used in figuring the interest on the investment, which was taken as the charge for the use of the land.

It is the practice in all the areas to borrow money to pay the men who perform the hand work on the beet crop. Even if a man has the ready money to meet this expense, it means an investment of $7.50 to $10 an acre from the time the beets are blocked and thinned to the harvesting of the crop. In either case the interest on this money is rightly chargeable against the beet crop.

If the operator rents the land, he gives a share of the crop or pays a stipulated cash price per acre for the use of the land. In the former case, the value received for that portion of the crop given to the landlord is charged; in the latter, the actual cash payment. Several factors affect the rental charge, namely, the share given as rent, the yield per acre, and the percentage of share renters in the different groups. In general, the value of the share of the beet crop given as rent exceeds the interest on the investment. The value of the share rent also exceeds the cash amount paid by the cash renters of beet land. The amount paid as rent must be sufficient to cover both interest on land and land taxes. Then, too, it must be remembered that there is more risk to the tenant who pays cash rent than to the one who gives a share of the crop. If the yield is low, the share renter gives a smaller number of tons of beets; while the cash renter pays the same amount, regardless of the yield. If a tenant gives to the landlord one-half of the crop, the value of the rent is greater than if only one-third or one-fourth were given. In northwestern Ohio this expense is over $2 higher than at Alma. Of a total of 14 share renters in the former area, 12 gave one-half of the crop as rent, one gave one-third, and one gave two-fifths. In the latter sections, three of the four share renters gave one-half and one gave only one-fifth of the crop. When the yield is high the value of the crop share is, of course, greater than when a low yield is produced. Northwestern Ohio farmers produced the highest yield per acre, Grand Rapids the lowest, the yields at Caro and Alma falling, in their respective order, between these two.

MACHINERY.

Certain farm implements, such as beet drill and lifter, are used exclusively in the production of sugar beets. The total annual expense of these implements must, therefore, be met by the beet crop. Other implements such as the plow, harrow, cultivator, wagons, etc., are used in common on all the crops grown on the farm. In this case, it is necessary to prorate the expense and charge the beets with a just proportion of the annual implement cost. Where machinery is hired, the actual cash paid out is considered. This was done in computing the machinery cost per acre of sugar beets. An average rate per acre was worked out for each district studied, and used for all the farms in that locality.

Since practically all of the implements employed were similar in the four regions, there is little variation in this charge, which was the same at Alma, Grand Rapids, and in northwestern Ohio, and a little lower in the Caro district.

MISCELLANEOUS EXPENSE.

There are a number of minor farm expenses, a portion of which every farm enterprise must stand, such as telephone, farm papers, interest on cash to pay regular farm help, and other general farm expenses.

This charge can be closely approximated, and, in this instance, is found by taking 3 per cent of the combined costs of materials and labor. There is very little difference in this charge for the four sections studied.

COST SUMMARY.

It is interesting to note the relative importance of the several classes of expense which, taken together, give the total cost of producing sugar beets. Table XXIV gives the percentage distribution of costs for all areas.

TABLE XXIV.—*Summary and distribution of costs.*

District.	Cost per acre.	Cost per ton.	Percentage distribution of costs.		
			Labor.	Materials.	Use of land and other costs.
Caro	$47.65	$5.62	65.9	11.4	22.7
Alma	57.42	5.04	61.3	10.5	28.2
Grand Rapids	53.05	5.21	64.4	11.4	24.2
Northwestern Ohio	56.04	4.26	60.7	6.7	32.6

The total cost per acre of producing sugar beets varied from $47.65 at Caro to $57.42 at Alma. This difference is due to three items—labor, manure, and rent. The cost per ton in the first three areas was above $5, while in the last district the cost was considerably below the five-dollar mark. It is interesting to note that the lowest cost per acre gave the highest cost per ton at Caro, and that the sections producing beets at a higher cost per acre than at Caro showed a lower cost per ton than the Caro figure. Here the difference in the yield per acre is the determining factor. The yield was low at Caro, and considerably higher in the other districts.

In order of importance, labor comes first, comprising over 60 per cent of the cost of production. "Other costs" come next, from 25 per cent to 32 per cent of the total, while materials constitute the remainder. It can be readily seen that any serious farm-labor problem is going to affect materially the cost of production of the sugar beet, since almost two-thirds of the total cost involves labor alone.

SUGAR BEET RETURNS VERSUS COST.

The sugar companies did not all pay a uniform rate to the farmer for his sugar beets. Several companies paid a flat rate of $6 a ton for beets either delivered on board the cars at the local shipping point or hauled to the factory bins. One company gave $5 a ton for the beets, plus an additional price, or bonus, per ton, depending on the increase in the New York market wholesale price for sugar above $5 per hundredweight, during the months of October, November, and December. Another sugar company paid for the beets on a sliding scale, dependent on the per cent of the sugar content of the beets. For beets testing 12 per cent, $5.25 a ton was paid, with an additional 40 cents per ton for each per cent above 12. Applying this scale, beets testing 13 per cent sugar were worth $5.65 a ton and 14 per cent beets brought $6.05 per ton.

It will be seen that, owing to the different methods of payment, the average receipts per acre will vary somewhat. In some cases in the same section, farmers contracted beets to different sugar companies and received different rates of payment.

Table XXV gives a comparison of the beet costs and receipts per acre and the margin above the cost of production received by the farmer.

TABLE XXV.—*Average returns and margin above cost in producing sugar beets.*

District.	Yield per acre.	Receipts per acre.	Cost per acre.	Net returns per acre for beets.	Net returns including beet tops.
	Tons.				
Caro	9.72	$54.62	$47.65	$6.97	$8.67
Alma	11.40	68.40	57.42	10.98	13.16
Grand Rapids	10.16	61.31	53.05	8.26	11.34
Northwestern Ohio	13.17	71.83	56.04	15.79	17.60

The receipts per acre depend on the yield of beets produced and the amount received per ton. Northwestern Ohio growers received the lowest average price per ton, or $5.45; Grand Rapids growers got $6.03, the highest rate received; Alma, $6; and Caro, $5.62 a ton. The yield per acre is the greatest factor affecting beet receipts in the districts studied.

The net return per acre was obtained by subtracting the cost from the receipts, this item varying from $6.97 at Caro to $15.79 per acre in northwestern Ohio. When the estimated value of the beet tops is added to this figure, a net return is obtained which ranges from $8.67 to $17.60 per acre. The relation of the net returns from beets alone and the net returns including tops varies somewhat for the four areas, depending on the estimated value of the tops. At Caro beet tops were given a value of $1.70 an acre, at Alma $2.18, at Grand Rapids $3.08, and in northwestern Ohio $1.81.

In no section did the average cost of production exceed the average returns. However, some individual growers produced beets at a loss and some realized only a small net return. It is possible to increase the yields in many localities and thereby add appreciably to the net returns.

FIG. 23.—Frequency curve showing the distribution of farm operators in this study in relation to cost per ton and yield per acre.

RELATION OF YIELD TO COST OF PRODUCTION.

As has been previously stated, the yield per acre is an important factor in the cost of producing a ton of sugar beets. The accompanying frequency curve (fig. 23) shows the distribution of the growers in the four regions on the basis of cost per ton in producing sugar beets.

It will be seen that sugar beets are grown at a cost of from $3 to $12 a ton. However, from the 320 records obtained, 229 growers, or about 72 per cent, produced beets at a cost ranging from $3.50 to $5.50 a ton. Dividing the records into two groups, 145 growers produced beets at $4.50 a ton or less, and 175 grew the crop at $5 a ton or more. Twenty-three per cent of the growers reported a cost of $6 a ton or more.

The farmers received from $5.45 to $6.13 a ton for the crop. The margin of profit is very small in a number of cases, a condition which does not make for a greater beet acreage, a higher tonnage, or an increase in the sugar supply of the country. However, the farmer expends considerable labor on the beet crop and has been given an allowance for his own work. Then, too, several benefits are derived from growing the crop on the land. Since deep tillage and thorough land preparation are prerequisite, the soil is in excellent tilth for the following crop. This condition is shown in the high yields of grain after beets. Clean cultivation also eliminates noxious weeds and insures to the following crop comparative freedom from these pests.

The curve also points out the importance of a good yield of sugar beets as a means of decreasing the cost per ton. From a cost of $3 a ton there is a gradual decrease in the yield until the cost becomes $8 a ton. From this point a decrease does not always appear. However, only 4 per cent of the growers exceeded this figure.

It is possible in a number of instances to increase the yield by employing better tillage methods, by the proper use of manures, and by the use of a well-planned cropping system.

Recently the sugar companies have advanced the price paid to the farmer to help take care of increased costs. However, the general relation between the new price and the new cost of production remains practically the same. There are suggestions brought out in this study that might be used by the sugar company as well as by the beet grower. Increasing the efficiency of the labor necessary to raise the crop, and the performance of certain operations when these become necessary, will go far toward decreasing the cost of labor, which constitutes such a large part of the total expense; and also in increasing the yield of sugar beets. Both results would tend to lower the cost per ton of production.

VALUE OF BEET TOPS.

The value of beet tops depends on the manner in which this by-product is utilized. There are three ways of disposing of the tops, namely, feeding on the farm, selling, and plowing under for manure. The value given the tops on farms where they were fed was the probable sale price of other feeds replaced by the tops. On farms from which the tops were sold the actual price received was used. The estimated manurial value was used where the tops were plowed under.

The general practice was to feed the beet tops, over 96 per cent of the growers in the first three sections doing this. (See Table XXVI.) In northwestern Ohio about one-half of the growers fed and one-half plowed the tops under. Beet tops were valued at from

$1.50 to $3.40 an acre. The lowest figure is shown where the tops were plowed under for manure, while the highest value was placed on tops used as feed. Grand Rapids growers gave the highest estimated value for tops fed. In this area many farmers hauled the tops to the barn or feed lot and fed them to dairy cattle. In some sections the tops were pastured on the ground after the beets were harvested. In such instances many of the tops were trampled by the stock, while some spoiled because of unfavorable conditions and could not be used for feed.

TABLE XXVI.—*Disposition and estimated acre value of sugar-beet tops (1915).*

District.	Number of farm records.	Per cent feeding.	Value when fed.	Per cent selling.	Value when sold.	Per cent plowing under.	Value when plowed under.
Caro	68	97	$1.78			3	$2.00
Alma	51	96	2.20	2	$2.00	2	1.50
Grand Rapids	33	97	3.40			3	2.50
Northwestern Ohio	82	48	2.00			52	1.60

Some growers follow the practice of feeding a portion of the tops and turning under the remainder. In such cases, where the greater part of the acreage was fed, the value of the tops was higher than where the larger portion was turned under. The utilization of the tops depends largely on the amount of stock kept on the farm. Many farmers do not keep enough live stock to consume all of the beet tops produced on the farm. In some sugar-beet sections cattle and sheep are fattened for market. The stock is turned in on the beet field after the beets are harvested. When the beet tops are cleaned up, alfalfa and corn are fed until the stock is ready for the market. The feeding period lasts from two to five months. If the grower has no stock to fatten, he may sell the tops to a stock feeder, who turns his cattle and sheep into the farmer's field, paying a certain sum per acre for the pasturing privilege. Only two farmers sold all of their beet tops in this manner.

RELATION OF BEET ACREAGE TO TILLABLE AREA.

There was a decided variation in the size of the beet acreage per farm. Grand Rapids farmers grew the smallest acreage and northwestern Ohio growers the largest. There is also a difference in the acreage of tillable land per farm in the four sections. However, when reduced to a percentage basis there is little variation for these regions. Approximately three-fourths of the farm land is tillable; at Grand Rapids, 71 per cent; at Alma, 72 per cent; at Caro, 75 per cent; and in northwestern Ohio, 83 per cent. (See Table XXVII.)

TABLE XXVII.—*Relation of beet acreage to tillable area.*

District.	Number of farm records.	Acres per farm.	Acres per farm tillable.	Acres per farm in beets.	Per cent of tillable area in beets.
Caro	134	109.6	82.3	15.1	18.33
Alma	53	103.65	74.47	9.54	12.81
Grand Rapids	36	126.11	89.33	6.40	7.17
Northwestern Ohio	97	134.75	111.96	15.72	14.00

Only 7.17 per cent of the tillable land was planted to beets in the Grand Rapids area, while 18.33 per cent was given over to sugar-beet production at Caro. In the former area there has been a tendency on the part of the farmer to decrease his beet acreage. At one time all the sugar beets contracted by the Holland factory were produced in this locality. Most of the beets for that factory are now shipped in from points in northwestern Michigan and eastern Indiana. The scarcity of farm labor to perform the handwork on this crop is probably responsible for this situation more than any other one factor. In many instances larger acreages could be grown, since the sugar beet has a place in the crop rotation of this section.

BEET ACREAGE PER FARM AND YIELD PER ACRE IN RELATION TO COST.

It seems reasonable to assume that the man who grows a large acreage of sugar beets can produce them at a lower cost per acre than the man who grows a small acreage. In general this is true, but the variation is small (see Table XXVIII). It is also natural to suppose that the larger the yield in tons per acre the greater the cost per acre, since the handling of more beets is involved.

TABLE XXVIII.—*Acres in beets versus yield per acre as influencing cost of production.*

Acres in sugar beets.	Yield, 8 tons or less per acre.			Yield, 9 to 13 tons per acre.			Yield, 14 tons and over per acre.		
	Number of farms.	Cost per acre.	Cost per ton.	Number of farms.	Cost per acre.	Cost per ton.	Number of farms.	Cost per acre.	Cost per ton.
6 or less	13	$48.98	$8.10	46	$54.88	$4.94	19	$60.59	$3.76
7 to 12	22	49.28	7.05	47	52.45	4.83	25	58.18	3.92
13 and over	24	47.06	7.00	51	52.37	4.75	23	60.38	3.80

Comparing the farms in each group on the basis of yield per acre, it was found that in each of the three acreage groups the greater the yield of sugar beets per acre the higher the cost of production per acre. However, the larger the yield per acre the smaller the cost per ton of beets. Where 6 acres of beets or under were grown, it cost

$8.10 per ton to produce 8 tons or under per acre, and $3.76 per ton for a yield of 14 tons and over per acre. There is also an increase per acre and a decrease per ton in each of the other two acreage classifications in the table.

COMPARISON OF BEET RECEIPTS WITH OTHER FARM RECEIPTS.

An analysis of the receipts from the different enterprises on the farms in the sugar-beet areas studied shows the importance of the sugar beet to the farmer as a cash crop. Table XXIX gives a comparison of the percentage of farm receipts derived from the total farm crops, from live stock and live-stock products, from miscellaneous items, and from the sugar beet alone.

TABLE XXIX.—*Beet receipts in comparison with other farm receipts.*

District.	Number of farm records.	Average total receipts per farm.	Per cent of total receipts from—			Per cent of total farm receipts from beets.	Per cent of total crop receipts from beets.
			Crops.	Live stock.	Miscellaneous.		
Caro	84	$1,750.00	69.32	29.54	1.14	43.54	62.82
Alma	53	1,930.00	68.19	31.71	.10	33.83	49.62
Grand Rapids	36	2,339.00	41.04	58.79	.17	16.80	40.94
Northwestern Ohio	97	1,128.49	73.45	26.53	.02	35.72	48.63

The Caro, Alma, and northwestern Ohio farms are essentially crop farms, over two-thirds of all the receipts coming from crops in the first two areas and almost three-fourths in the last. At Grand Rapids almost 60 per cent of the total farm receipts was derived from live stock, while 40 per cent came from crops. This is not surprising, since farmers in the Grand Rapids region keep dairy cows and sell cream and milk to the creameries and cheese factory in that locality. Along with dairying go hogs and poultry, which provide a considerable portion of the live-stock returns.

In the former areas over one-third of the receipts came from the sugar beet alone, while beets brought in 17 per cent of the receipts at Grand Rapids. When changed to the basis of per cent of crop receipts over 40 per cent of the crop receipts came from beets, while at Caro they constituted over 60 per cent of the total crop receipts.

The highest total farm receipts were found at Grand Rapids. Live stock is probably responsible for this large amount. The lowest farm receipts were reported in northwestern Ohio. Over $2,000 was received per farm at Grand Rapids and slightly more than $1,100 in the northwestern Ohio region.

