U. S. DEPARTMENT OF AGRICULTURE.

Department Bulletins

Nos. 101-125,

WITH CONTENTS
AND INDEX.

Prepared in the Division of Publications.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

CONTENTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 101

Contribution from the Forest Service, Henry S. Graves, Forester.
September 25, 1914.

(PROFESSIONAL PAPER.)

RELATIVE RESISTANCE OF VARIOUS CONIFERS TO INJECTION WITH CREOSOTE.

By C. H. Teesdale,
Engineer in Forest Products, Forest Products Laboratory.

PURPOSE OF THE EXPERIMENTS.

It is very difficult and sometimes apparently impossible to secure uniform treatments of wood with preservatives. If, for example, an average treatment is given of 10 pounds of creosote per cubic foot, some pieces of wood in a charge will receive twice the average amount, while others will receive less than one-half of it. Efficient use of the preservative obviously requires that each timber receive its full portion and no more. One essential condition for securing uniformity of treatment is that all pieces in any one charge shall present equal resistance to injection. This requires that the wood be graded in accordance with its ease of treatment, and the experiments here described were made to investigate this subject. To obtain a logical basis for such classification it was necessary to study the relation between the structure of wood and the manner in which it receives treatments. This study was carried out at the Forest Products Laboratory maintained in cooperation with the University of Wisconsin, at Madison, Wis. The present publication is confined to coniferous woods.

STRUCTURE OF THE CONIFERS.

The woods of cone-bearing trees, or conifers, have certain similarities of structure which distinguish them from the woods of broad-leaved trees. In commerce the terms " softwoods " and " hardwoods " are applied respectively to these two classes of wood. The following description of wood structure applies only to the conifers.

Note.—The purpose of this bulletin is to show how woods should be graded in order that they may give uniform results when subjected to treatment with preservatives; it is intended for those interested in wood preservation.

41702°—Bull. 101—14——1

GROSS STRUCTURE.

On any cross section of a log a zone of light-colored wood next to the bark may usually be distinguished from the inner portion of the log. This outside zone is the sapwood; the inner darker portion is the heartwood. In the sapwood many of the cells are used for conduction and storage of materials necessary in the life processes of the tree; the outer layer of cells, called the cambium, forms the growing part. The darker color of the heartwood is due to the infiltration of chemical substances into the cell walls, but the cavities of the cells generally are not filled up, as is sometimes believed. Sapwood varies, even within the same tree, in its relative width and in the number of rings which it contains; the same year's growth may be sapwood in

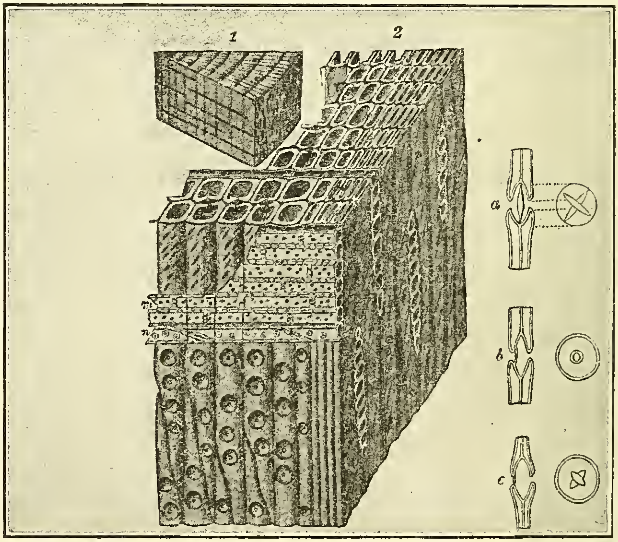


FIG. 1.—Wood of spruce. 1, natural size; 2, small part of one ring magnified 100 times. The vertical tubes are wood fibers, in this case all "tracheids." *m*, medullary or pith ray; *n*, transverse tracheids of pith ray; *a*, *b*, and *c*, bordered pits of the tracheids, more enlarged.

one part of the cross section and heartwood in another part. In some species (those of *Abies*, *Tsuga*, and *Picea*) there is no sharp color distinction between the sapwood and heartwood.

The concentric rings, each of which represents one year's growth, also vary in thickness in different trees and in different parts of the same tree. Each ring consists of two portions; one is an inner, softer, lighter-colored portion formed early in the season, called springwood; the other is an outer, firmer, and darker-colored portion, formed late in the season and called summerwood. In some species, as in longleaf pine, the dark summerwood appears as a distinct, sharply defined band, constituting 50 per cent or more of the cross section; in other species, as in white pine, the springwood passes gradually into the darker summerwood.

MICROSCOPIC STRUCTURE.

The structure of wood is illustrated diagrammatically in figure 1, while Plates I, II, and III are photographs of magnified sections seen in transverse, radial, and tangential planes, respectively.

TRACHEIDS.

The fibers called "tracheids," forming the greater portion of the wood, are between one-twentieth and one-fifth of an inch long, or from 40 to 100 times their radial diameter. They are tapered and closed at their ends. (Pls. II and III.) In the springwood the tracheids have thin walls and large cell spaces, and are polygonal or rounded in form; in the summerwood they have thick walls and small cell spaces, and are flattened radially. (See fig. 1 and Pl. I.) Located on the walls of the tracheids are numerous circlet-like structures, the "bordered pits," which are plainly visible in Plates II and III. These pits or pores are partitioned off by the "pit membrane," the central portion of which is thickened, and is known as the torus. Owing to the peculiar overhanging contour of the border, the orifice of the bordered pit, where it opens to the cell cavity, is of much smaller diameter than where it abuts on the pit membrane. (Fig. 1, *a*.) When the membrane is forced toward one of the two cell lumina, which it separates, the thickened portion or torus is capable of blocking the narrow opening, and thus acting as a valve. (Fig. 1, *b*.) In the heartwood the torus often is permanently displaced from its central position and is sometimes cemented to one side or other of the pit, effectually blocking it.

MEDULLARY RAYS.

The cells of the medullary rays are smaller and much shorter than the longitudinal tracheids and lie with their long axis at right angles to the latter. These ray cells are distinguished by their abrupt ends, thin walls, numerous simple pits,[1] and by their short length, only 8 to 10 times their diameter. They are seen as bands on the radial face (Fig. 1 and Pl. III), and as pores on the tangential face. (Pl. II.) Although quite small in the conifers they can be seen readily without a magnifier on the radial surface.

RESIN CELLS.

Many of the conifers contain what are known as resin cells. These resemble the ray cells in general appearance, but, except for those in the medullary rays themselves, have their long axes parallel with the major axis of the tree.

[1] Simple pits do not have the circlet-like border. They are simple openings in the cell walls closed only by the pit membranes.

RESIN CANALS.

In many species numerous large openings known as "resin canals" exist. (Pl. I.) These passages are intercellular spaces, surrounded by so-called "epithelial cells," the chief sources of resin production in the tree. In a less number of species these canals occur within the medullary rays, there known as "fusiform rays." These radial canals intersect the longitudinal ones and thus form a partially complete network of resin ducts penetrating all portions of the wood. Resin ducts in pines are sometimes wholly or partially blocked by growths called tyloses.

DISTRIBUTION OF RESIN STRUCTURES.

With very few exceptions, all of the conifers contain either resin cells or resin canals, and some species contain both. The distribution of resin cells varies in different species; in some they are scattered through the wood, while in others they are concentrated in zones. The character and number of the resin canals also vary greatly. Those in some species, as in Douglas fir, are few in number, are small, and have frequent constrictions tending to close the canal; those in other species, as in longleaf pine, are abundant, large, and entirely without constrictions.

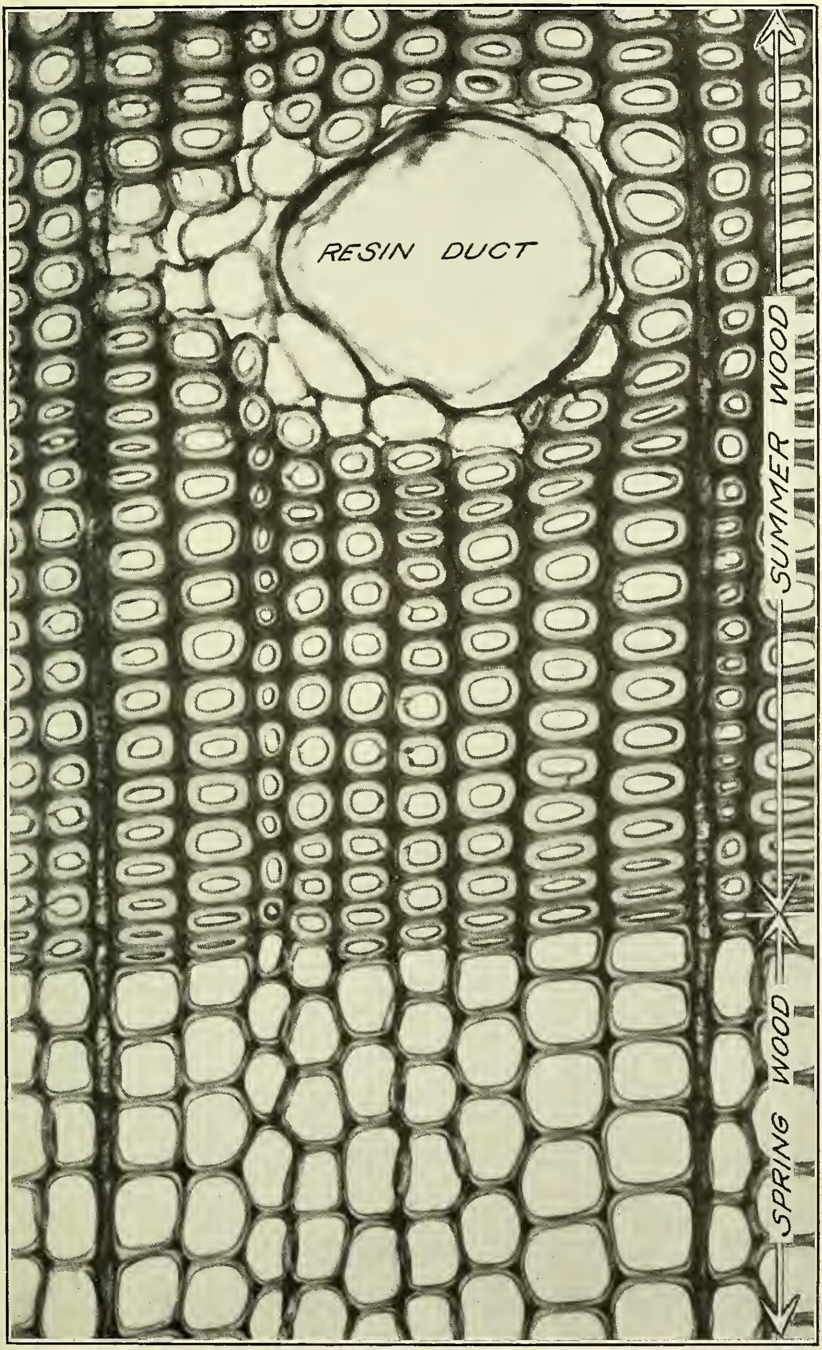
EXPERIMENTAL METHODS.