In several sections beans compete with the sugar beets. At Caro 20 per cent of the total farm receipts came from beans and at Alma 15 per cent. About 15 per cent of the farm receipts in northwestern Ohio was due to the sale of corn and 11 per cent to returns from oats.

LABOR REQUIREMENTS.

It is the general practice in all the areas studied to hire a part of the work on the sugar beets. Usually, if a man has more than 5 acres in beets all of the handwork is performed by hired help on an acre-contract basis. In some instances the hoeing was done by the farmer and his family, and the topping was hired; in other cases the hoeing was hired and the topping performed by the farmer. Where a very small acreage of beets was grown, usually none of the handwork was contracted. As stated previously, the contract labor was paid at a stipulated rate per acre or per ton. This contract expenditure has been changed to its equivalent in man hours by a computation assuming a rate of 25 cents per hour as the value of man labor. (See Table XXX.)

TABLE XXX.—*Labor requirements in producing an acre of sugar beets.*

District.	Acres grown.	Yield per acre.	Hours of man labor.	Hours of horse labor.
Caro	2,018	9.72	105.5	80.03
Alma	506	11.40	114.8	95.34
Grand Rapids	230	10.16	111.3	93.88
Northwestern Ohio	1,525	13.17	113.4	79.21

The number of horse hours spent at Caro and in northwestern Ohio are approximately the same, as are the hours for Alma and Grand Rapids. However, more labor was required in the former than in the latter areas.

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

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PRODUCTION OF GOATS ON FAR WESTERN RANGES.

By W. R. Chapline, *Grazing Examiner.*

CONTENTS.

THE GOAT RANGE PROBLEM.

On far western ranges goats are raised mainly for mohair and meat and secondarily for milk and hides. On farms they are valuable also for clearing brush. The possibility of clearing brushy areas by heavy stocking with goats and the excessive overgrazing and injury to the range which has resulted on many goat ranges from lack of proper management have created the impression that goat grazing can not be conducted without unwarranted damage to range and timber reproduction. Furthermore, a lack of proper selection, care, and management of the range goats has resulted in a low average production of mohair and meat and small profits. There are individuals, however, who have improved their methods of management for the range and the goats so that they have eliminated overgrazing and injury to the range and established a profitable business. The adoption of similar improved methods more generally by range goat growers would greatly decrease injury to the range and to tree growth and watersheds where these are factors, and would place the range goat industry upon a more stable and remunerative basis.

The goat range problem to-day has three important phases: first, determining the character of range suitable for goat grazing; second, developing methods of management of goat range which will insure profitable production of goats without detriment to cattle and sheep raising, timber reproduction, watershed protection, and other uses of the land; third, increasing the production of mohair and meat by decreasing loss and by better selection, care, and management of the goats. Investigations have been made of all these phases of the problem and the results are incorporated in this bulletin in the following order: (1) the character of range required by goats; (2) methods of management of range which will insure profitable goat production without effects detrimental to the other uses of the area grazed; and (3) the selection, care, and management of goats so as to increase the production of mohair and meat.

RANGE SUITABLE FOR GOATS.

The suitability of range for goats depends to some extent upon climate and water, but chiefly upon forage.

The ideal goat range should possess forage suitable for goats at all times of the year, be well drained and free from continued heavy rains, and be adequately supplied with watering places and suitable bed grounds. Since browse furnishes the bulk of range feed for goats throughout the year, there should be an abundance of this available. Grass and weeds are necessary for does and kids during the spring and summer, but not during the winter. They are not essential for wethers at any time. They are of considerable value at all times, however, to give variety to the forage. On extensive brush areas, the stand of brush should be sufficiently open to allow herding of the goats. On small areas the brush may be dense. Extensive areas where brush grows too dense for immediate use can eventually be made wholly usable by allowing the herds to graze into them gradually from adjacent more open areas.

The value of the different kinds of range forage plants varies greatly with variation in the associated plant species, the stage of growth, the region, and the tastes of individual goats. However, it is the general opinion that the relative importance of browse, grasses, and weeds is in the order named.

BROWSE.

Browse furnishes most of the forage for goats on the ranges. During the summer browse and grass are often grazed in approximately equal quantity, provided about equal amounts of palatable species of both make up the forage. In the winter, however, browse is the principal goat feed, and it is absolutely necessary on any winter goat range which is subject to continued snow. Evergreen browse species are of value throughout the year, but are ordinarily grazed most during the winter. Deciduous species are of greatest value during the summer, but twigs and buds of such species often furnish much winter forage.

Browse should be available on kidding ranges, to provide buds, fresh leaves, tender twigs, and variety in the feed, which are fundamental requirements, especially when the growth of grass is deferred by drought or late season.

Nearly all species of browse are grazed to some extent by goats, though certain species are of much greater value than others. The species of mountain mahogany (*Cercocarpus spp.*) are among the most important kinds of goat forage. They are very palatable, abundant, and widely distributed; they produce a large amount of forage; are not easily injured by grazing; and most of them are evergreen.

The palatable oaks (*Quercus spp.*) also furnish a considerable proportion of the browse forage for goats. The evergreen oaks are of great importance throughout the entire year. Gambel oak (*Q. gambelii*), New Mexican oak (*Q. novomexicana*), and other deciduous oaks are of value chiefly during the summer, not only because they drop their leaves in winter but because ordinarily they grow at elevations too high for satisfactory winter use. The oaks are generally of only moderately high palatability; they derive their importance as goat forage chiefly from their distribution and abundance. Several other important browse species of moderately high palatability are garrya [1] (*Garrya spp.*), maple (*Acer spp.*), snowberry (*Symphoricarpos spp.*), cherry (*Prunus spp.*), willow (*Salix spp.*), sage (*Artemisia spp.*), and Apache plume (*Fallugia paradoxa*).

The blue brush [2] (*Ceanothus integerrimus*) of the Pacific coast and Fendler's ceanothus (*C. fendleri*) of the Rocky Mountains are of very high forage value. The blue brush is probably the most valuable browse species on the Pacific coast. Several other species of ceanothus [3] furnish considerable forage for goats. Other important browse species of very high palatability are fendlera (*Fendlera spp.*), bitter brush (*Kunzia tridentata*), lemita or skunk bush (*Schmaltzia spp.*), New Mexican locust (*Robinia neomexicana*), service berry (*Amelanchier spp.*), and rose (*Rosa spp.*).

Manzanita (*Arctostaphylos spp.*) is grazed rather freely in southern New Mexico, but in California and Oregon it is eaten only when the range is overgrazed. In the spring it is often peeled by the goats, apparently for the sap.

There are undoubtedly many other browse species of high forage value for goats. Additional observations are necessary to determine their importance. Among such species are probably simmondsia

[1] Locally called quinine bush.

[2] Also called wild lilac, sweet birch, and white birch.

[3] Some of the most important are Gregg's ceanothus (*C. greggii*), white thorn (*C. cordulatus*), red ceanothus (*C. sanguineus*), and wedge-leaved ceanothus (*C. cuneatus*), locally called "chamise."

(*Simmondsia californica*), palo verde (*Parkinsonia spp.*), franseria (*Franseria dumosa*), mesquite (*Prosopis glandulosa*), and screw-bean (*Strombocarpa pubescens*).

The berries of the cedars (*Juniperus spp.*) and junipers (*Juniperus spp.*) and the nuts of piñon (*Pinus edulis*) are eaten readily by goats; but conifers as forage for goats are of low value and, as a general rule, are not seriously grazed when there is a sufficient amount of more palatable browse available. Frequently, however, on overgrazed goat ranges there is considerable injury to conifer reproduction.

GRASSES.

It is essential to have grass available for does at kidding time and during the summer, to provide succulent forage so that there may be an adequate supply of milk for the kids. Young kids also receive much nourishment from grass forage.

Many grass species are of high value for goats during the summer, and give an excellent "finish" to the flesh of those which are to be sold for meat in the fall. As grass becomes coarse and tough in the fall it becomes less palatable to goats, and generally from this time on through the winter it is grazed very little.

Where grass grows scattered in dense brush stands, it is more closely grazed than where it forms a considerable part of the forage.

On southwestern ranges the gramas[1] and eragrostes[2] are probably the most valuable grasses for goat grazing. Of medium palatability are some of the muhlenbergias,[3] small feather-grass (*Andropogon scoparius*), piñon mountain-rice (*Oryzopsis fimbriata*), prairie-grass (*Sphenopholis obtusata*), and wolftail (*Lycurus phleoides*). Grasses of low palatability are grazed only when the range is overgrazed or when there is a scarcity of grass.

WEEDS.

The herbaceous flowering plants, "weeds" as they are generally called on National Forest ranges, are usually of greater palatability when green and tender than when dry. Accordingly, they furnish little feed during the winter, but are often important at other times of the year. Alfileria (*Erodium cicutarium*) on low ranges, however, furnishes considerable winter feed. The chief value of most weeds lies in providing variety in the forage for does and kids during the spring and summer.

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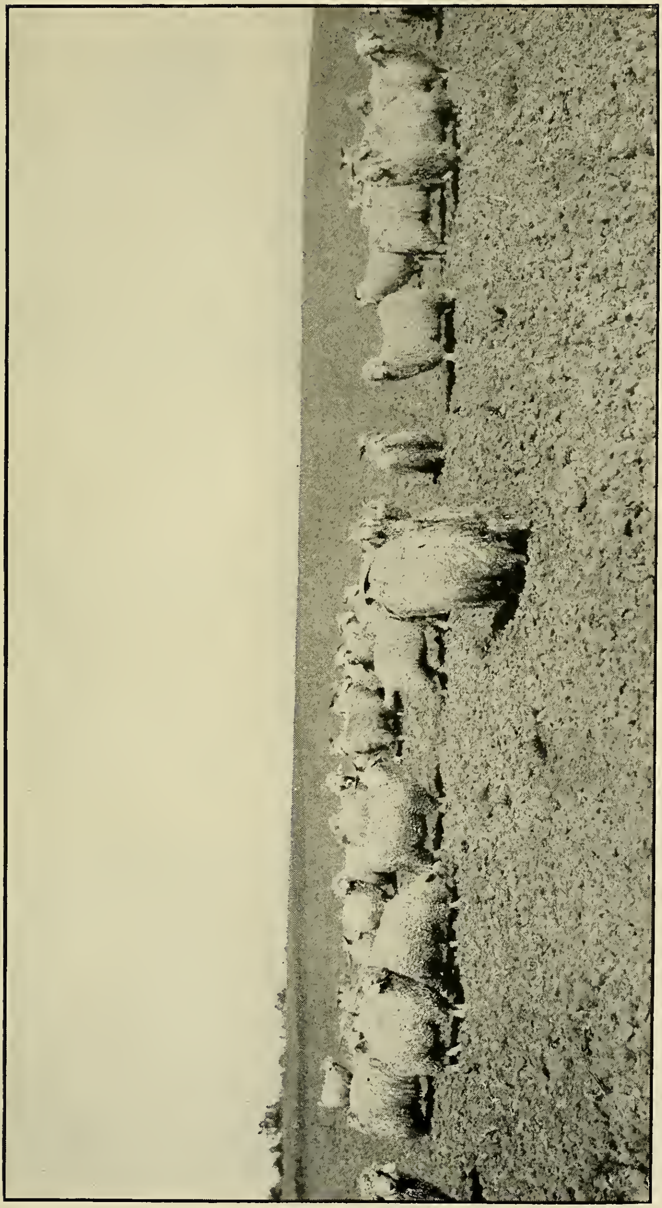
[1] Side oats (*Bouteloua curtipendula*), blue grama (*B. gracilis*), and hairy grama (*B. hirsuta*).

[2] Panicled eragrostis (*Eragrostis erosa*) and Mexican eragrostis (*E. mexicana.*)

[3] Wright's muhlenbergia (*Muhlenbergia wrightii*) and Berlandier's muhlenbergia (*M. berlandieri*).



F–I–WRC

A BUNCH OF EXCELLENT KIDS, ABOUT 6 MONTHS OLD.

Careful selection and breeding in conjunction with good care and management are essential for the production of such animals.

F-2-WRC

FIG. 1.—GOATS GRAZING ON GRASS-BRUSH RANGE.

A mixture of grasses, browse, and weeds furnishes the most desirable range for goats. Variety of forage is especially important for does and kids.

F-3-WRC

FIG. 2.—GOATS GRAZING IN DENSE BRUSH.

Extensive areas of dense palatable brush may be utilized by working the goats in gradually from adjacent open areas.

SUPPLEMENTAL FEED.

If range forage is covered with snow for more than a few days at a time, some other feed must be provided for the goats. On northern ranges and at high altitudes this condition sometimes prevails for long periods. On most winter ranges in the Southwest light snows which soon melt are the rule, so that little feeding is necessary. However, even here a small amount of supplemental feed on wintry days and during kidding will pay for itself by keeping the animals in good condition.

All kinds of hay from alfalfa or clover to dried brush or straw can be fed advantageously. Where alfalfa, clover, vetch, or cowpeas are fed no grain is necessary; but it is well to supplement rough fodder with cottonseed cake, oats, barley, or other grains. Roots are sometimes fed as a substitute for green feed. Goats like good feed and will ordinarily not eat anything soiled by dirt or trampled. Accordingly, they have sometimes been considered wasteful. To prevent waste, hay should be fed in a feeding rack and grain in troughs. The amount of hay and grain fed depends largely on whether the object of feeding is merely to prevent loss or to keep the goats in a thrifty, growing condition. With most range herds, from 1 to 2 pounds of hay or from one-quarter to 1 pound of cottonseed cake are fed to each goat on days when they are unable to obtain sufficient range feed.

CLIMATE.

Climate limits the suitability of range for goats through the effect of heavy rains and snows. Dry, rugged areas are generally better suited for goat grazing than wet, marshy lands. Goats seek the shelter of timber or of sheds during heavy rains. Continued cold rains may keep them unduly confined to sheds and have often caused serious losses soon after shearing where sheds were not available. The heavy losses that have occurred in the fog belt near the coast of northern California and southwestern Oregon would indicate that areas subject to heavy fogs and rains are not well suited for goat ranges. Despite these heavy losses, however, small herds of goats are being grown successfully in portions of the fog belt, though they require more care in sheltering and handling than where the climate is drier. Ranges subject to heavy snowfall should not be used for winter grazing unless warm, dry sheds, and plenty of supplemental feed are provided.

WATER.

The amount of stock water available determines the suitability of a given range for goats, especially at certain seasons of the year. Abundant water should be available on ranges used during the spring and summer. It is not necessary to have very much water on winter ranges if snow is available. Pure, fresh water should be provided wherever possible, but in the Southwest it is often necessary to utilize rain water caught in large storage reservoirs. The goats drink this readily when once accustomed to it.

Deep wells must sometimes be drilled on southwestern ranges if there is to be a supply of water throughout the year. The cost of such operations is often prohibitive considering the amount of forage available in the locality. When this is true such areas are sometimes used only during the rainy seasons and when stored rain water can be used.

MANAGEMENT OF THE GOAT RANGE.

Most goat ranges are used throughout the year. This and the general practice of driving the goats out from a corral at the ranch headquarters and back every day for months or throughout the year have been largely responsible for such a deterioration of the range as to cause a widespread belief that any grazing by goats is extremely destructive to range. The fault is largely in the method of management, which with large herds is sure to concentrate grazing to the point of overstocking and to cause continued premature grazing. Where a similar practice has been followed in the management of cattle and sheep, the range has been similarly depleted.

The remedy lies in working out a plan of grazing which will give the vegetation a chance to grow sufficiently to maintain itself. To do this on an area which is grazed throughout the year necessitates light stocking, at least during the main growing season of the important forage plants. Investigation and practical tests have shown that a better plan is to divide the range into three areas, one for spring, another for summer and fall, and a third for winter. Dividing the range for seasonal use so as best to meet the needs of the forage and of the goats and distributing the grazing more evenly over the range make possible the maintenance of the forage under heavier grazing and the reservation of suitable feed for the most critical periods of the year.

DIVISION OF THE RANGE.

Spring range.—During the period of kidding and immediately afterwards more than during any other period of the year the does and kids need plenty of green, tender feed and plenty of water. For this reason there should be an abundance of grass and weed forage on the kidding range, but there should also be some browse to provide tender, green twigs in case drought or a late season prevents a sufficient growth of grass.