The presence of resin canals and cells in the wood and the character of these structures at once suggest that they may have a considerable influence on the manner in which the wood takes impregnation with preservatives. A considerable portion of the experimental work was given to determining the extent of this influence.

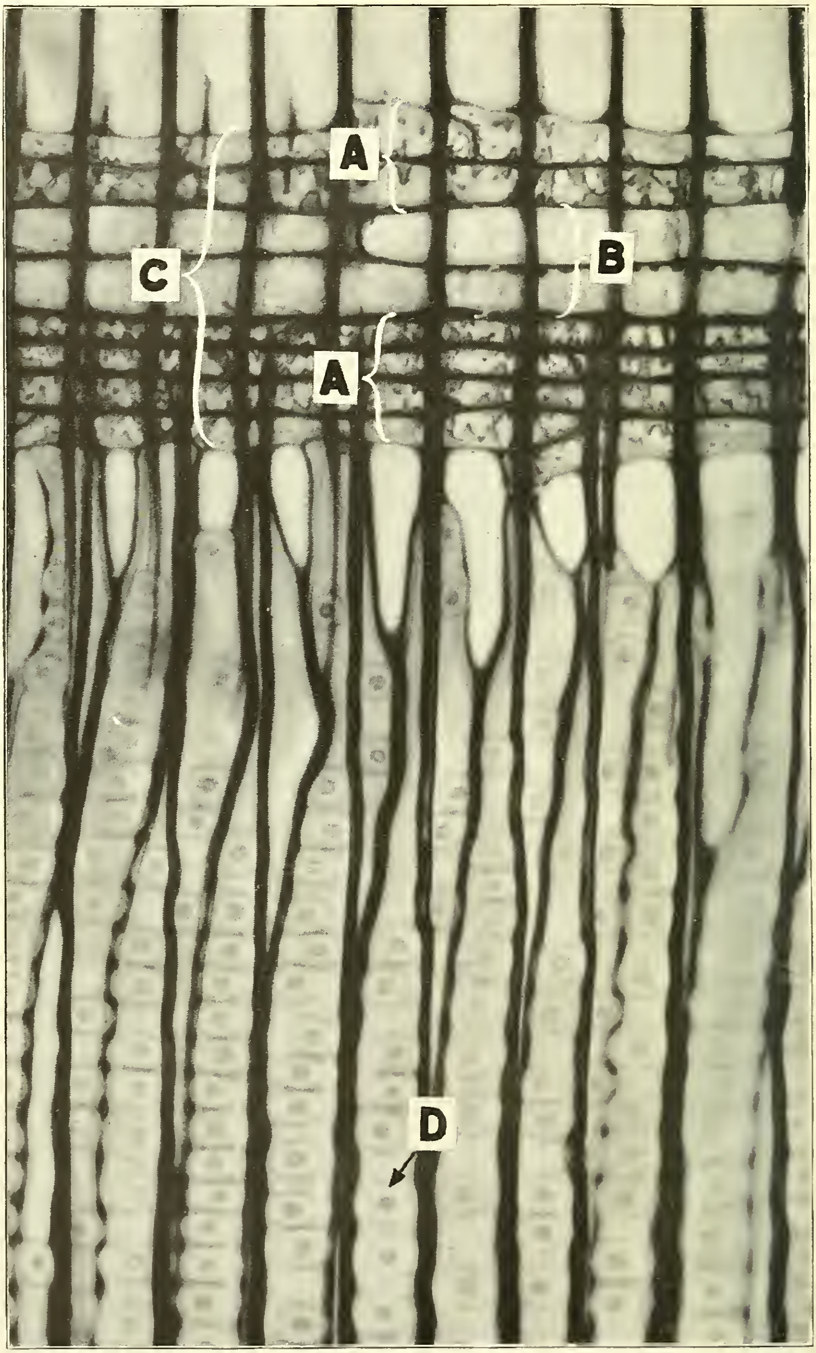
The resistance of the wood to treatment was determined by two forms of tests: (1) by applying the creosote to a small area on a specimen and measuring the penetration in different directions; and (2) by impregnation in a treating cylinder. In the latter tests blocks from each of the species were treated together in the same run.

APPARATUS.

The "penetrance apparatus," illustrated in figure 2, was designed for the first class of tests. The wood under test, which had a 1-inch hole bored in it, was clamped against the open end of the pipe A leading to the bottom of a pressure tank B. The pipe and lower portion of the tank were filled with creosote. Pipe C, opening into the top of the tank, was connected with an air reservoir in which a pressure was maintained. When desired, air under pressure was turned into tank B, which thus placed the preservative under pressure. The apparatus was surrounded by a wooden oven, as shown, with double



TRANSVERSE SECTION OF SHORTLEAF PINE (PINUS ECHINATA). (MAGNIFICATION 250 DIAMETERS.)



RADIAL SECTION OF SHORTLEAF PINE (PINUS ECHINATA). (MAGNIFICATION 250 DIAMETERS.)

A, ray tracheids; **B**, ray cells; **C**, medullary ray; **D**, bordered pits.

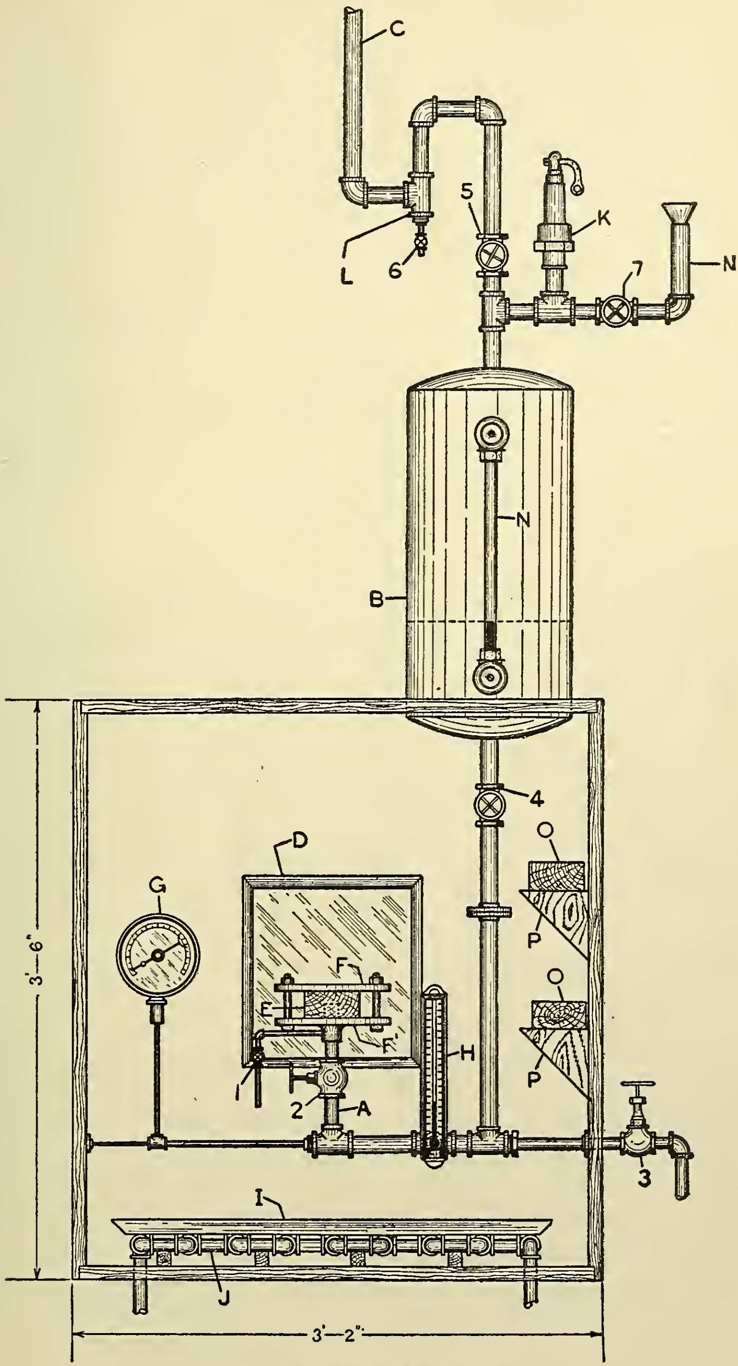


FIG. 2.—Penetrance apparatus.

glass windows in the front and back. Steam coils J in the bottom of the oven heated the specimens and preservatives to a uniform temperature, which duplicated as nearly as possible the temperature conditions of the treating cylinder. The pressure was determined from the gauge G and the temperature from thermometer H. A safety valve K aided in maintaining a uniform pressure. Shelves were provided and specimens were placed in the apparatus previous to testing in order to heat them uniformly to the required temperature. By the aid of mirror D, placed at the back of the oven, both ends of the specimens were made visible.