It is important that this vegetation be kept thrifty, so that growth will start promptly and vigorously as soon as weather is favorable in the spring. Where the range is used from the kidding corral by large herds during the greater part of the year, much of the choice forage is killed out or is greatly weakened by continuous grazing, so that the spring growth is greatly delayed and is scanty when it does come. As a result the does have to travel too far, are not sufficiently nourished during kidding time, and fail to provide ample milk and also to mother their kids properly. Under such conditions there is considerable trouble in handling the flock during kidding, and it is difficult to keep down the losses.

It is necessary to graze the does continuously from the kidding corrals during the kidding period and for two or three weeks after the close of kidding. Only strong, vigorous plants which have stored considerable food material in their roots during the growing period of the former year can withstand such continued, premature grazing. Accordingly, the does and kids should be moved to the summer-and-fall range just as soon as possible, so that the plants on the kidding range will have an opportunity during the summer growing season to make sufficient growth to insure an early, vigorous growth the following spring. If the goats are moved shortly after kidding and are not grazed on this spring area until the next spring, the plants will recuperate during the summer from the heavy early spring grazing and there will be no deterioration in the range forage.

The spring range should have enough forage so that the goats will be properly nourished during the period they are on it and no part of it be overgrazed. If there is surplus forage in the fall, it may be possible to graze it lightly, but care should be taken to see that the grass and weed forage is not grazed so much as to injure it, and that the buds of the brush are not consumed.

It is best to refrain from grazing the kidding range during the winter, and under no circumstances should the winter grazing on this range be more than very light.

Summer-and-fall range.—When the does and kids are removed from the kidding range they should be taken to the range set aside for summer-and-fall use. Since the kids depend largely upon their mothers' milk and upon green, succulent food for nourishment during the summer, there should be plenty of grass and weed forage on the summer range. Such forage when young may be injured by grazing. The forage, therefore, should be as far advanced as possible when grazing begins.

On the summer range it is necessary to graze the plants during their principal growing period and while they are producing their flower stalks and seed. The summer is also the most successful period for establishing seedlings. A normal plant growth, the production of fertile seed, and the establishment of seedlings are most important; and the goat grazing should be adjusted so as to interfere as little as possible with these plant functions.

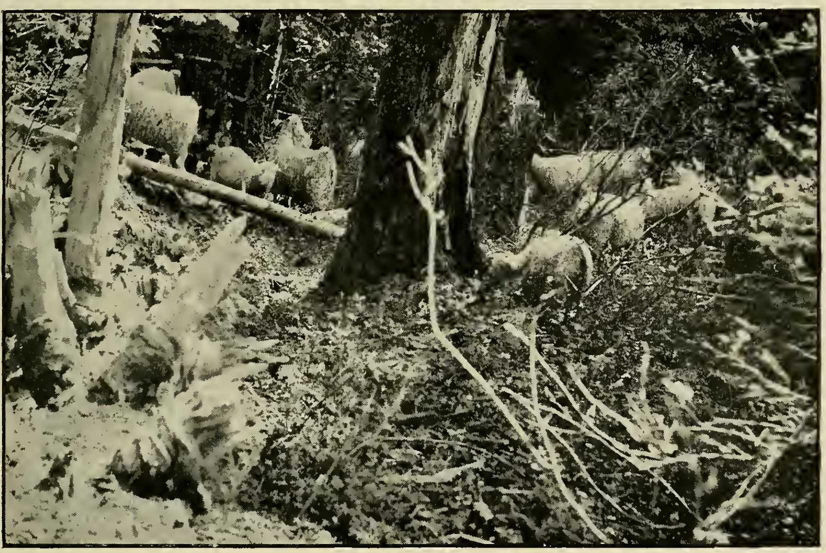
Continuous close cropping of the forage during the growing season removes the leaves of the palatable species as fast as they are produced. If the roots are not killed by starvation, they are often trampled out of the ground by the goats' hoofs. Hence the palatable species fail to reproduce and gradually disappear; and the unpalatable species, having a greater chance for growth and reproduction, gradually take the place of the palatable species. Only a very open stand is formed. Erosion follows, the valuable surface soil is washed and blown away, and reestablishment of the palatable forage cover is made most difficult.

This denuded condition prevails especially where grazing has been excessively concentrated around bed grounds used every night throughout the growing season. It is important, therefore, that goats be bedded in any one place for only a short period. This will not only eliminate the concentration of grazing but will also secure a more uniform utilization of all the range forage.

If the forage is given a complete rest, or is only lightly grazed during the growing season, the palatable vegetation has an opportunity to make normal growth. With normal growth fertile seeds are produced, the seedlings are given a chance to become established, and an appreciable increase in the palatable vegetation may result.

To ascertain the effect of giving the forage a rest from grazing, plots were established on seriously overgrazed, southwestern goat ranges; and for two years the areas were protected from grazing during part or all of the growing period, and closely grazed at other times, the browse, because of its scarcity, being overgrazed. The increase in density of palatable forage in the two years averaged approximately 67 per cent for grasses and 4 per cent for browse. The greatest increases were approximately 125 per cent for the grasses and 27 per cent for the browse. When overgrazed goat range is given a rest during the growing season and not overgrazed at other times, the grass recuperates readily. The brush recovers more slowly. When the range has been only lightly overgrazed the brush also recuperates readily with protection, but if the range has been badly overgrazed the brush requires several years before it makes normal growth.

When range is fully stocked it is not always possible to allow all the summer range a rest from grazing during the growing season. If the winter range and the summer-and-fall range can be interchanged advantageously each of these divisions can be given protection in different years; but it is often impossible to interchange them because snow prevents winter use of the range reserved for summer



F-4-WRC

FIG. 1.—GOATS GRAZING ON THE BRUSH UNDERSTORY OF THE TIMBER TYPE, SUMMER AND FALL RANGE.

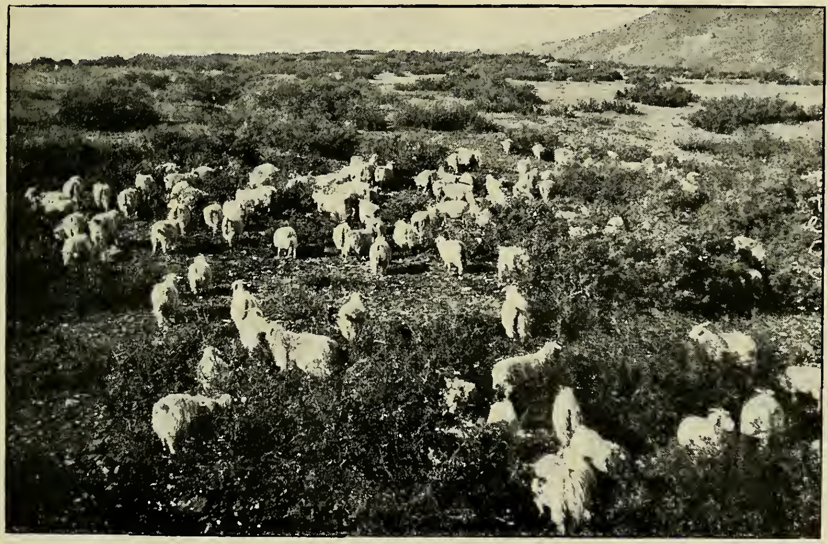


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FIG. 2.—GOATS GRAZING IN THE OPEN BRUSH TYPE OF THE LOWER ELEVATIONS, WINTER RANGE.

F-27045-A

FIG. 1.—RANGE GRAZED BY GOATS CONTINUOUSLY FOR OVER 30 YEARS.

Destruction of the palatable forage cover, followed by erosion, results from continued heavy grazing.

F-31368-A

FIG. 2.—SAME RANGE AS SHOWN ABOVE AFTER PROTECTION FROM GOAT GRAZING DURING PART OF THE GROWING SEASON FOR TWO YEARS.

With protection the grass recuperates readily; the brush more slowly.

and fall. It is unnecessary, however, to give the entire summer-and-fall range a rest from grazing during the growing season. If it is stocked so as to prevent overgrazing, and if grazing is deferred on successive parts until after seed maturity and then the surplus forage utilized, all of the forage may be fully grazed and the vegetation maintained in a state capable of maximum production.

This system is known as "the deferred and rotation system of grazing."[1] For example, in the Southwest the summer-and-fall ranges are grazed from about June 1 to November 1, or approximately five months. The greater part of the principal forage species have matured seed by September 1. Grazing, then, should be deferred on certain successive parts until some time after this date.

To apply successfully the deferred and rotation system of grazing three points must be observed. First, the grazing must be distributed so as to avoid concentration to the point of overstocking. To do this with herds of about 1,200 grown goats will require the use of about 20 bed grounds on the summer-and-fall ranges. Second, the goats must be grazed quietly on range adjacent to each of the bed grounds, and different parts of the range must be grazed at different times of the period. This can easily be done by using 20 bed grounds. To use all the summer-and-fall range throughout the entire grazing period should not be attempted. Third, instead of using the bed grounds in the same order year after year, rotation in time of use by groups of four bed grounds each must be practiced.

This plan would make possible the division of the summer-and-fall range into five parts of equal carrying capacity, each part suitable for a month's use. Two parts, each containing four bed grounds, could then be protected from grazing until after September 1 each year. Each part grazed in any month for any given year should be grazed a month earlier in the succeeding year, except the part grazed first which would then be grazed last. For example, if the parts are designated by A, B, C, D, and E, in any year A, B, and C may be grazed during June, July, and August, respectively, leaving D and E to be grazed in September and October after seed maturity; then in the succeeding year B, C, and D would be grazed in June, July, and August, respectively, leaving E and A to be grazed in September and October, and so on. This would allow the forage around the four bed grounds grazed last each year a second year of protection until after seed maturity, and would give the seedlings from the first year's crop of seed a good chance to become established. Such a grazing system results in a five-year rotation with each fifth of the

[1] This system is described in detail by Arthur W. Sampson, "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation," Journal of Agricultural Research, U. S. Dept. Agri., Vol. III, No. 2 (Nov. 16, 1914), and by James T. Jardine, "Improvement and Management of Native Pastures in the West," U. S. Dept. Agri., Yearbook 1915, pp. 299–310.

range being given protection from grazing until after seed maturity two years in every five.

TABLE 1.—*Part of summer-and-fall range to be used during each month through a series of six years under the deferred and rotation system of grazing.*

[Letters indicate parts of range.]

	June.	July.	Aug.	Sept.	Oct.
First year	A	B	C	D	E
Second year	B	C	D	E	A
Third year	C	D	E	A	B
Fourth year	D	E	A	B	C
Fifth year	E	A	B	C	D
Sixth year	A	B	C	D	E

Winter range.—Under the present methods of management the goats on many ranges often lose much in weight during the winter, and occasionally many of them die. Where the range is grazed by large herds throughout the year or even throughout the entire winter, from the corral and shed at the winter ranch the browse in the vicinity of the camp is killed out or is weakened to such an extent that it provides very inadequate forage. When heavy snow comes the feed is still more scarce and goats must be fed if they are to maintain their weight.

To reduce the extra feeding required and to decrease the liability of loss, the winter range should be situated low enough to be out of the range of severe storms. It is also essential that enough forage be protected at other times of the year so that the goats may obtain ample feed during the winter without excessive traveling. The browse areas at the lower elevations generally furnish the best winter forage. Practice has shown that it is best to reserve the feed close to the shed for use during heavy snows and after shearing in the fall or late winter. In order to preserve this feed and prevent overgrazing, and still have the goats close enough to the shed to be brought in if a storm threatens, the goats may be bedded at a number of places about half a mile in different directions from the shed.

PREVENTION OF OVERGRAZING.

The most prominent signs of overgrazing are a reduction in the quantity of palatable forage, an increase in the nonpalatable plants, a stubby appearance in the browse species, an increase in the number of rocks showing above the soil, and a thinness in the goats due to insufficient nourishment. Signs of overgrazing which are not so readily noticed, but which should be watched for, are the failure of palatable species to flower and fruit, the removal of most of the leaves of important palatable browse species before fruiting, and the covering of considerable grass on slopes with sliding soil brought down by trampling.

If any of these conditions prevail, steps should be taken immediately to stop the overgrazing. The overgrazed areas should be protected from grazing until after seed maturity of the main forage plants, excessive concentration of grazing should be stopped, and the goats should be handled under the methods outlined in this bulletin. If this fails to eliminate the overgrazed condition, there are too many goats grazing the area allotted to them, and either the number of goats should be reduced or the area increased so that sufficient forage will be provided.

An average of approximately four acres of the grass-brush type and from three to six acres of the true-brush type, depending upon the palatability of the browse species, should be allotted to each goat for yearlong grazing. This is for normal utilization of the forage by goats when they are grazed alone under good management and kept in good growing condition. So many varying factors, however, enter into the grazing capacity of every range that even though goats are allotted a carefully ascertained area the range should be watched at all times and the number of goats adjusted to the available forage.

Plenty of fresh, palatable feed reduces the death rate and has a marked beneficial effect upon the mohair production, the growth of the goats, and the proportion of kids raised. Two goats in good condition producing 4 pounds each of high-class mohair may yield a greater net revenue than three goats in poor flesh producing only 3 pounds of mohair each. Therefore, instead of overstocking a range with a large number of low-grade goats, high-grade goats should be grazed to the number the range can conservatively carry. The net revenue will be just as great, if not greater, and the probability of occasional heavy losses will be largely eliminated.

MANAGEMENT OF A RANGE HERD OF GOATS.

The management of the goats is closely associated with the management of the range, and determines largely whether they will show a profit or loss. The effect on the forage is reflected in the growth and production of the animals using the range. In addition, methods of handling affect the animals directly. Bad management of goats on the range may offset all the good effects of careful range management and careful selection of the breeding herd.

SIZE AND COMPOSITION OF THE HERD.

On the range, goats are grazed in herds of from a few hundred head to over two thousand. General range practice has shown, however, that it is most economical to graze goats in herds of approximately 1,200 head of grown goats. Herds of this size produce the most satisfactory results. With herds of less than 1,200 average range costs per goat are usually greater, and with herds of more than 1,200 grown goats more care is required in herding, and a greater number of bed grounds must be used to keep the goats in good condition and avoid damage to the range.

The breeding does should be grazed separately from the dry does, wethers, yearlings, and weaned kids. This allows the does to graze more quietly while with their kids and insures their being in better condition, which is especially important at breeding and kidding times. Range kids should be weaned at about five months of age. Buck kids older than this should never be allowed to run with the does, as they will often breed and otherwise cause much annoyance to the does. Wethers also annoy does at breeding time, and just before kidding may worry them sufficiently to cause abortions.

HERDING.

It is sometimes stated that a herder is not needed for goats, and it is true that a poor herder may be much worse than none at all. Small herds of a few hundred head or less may be watched successfully by a well-trained dog if there is an abundance of good range for the goats; but when the herds are large, and the range fully stocked, a herder is absolutely necessary to secure proper utilization of the forage, and to prevent trailing of the goats and loss from straying, accidents, and predatory animals.

Too often the method of range herding has been to keep the goats in a compact band and trail them over the range throughout the day with the object of keeping the entire herd together and in sight at all times. The herder and his dogs fall in behind the band and continue to push forward the rear goats, which are ordinarily the kids and the weak and crippled old ones. Such herding causes unnecessary traveling and prevents the rear goats from obtaining sufficient feed. The feed they do obtain is dirty and of inferior quality. The majority of the herd are kept in a medium or poor condition, the growth of a great many kids is stunted, and the running and bunching of the goats by dogs causes many cripples and a loss from leaving goats on the range.

Instead of being driven the goats should be grazed slowly, quietly, and openly, and the leaders should be held down to the rate the rear goats desire to take. As the goats leave the bed ground in the morning the leaders should be turned in the direction the herder wishes to graze the goats that day. Throughout the morning they should be allowed to drift slowly away from the bed ground. In the warm part of the day most of the goats will take shade under trees and bushes, but a few may graze intermittently during the entire day. In the afternoon the leaders should be turned into the herd and started toward the bed ground selected for the night. By taking the goats back over the same area grazed in the morning it is possible to pick up any goats that have remained behind through failure to herd them carefully enough.

Ordinarily goats should be taken from the bed ground early in the morning and returned about sundown. On ranges where there is danger of foot rot resulting from wet grass, however, it may be best to hold the herd on the bed ground until about 7 a. m. Goats can not secure sufficient feed when driven over the range for only a few hours during the middle of the day. Accordingly, it is poor practice to hold them on the bed ground until late in the morning or bring them in early in the afternoon. Goats graze more quietly in the cool of the morning and evening, and thrive best when allowed four or five hours of quiet grazing at each of these periods and a rest on the range of from an hour to several hours during the heat of the day.

BEDDING.

Many herds of goats, regardless of size, are bedded in a corral at the main ranch throughout the entire year. Some growers, having observed the detrimental effects to range and goats of such a method, have used more bed grounds. However, this is only a step in the right direction. When just a few bed grounds are used with large herds there is considerable concentration of grazing, which may prevent proper growth of the goats. Range practice has shown that the more bed grounds used the greater the benefits to range and goats. This leads to the conclusion that the bedding-out system as used with sheep would be the most successful method for handling goats.

Single bed ground.—Bedding the goats on the same ground every night in the year prevents proper management of the range. A large area is overgrazed and trampled and the forage on the range is not utilized evenly. As the palatable species disappear from the overgrazed area the goats are forced to turn to the less palatable plants, and excessive traveling is required to secure fresh forage. The combination of these circumstances keeps the goats in a moderate or poor condition at all times of the year. They fail to make normal gains in weight, the does fail to give sufficient milk, and the growth and value of the mohair is lessened. The decrease in value of the mohair is due partly to the dust from the overgrazed area which adheres to the mohair, and partly to the uneven staple resulting from changes occurring in the condition of the goats.

Because of the lack of browse on the overgrazed area close about the bed ground much supplemental feed is required when snows cover the other range forage, and this increases materially the cost of goat production. The general practice, however, is to furnish very little supplemental feed, the result being suffering and loss. The goats become thin and it is extremely difficult to bring them back to good condition during the remainder of the winter. Young animals quit growing and may even lose weight. The hardship, however, falls most heavily upon the does, whose physical condition in turn often prevents proper development of the unborn offspring.

In the spring at kidding time the weak and half-starved roots of the palatable grasses and weeds are unable to furnish fresh, green feed in sufficient quantity for the does. The amount of milk produced is lessened, and as a result many kids are either lost or become stunted. Occasionally some does die. Furthermore, weak does have considerable difficulty in mothering their kids properly.

The reasons advanced in favor of a single bed ground are its low cost, the advantage of having the goats at the shed each night, the proximity to water, the supposedly smaller loss from straying, and the difficulty of obtaining herders who will herd under any other method. Such reasons appear trivial in comparison with the detriment to the range and the goats and the possible injury to the general welfare of the community. The slightly increased cost of maintaining the goats as a result of changing their bed grounds is more than offset by the increased production of mohair and meat and the reduction in losses from death.

By having the goats at a shed every night throughout the year the principal value of the shed is lost. Goats prefer open bed grounds and seldom enter a shed unless the weather is very cold or very wet. Warm summer rains seldom cause any trouble, but cold rains may result in serious losses in the herd. Accordingly, it is best to graze the goats near the shed for several weeks after shearing and during stormy periods of winter, so that, if necessary, they may obtain shelter immediately. After the choice forage has been consumed for some distance from the shed as a result of yearlong grazing, it becomes necessary at critical winter periods to graze the goats far away from the shed so as to get fresh feed. As a result heavy losses often occur.

For protection in the winter and after shearing a single shed is all that is usually needed, but if the winter range is some distance from the range used at shearing time it is best to have a shed on each of these ranges. The shed should not be expensive, but it should be substantial and of sufficient size to prevent crowding. Where it is used only for shelter, 3 square feet of floor space per goat will suffice, but 5 square feet or more per goat is better. As dryness under foot is essential, the shed should be built on well-drained ground and the roof should be waterproof.

The loss from straying is thought to be greater when the goats are grazed from more than one bed ground. Small bunches of strays will often find their way back to a central bed ground, but without a central bed ground it is said that they do not know where to go. Experience with the use of many bed grounds has shown, however, that where goats are quietly grazed for short distances from the bed ground each day the straying is materially reduced.

The bad results of the use of a single bed ground throughout the year are uneven utilization of the entire allotment, a large overgrazed area about the bed ground, poor condition of the goats throughout the year, decrease in the value of mohair produced, slow growth of goats, loss and suffering from lack of feed when snow is on the ground, and loss and stunting of kids at kidding time. In addition, there may be injury to timber reproduction, erosion, and even pollution of the water supply to such an extent as to necessitate exclusion of goats from the area.

Several bed grounds.—The use of several bed grounds at different places on the range aids materially in securing more even utilization of the forage over the entire allotment, lessens the concentration of grazing, and makes possible the recuperation of the overgrazed areas and the utilization of each part of the range at the most advantageous time. The improvement in the quality and quantity of the forage and the reduction in trailing and driving of the goats results in better growth of goats and mohair.

Representative kids in two herds using several bed grounds during the year showed 6.5 and 8.3 pounds greater increases in weight than was made by kids of the same grade in a herd using only a single bed ground for the whole year. The does in all three herds were practically the same size when grazing began. Those in the two herds using several bed grounds were kept in a superior condition, which aided materially in the growth of the kids. Kids of average size and condition in the two herds using several bed grounds weighed in the late fall an average of 38.3 and 40.1 pounds, respectively. Representative kids in the herd using the single bed ground weighed an average of only 31.8 pounds at the same time. In this herd a few kids of does in good condition averaged 44 pounds. In the other two herds some kids of does that were in very good condition throughout the summer weighed approximately 50 pounds.

It is seldom possible to apply successfully the principles of improved goat range management when only a few bed grounds are used. The use of many bed grounds, however, makes possible application of these principles. When a bed ground is used for only a short period the goats can be quietly grazed close by throughout the day. The longer a bed ground is used the greater distance it is necessary for the goats to travel for fresh feed. When a bed ground has been used a week, the feed around it is dirty, and since goats are fastidious animals they trail over much unused, soiled feed. The increased trailing is apt to cause overgrazing, at least to some extent. Just as soon as overgrazing begins to take place, and the goats must either graze the less palatable species or travel farther to obtain more palatable feed, they will lose flesh and the growth of mohair will be impaired. It is highly desirable, therefore, to use many bed grounds and each one only so long as the goats can be grazed quietly near it throughout the day.

Bedding-out system.—The bedding-out system, which is followed successfully with sheep on western ranges, is the ideal bedding method toward which growers of goats should work. Under this system the goats would be bedded wherever night overtakes them. Open, quiet herding would be practiced, and the goats would be allowed several hours of quiet grazing in the cool of the morning and the afternoon and a rest in the middle of the day.

The bedding-out system can not be strictly adhered to during kidding, nor during periods of stormy winter weather, nor just after shearing, but its use at other times of the year is practicable and reserves the feed on the kidding range and near the shed for critical periods.

If the bedding-out system is used and the range properly managed, the maximum of forage is produced, forage is utilized to its best advantage, overgrazing is eliminated, and the goats have fresh feed at all times. This makes possible the grazing of a greater number of goats and secures greater production of meat and mohair. The mohair is cleaner and of a more even staple, which materially increases its value. The percentage of kids raised also is greater because the does are maintained in good condition, which is of especial value at breeding and kidding time and during the winter while the fetus is developing.

National Forest Regulation G–26 requires that on National Forests " sheep and goats must not be bedded more than three nights in succession in the same place, except when bedding bands of ewes during the lambing season; and must not be bedded within 300 yards of any running stream or living spring, except in rare cases where this restriction is clearly impracticable." The object of this regulation is largely to reduce damage to the range and danger of pollution of water supply resulting from prolonged use of the same bed ground. When the advantage to range and goats from the use of each bed ground for only three successive nights or less is realized many growers will adopt this method on the range.

WATERING.

How often goats are watered depends largely on the availability of stock water, the weather, and the nature of the forage. If the dew is heavy, the forage succulent, and the weather cool, goats can go without water for several days. When snow is available in winter

F—5—WRC

FIG. 1.—GOATS HERDED IN A COMPACT BAND.

When goats are trailed over the range in a compact band much feed is wasted through trampling, the goats are kept in medium or poor condition, normal growth is hindered, and loss from crippling and straying often results.

F—5—WRC

FIG. 2.—GOATS GRAZING QUIETLY UNDER LOOSE HERDING.

When goats are grazed quietly and are widely distributed over an area of about one-half mile in diameter, the forage is conserved, trailing and loss are reduced, and the goats are given a chance to make normal growth.

F-7-WRC

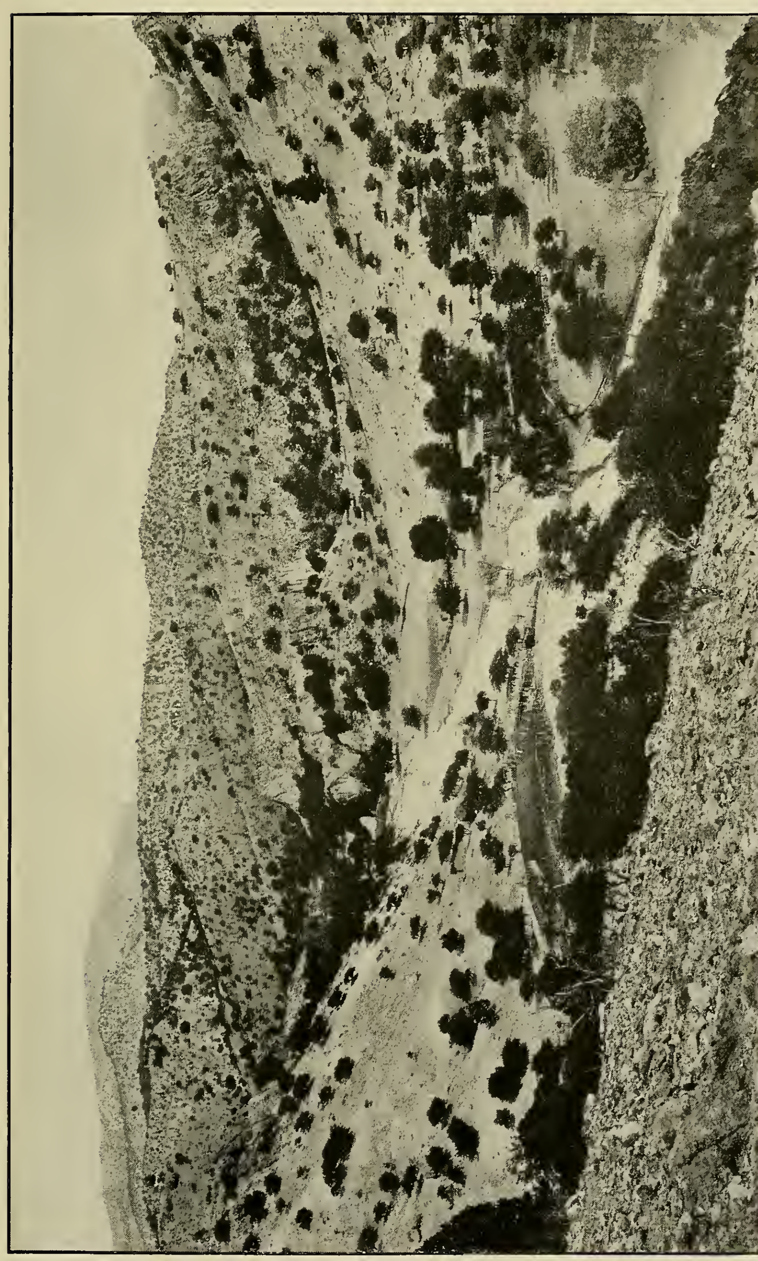
FIG. 1.—GOATS RESTING IN THE MIDDLE OF THE DAY.

Goats thrive best when allowed several hours of quiet grazing both in the cool of the morning and evening and a rest on the range during the heat of the day.

F-33918-A

FIG. 2.—BED GROUND USED THREE NIGHTS BY GOATS.

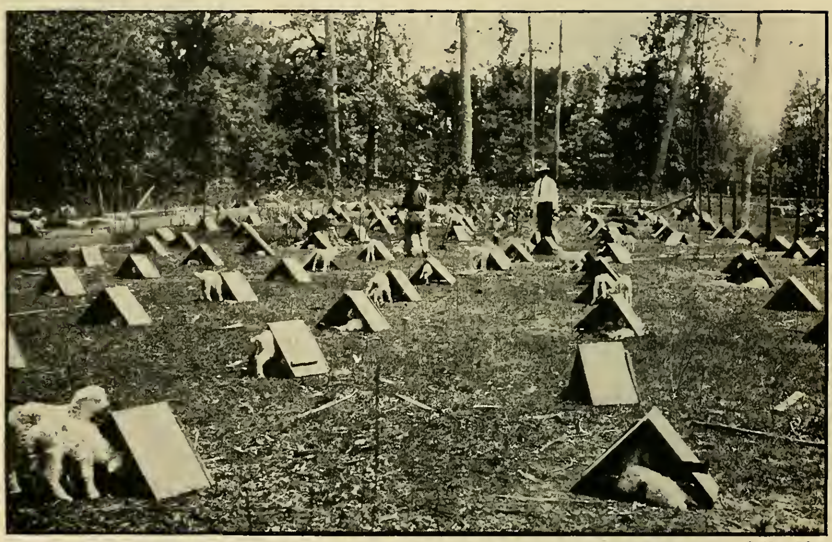
The forage is closely grazed but uninjured. Besides the goats, cattle also have bedded on this area. The use of many bed grounds for short periods makes possible the elimination of over-grazing, fresh feed at all times, greater grazing capacity, and greater production of mohair and meat.



F-8-WRC

GOAT RANGE USED FROM THE HEADQUARTERS RANCH THROUGHOUT THE YEAR FOR A NUMBER OF YEARS.

Yearlong use of the same bed ground results in a large overgrazed area, poor condition of the goats throughout the year, slow growth of goats and mohair, and much suffering and even deaths from lack of feed at critical periods. Continued yearlong use causes erosion and injury to timber reproduction.



F-19-WRC

FIG. 1.—TOGGLED KIDS IN THE SHADE OF THEIR INDIVIDUAL SHELTERS.

In the toggle system the kids are left toggled for eight or ten days, their mothers going out each day for feed.

F-27519-A

FIG. 2.—KID NUMBERED AND TOGGLED ON THE RANGE.

they can go without water for longer periods. When the forage becomes dry and the dews are light, wethers and dry does should be watered every other day and does with suckling kids should be watered every day.

Goats should be bedded away from water and grazed quietly to and from it. They should never be driven hurriedly to it, nor be allowed to "shade up" at water, nor be held there for more than an hour. An hour is usually sufficient time for them to obtain all the water they need. Often greater use of the range is made by bedding the goats away from water than would be possible if the goats were bedded at the few watering places. The success of this plan depends to a great extent upon the topography of the range, the presence or absence of enough water for camp use away from the stock water, and the cost of transporting water for camp use when there isn't enough.

SALTING.

Goats are more easily handled and thrive better if salted regularly at short intervals than if salted at long intervals. Rock salt is often placed on the bed ground, so that the goats can eat of it every night if they desire. Coarse granulated salt is fed either in small quantities every night or in larger quantities at intervals of approximately a week. It is ordinarily placed on rocks, in troughs, or in boxes to prevent waste and to keep it clean. It is believed best to feed every night, giving just the amount the goats will eat. If salt is fed at great intervals or if rock salt is used, the goats are apt to crowd and injure one another.

Medicated salt is fed by many growers with success, although some growers think that it may cause the goats to shed if fed too freely in the spring.

The amount of salt fed varies from about one-half pound to six pounds for each goat per year. However, it is probable that on most goat ranges three and one-half or four pounds per goat per year will prove to be most satisfactory. A greater amount should be fed when the range is green and succulent than when it is dry.

SHEARING.

Angoras are sheared once or twice a year. In the colder climates they are generally sheared once, in March or April. This gives a longer staple and a more valuable fleece than when they are sheared twice during the year, but the amount of mohair from the single clip is usually slightly less than from the two clips. In warm climates, especially in the Southwest, many Angoras are sheared twice during the year, usually in February or March and in September or

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October. At the lower elevations of the Southwest many Angoras will often shed a considerable amount of mohair in the fall if not sheared at that time. In the mountains, however, growers shear twice to lessen the burden of carrying so much mohair during the winter and to prevent the loss of a large amount of mohair as a result of its being pulled out by the brush. One prominent New Mexico grower finds that it is most profitable to shear the kids in January and then shear the yearlings in the following fall. This gives two clips up to about 18 months of age in place of three, but a larger amount of fine, long-staple kid mohair is obtained.