The impregnation tests were made in a cylinder 1½ feet in diameter and 4 feet long. Temperature and pressure conditions within the cylinder were accurately regulated by means of steam coils and a pressure pump. A cage was used that held the specimens in a vertical position and separated from each other during treatment.

MATERIALS USED.

CREOSOTE.

Coal-tar creosote of a good grade was used, having a specific gravity of 1.0483 at 60° C. The viscosity at 60° C. was 1.3, determined by the Engler orifice-type viscosimeter. The distillation range was as follows:

	Per cent.
0°–205° C.	11.0
205°–255° C.	34.9
255°–295° C.	15.8
295°–320° C.	11.4
Residue	25.8
Loss	1.1

The residue was solid with a lustrous fracture, indicating an admixture of undistilled tar.

WOOD.

The wood used was obtained from 20 species of conifers. All of the material of each species was taken from the same log, and the specimens were so cut that individual pieces were as similar as possible; but in most cases both heartwood and sapwood sets were prepared. The results obtained on each piece are, therefore, comparable with those obtained on other like specimens of the same species. The following species were tested:

Common name.	Botanical name.
Yew	*Taxus brevifolia.*
Alpine fir	*Abies lasiocarpa.*
Eastern hemlock	*Tsuga canadensis.*
Big tree	*Sequoia washingtonia.*

Common name.	Botanical name.
Western hemlock	*Tsuga heterophylla.*
White fir	*Abies grandis.*
Noble fir	*Abies nobilis.*
Douglas fir	*Pseudotsuga taxifolia.*
Sitka spruce	*Picea sitchensis.*
Engelmann spruce	*Picea engelmanni.*
White spruce	*Picea canadensis.*
Western larch	*Larix occidentalis.*
Tamarack	*Larix laricina.*
Lodgepole pine	*Pinus murrayana.*
Jack pine	*Pinus divaricata.*
Western yellow pine[1]	*Pinus ponderosa.*
Spruce pine	*Pinus glabra.*
Longleaf pine	*Pinus palustris.*
Shortleaf pine	*Pinus echinata.*
Loblolly pine	*Pinus tæda.*

Three pieces of heartwood and three of sapwood[2] were prepared from each species for the penetrance tests. These specimens were each 2 by 4 by 25 inches and were surfaced on all sides. A hole 1 inch in diameter and 1 inch deep was bored in each piece at the center of one of the 4 by 25 inch faces. The specimens were seasoned until air dry before testing, and only those free from checks and other defects were selected. The oven-dry weight and moisture content of each piece at the time of treatment were determined.

The specimens for the impregnation tests were cut 2 by 2 by 12 inches. Seven pieces of heartwood and seven of sapwood from each species were tested. Those used were free from defects. The pieces were allowed to season until thoroughly air dry. Just before impregnation they were placed in an oven and held at a temperature of 100° C. for 48 hours. This rendered them practically oven dry and eliminated the effect of moisture.

METHOD OF APPLYING THE CREOSOTE.

PENETRANCE TESTS.

In the penetrance tests the specimens were subjected to creosote at a pressure of 85 to 90 pounds per square inch, the maximum obtainable with the apparatus employed. The length of time required to heat the apparatus made it necessary to carry on the tests at tempera-

[1] A tree from California and one from Montana were tested.

[2] In the case of yew, tamarack, and western larch the sapwood was so thin that no sapwood specimens could be obtained. In the cases of Alpine fir, eastern hemlock, western hemlock, white fir, noble fir, Sitka spruce, Engelmann spruce, and white spruce there was no color distinction between sapwood and heartwood. Wood from the outer 2½ inches of growth, however, was considered sapwood and that from the portion within this area was considered heartwood.

tures between 120° and 160° F. Readings of temperature and pressure were made every 10 minutes.

The specimens were removed after definite periods and the time noted when oil first penetrated a surface. Three periods were taken, one-half hour, one hour, and two hours. One of each set of three specimens was treated for each of these periods. The measured penetrations of the various species are, therefore, directly comparable with each other.

The wood of some of the specimens was completely penetrated within a few seconds. This was true of the sapwood of some of the pines and, in a few cases, of the heartwood also. When this occurred, the pieces were removed as soon as penetrated, instead of at the end of the period.

The treated pieces were sawed transversely and longitudinally along the center lines (Pl. IV, fig. 1) and the sawed surfaces immediately coated with collodion to prevent the creosote from staining the untreated surface. The maximum penetration of oil in longitudinal, tangential, and radial directions was measured to the nearest 0.01 inch and the average penetration in each direction estimated as closely as possible. Each specimen was photographed.

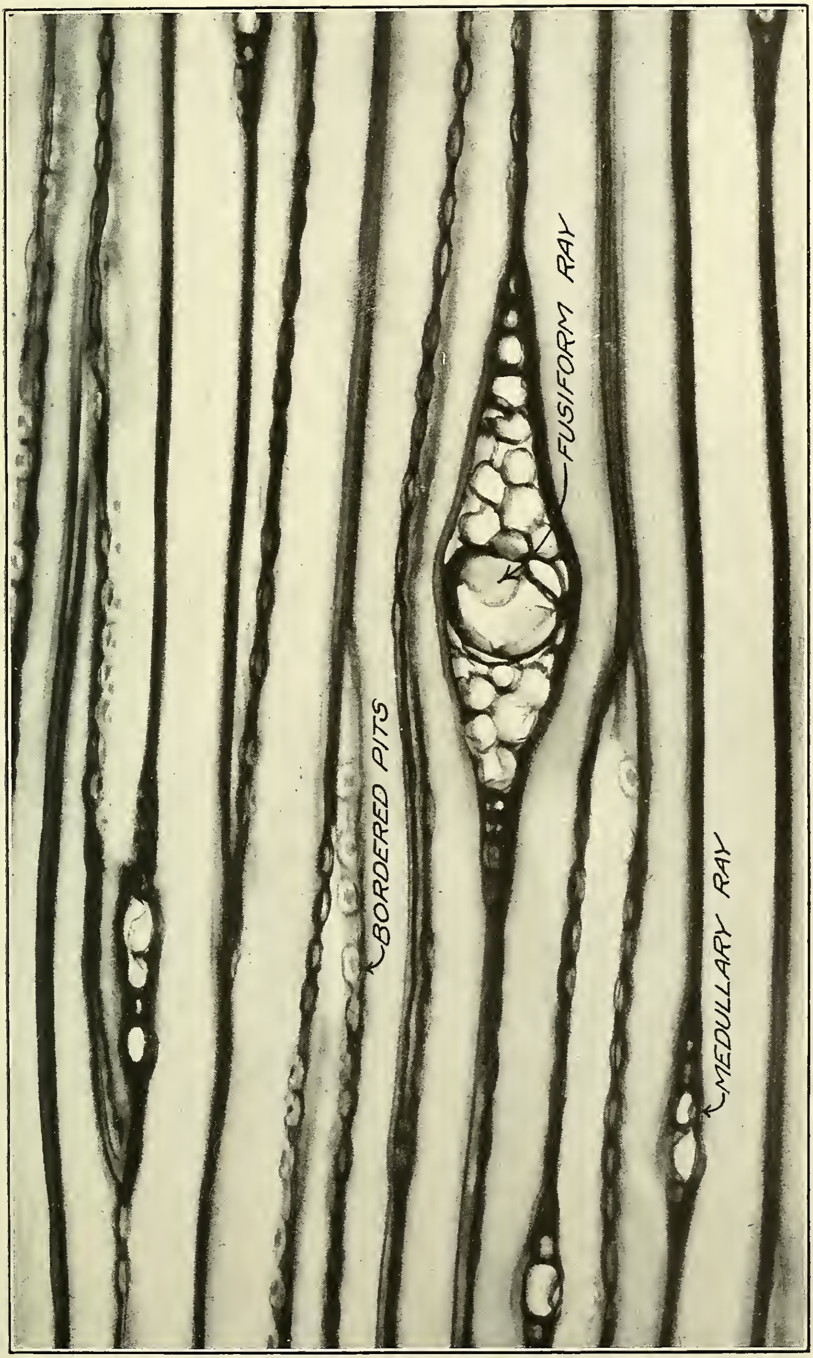
IMPREGNATION TESTS.

The specimens prepared for impregnation tests were separated into seven series, with one heartwood and one sapwood piece of each species in a series. Seven runs were made, in which all conditions of treatment except pressure were maintained as nearly uniform as possible. The conditions of treatment are given in Table 1.

TABLE 1.—*Conditions of treatment in impregnation cylinder.*

Run number.	Pressure.	Time of pressure.	Temperature of preservative.
	Lbs. per sq. in.	*Hours.*	°*F.*
1	25	1	175 to 185
2	50	1	175 to 185
3	75	1	175 to 185
4	100	1	175 to 185
5	125	1	175 to 185
6	150	1	175 to 185
7	Atmospheric.	1	175 to 185

All pieces were weighed before treatment, also within 1 hour after treatment, and again after 48 hours. The weights taken after 48 hours are the ones used in this report.



TANGENTIAL SECTION OF SHORTLEAF PINE (PINUS ECHINATA). (MAGNIFICATION 250 DIAMETERS.)

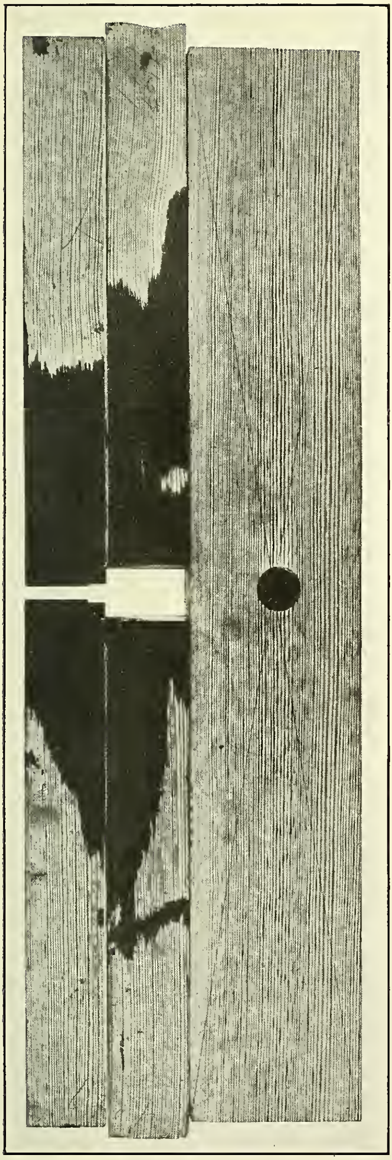


FIG. 1.—FORM OF SPECIMENS FOR PENETRANCE TESTS AND MANNER OF SAWING TO DETERMINE PENETRATIONS.