Both hand and machine shears are used, but the latter are generally considered best. Fleeces should be rolled up inside out and packed, without tying, in sacks, or baled. Sacks that have been used previously for wool should never be used for mohair, because wool requires different dyes and whatever wool is left in the sacks must therefore be separated from the mohair before the mohair is manufactured.

DIPPING.

It is advisable to dip goats once or twice a year to rid them of lice, with which they are usually infested. Goats can not thrive to best advantage and carry lice; and in the winter especially infested goats will require more feed, and may become thin and produce a poor quality of mohair, and does may even fail to produce kids. Any of the common sheep-dip preparations are satisfactory.[1]

KIDDING.

To save a high percentage of kids, and thereby insure larger profits, special care must be given to does and kids during kidding. The suggestions in the following paragraphs may prove helpful in reducing loss and in facilitating the mothering and proper growth of the kids. These suggestions are for range herds of approximately 1,000 to 1,200 does; but, with slight modifications, they can be used successfully on any range and with a herd of any size.

THE KIDDING PERIOD.

The time and length of the kidding period are regulated by the service of the bucks. On most southwestern ranges kidding may start any time between February 1 and May 1, and may last from 30 to 45 days. To be certain of ample green feed and to insure proper growth of the kids before the June dry period comes and still avoid the danger of severe storms, it is generally best to have

[1] Full information regarding dipping of sheep will be found in Farmers' Bulletin 713, "Sheep Scab," Marion Imes, and Farmers' Bulletin 798, "The Sheep Tick and Its Eradication by Dipping," Marion Imes.

kidding start in this region not later than April 15 and last approximately 30 days.

On farms of the Northwest kidding usually starts in March or early April, just before the feed becomes plentiful. If there is an overabundance of fresh, green feed, the does overeat and exercise too little prior to kidding, and this, it is thought by growers, causes goitre among the kids. There is little danger of range does obtaining too much feed without exercising sufficiently in obtaining it; still, if the does are kidded in pasture this should be guarded against.

THE KIDDING CAMP.

Kids are generally very delicate when first born, and for several days can not stand much cold or rain. Furthermore, it is the general belief that they can not be grazed along with their mothers until several weeks old. Therefore, to facilitate the handling of the does during kidding, and to care for the kids until old enough for the range, a permanent camp should be established near water. The pens constructed at this camp should be kid tight; for the larger pens 34 or 36 inch woven wire, with the lower meshes small enough to prevent a kid getting its head caught, is preferable, but for small pens boards are best. A shed should be provided to give protection during storms. It may be made either with a permanent roof or with a framework of poles over which heavy canvas is temporarily stretched.

HERDING AT KIDDING TIME.

As most kids are born during the middle of the day, the drop band should be taken out to graze about 7 a. m. and brought in about 11 a. m., or before that if many kids are being dropped. By 3 p. m. most of the does to kid during the day have kidded or have shown signs of kidding, and may be separated from the herd. Then the drop band should be taken out again and kept out until sundown. Kids dropped on the range should be carried in and their mothers marked and brought in with the herd; or, if there are about 8 or 10 that kid on the range, the mothers may be brought in as a separate bunch from the main drop band.

The does which have kidded should be formed into a band each day and quietly grazed from about 9 a. m. to 4 p. m., the kids being left at the camp. A herder should be continually with the wet band (does that have kidded) to prevent its mixing with the drop band and to protect it from predatory animals. Grazing the wet band at some distance from the camp saves the feed close about camp for the drop band.

A crew of at least three or four men is necessary to attend the goats properly during the kidding period. One or two men should herd the drop band. Another man should herd the wet band. While not herding, these men may work about the corrals. One other man, usually the foreman of the crew, is needed about the corrals at all times and to direct the work.

CARE OF DOES WHILE GIVING BIRTH TO KIDS.

If a doe while kidding is with the herd in a large corral, or even is with only a few other does in a medium-sized pen, there is danger of her disowning her kid. Among the preventable causes which may lead a doe to disown her kid immediately after kidding are, chiefly, separation of the doe and her kid, interference of other does or of other kids than her own, fright, and excitement. To persuade a doe which disowns her kid to mother it properly usually causes considerable trouble. If, however, the doe is kept quiet during kidding, and just afterwards is kept close to and alone with her kid, she ordinarily recovers quickly from her labor and fright and properly mothers her kid.

To have the mother in quietness while giving birth, and alone with her kid immediately afterwards, and to facilitate the giving of assistance to the doe if necessary, or to the kid should it fail to draw milk, individual kidding pens about 4 feet square should be provided. About 60 of these pens should be provided for a herd of 1,200 does, though it is well to have more if possible. At morning, noon, and night all does that show signs of immediate kidding should be quietly separated from the drop band by means of the shepherd's crook, and each doe placed by herself in one of the individual kidding pens. It is best to leave the does and their kids in the kidding pens until the following morning; but if there is a shortage of these pens, does that have kidded in the morning may be removed in the afternoon if they are properly mothering their kids.

CARE OF DOES AND KIDS.

There are two systems of handling the kids during the first few weeks of life, "the toggle system" and "the pen or corral system." In the toggle system the young kids are staked, while in the pen system they are turned loose in small pens. The does in either case are taken out to feed each day and are returned to the kids for the night.

The toggle system.—Formerly the toggle system was used in a very haphazard way, the kid being staked wherever it was dropped, or as near by as possible, under a bush or in some other place where it would have shade. The heavy losses and extra work incident to such methods caused progressive goat growers to improve the system. The best results are obtained by the methods outlined below, which are based upon the experience of these men.

When the doe has kidded and claimed the kid, the kid should be carried to the place where it is to be staked and the doe should be quietly brought along with it. The kid is then staked with a toggle

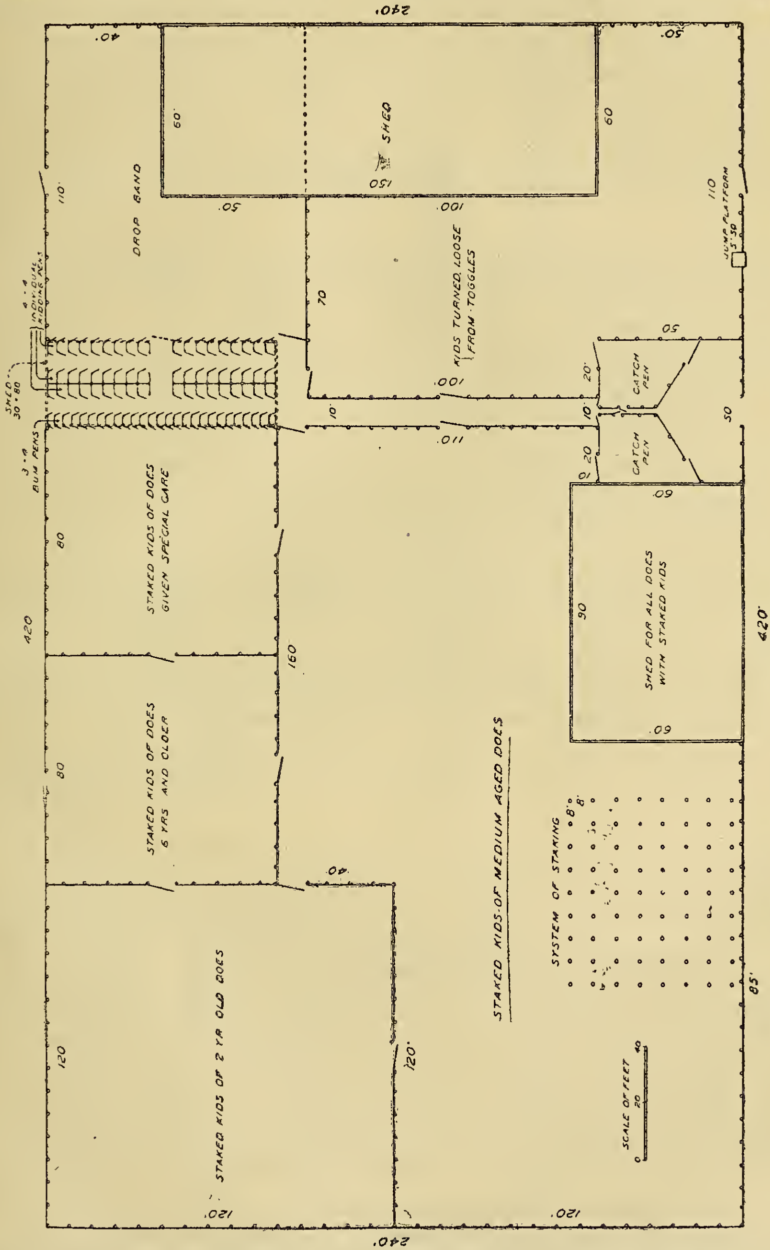

FIG. 1.—Plan for arrangement of pens and sheds for use in toggle system of kidding.

from 8 to 18 inches long, which is fitted with a swivel. Each staked kid should be furnished with an individual shelter to protect it from rain and heat. Shelters for this purpose are usually made of 12-inch boards in a gable or box form.

To facilitate care of does and kids and to lessen the chance of the does fighting, it is best to stake the kids in rows 8 feet apart each way, and separated in pens set aside for kids of old does, medium-

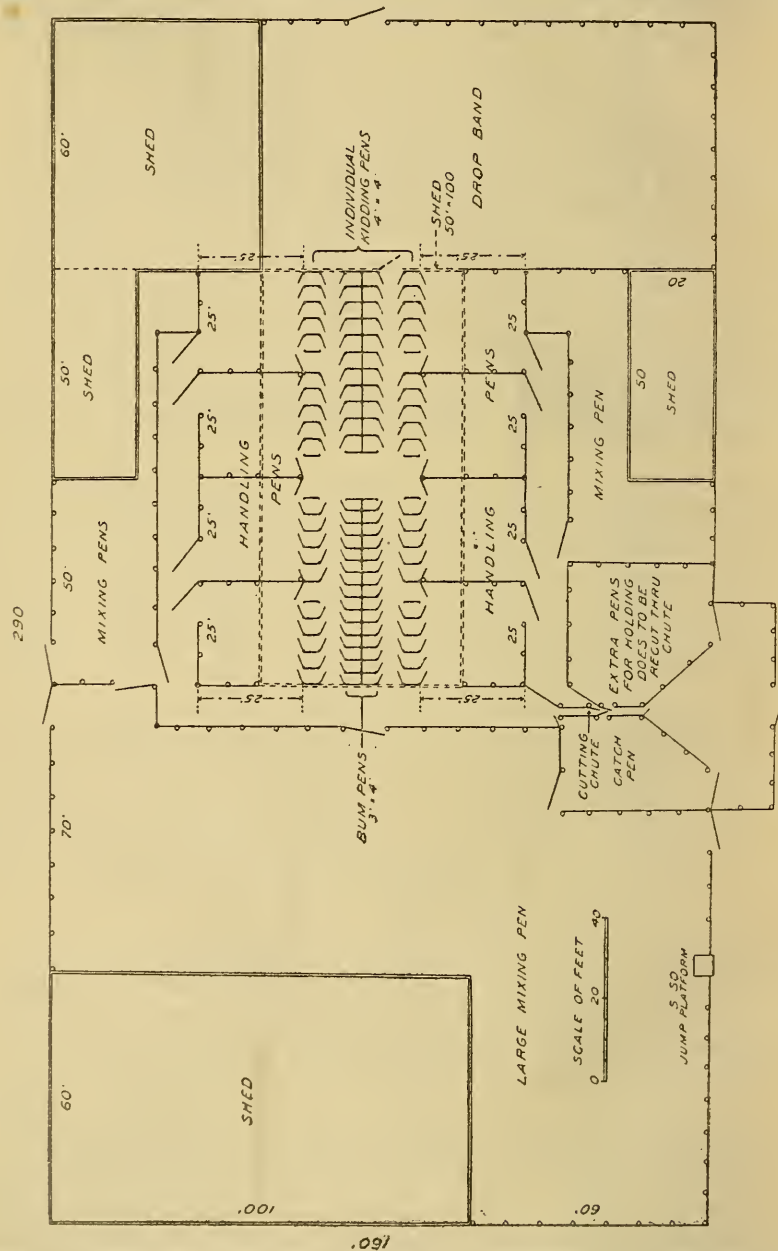

FIG. 2.—Plan for arrangement of pens and sheds for use in pen system of kidding.

aged does, two-year-old does, and does which have received special care. After the kid is staked, care should be exercised to see that the doe does not leave the kid for an hour or more. Then the doe is taken out with the wet band to graze. In order to identify the doe and its offspring, should the doe fail to return to its kid or the kid break loose, each doe and her kid should be numbered with a tag or paint before the kid is staked.

Every day the toggles should be changed, the shelters straightened if need be, the hardened obstructions removed from the hind parts, and examinations made for scours, worms, and other troubles.

The kids should be left staked for at least eight or ten days. When turned loose from the toggles the kids should be removed from the staking pens to a large pen where they should remain until turned out to graze.

The pen system.—In the pen system the following procedure is now accepted as the best. After removal of the does and their kids from the kidding pens they are placed in handling pens suitable for holding about 50 does and their kids. These handling pens should be at least 20 feet square. For a herd of 1,200 does about 6 or 8 such pens should be provided. With small farm flocks and ample pasturage it may prove advantageous to place about 10 or 15 does with their kids in each handling pen and leave them together for from one to several days before grouping them into pens holding 50 does. Where pasturage is scarce, the range of low carrying capacity, and the herd large it is generally necessary to take the does out to graze while their kids remain in the pens. The necessity of cutting the does through a chute each evening upon their return from the range makes it impracticable to separate them for pens holding only 10 or 15 does. Very satisfactory results are obtained when 50 does are placed in each handling pen. Not more than this number, however, should be placed in a handling pen and ample room should be provided.

At all times the aim should be to group kids of the same age in the handling pens. If a difference of more than five days in age is allowed in any one handling pen, the older kids may cause considerable trouble to the does with younger kids.

When a doe and her kid are first placed in the handling pen care should be exercised to see that they are together. They should be left together and undisturbed for at least an hour before the doe is taken out to graze. Each doe should be marked with paint to show the pen in which her kid is left, and she and her kid should be marked or numbered so that they can be identified as belonging to each other. It is best to do this before removing them from the kidding pens.

When all the handling pens are filled, the does with kids several days old may be changed from several of the handling pens to a mixing pen. At least 6 or 8 square feet of space should be allowed in the mixing pens for each doe and kid. There should be two mixing pens, so that the does and kids may be left in them for a week or more. The use of the mixing pens permits the does to become accustomed to finding their kids in a medium-sized bunch. Then when they are all placed together they seldom fail to find their kids. From the mixing pens the does and kids are moved into a pen large enough to hold the entire herd of does and kids. The kids remain in this pen until taken on the range.

Castration.—The buck kids not reserved for breeding purposes should be castrated when from a few days to three weeks old. This should be done early on a bright, cool morning and never on a rainy day. The lower one-third of the scrotum should be cut off with a sharp knife, then each testicle should be gradually worked down with the fingers and caught hold of, and either the testicle and spermatic cord should be pulled out, or when the spermatic cord is stretched it should be cut off at the base. All fatty matter attached to the cord should come out. Pulling of the testicles until the cord breaks is generally preferred. For several days the kids should be carefully watched. If flies are bad a disinfectant should be used.

Bucks in which only one testicle descends should have this testicle removed. They should be marked to distinguish them from wethers and should be killed or sold for meat as soon as practicable, for when a few months old they will bother the does. They make good meat when less than a year old.

Care of kids needing individual attention.—The kids which need individual attention are chiefly those which have been disowned by their mothers and those which have been given to does other than their mothers. Also, there are always a number of twin kids, kids of poor and weak does, and prematurely born and deformed kids that need special attention.