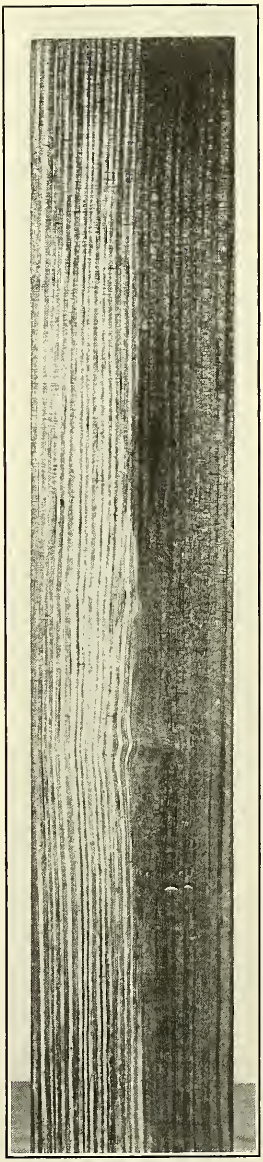


FIG. 2.—LONGLEAF PINE HEARTWOOD, TREATED IN CYLINDER.

The left half of this specimen shows the usual appearance of creosoted heartwood pine; the dark bands are heavily treated summerwood and the lighter ones are treated springwood. On the right side both summerwood and springwood are evenly treated. No difference could be detected in the wood with the microscope that might have caused a difference in the treatment. The right side is toward the pith of the tree.

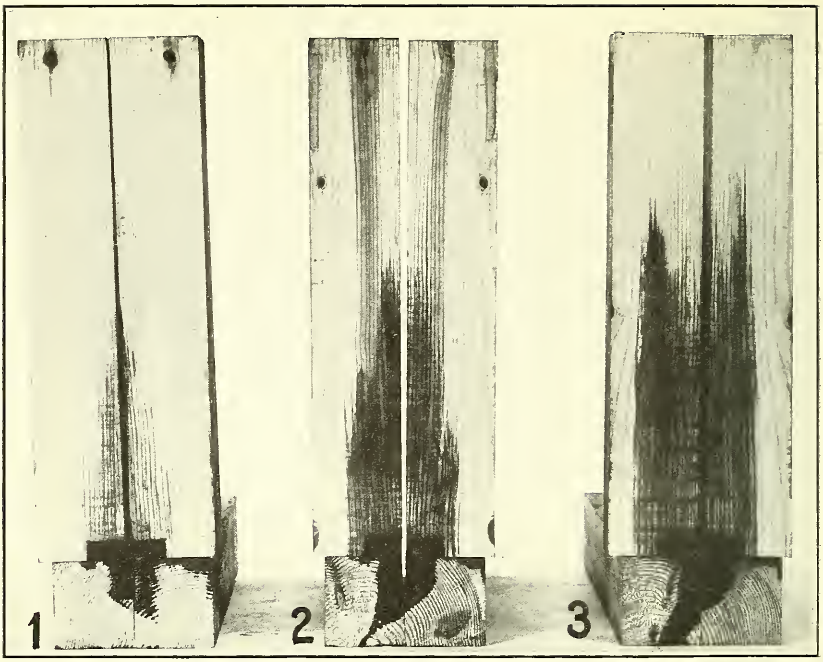


FIG. 1.—PENETRATIONS IN JACK PINE (PINUS DIVARICATA) HEARTWOOD.

1, piece No. 296, treated 30 minutes; 2, piece No. 298, treated 60 minutes; 3, piece No. 297, treated 120 minutes. The structure surrounding the resin ducts was easily penetrated, allowing the heartwood to be satisfactorily treated. Note the well-defined radial penetration which followed the radial ducts toward the pith.

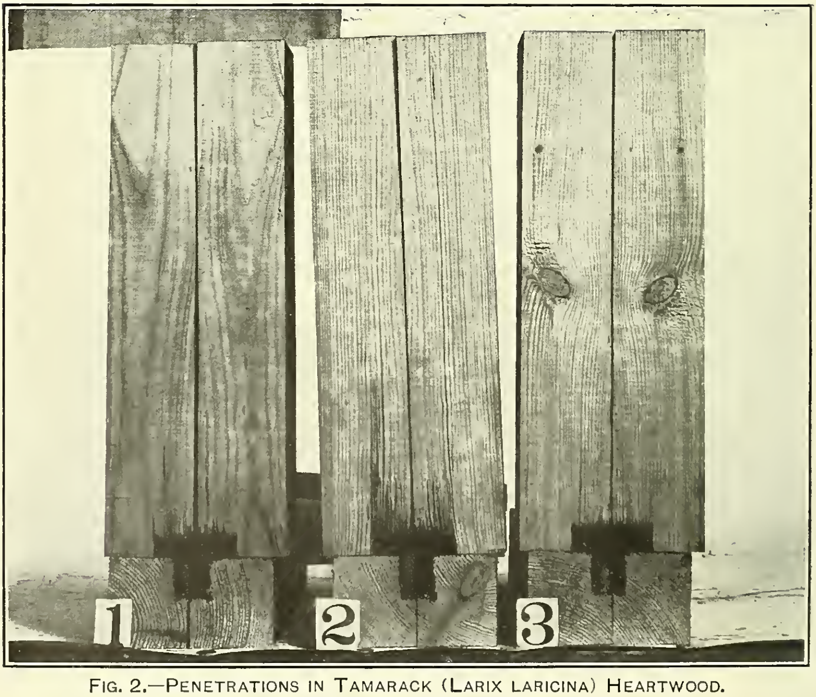


FIG. 2.—PENETRATIONS IN TAMARACK (LARIX LARICINA) HEARTWOOD.

1, piece No. 312, treated 30 minutes; 2, piece No. 313, treated 60 minutes; 3, piece No. 311, treated 120 minutes. This is a good example of a species containing resin ducts that may be easily impregnated, but in which the nonresin structure is almost impenetrable. Note the absence of radial or tangential penetration.

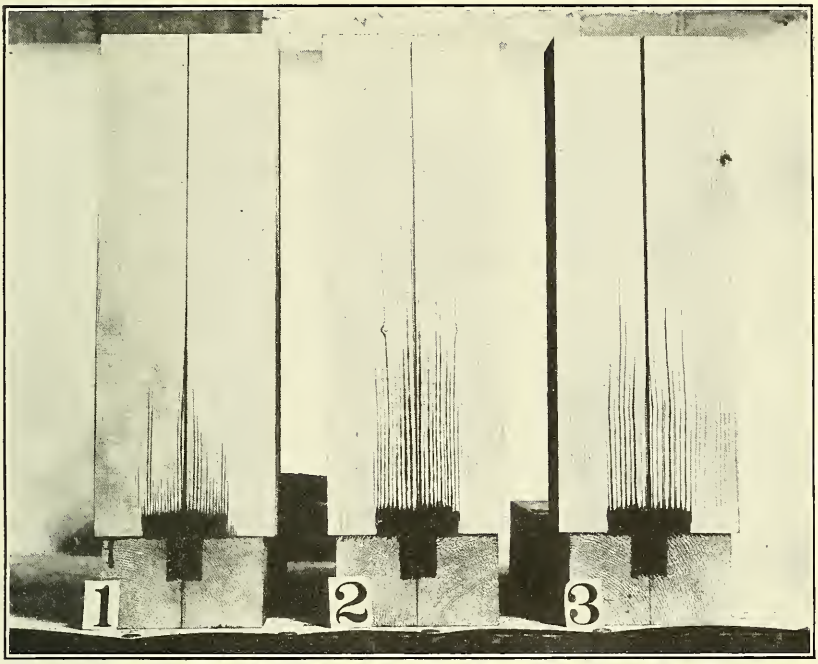


FIG. 1.—PENETRATIONS IN EASTERN HEMLOCK (TSUGA CANADENSIS) HEARTWOOD.

1, piece No. 256, treated 30 minutes; 2, piece No. 265, treated 60 minutes; 3, piece No 259, treated 120 minutes.

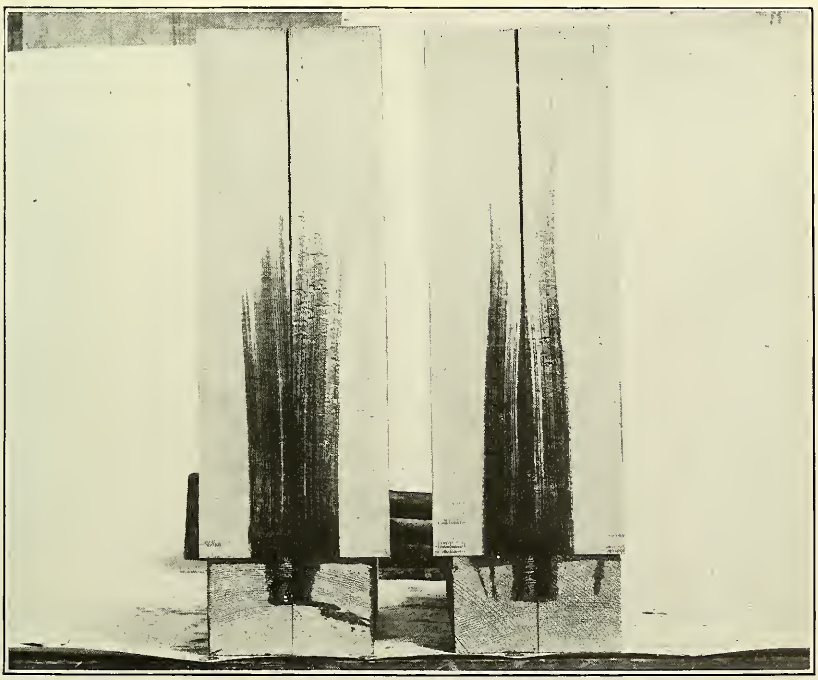


FIG. 2.—PENETRATIONS IN EASTERN HEMLOCK (TSUGA CANADENSIS) SAPWOOD.