Even with the use of the individual kidding pens a doe may disown her kid because of severe pains in labor, lack of proper nourishment, or the doe's being without milk or having only a scanty supply. While the most critical time is right after the kid is born, there is danger even until the kid is several weeks old of the mother's disowning it for one or more of the following reasons: Rubbing together of kids dropped on the range in bringing them in, failure of a doe to find her kid, separation of a doe and her kid because of the fences not being kid tight, other kids than her own stealing the doe's milk, a doe's adopting some other kid than her own, fighting between does, or any unusual disturbance. Young does with their first kids and does with an insufficient amount of milk are the main offenders.

To assist in persuading the doe to own her kid small pens, generally known as "bum pens," 4 feet by 3 feet in size and with sides 3 feet high, should be provided. About 25 of these are needed to meet any usual eventuality with a herd of 1,200 does. Any doe which fails to claim her kid is placed with it in a bum pen, the kid is suckled, and then they are left together until the doe needs feed and water. Each day the doe is grazed with the wet band and put back with the kid at night. The pen should be examined morning and night to see that the kid receives sufficient milk.

If the doe fights the kid it is best to hold her until the kid has suckled, but if other work is more pressing than this she may be tied to the side of the pen for a short time. It usually requires only one night in a bum pen for a doe properly to own her kid. Sometimes, however, does with a small amount of milk may require much longer.

One of twin kids is usually neglected by its mother. Even if she mothers both well, however, there is seldom sufficient milk, and the weaker of the two will probably be stunted unless given special nourishment. Some does will drop premature, deformed, or dead kids, or may lose good kids. If such a doe has a good flow of milk she may well be given a twin kid, a motherless kid, or a kid of a sick or weak doe. By using a bum pen and exercising care and patience a doe can be given the kid of another doe without difficulty. Often when the doe drops a dead kid she can readily be given another kid if the liquids expelled along with the dead kid are well smeared on the strange kid, especially on its hind parts, head, and belly. It will sometimes assist in having the doe claim another kid if the pelt is removed from her own kid and fitted on the kid being given her.

Kids of does giving a small amount of milk may usually be kept in better condition if their mother's milk is supplemented with milk from does having a surplus. Either does giving such a surplus may be milked by hand or the needy kids may be allowed to draw it. Care should be exercised in nourishing surplus kids being held for substitution, since the kid's stomach is very delicate. A new-born kid will usually not do well on milk of a doe which has given milk for several days, nor will an older kid do well on milk of a very fresh doe, because of changes which occur in the doe's milk from day to day.

It is usually necessary to assist for about a week a kid suckling a doe with extra large teats. Such cases, as well as sick does and does with weak or sick kids, can well be placed in bum pens or in a separate handling pen to facilitate the giving of extra care.

Starting the kids to graze on the range.—After kids are from a month to six weeks old it is best to give them some other feed in addition to their mothers' milk. If a pasture is available, the kids loose in the large pen may be turned into the pasture after the does have been separated and taken to the range. To separate the does from the kids it has been found best to use a platform from 16 to 18 inches high, over which the does pass in leaving the pen. As the herd approaches this the kids pass under it and the does go over. A substitute for the platform is a jump board, but with this there is danger of kids being crushed. If a pasture is not available, the larger kids may be allowed to go with the does when they are able to jump upon the platform as the herd is leaving the corral.

About two weeks after the close of the kidding period most of the kids may be taken with the herd. During the first few days that the kids are in the herd the entire herd is grazed only a short distance from the corrals. The distance is gradually lengthened as the kids become accustomed to going with the herd. Where the range is closely grazed, the does are taken out for their usual amount of grazing and when they are brought back to the corrals in the afternoon the kids are taken out with them for about a half hour's grazing close by. It is bad practice to herd the does and kids in separate bands. The kids obtain milk only at night while they are being grazed separately, whereas it is best for them, after they are several weeks old, to be able to get it at any time. Also separate grazing often makes it difficult to keep the does and kids together when placed in the same herd. When the kids are old enough to graze on the range with their mothers it has been found best to change from grazing the wet band during the middle of the day, as is done during the kidding period, to the general practice of several hours' quiet grazing in the morning and evening with a rest on the range in the middle of the day.

SELECTION OF GOATS FOR THE RANGE.

The goats on the ranges to-day are generally of two breeds—the Angora and the common, which is sometimes called the Mexican or Spanish-Maltese. In certain places near ranches a few head of the true milch breeds graze on the range. The Angora is by far the most important on the ranges both in numbers and the value of its products, and without doubt the principal increase in goats on the ranges will be in Angoras.

In connection with the study of range practices to determine the best methods of management, certain points regarding the type and grade of goats for the ranges were noted which it is deemed worth while to bring to the attention of goat growers generally. Large range herds of common goats and of low-grade Angoras often fail to yield sufficient revenue to pay for running them. Range Angoras vary so greatly in size, conformation, and production of mohair, and this has so great an effect on the profits of the industry, that a few suggestions as to selection of the goats making up range herds may assist materially in increasing the production of mohair and meat and in placing the industry on a more stable and remunerative basis.

TYPE AND GRADE OF GOATS FOR THE RANGES.

The greatest profits are made from the growing of pure-bred Angoras and the sale of the surplus for breeding. Very few range growers, however, are properly equipped to produce and dispose of valuable pure-bred breeding animals. The effort on most ranges, therefore, should be to produce high-class grade Angoras. Grade Angoras have been developed until the production of mohair from some of them equals the production from some pure-bred Angoras. Range herds of grade Angoras made up of young, fine-haired, heavy-shearing does and wethers furnish very substantial profits.

The mohair should be of fine, strong, even, long staple, be closely curled, pure white, lustrous, and as free from kemp as possible. It should also be dense on the animal, though fleeces of equal length and weight are more dense on a small animal than on a large one. Mohair becomes coarser as the age of the goat increases. Mohair from kids is very fine, and that produced by yearlings,[1] while coarser, is often sold as kid mohair. The very fine mohair not only brings a higher price but is much more easily marketed. Accordingly effort should be exerted to produce mohair of fine quality on all the goats, and just as much high-quality kid mohair should be produced as is possible.

The quantity of fine mohair produced by grown does and wethers varies from 1½ to 9 pounds, the average being about 3½ pounds. Better selection of the present range-breeding stock and better care and management should make possible an average annual production of at least 4 pounds of fine mohair per range goat. While this is an increase of about 15 per cent over the present range average, 4 pounds is so far below what some Angoras produce that the average should increase much above this by further improvement.

Most range growers have emphasized the mohair side at the expense of other desirable qualities. Where mohair alone is the object and the production of meat has been lost sight of, it is sometimes difficult to make a profit from goats during times when the market for mohair is dull. With a dual-purpose type of Angora, raised for the production of both meat and mohair, the double revenue not only furnishes a greater profit at all times but insures a profit when either the mohair or slaughtering market is dull.

Range Angoras should be heavy producers of fine mohair, but they should also have a large, plump, symmetrical body and a good constitution. The body and chest should be relatively broad and deep, the shoulders broad and nearly flat, the back wide and straight, the thighs full, the ribs well sprung, and the legs short, strong, and

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[1] "Yearling" is used throughout this bulletin to mean a goat in the second year of its life.

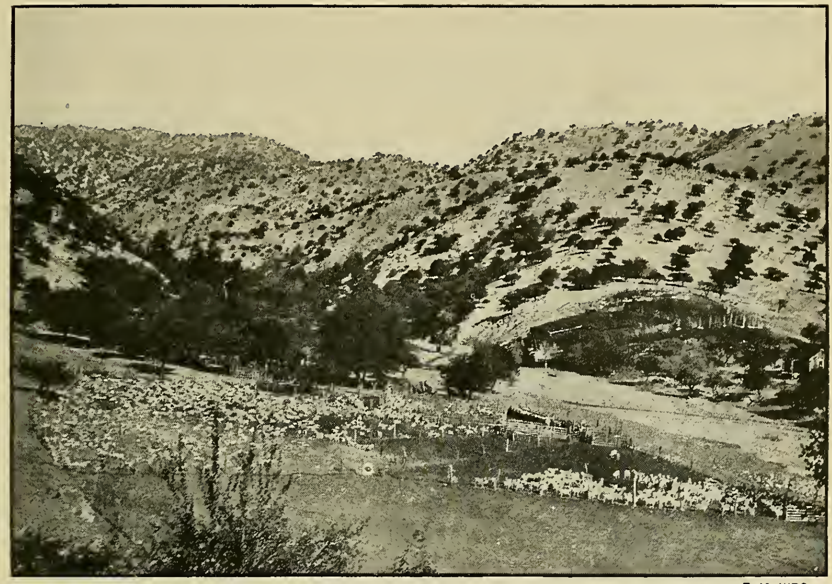
set wide apart. Such dual-purpose Angoras make possible a substantial double revenue from two sources, mohair and the sale of animals for meat. Heavier and earlier maturing animals are produced, which have a more ready sale and a greater value for meat, because there is less waste and a greater proportion of valuable cuts on the animal. This makes it possible to sell at a profit poor producers of mohair when about 6 months of age, and all surplus can be sold advantageously when 18 months or 2 years old.

In weight, grown Angoras vary from 60 to 150 pounds for both bucks and does, though the average is approximately from 100 to 125 pounds for bucks and 75 pounds for does. In the fall, kids of fine-mohair goats weigh, in good condition, from 30 to 75 pounds, with an average of about 35 to 40 pounds, and yearlings from 50 to 100 pounds or more, with an average of 60 to 65 pounds. Better selection of breeding animals from the present range Angoras to approximate the dual-purpose Angora as herein suggested, together with better care and management, will result in the production of kids averaging 50 pounds and yearlings averaging 80 pounds in the fall of the year. This is an increase of from 25 to 30 per cent over the averages to-day. These weights can be increased still further.

The disposal of surplus animals has always been one of the drawbacks of the goat industry. Though several hundred thousand are annually slaughtered, goats are usually placed on the market in small numbers of all ages and sizes and in all conditions of flesh. This has often made it impossible to establish a market classification and has generally caused slaughterers to pay only such prices as would insure a profit on the poorer animals. The production of the dual-purpose type of Angora under good management and the disposal of the surplus when 2 years old or under would make possible the placing of large numbers of well-built, fat goats on the market. With a steady supply of large, fat goats of even size and condition a better market for goats and goat meat might be established.

The type and grade of goat, then, that should be raised on the ranges is a large, well-built, early maturing Angora, producing a large quantity of fine mohair. The herd should be as uniform as possible. Uniformity of the mohair in the fleece and from the herd, reducing the work of grading, increases the value of the mohair. Also uniformity in size and conformation of the surplus stock sold for meat causes it to bring a higher price.

Selection of does.—The does making up the herd should be carefully selected for uniformity, and as nearly as possible to approximate the ideal range goat. In general, high-class does produce high-class offspring. Considering present prices, each doe should produce



F-10-WRC

FIG. 1.—GENERAL VIEW OF PENS USED IN THE PEN SYSTEM OF KIDDING.

F-27047-A

FIG. 2.—KIDS IN THE HANDLING PEN ADJOINING INDIVIDUAL KIDDING PENS.

In the pen system the does and kids are removed from the individual kidding pens to handling pens, where the kids in groups of about 50 remain for several days before being moved to mixing pens capable of holding the kids from several handling pens.

F-11-WRC

AN EXCELLENT TYPE OF BUCK—FIVE MONTHS' FLEECE.

The type of Angora that should be grazed on the range is a heavy producer of fine mohair, with a large, plump, symmetrical body.

AN EXCELLENT TYPE OF DOE—FIVE MONTHS' FLEECE.

The does making up the herd should be carefully selected for uniformity, and as nearly as possible to approximate the ideal range goat.

F—27044—A

FIG. 1.—YOUNG KIDS SHOULD BE PROVIDED WITH SHADE.

When turned loose from the toggles or removed from the mixing pens, the kids are removed to a large pen where they remain until old enough to graze.

F—13—WRC

FIG. 2.—DOES LEAVING LARGE PEN OVER PLATFORM.

As the does go over the kids pass under the platform and are not injured by crowding.

mohair of sufficient amount and value to cover approximately the cost of maintenance, so that the offspring is nearly clear profit. All does should produce sufficient milk to insure proper growth of the kids, and any range does that refuse to claim their kids or fail to give birth to kids after two years' trial should be disposed of.

Range does should be sold for meat at approximately 6 years of age at the latest, because at that age the mohair has become so light in weight and so coarse, and the milk supply so uncertain that they are apt to be unprofitable. The practice of retaining unprofitable does just as long as they are capable of producing offspring has been responsible for much of the low profit from goats.

Selection of bucks.—The bucks are the most important animals in the herd, and should be of as high breeding as is economically possible. Every buck should more nearly approximate the ideal than any of the does. Bucks of superior breeding usually stamp their characteristics on the offspring. If the bucks are of high quality, the herd can be improved through the retention of the high-class offspring. The bucks should not only show quality and quantity of mohair, but also should be of good size and symmetrical build, and should have a good constitution and two well-developed testicles.

Disposing of wethers.—Every wether retained in the herd takes the place of a doe on the range. The greater the proportion of does in the herd the greater the number of kids raised, and the greater the proportion of kid mohair in the clip from the entire herd. As before stated, the kid mohair brings the highest price and is the most readily sold. Therefore, if the wethers are to be retained in the herd they should be able, other factors being equal, to produce a net revenue over running expenses equal to the net revenue from the same number of does, and in determining this the possibility of selling the wether mohair should be carefully considered. The net revenue from does is considered as the total revenue from the does' mohair, the value of the kids and of the kids' mohair at 1 year of age, less the total cost of maintaining the does and kids during the year.

Both wether kids and doe kids which produce a poor quality of mohair should be disposed of either as fall kids or when 1 year old. It will be found most economical to sell the bulk of the other wethers as fall yearlings or when 2 years old. Up to this age there is the greatest production of fine mohair and the greatest gain in weight. Few wethers after 2 years of age can produce a net revenue from mohair and increase in value as a result of gain in weight equal to the does' net revenue, and therefore should be sold. Only wethers producing a very large quantity of fine mohair should be retained after they are 2 years old.

BREEDING.

The time of mating depends largely on the time when it is best for the kids to come. The period of gestation is from 147 to 155 days, and the time of mating is adjusted accordingly.

BUCKS.

Bucks to be used for breeding should be over 18 months of age. They should be kept in a thrifty, growing condition throughout the entire year, but particularly so during the mating season. Before breeding, the mohair should be clipped from the underside of the buck.

The number of does a buck may serve depends largely on the methods used. When the bucks are turned loose on the range with the herd there should not be more than 40 does to each buck. When the bucks are kept up in the daytime and fed grain in addition to pasturage, and are placed with the does only for the night, a buck can often serve more than 50 does, especially if it is desired to have the kids come well distributed through about 30 or 35 days, as is usually the range practice. By careful handling of the bucks some growers have had good success using one buck for about 80 does. In such cases the bucks are well fed and are placed with the herd only at night. With the possible exception of a few nights during the breeding season, only half the bucks are placed with the herd one night and the other half the next night. They are mixed so that if there is an exceptionally thrifty one and one that is not thrifty, these are placed with the herd on the same night. No two bucks that fight are placed with the herd on any one night.

DOES.

Does come in heat about the latter part of August or the first of September, and, unless mated, have periods of about three days in heat at intervals until January. Before breeding the mohair should be clipped from the hind parts of the doe well under the tail.

The does should be in good condition at the time of breeding. They should not be bred until they are 18 months of age. With small does it will often prove best to allow them still another year's growth before breeding. This gives them a chance to attain full growth, and as dry young does they will furnish a greater amount of valuable mohair than if they are nursing kids. When small does are bred at 18 months of age and raise a kid during their third year, they often fail to have a kid the next year and are usually permanently stunted, and their kids are generally small.

COSTS AND RECEIPTS.

COSTS.

The cost per head of running goats varies rather widely between herds. The items making up this expense are feed, loss, depreciation, labor, buck service, interest on investment, and other miscellaneous costs. These costs vary considerably with variation in efficiency of management, economic location, topography of the range, improvements and equipment necessary, labor supply, and the demand for range by other classes of stock.

On southwestern ranges very little feed other than range forage is provided except for the bucks. The cost of such range feed in Arizona and New Mexico is often small since the goats are generally run on public domain free of charge or on National Forests for a small fee. Where it is necessary to graze them on private or leased land, as is sometimes done in these States and nearly always in Texas, the interest on the investment in the land or the lease fee generally increases the forage cost. In the Northwest the cost for supplemental winter feed usually increases the total feed charges.