1, piece No. 251, treated 30 minutes; 2, piece No. 254, treated 60 minutes. Eastern hemlock is a good example of an easily treated wood that contains no resin ducts. The resin cells had little effect on the penetration. Note the similarity of the treatment in the sapwood and heartwood.

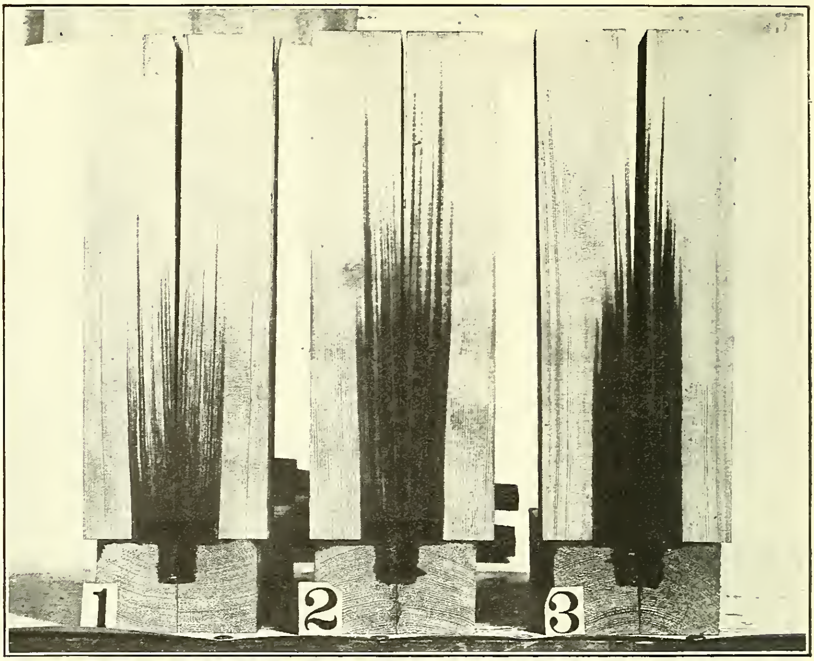


FIG. 1.—PENETRATIONS IN ALPINE FIR (ABIES LASIOCARPA) HEARTWOOD.

1, piece No. 308, treated 30 minutes; 2, piece No. 307, treated 60 minutes; 3, piece No. 309, treated 120 minutes. This species contained no resin ducts or cells and is almost impenetrable.

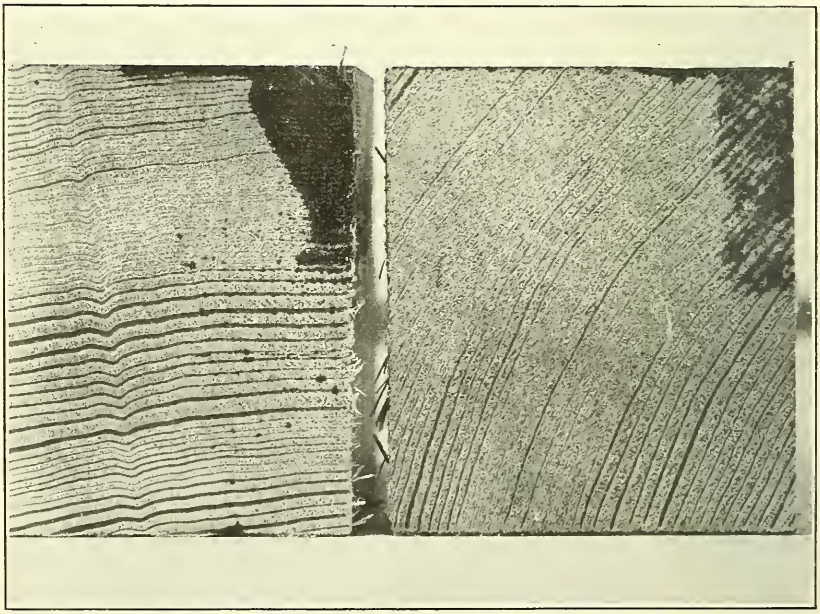


FIG. 2.—DOUGLAS FIR (PSEUDOTSUGA TAXIFOLIA) TREATED IN PENETRANCE APPARATUS.

The piece to the left is sapwood; that to the right is heartwood. The spots on the sapwood piece are treated resin ducts outside of the range of ordinary penetration. They show that the creosote must have penetrated radially and then longitudinally. Most of the spots are in the summerwood.

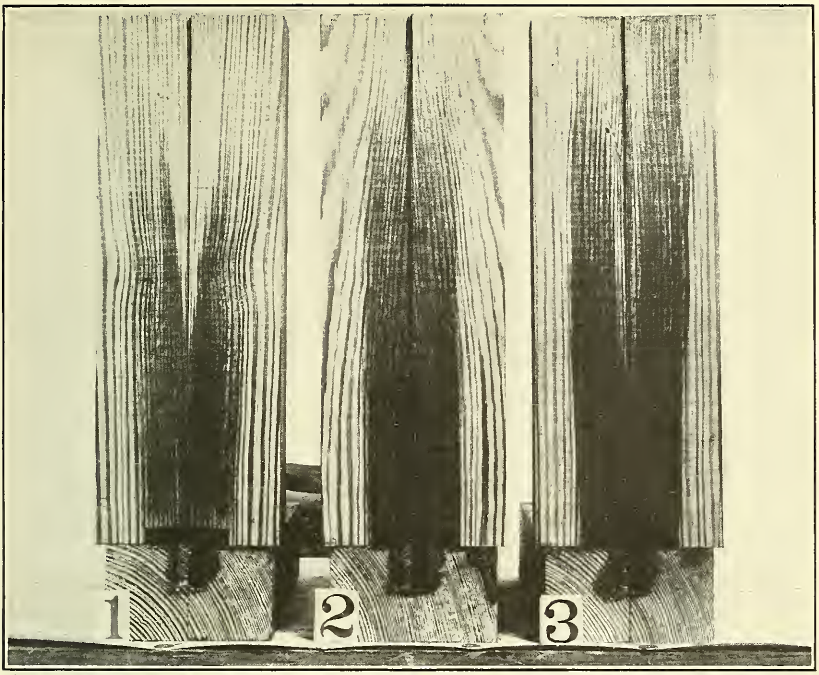


FIG. 1.—PENETRATIONS OF LONGLEAF PINE (PINUS PALUSTRIS) HEARTWOOD.

1, piece No. 248, treated 30 minutes; 2, piece No. 135, treated 60 minutes; 3, piece No. 242, treated 120 minutes.

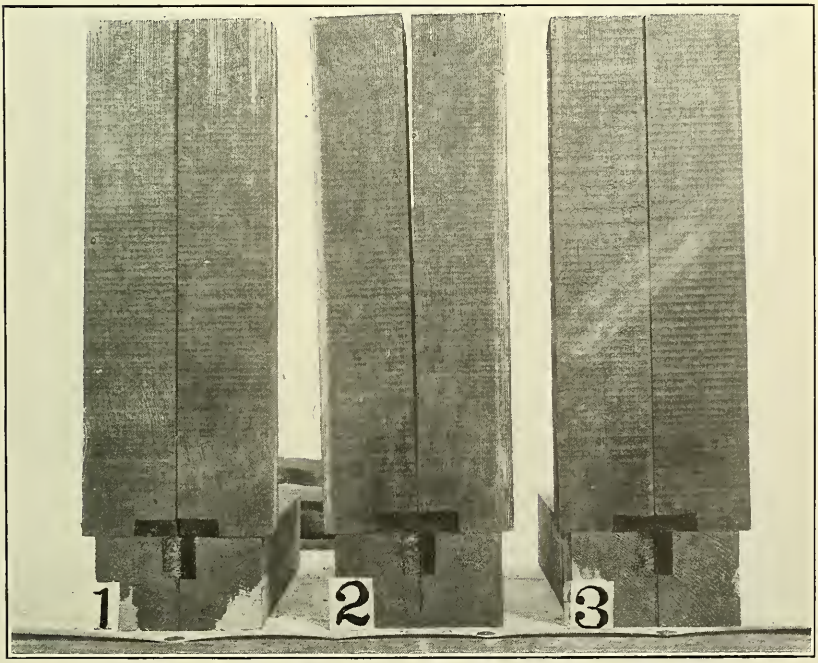


FIG. 2.—PENETRATIONS IN LONGLEAF PINE (PINUS PALUSTRIS) SAPWOOD.

1, piece No. 143, treated 45 seconds; 2, piece No. 136, treated 45 seconds; 3, piece No. 202, treated 45 seconds. The appearance of these specimens is typical of treated southern pines; very similar results were obtained with shortleaf, loblolly, and spruce pines. Note the difference in appearance of heartwood and sapwood.

PENETRATION AS AFFECTED BY WOOD STRUCTURE.

PENETRATION IN THE RESIN STRUCTURES.

The resin ducts were first thought to be the most important factor in the penetration of wood by creosote. It was soon found, however, that this was not the case; many species that had well-developed systems of resin ducts proved much more difficult to impregnate than others that had none. Thus the heartwood of Douglas fir and tamarack, both of which have highly developed radial and longitudinal ducts, proved extremely resistant to impregnation, while eastern hemlock, white fir, and other species, having no resin ducts, proved fairly easy to penetrate. Close examination showed that the resin ducts of the former received the oil but that the wood surrounding the ducts was not penetrated. (See Pl. V, fig. 1.) Thus the question of penetration in the wood fibers was shown to be of fundamental importance, while that in the ducts was of secondary importance.

On the other hand, when the wood fibers themselves were readily penetrable a system of resin ducts became of great importance. These ducts, forming a network of passages through the wood, caused the oil to be applied at numerous points within the wood, as well as on the surface, and in this manner greatly facilitated penetration of the entire structure. (Pl. V, fig. 2.)

PENETRATION IN RADIAL, TANGENTIAL, AND LONGITUDINAL DIRECTIONS.

WHEN NO RADIAL RESIN DUCTS WERE PRESENT.

In this case the penetration longitudinally was between 20 and 120 times as great as the penetration radially or tangentially.

When the oil was applied under pressure to a small area on the surface of a hemlock board 12 inches long, 3 inches wide, and one-half inch thick, it would appear at either end of the board before it would pass through one-half inch of wood radially. Much difference was found in the longitudinal penetration of such species. Eastern hemlock (Pl. VI) is an excellent example of easily penetrated wood which contains no resin canals, while Alpine fir (Pl. VII, fig. 1) is an example of a species having similar structure but very resistant to impregnation.

WHEN RADIAL RESIN DUCTS WERE PRESENT.

In this case the oil followed the ducts and spread longitudinally in each summerwood band as it was traversed. Also at numerous intersections of the radial and longitudinal ducts the oil changed its course and penetrated longitudinally. (Pl. VII, fig. 2.) In this case the average radial penetration varied from one-fourth to three-fourths of the average longitudinal penetration.

PENETRATION IN SAPWOOD AND HEARTWOOD.

The sapwood was much more easily penetrated than the heartwood in those species having highly developed resin systems, such as Douglas fir, larch, tamarack, and the spruces and pines. Species having no resin ducts treated but little better in the sapwood or outer portion than in the heartwood or inner portion. But the latter tendency does not always hold, since cedars, cypresses, and other woods (which were not here tested) are known to be more easily treated in the sapwood. These species have, however, a distinct color difference between heartwood and sapwood.

It is true that the harder and more insoluble resin in the ducts of the heartwood adds to the difficulty of penetrating heartwood. The great ease of penetration of the sapwood of pines, spruces, and other species seemed to be a property of the nonresin structure which, in conjunction with the resin ducts, rendered these woods very susceptible to treatment.

PENETRATION IN SPRINGWOOD AND SUMMERWOOD.

It was found in most species that the summerwood was more penetrable than the springwood. But this rule did not hold for redwood, yew, and tamarack. Redwood not only treated more easily in the springwood, but the summerwood was scarcely penetrated. In the yew and tamarack the springwood and summerwood were about equally resistant. In all other species tested the dense summerwood was the portion penetrated first, and usually the tracheids last formed, those with the thickest walls and smallest lumen, were the most penetrable.

The summerwood not only permitted the oil to enter more quickly and penetrate farther than did the springwood, but actually absorbed a greater amount of it. This last fact was indicated by the difference in color between treated summerwood and treated springwood. It was shown also in the case of a treated specimen of loblolly pine, in which, by actual determination, the summerwood contained 80 per cent more oil than the springwood.

In no case was any stick of wood absolutely impermeable. The springwood of the most impermeable species could always be penetrated longitudinally for three or more tracheids from the point of application of the pressure. (Pl. VII, fig. 1.)

PENETRATION IN THE MEDULLARY RAYS.

Except in the case of ray ducts the medullary rays, as a rule, were not penetrated. In some of the spruces, however, the upper and lower ray tracheids were penetrated and in some of the pines the entire ray. In no case except the spruces and pines was any penetration noted in the rays unless the specimen was very heavily treated.

GROUPING OF SPECIES.

GROUPING WITH RESPECT TO PENETRATIONS AND ABSORPTIONS.

Table 2 gives the average longitudinal and radial penetrations[1] and the absorptions obtained in the penetrance and impregnation tests, respectively. The species are arranged in order of the longi-

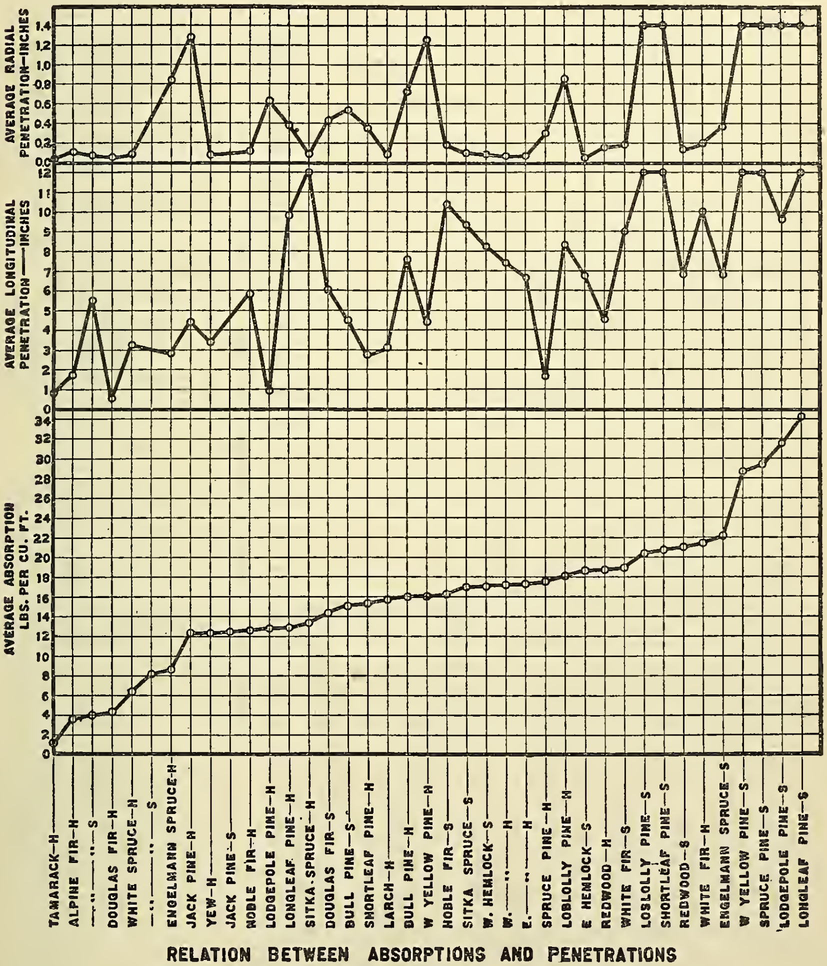


FIG. 3.—Relation between absorption and longitudinal and radial penetration. (Species platted in order of magnitude of absorptions.) (S=sapwood; H=heartwood.)

tudinal penetrations, beginning with the least; the order in respect to radial penetration and absorption, respectively, is indicated numerically, each in a separate column. The relation between absorption and penetration is shown more clearly in figure 3, in which the absorption and corresponding radial and longitudinal penetrations

[1] In obtaining average penetrations only the region in direct line with the pressure was taken into account.

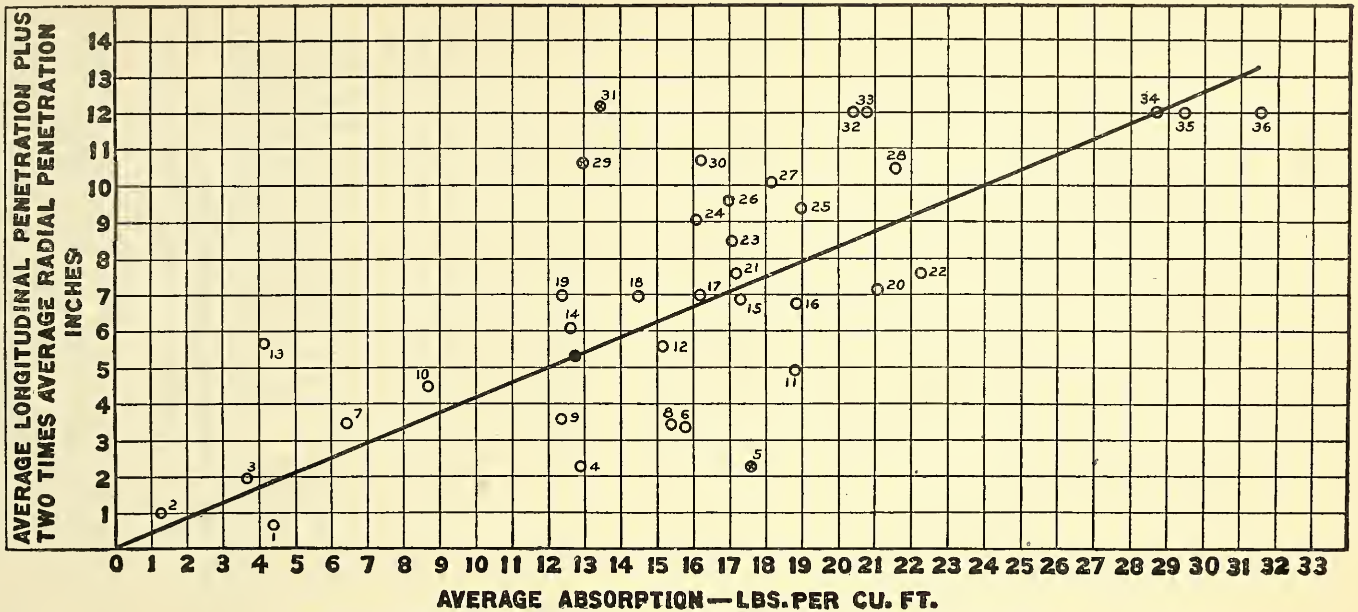


FIG. 4.—Relation of absorption to chemical, radial, and longitudinal penetrations.