The loss by death in the Southwest is generally about 10 per cent of the grown goats, and is due mainly to predatory animals but somewhat to poisonous plants, disease, straying, adverse climatic conditions, and in a few cases to starvation. In many herds the average loss is much less than 10 per cent, often being less than 5 per cent.

The depreciation in wethers is practically nothing if they are not retained too long. In does the depreciation varies from 5 to 10 per cent annually. Where there is a good market for goats as meat the depreciation may even be less than 5 per cent.

One or two herders are provided per herd of 1,200 to 1,500 grown goats. Mexicans are generally employed and up to 1917 received wages of from $20 to $60 per month and board. During 1917 and 1918 it was often necessary to pay higher wages than these. A camp tender is sometimes provided for each herd or for several herds if owned by the same person. The camp tender's wages are about the same as the wages of the herders. A manager is sometimes hired for a large outfit. Two or more extra men are required for from one to two months at kidding time with each herd of 1,000 to 1,200 head.

Buck service costs vary widely in different herds, because of variation in the value of the bucks, the number of does allowed for each buck, whether they are traded with neighbors after two or three years' use, and the feed and care given. The average value of bucks used in range herds is $35 to $50.

There are a number of other miscellaneous costs. Shearing, which is done once or twice a year, usually costs about 4 to 8 cents per head for each shearing. Salt is usually furnished at the rate of from 1½ to 4 pounds per goat per year. Goats are dipped once or twice a year for lice at a cost of about 2 or 3 cents per goat for each dipping. Interest on the investment, taxes, depreciation of improvements and equipment, which includes maintenance and repairs, and minor costs of running, also add to the total.

In a number of New Mexican range herds of Angoras grazing on National Forests, and made up of does and wethers, it was found that, exclusive of interest on investment and owner's labor, the annual cost of running the yearlings and wethers during 1915 and 1916 varied from about 95 cents to over $2 per head, and the cost of running the does and their kids varied from about $1.62 to $2.78 per doe. In some herds it costs more than the highest figure given here; but few herds can be run for less than the lowest figure under such conditions as prevailed in 1915 and 1916.

RECEIPTS.

The receipts vary widely in different herds, mainly because of variation in the type and grade of goats and in the care and management they receive. The receipts from does are materially affected by the percentage of kids raised. This percentage based on the number of does bred varies on the range from about 50 per cent to nearly 100 per cent, though the average is about 60 per cent. The receipts from goats include receipts from mohair, net receipts from sales of goats which were on hand at the beginning of the year, the value of the kids raised during the year, whether sold or retained in the flock, and miscellaneous receipts.

The average gross receipts during 1915 and 1916 from grown wethers in the herds studied were about $2 per head or slightly more. From yearlings the receipts were higher, because the mohair from goats of this age is of high quality, a large amount is produced, and there is a considerable increase in value of the animals as a result of gain in weight. The total receipts from does, which include receipts from kids up to 12 months of age, were usually higher than from either grown wethers or yearlings. The total annual receipts during 1915 and 1916 from average does in the range herds of grade goats studied varied from about $3 to more than $5.50 per doe.

SUMMARY.

On far western ranges goats are raised mainly for mohair and meat and secondarily for milk and hides. There is need for improvement in methods of management in order to eliminate damage to the range so common on goat ranges and to place the industry on a better financial basis.

Range suitable for goats should possess a mixture of browse, grasses, and weeds, be free from continued heavy rains and snows, and be well supplied with bed grounds and watering places.

For proper management of any goat range the forage should be utilized in such a manner as best to meet the needs of range and goats. The entire range should be divided for seasonal use into three parts, spring range, summer and fall range, and winter range. The grazing on these divisions should be of such intensity and distribution as to secure a uniform utilization and to allow the forage to make sufficient growth to maintain itself.

The spring range must necessarily be grazed heavily at that time, but it should not be overstocked and should be protected from grazing at other times of the year.

The summer-and-fall range, containing the forage at the higher elevations, must usually be grazed during the growing period of the vegetation. The grazing, accordingly, should be well distributed and should be deferred until after seed maturity on successive parts of the division so as to insure proper revegetation.

The winter range, located on areas low enough to avoid severe storms, should be reserved for winter grazing only, in order to insure an ample supply of suitable winter forage. The grazing should be well distributed over the division, and the range close to the sheds should be reserved for use during stormy periods only.

Overgrazing causes deterioration of the range, erosion, injury to timber reproduction, and impairment of the growth of goats and mohair. Excessive overgrazing may even cause serious loss and suffering among the goats at critical periods. The number of goats should be regulated so as to prevent overgrazing.

Plenty of fresh, palatable feed has a marked beneficial effect on mohair production, growth of the goats, percentage of kids raised, and proportion of losses. Therefore, instead of overstocking a range with a large number of inferior-grade goats, the producer should graze high-grade goats to the number the range can conservatively carry. The net revenue will be just as great if not greater.

On the range it is most economical and gives the most satisfactory results to graze goats in herds of about 1,200 head. It also proves best to graze breeding does separate from dry does, wethers, yearlings, and weaned kids.

Open, quiet herding, and grazing of the goats for four or five hours both in the cool of the morning and the cool of the evening with a rest on the range during the heat of the day is the most successful method.

The use of the same bed ground throughout the year results in uneven utilization of the forage, a large overgrazed area about the bed ground, poor condition of the goats throughout the year, slow growth of goats and mohair, and much suffering and even deaths at critical periods. In addition, the use of a single bed ground may cause injury to timber reproduction, erosion, and possibly a pollution of the water supply.

The use of many bed grounds makes possible a more even utilization of the forage, the elimination of overgrazing, the recuperation of the overgrazed areas, the use of the forage at the most advantageous time, the reserving of an ample supply of suitable feed for critical periods of the year, and in short the successful application of proper range management. The benefits to the range of proper management, the elimination of driving and trailing of the goats, and the possibility of having the goats on fresh choice feed at all times not only permit the grazing of a greater number of goats but also result in raising a greater percentage of kids and in greater growth of goats and mohair. The mohair is of greater value because it is cleaner and of a more even staple.

The success attained by the use of many bed grounds leads to the conclusion that the bedding-out system, whereby the goats are quietly and openly grazed for short distances during the day and bedded where night overtakes them, would give even better results to range and goats and allow for the grazing of even a greater number than where each bed ground is used for only several consecutive nights.

The kidding range should be so located, and the time of kidding so adjusted, as to avoid severe storms and to insure ample green feed. The use of individual kidding pens, good management in either the toggle or pen system, care in seeing that each doe properly mothers her kid, and that motherless kids are given to does which have lost their kids will result in a larger and more thrifty kid crop.

The range goat should be the large, well-built, early-maturing Angora, producing a large quantity of fine mohair. The does should be uniform, of good size, have good constitutions, be good producers of mohair, and should produce sufficient milk to insure proper growth of kids. The bucks should more nearly approximate the ideal than the does; they should be large, vigorous, and producers of a large quantity of high-quality mohair. Only those wethers which produce a very large quantity of fine mohair should be retained in the herd after they are two years old.

For breeding purposes both the bucks and does should be in a thrifty condition and over 18 months of age. When bucks are placed with the does at night and are fed grain in addition to good pasturage they may serve 50 or more does with success.

In a number of New Mexican range herds of Angoras it cost, during 1915 and 1916, exclusive of interest on investment and owner's labor, from about 95 cents to over $2 per head per year for running wethers. For the same years the average annual gross revenue per grown wether from these herds was approximately $2. From yearlings the gross revenue was somewhat greater.

In the same herds and during the same years the annual cost of running the does and their kids varied from $1.62 to $2.78 per doe. The average annual total revenue per doe varied from about $3 to more than $5.50.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 750

Joint Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief
and the Insecticide and Fungicide Board
J. K. HAYWOOD, Chairman

Washington, D. C. Professional Paper October 5, 1918.

A METHOD FOR PREPARING A COMMERCIAL GRADE OF CALCIUM ARSENATE.

By J. K. HAYWOOD, *Chief, Miscellaneous Division,* and *Chairman, Insecticide and Fungicide Board,* and C. M. SMITH, *Assistant Chemist.*

CONTENTS.

CALCIUM ARSENATE AS A SUBSTITUTE FOR LEAD ARSENATE.

Recently attention has been directed to the use of calcium arsenate as a substitute for lead arsenate, principally because of the cheapness of lime as compared with lead oxid. While no one recommends the use of calcium arsenate alone on tender foliage, experiments by the United States Department of Agriculture[1], the Canadian Department of Agriculture[2], and others have shown that it gives excellent results on some of the more resistant plants, as well as very promising results when combined with other sprays, especially sulphids, which cause to a greater or less extent the breaking up of lead arsenate.

[1] U. S. Dept. Agr. Bul. 278, Farmers' Bul. 908.
[2] Crop Protection Leaflet 10.

PREPARATION OF CALCIUM ARSENATE.

The Bureau of Entomology of this Department has carried out experiments with "homemade" calcium arsenate prepared by slaking burned lime with a solution of sodium arsenate. Others[1] have recommended calcium arsenate prepared by the action of soluble lime salts on sodium arsenate. In all such cases soluble by-products are formed. Since these may influence the action of the spray if not removed, they should be washed and filtered out if a good grade of commercial calcium arsenate is desired.

From the chemical standpoint, the simplest means of producing calcium arsenate is the direct union of calcium hydroxid and arsenic acid. As the only by-product of this reaction is water, filtration of the material is the only treatment that should be required, thus eliminating the washing necessary with most products. The following experiments were made with the idea of determining the proportions and procedure necessary to obtain a product having the properties desired for spraying purposes[2]. The arsenic acid used was commercial 75 per cent acid. Its density was found to be 1.88, corresponding to 61 per cent As_2O_5, or 75 per cent arsenic acid, H_3AsO_4. The lime was a good grade of commercial lime of the following composition:

	Per cent.
Loss on ignition	5.07
Calcium oxid, CaO	93.36
Magnesium oxid, MgO	.69
Silicon dioxid, SiO_2	.54
Oxids of iron and aluminum, R_2O_3	.68
	100.34

In the absence of other drawbacks, the most desirable method of uniting lime and arsenic acid is to have both ingredients in solution before they are mixed. This necessitates the use of lime water which contains only about 1 gram of CaO per liter, and of a quantity of water so large that it probably would be prohibitive in commercial practice. Nevertheless, a few experiments were made to discover the nature of the product so formed.

[1] Oregon Agr. Exp. Sta. Bul. 131.

[2] The desirable features of a good arsenical spray material may be enumerated here. It should not contain an excessive amount of soluble arsenic, which would cause injury to foliage; it should be very finely divided in order that it may be distributed well over the foliage; it should be light when in the dry form, to permit of ready application by dusting; it should suspend well in water, to permit of even distribution when applied in the form of a spray; and when sprayed and subsequently dried it should stick well to the foliage.

If arsenic acid of any strength is added slowly to lime water containing phenolphthalein until the latter is just about to decolorize, a gelatinous, slow-settling precipitate is formed. After the lapse of an hour or so, this crystallizes and settles to about one-eighth of the volume of the liquid used. The precipitate filters very readily, leaving a cake which on the steam bath dries fairly rapidly to very light lumps easily powdered between the fingers. Its extreme lightness is very noticeable, and it does not require grinding, simply a disintegration of the lumps. One preparation, dried at about 70°C. on the steam bath, had the following composition:

	Per cent.
Calcium oxid, CaO	32.00
Arsenic oxid, As_2O_5	42.96
Water (by difference) (slight amount of CO_2)	25.04
	100.00

The molecular ratio of CaO to As_2O_5 is here 3.05, showing the compound to be tricalcium arsenate. It approximates most closely to the formula $Ca_3(AsO_4)_2.8H_2O$. In an investigation on the chemistry of the calcium arsenates, the results of which will be published later, it has been shown that such a compound exists. Drying at 110°C. results in the loss of about seven of the eight molecules of water of crystallization. The lightness of this material may be judged from the fact that 2 ounces of it filled a graduated cylinder to the 500 cubic centimeter mark, which is equivalent to 240 cubic inches per pound, this, of course, without any attempt at packing. If jarred for a sufficient time the space occupied will be reduced to about 60 per cent of this figure.

The compound thus formed yields appreciable amounts of soluble arsenic when treated with water. In one experiment 1.8 grams were treated with 1 liter of water (equivalent in arsenic content to 1 pound of dilead arsenate in 50 gallons) for 24 hours, and 55 milligrams, or 3.04 per cent, of As_2O_5 were rendered soluble. R. H. Robinson[1] found 79 milligrams of As_2O_5 per liter for somewhat similar material. This, of course, is an excessive amount, and would render the material unfit for use alone on any but the hardiest foliage, such as will stand applications of paris green.

If the manufacture of calcium arsenate by this process were attempted commercially, the liquid left from the settling of one batch of arsenate could be used again for the preparation of more lime water, and thus the consumption of water might be greatly reduced. However, methods requiring the handling of as little material as

[1] Oregon Agr. Exp. Sta. Bul. 131, p. 7.

possible probably would be preferable. On first thought, such a process would be the direct slaking of the stone lime with the requisite strength arsenic acid solution. But such a procedure is not practicable. Owing to the slow surface action, the As_2O_5 is locally always in excess, resulting in the formation of dicalcium or even monocalcium arsenate (if the H_3AsO_4 is strong enough), which, while it may be changed later by the excess of lime, renders the product lumpy or granular. Even the use of strong arsenic acid with a concentrated lime paste suffers from the same drawbacks—the addition of the acid causes a further thickening of the paste, and thorough and rapid mixing becomes impossible.

SLAKING THE LIME.

Only more or less dilute lime paste, made by the slaking of quicklime, was used in the experiments here reported. It is self-evident that the ease with which such a paste will combine with acid is directly dependent on the smoothness of the paste. Consequently experiments to determine the best procedure to follow in slaking so that the paste would be smooth and free from lumps were made first. It was soon found that the use of 3 to 3½ times as much water (by weight) as lime gave a paste which was entirely satisfactory, if the lime employed was sufficiently pure. This produces a paste rather thick, but not thick enough to interfere with good mixing when working with small quantities. Best results were obtained by using boiling water for slaking, although in bulk the natural heat of reaction would be sufficient.

PROPER PROPORTION OF ARSENIC OXID AND LIME.

As previously noted, it is essential that a compound for spraying purposes shall be free, or nearly so, from arsenic in water-soluble forms. As seen by reference to the description of practically pure crystalline tricalcium arsenate, that material is appreciably acted upon by water. Other work done in the Bureau of Chemistry on this subject has shown that all of the calcium arsenates more acid than this are likewise somewhat soluble (or decomposable), the action increasing until the monoarsenate, which is very readily soluble in water, is reached. Evidently, then, it is necessary to look toward the basic side. It has long been known that the addition of an excess of lime to a spraying compound renders the arsenic insoluble. The object here was to find the right proportions to produce a material combining high arsenic oxid content with sufficiently low water-soluble As_2O_5 to prevent burning or reduce it to the lowest possible limit. Two series of experiments were made along this line. Each series included 8 experiments, the molecular ratio, CaO/As_2O_5 being varied from 3 to 5 by appropriate steps. The amount of As_2O_5 used was kept constant, being 25 cubic centimeters of a solution containing 0.4 gram As_2O_5 per cubic centimeter (in other words, a total of 10 grams As_2O_5). The weighed amounts of lime were slaked in beakers with 3 times their weight of boiling water, and the cold arsenic solution added rather slowly, from a pipette, with constant stirring. In one series (A) the acid was added to the lime while still hot from slaking; in the other series (B) the lime paste was permitted to cool to room temperature before mixing. Each mixture was then divided into two portions, one of which was permitted to stand over night, then decanted, the other being filtered and sucked as dry as possible on a Büchner funnel for the purpose of determining the amount of water each process left in the paste. Water was determined in portions of each paste by drying in the oven at 105°C. The dried portions were used for chemical analysis. The water-soluble arsenic was determined on the dry material, using 1.2 grams in 500 cubic centimeters (equivalent to 1 pound in 50 gallons). The results of these experiments are summarized in Table 1.