1.	Douglas fir	Heartwood.
2.	Tamarack	Heartwood.
3.	Alpine fir	Heartwood.
4.	Lodgepole pine	Heartwood.
5.	Spruce pine	Heartwood.
6.	Western larch	Heartwood.
7.	White spruce	Heartwood.
8.	Shortleaf pine	Heartwood.
9.	Yew	Heartwood.
10.	Engelmann spruce	Heartwood.
11.	Redwood	Heartwood.
12.	Bull pine	Sapwood.
13.	Alpine fir	Sapwood.
14.	Noble fir	Heartwood.
15.	Eastern hemlock	Heartwood.
16.	Eastern hemlock	Sapwood.
17.	Western yellow pine	Heartwood.
18.	Douglas fir	Sapwood.
19.	Jack pine	Heartwood.
20.	Redwood	Sapwood.
21.	Western hemlock	Heartwood.
22.	Engelmann spruce	Sapwood.
23.	Western hemlock	Sapwood.
24.	Bull pine	Heartwood.
25.	White fir	Sapwood.
26.	Sitka spruce	Sapwood.
27.	Loblolly pine	Heartwood.
28.	White fir	Heartwood.
29.	Longleaf pine	Heartwood.
30.	Noble fir	Sapwood.
31.	Sitka spruce	Heartwood.
32.	Loblolly pine	Sapwood.
33.	Shortleaf pine	Sapwood.
34.	Western yellow pine	Sapwood.
35.	Spruce pine	Sapwood.
36.	Lodgepole pine	Sapwood.

are platted in order of the magnitude of the absorptions. The general tendency of the longitudinal penetrations is to increase as the absorptions increase, but the curve is very irregular. The radial penetrations show even less relation to the absorptions than do the longitudinal penetrations, but inspection of the figure shows that a few of the irregularities would be eliminated by combining the two penetration curves. In other words, a high longitudinal penetration and a low radial penetration may accompany a moderate absorption. Figure 4 shows the relation of absorptions to the combined radial and longitudinal penetrations in a slightly different manner. The absorptions are platted against a quantity obtained by adding twice the radial penetration to the longitudinal penetration.[1]

Although the average curve indicates a constant ratio between penetrations and absorptions, the variation of the individual points from the average is again very marked. Reasons for this behavior were frequently apparent upon examination of the treated sticks. For example, when the creosote followed merely the summerwood band of the annual rings, much less oil was required for a given penetration than when the entire ring was saturated.

GROUPING WITH RESPECT TO TREATMENT.

While it is desirable to have classifications based upon elementary characteristics rather than upon empirical results, it has been found that the development of the resin canals and cells, which form the most tangible structural differences between the conifers, is insufficient to grade these woods for preservative treatment. The following method of classification, based upon both empirical results upon air or oven-dry wood and structural characteristics, is therefore proposed:

A. Species in which the wood other than the resin structures treats with great difficulty or is impenetrable:
   1. Containing no resin ducts, Class I.
   2. Containing resin ducts, Class II.

B. Species in which the wood treats easily:
   1. Containing no radial ducts, or radial ducts not easily penetrable, Class III.
   2. Containing easily penetrable radial ducts.
      a. In the heartwood, Class IV.
      b. In the sapwood, Class V.

The division is primarily between species which treat with difficulty and those which treat easily. As a basis for this distinction

[1] Since the radial and tangential surfaces of the sticks treated in the absorption tests amounted to 12 times the end surface, it might be considered that the penetrations in the two directions should be combined in this ratio, assuming that radial and tangential penetration is equal and that absorption is proportional to surface area. By actual computation, however, this method seemed to give too much weight to radial penetration; and further trial showed that twice the radial penetration added to the longitudinal penetration gave the most nearly constant relation to the absorption.

it was necessary to adopt some standard by which the classification could be made. The wood was considered easily treated if, under the conditions of these tests, it fulfilled any one of the following conditions:

1. Received an average longitudinal penetration of more than 6 inches.[1]
2. Received an average radial penetration of more than 0.30 inch.[1]
3. Received an average absorption of more than 15 pounds per cubic foot.[2]

While this basis of classification is to a large extent arbitrary, the specification in regard to radial penetration divides the species which were penetrated by means of the radial ducts from those which were not so penetrated. Woods penetrated radially are, of course, most suitable for treatment in all forms. It was considered, however, that the species which in these tests received an average longitudinal penetration of 6 inches or more are sufficiently penetrable to be treated in short lengths, even though the radial penetration is very slight. The clause in regard to absorption was intended to include, among the easily treated species, those which received a fairly good treatment in the impregnation tests, although neither the longitudinal nor radial penetrations determined in the penetrance apparatus were especially good. The only woods affected by this clause are the heartwood of redwood and of western larch.

The species falling in each of the five classes are given in Table 3, together with the penetrations and absorptions of each species. In this table sapwood and heartwood are considered as if separate woods.

Species in Classes I and II are not very suitable for preservative treatment. While Douglas fir is extensively treated, very severe processes are used. However, the sapwood of both tamarack and Douglas fir can be treated easily.

Species in Class III are not very suitable for treatment, except in short lengths, on account of the lack of radial penetration. However, western larch and Sitka spruce contain radial ducts and it is possible that by more severe treatments than were employed in the tests these ducts may be penetrated. If western larch be excepted, each species in this class includes both heartwood and sapwood, and such species may be treated therefore without regard to the amount of sapwood present.

Woods in Class IV permit of thorough treatment. While there is much variation in the penetrability of these species, all are capable of being penetrated readily.

The woods in Class V can be saturated with creosote in a very short time. All species in Class IV occur in Class V. In actual treating operations the amount and location of the sapwood will determine in which class a given timber shall be placed.

---

[1] Determined by penetrance tests.
[2] Determined by impregnation tests.

GROUPING WITH RESPECT TO SUITABILITY FOR TREATMENT IN PARTICULAR FORMS.

In this sort of grouping the main considerations are whether or not the sapwood treats more easily than the heartwood, and whether the wood can be easily penetrated radially. Round forms, such as fence posts, mine props, telephone posts, and piling constitute one class, while sawed heartwood ties, bridge timbers, sawed mine timbers, and other dimension timbers constitute a second class. Paving blocks are considered separately.

ROUND TIMBERS.

The penetration of the sapwood in round timbers is more important than that of the heartwood, since the latter is inclosed by the former. Railroad ties in which the heartwood is not exposed by hewing or sawing may be considered as round timbers. Since round timbers to be treated must be penetrated radially through the resin ducts it is essential that all of the bark be removed before treatment. The results obtained in these experiments and the experience of the Forest Service generally indicate that the following species may be successfully treated in the round form:[1]

Engelmann spruce.
Douglas fir.
Tamarack.
Western larch.
All of the pines.

Species which received practically no radial penetration and, therefore, are not well adapted to treatment in the form of round timbers, include the following:

Alpine fir.	Eastern hemlock.
Yew.	Western hemlock.
Noble fir.	Redwood.
White fir.	Sitka spruce.

DIMENSION TIMBERS.

In dimension timbers the treatment of the heartwood is of chief importance, since the sapwood is generally removed at least from part of the faces. These experiments indicate that—

Species in Class I are entirely unsuitable for treatment in the form of dimension timber.

Species in Class II are also unsuitable for this purpose, but may be treated under very severe pressure.

Species in Class III are not especially suitable for treatment as dimension timbers, but satisfactory results are being obtained in practice.

[1] Probably also the cedars and cypresses. No data have been obtained on these, however.

Species in Class IV are admirably adapted for this class of timbers. The presence of radial resin ducts with the easily penetrated wood structure makes possible the penetration radially of a large portion of the volume of such timbers.

If there is considerable difference in the penetrability of heartwood and sapwood, dimension timbers are best treated when all of the sapwood is removed. There is no advantage in protecting parts of a timber by heavily treated sapwood if other exposed parts have only the lighter treatment possible in the heartwood. Such treatments result in a practical loss of most of the oil absorbed by the sapwood which may represent a very large proportion of the cost of treating this kind of timber. A system of selecting timbers in accordance with their suitability for treatment may prove very profitable to the user of such timber.

PAVING BLOCKS.

These experiments indicate that with the possible exception of Alpine fir and the heartwood of Tamarack,[1] a fairly thorough penetration of the conifers in any form less than 12 inches in length can usually be obtained. This fact is significant as regards treatment of paving blocks. However, since the springwood, as a rule, can not be thoroughly treated, woods with wide springwood bands should not be used for this purpose. Other factors, such as strength or wearing qualities, will of course greatly limit the number of species suitable for paving blocks.

THEORY OF PENETRANCE.

It is a disputed question whether the cell walls under treatment are permeable to creosote, or whether they contain openings through which the oil passes. The first supposition does not account for the very rapid penetration of certain species, nor does it account for the greater ease of penetration in the thicker walled summerwood tracheids than in the thin-walled springwood tracheids. As regards the second supposition, it has been suggested[2] that the minute slits which frequently occur in the cell walls of seasoned wood are the openings through which the oil passes. Seen in transverse section, these slits appear as V-shaped openings extending about midway through the wall. They extend spirally around the cell and there is the possibility that where the slits in adjacent walls cross each other the cell wall is sufficiently broken down to allow the passage of oil. Another possibility is that a rupture occurs in the pit membrane brought about by internal stresses of the wood during seasoning or otherwise. While it seems that such ruptures are likely to occur, there is little or no evidence to support this hypothesis.

[1] Tamarack blocks will take a good treatment in the green condition after steaming.

[2] The Physical Structure of Wood in Relation to the Penetrability, by H. D. Tiemann; Bull. 120, Am. Ry. Eng. and Main. of Way Association, January, 1910.

No satisfactory theory has yet been offered to explain the penetration of wood by creosote. The following observations, based on the experiments described in this bulletin, indicate the variety of phenomena which such a theory would have to take into account.[1]

1. The summerwood in the conifers was, as a rule, easier to penetrate than the springwood; but exceptions were noted, as (*Sequoia washingtonia*), which treated more easily in the springwood.

2. In the pines the summerwood was usually well penetrated, but the springwood penetrations were very erratic, often taking place very readily in some portions of the wood and with great difficulty in other portions of the same piece. (See Pl. IV, fig. 2.)