TABLE 1.—*Analysis of experimental spraying compounds.*

Designation.		Lime used.	As_2O_5 used.	Water in—		Analysis of material dried at 105°C.		Molecular ratio, CaO/As_2O_5.	Soluble arsenic, As_2O_5.	Dried material per pound.
Exp. No.	Series No.			Settled material.	Filtered material.	CaO.	As_2O_5.			
		Grams.	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Cubic inches.*
1	A.......	7.30	10	52.5	36.2	35.52	52.71	2.76	11.51	60
	B.......	7.30	10	66.1	58.8	37.30	51.76	2.95	8.26	82
2	A.......	7.79	10	59.2	47.7	38.75	51.84	3.07	5.06	66
	B.......	7.79	10	67.5	59.2	38.70	51.53	3.08	4.52	77
3	A.......	8.28	10	61.7	51.2	39.70	50.77	3.20	2.51	68
	B.......	8.28	10	67.8	53.8	40.59	50.17	3.17	1.52	76
4	A.......	8.77	10	64.6	51.1	41.15	49.46	3.41	1.83	68
	B.......	8.77	10	66.8	53.9	41.49	48.00	3.54	1.14	80
5	A.......	9.25	10	59.8	50.4	40.45	46.38	3.58	.48	60
	B.......	9.25	10	67.7	54.3	42.32	46.22	3.75	.42	76
6	A.......	9.74	10	59.2	52.4	42.02	46.17	3.73	.50	62
	B.......	9.74	10	66.9	51.5	42.90	43.22	4.07	.19	72
7	A.......	10.96	10	60.7	48.5	43.67	41.42	4.32	.25	70
	B.......	10.96	10	66.7	49.6	44.80	43.36	4.24	.06	80
8	A.......	12.17	10	67.7	54.2	45.76	39.26	4.78	.27	74
	B.......	12.17	10	66.1	58.0	47.06	40.32	4.79	[1]	83

[1] Lost.

It will be noted that in every case series B gave lower soluble arsenic figures than series A, and also that only when the ratio equals 4 or more does the soluble arsenic decrease to about 0.2 per cent. Consequently, all commercial calcium arsenates should be at least as basic as $4CaO.As_2O_5$, upon which ratio all later experiments were based. The content of water of constitution, and probably crystallization (about 14 per cent), might be reduced by heating to a sufficiently high temperature if this were found to be desirable from a commercial standpoint. Probably next in importance to the question of soluble arsenic comes the question of lightness of material, that quality which governs the suspension in water. This is controlled by two things, actual density and size of particles. All the calcium arsenates have densities around 3, approximately half that of the corresponding lead compounds. This is a characteristic property of each compound, practically independent of conditions. The size of particles, however, is influenced by the manner of mixing, the temperature, the concentration, etc. In the experiments reported in Table 1, the arsenic acid was added quite slowly to the lime, in the belief that it was best to prevent even the slightest local excess of acid. It was found later, however, that rapid mixing gave a product which was much more easily powdered. Table 1 also shows that temperature has a marked effect, a more bulky product being formed when the solutions are mixed in the cold.

EFFECT OF DILUTION AND TEMPERATURE UPON THE COMPOUND.

A group of 16 experiments was designed to show the effect of dilution and temperature upon this quality of lightness. In all the experiments the quantity of lime and acid used was the same—11 grams of lime (93 per cent CaO) and 10 grams of As_2O_5. In every case the lime was slaked with 35 cubic centimeters of boiling water. Four temperature combinations were used: Both hot; lime hot, acid cold; acid hot, lime cold; both cold. Four dilutions were used. In every case the acid was dumped as fast as possible into the lime. In the more concentrated mixtures, especially when warm, reaction took place rapidly, phenolphthalein being reddened immediately. But as dilution increased and the temperature fell, action was delayed, the solution remaining acid for perhaps 10 minutes. This is no doubt due to the fact that the acid does not penetrate instantaneously into the small particles of lime in suspension. When both solutions are hot the reaction is violent, causing rapid boiling, while when both solutions are cold, only a moderate rise in temperature occurs. For instance, in 4 A the temperature rose from 32°C. to 65°C., and in 4 D from 32°C. to 40°C.

After mixing and standing for 15 to 20 minutes the precipitates were filtered off, and dried over night on the steam bath. Portions were then sieved through a No. 100 mesh sieve, and their bulkiness compared by measuring the volume occupied by 2.77 grams in a 10 cubic centimeter graduated cylinder. Ten times the figure read on the cylinder equals the number of cubic inches per pound. The measurements were taken just as the material was poured into the cylinders, no attempt being made to pack it. Entomologists have stated that a good calcium arsenate for dusting purposes should occupy from 70 to 90 cubic inches per pound. Such determinations, however, are comparable only when conducted in the same way.

The results of these experiments are summarized in Table 2.

TABLE 2.—*Effect of dilution and temperature on lightness of spraying compounds.*

Experiment No.	Temperature.	Series number, degree of dilution, and lightness of compound.			
		A.	B.	C.	D.
		11 gm. lime—35 cc H_2O 10 gm. As_2O_5—25 cc H_2O.	11 gm. lime—70 cc H_2O 10 gm. As_2O_5—50 cc H_2O.	11 gm. lime—105 cc H_2O 10 gm. As_2O_5—75 cc H_2O.	11 gm. lime—140 cc H_2O 10 gm. As_2O_5—100 cc H_2O.
		Cu. in. per lb.	*Cu. in. per lb.*	*Cu. in. per lb.*	*Cu. in. per lb.*
1	Lime hot, acid cold	60	96	104	128
2	Acid hot, lime cold	60	104	126	112
3	Both hot	65	78	92	98
4	Both cold	86	104	90	80

These results show that the general tendency is the production of the lighter material in the lower concentrations. But here a new feature, the hardness of the lumps and the effort necessary to reduce them to powder, makes its appearance. Amorphousness is usually associated with the production of hard, lumpy residues on drying, as, for example, in the case of aluminum hydroxid. So here we have 1 D, 2 C, and 2 D, the lightest of the powders, producing hard lumps, 2 D being the hardest of the lot. It was difficult to break them in the fingers, and for commercial use they would almost certainly have to be ground. On the other hand, 4 A and 4 D were crumbly, and could be readily reduced to powder by simply shaking them. Probably, then, a compromise between a method of preparation which produces the lightest powder and a method which produces the most easily pulverized powder would be necessary.

The results show equal bulkiness for 2 B, 4 B, and 1 C, and all of these, especially 1 C, were easily powdered. *Based on this work, the authors are of the opinion that the most advantageous method to produce a reasonably light material, which at the same time is easily pulverized, is to slake the lime, add two more volumes of hot water, and then add the cold arsenic acid solution as rapidly as possible* (method 1 C). Methods 4 B, 2 B, and 4 A also, however, give a product which is reasonably light and easily pulverized.

None of these products, except the tricalcium arsenate mentioned in the beginning of this article, is quite as bulky as some of the commercial dilead arsenates, some of which run as high as 140 cubic inches per pound when measured in the manner prescribed here. However, this calcium arsenate, as aforesaid, yields an excessive amount of water-soluble arsenic, and is prepared by a method that is hardly practicable under manufacturing conditions.

EXPERIMENTS WITH LIMESTONE.

It was at first thought that calcium arsenate might be made directly from limestone, instead of from lime, thus saving the expense of burning. A few experiments along this line showed that calcium carbonate reacts quite readily with arsenic acid at room temperature, and continues to do so until the solution is about neutral to methyl orange. At this point, the solution contains CaO and As_2O_5 in the proportions to form calcium monoarsenate, $CaH_4(AsO_4)_2$. If this solution is heated by itself, it deposits crystals of dicalcium arsenate, $CaHAsO_4.H_2O$, which on continued boiling change to $CaHAsO_4$. In the presence of excess $CaCO_3$, reaction continues until practically all the As_2O_5 has been precipitated as $CaHAsO_4$. This, however, takes place readily only if the carbonate is in a fine state of division, and hardly at all if it is in pea-sized lumps. Calcium carbonate is not alkaline enough to carry the conversion to the tricalcium arsenate stage. This dicalcium arsenate is fairly crystalline and granular, and, owing to its solubility and other physical properties, is not well suited for use as a spray. It could, of course, be mixed with excess lime, but, owing to its granular nature, reaction would be slow and when sprayed the lime might be completely carbonated before some of the crystals were changed, thus giving a chance for injury by the soluble arsenic. All things considered, it appears that there is no advantage in attempting to substitute limestone for lime.

SUMMARY.

The most desirable procedure for making calcium arsenate from lime and arsenic acid may be summarized as follows:

1. Use a good grade of lime, containing a high percentage of CaO.

2. Slake the lime to as smooth a paste as possible, for upon this depends the smoothness of the final product, as well as the readiness with which the lime and acid react. Use from 3 to 3½ times as much water, by weight, as lime, and have it, preferably, warm. Let stand for a while, then thoroughly mix, after which add twice as much hot water as used for slaking, and mix again.

3. The lime and arsenic should be in such proportion that the weight of actual CaO used will equal that of the As_2O_5 used. This gives a product with a molecular ratio slightly over 4, which is necessary if the soluble As_2O_5 is to be kept down to desirable limits.

4. Add the acid at room temperature to the lime as quickly as possible, and stir well until the liquid becomes alkaline to phenolphthalein.

5. Filter to as dry a state as possible, do not wash, and if a dry product is desired dry directly in any suitable manner.

6. Crush in a suitable disintegrator, or grind if necessary.

To produce 100 pounds of a commercial grade of calcium arsenate by this process will require 45 pounds of CaO (approximately 50 pounds of a high-grade lime) to be slaked with 18 gallons of water, the addition of 36 gallons more of water, and then 45 gallons of a solution containing 1 pound of As_2O_5 per gallon. Slight departure from the figures given for water will probably have little effect.

LABELING THE PRODUCT.

A product prepared in accordance with the procedure outlined is, of course, not pure calcium arsenate, but consists of tricalcium arsenate, probably with some water of crystallization, together with excess of other calcium compounds, such as calcium hydroxid and calcium carbonate. The product, therefore, should not be designated simply "Calcium Arsenate," but by some such designation as, "Calcium Arsenate Containing other Calcium Compounds." In labeling such a product, the following is suggested by the Insecticide and Fungicide Board of this Department as the simplest form of statement which will fulfill the requirements of section 8 of the Insecticide Act of 1910, relative to the statement of active and inert ingredients and total and water-soluble arsenic.

Active ingredient:
  Tricalcium arsenate .... ———%
Inert ingredients .... ———%
Total arsenic (as metallic)........................ ———%
Arsenic in water-soluble forms (as metallic).......... ———%

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 726

OFFICE OF THE SECRETARY
Joint Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief
and
Bureau of Plant Industry
W. A. TAYLOR, Chief

Washington, D. C. December 14, 1918

FARM PRACTICE IN GROWING SUGAR BEETS FOR THREE DISTRICTS IN COLORADO 1914–15

By

L. A. MOORHOUSE, Agriculturist, R. S. WASHBURN, Scientific Assistant, and T. H. SUMMERS, Scientific Assistant, Office of Farm Management
and
S. B. NUCKOLS, Assistant Agriculturist, Office of Sugar-Plant Investigations, Bureau of Plant Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 727

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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ANTHRACNOSE OF CUCURBITS

By

M. W. GARDNER, Scientific Assistant
Cotton, Truck, and Forage Crop Disease Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 728

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ December 18, 1918

CERTAIN DESERT PLANTS AS EMERGENCY STOCK FEED

By

E. O. WOOTON, Agriculturist

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

UNITED STATES DEPARTMENT OF AGRICULTURE.

BULLETIN No. 729

Contribution from the Bureau of Markets, CHARLES J. BRAND, Chief

Washington, D. C. July 24, 1918

SUITABLE STORAGE CONDITIONS FOR CERTAIN PERISHABLE FOOD PRODUCTS

Apples, Potatoes, Sweet Potatoes, Onions, Cabbage, Eggs, Frozen Eggs, Poultry, Butter, and Fish

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1918

WASHINGTON

THIS bulletin has been prepared in explanation of a chart recently drawn up by the Department of Agriculture for the use of the Federal Reserve Board, in which information regarding storage conditions for certain perishable farm products is set forth.

The information contained in this bulletin and the accompanying chart has been contributed by L. C. Corbett, William Stuart, and H. C. Thompson of the Bureau of Plant Industry; M. E. Pennington of the Bureau of Chemistry, and I. C. Franklin, N. A. Hardin, C. W. Mann, H. J. Ramsey, and W. M. Scott of the Bureau of Markets.

Owners and managers of storage warehouses, members of the Federal Reserve Banks, and producers of the farm products discussed will find information of value in the data included in this publication.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 730

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPERS December 24, 1918

PAPERS ON DECIDUOUS-FRUIT INSECTS

I. THE GRAPE CURCULIO
II. THE GRAPE ROOT-BORER

By FRED E. BROOKS
Entomologist
Deciduous-Fruit Insect Investigations

III. EXPERIMENTS IN THE CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS

By B. R. LEACH
Scientific Assistant
Deciduous-Fruit Insect Investigations

WASHINGTON
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 732

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. November 14, 1918

SMYRNA FIG CULTURE

By

G. P. RIXFORD, Physiologist, Crop Physiology and Breeding Investigations

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

THE PUBLICATION of a bulletin on the Smyrna fig has become necessary, because recent investigations have developed facts not previously noted and no literature is available which gives all the particulars necessary to a perfect understanding of the intricacies of the industry in this country.

It is thought important to encourage the more extensive cultivation of one of the most wholesome fruit foods known to agriculturists, a fruit the culture of which promises in the near future to become an important industry in this country, and also to correct errors into which authors have fallen for the lack of the opportunities for investigation presented in California, among which may be mentioned inaccuracies in relation to the classification of fig flowers and the reason for the paucity of seeds in caprifigs.

The writer desires to express his obligation for valuable suggestions to Dr. L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture, the author of a valuable article on Smyrna figs.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 735

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ November 15, 1918

FARM PRACTICE IN GROWING SUGAR BEETS IN THE BILLINGS REGION OF MONTANA

By

S. B. NUCKOLS, Assistant Agriculturist, Office of Sugar-Plant Investigations, and E. L. CURRIER, Professor of Farm Management, Montana Agricultural College

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 737
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. | PROFESSIONAL PAPER | March 17, 1919

THE TOBACCO BEETLE: AN IMPORTANT PEST IN TOBACCO PRODUCTS

By

G. A. RUNNER
Entomological Assistant

[With Technical Descriptions of Coleopterous larvæ
By Adam G. Böving]

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Contribution from the Bureau of Animal Industry
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Washington, D. C. PROFESSIONAL PAPER December 30, 1918

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By

S. HENRY AYERS and PAUL W. CLEMMER
Bacteriologists, Dairy Division

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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ April 17, 1919

THE AVOCADO IN GUATEMALA

By

WILSON POPENOE, Agricultural Explorer, Office of Foreign Seed and Plant Introduction

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER January 17, 1919

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By

JAMES A. GAMBLE, Market Milk Specialist, and
JOHN T. BOWEN, Technologist, Dairy Division

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 18, 1919

THE SUGAR-CANE MOTH BORER

By

T. E. HOLLOWAY and U. C. LOFTIN
Entomological Assistants, Southern Field Crop Insect Investigations

WITH TECHNICAL DESCRIPTIONS BY
CARL HEINRICH

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UNITED STATES DEPARTMENT OF AGRICULTURE
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Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ January 9, 1919

THE ECONOMICAL USE OF FUEL IN MILK PLANTS AND CREAMERIES

By

JOHN T. BOWEN, Technologist, Dairy Division

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 748

Office of the Secretary

Joint Contribution from the Office of Farm Management
E. H. THOMSON, Acting Chief
and
Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. | PROFESSIONAL PAPER | January 28, 1919

FARM PRACTICE IN GROWING SUGAR BEETS IN MICHIGAN AND OHIO

By

R. S. WASHBURN, Scientific Assistant, L. A. MOORHOUSE, Agriculturist, and T. H. SUMMERS, Scientific Assistant, of the Office of Farm Management; and C. O. TOWNSEND, Pathologist in Charge, Sugar Plant Investigations, Bureau of Plant Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 749
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HENRY S. GRAVES, Forester

Washington, D. C. ▼ April 30, 1919

PRODUCTION OF GOATS ON FAR WESTERN RANGES

By

W. R. CHAPLINE
Grazing Examiner

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