3. In most cases the resistance to penetration was least in the last-formed summer tracheids (having the thickest walls and the smallest cell cavities), and was greatest in the first-formed spring tracheids (having the thinnest walls and the largest cell cavities).

4. The color of the creosote oil in the springwood was often transparent and amber, while in the summerwood it was very dark.

5. In springwood apparently untreated the bordered pits frequently were strongly discolored and seemed to contain creosote.

6. In the pines, spruces, sequoia, larches, and Douglas fir the sapwood was more penetrable than the heartwood. In eastern and western hemlock and in the firs the sapwood and the heartwood were about equally penetrable.

7. As a rule, the medullary rays had no influence on penetrance, except when they contained resin ducts. Then they were usually very difficult to penetrate, but in *Picea* certain tracheids of the rays were readily treated, the upper and lower cells being usually the first. Frequently from these rays one or more longitudinal spring tracheids were penetrated. Sometimes all of the ray cells were penetrated, but never as heavily as the summerwood tracheids.

8. Of two sticks of wood similarly treated one was split immediately after treatment and the other several weeks later. They differed greatly in appearance. Springwood adjacent to treated summerwood in the first piece was apparently untreated, but in the second piece showed a marked discoloration. Microscopic examination of the latter showed that the cell walls were uniformly discolored.

CONCLUSIONS.

The following conclusions were drawn as a result of the tests described in this report:

1. Radial and longitudinal resin ducts penetrate intimately the interior of the wood and thus form passages for the preservative.

[1] Irving W. Bailey has recently published a paper in Vol. XI, No. 1, of the Forestry Quarterly which throws considerable light on this subject.

Radial resin ducts were found to be especially important. Where these occurred the wood was usually penetrated radially from one-fourth to three-fourths as far as longitudinally, and tangential penetration could usually be disregarded. Where no radial ducts were present, radial and tangential penetrations could be considered as equal, and they were found to be between one-twentieth and one one-hundred-twentieth of the longitudinal penetrations.

2. Absorption curves (see Appendix) platted for the specimens treated in the cylinder show that those species which were most difficult to impregnate gave the most uniform absorption results, and that the sapwood of those species containing resin ducts gave the most erratic absorption results. They showed also that sapwood of pines, as distinguished by its color from heartwood, was not always easier to treat than the heartwood. The color line in the wood does not necessarily separate the easily treated wood from the portions treated with difficulty. Some sapwood treated like heartwood and some heartwood treated like sapwood; all of these conditions are possible in the same cross section of a tree. As a consequence of this, the absorption curves for pines were, as a rule, very erratic, especially the sapwood curves.

3. The results obtained with a given species of wood can not always be applied to another species, however similar in structure the two may appear to be. This fact is strikingly evident in the treatment of heartwood larch and tamarack. Even woods of the same species show variations when grown under widely different conditions, as, for example, western yellow pine from California and from Montana.

Detailed results of the tests on each species are given in the Appendix.

APPENDIX.

DESCRIPTION OF SPECIMENS AND MANNER OF TREATMENT.[1]

YEW (TAXUS BREVIFOLIA).

The summerwood in the yew specimens was equal to about one-fourth of the width of the springwood. Resin cells and resin canals are entirely absent in this species.

The average oven-dry weight per cubic foot of eight heartwood specimens of yew was 38.5 pounds.

The penetration in both penetrance and cylinder treatments was found to take place equally in springwood and summerwood. Radial and tangential penetrations were also about equal. The average longitudinal penetration was about 50 times the average radial or tangential penetrations.

---

[1] In describing the woods used in these tests the observations made on the specimens are in some cases supplemented by remarks on the general characteristics of the species taken from Penhallow's "North American Gymnosperms."

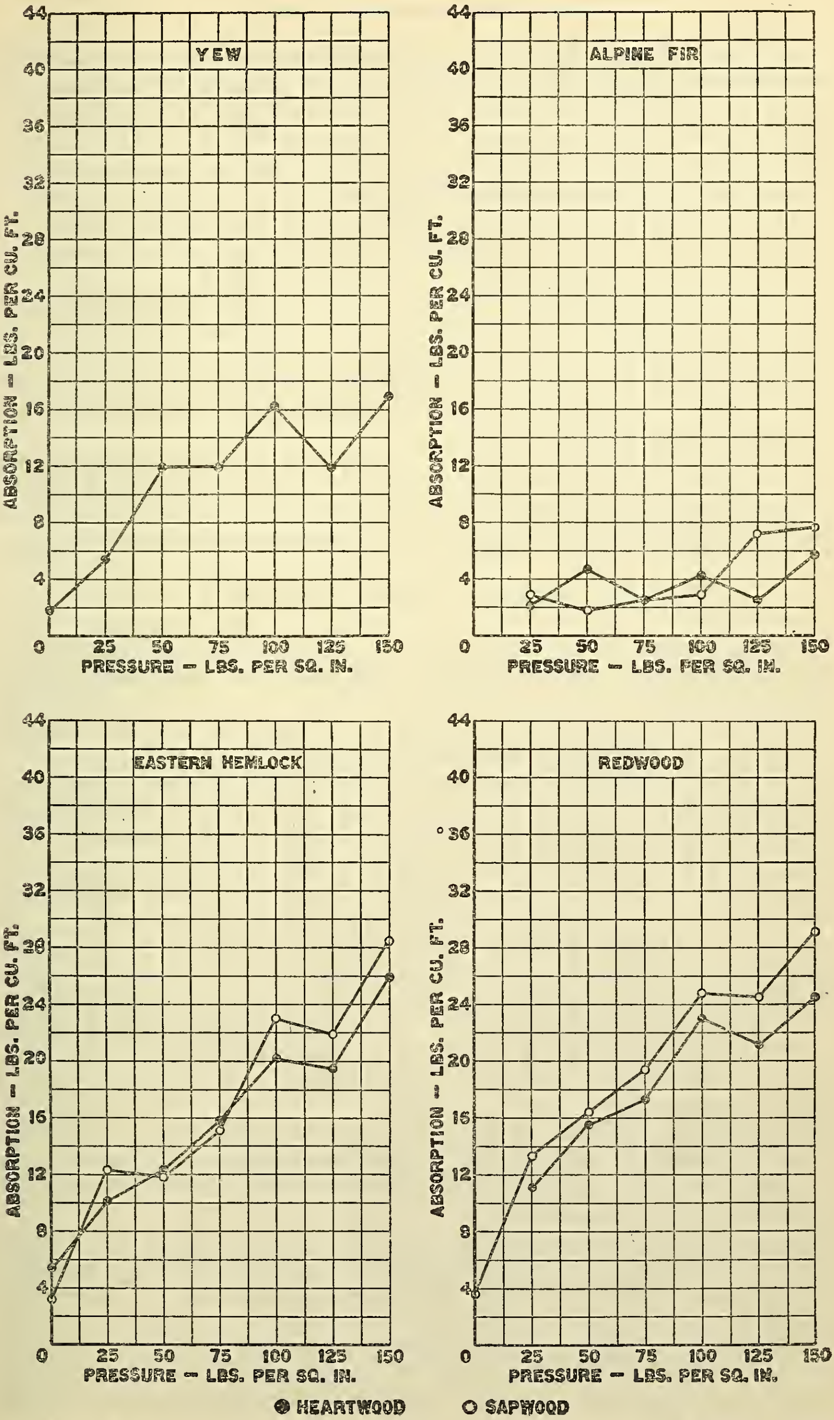


FIG. 5.—Absorption in the heartwood and sapwood of yew, Alpine fir, eastern hemlock, and redwood.

ALPINE FIR (ABIES LASIOCARPA).

The Alpine fir was very light, soft, close-grained, and compact. The growth rings were narrow and uniform in width, and the summerwood was thin. The springwood tracheids were large and had rather thin walls. Neither resin cells nor resin canals were present.

The average oven-dry weight per cubic foot of three sap specimens was 22 pounds, and of six heart specimens 22.2 pounds.

The penetration took place more readily in the summerwood than in the springwood, and in many cases only the last half dozen rows of tracheids of the summerwood were treated.

The character of penetration in the cylinder treatments was quite similar to that in the penetrance tests. Although the summerwood was often treated throughout the stick, in most cases only a few tracheids of the summerwood were penetrated. The springwood penetration averaged about 0.15 inch longitudinally. In some places, however, the springwood of several growth rings was treated to the center of the stick.

The sapwood apparently treated a little more easily than the heartwood, but the difference was so small as to be negligible. Radial and tangential penetrations were both of slight importance. The average longitudinal penetration was 60 to 70 times as great as the average radial and tangential penetrations.

EASTERN HEMLOCK (TSUGA CANADENSIS).

The summerwood of eastern hemlock was dense and was from one-fourth to one-half the width of the springwood. The latter had large and very thin-walled tracheids.

The average oven-dry weight per cubic foot of eight sap specimens was 20.7 pounds, and of eight heart specimens 22.7 pounds.

This species is simple in structure. It differs from the yew and Alpine fir, however, in having large but not numerous resin cells located in a single row on the outer face of the summerwood. Resin passages are never present.

The penetration took place more readily in the summerwood than in the springwood, but near the point of pressure the springwood was penetrated in some cases for 1 or 2 inches. The summerwood treated most quickly in the two to five last-formed rows of summer tracheids, and apparently the heaviest absorptions were along the zone of the resin cells. The line between the treated summerwood and the untreated adjacent springwood was very sharply defined.

The character of penetration in the cylinder-treated sticks was very similar to that in the penetrance specimens. The summerwood was in most cases treated to the center of the stick. The springwood was treated from 2 to 3 inches longitudinally.

Practically no difference either in absorption or penetration was noted between the heartwood and sapwood. Radial and tangential penetrations were of small importance. The longitudinal penetration averaged about 80 times the radial or tangential penetrations.

The influence of the resin cells on penetration was very difficult to determine. The creosote appeared to penetrate more easily in the summerwood tracheids lying adjacent to the resin cells, but the adjacent springwood tracheids were not treated.

A peculiarity of hemlock was its tendency to exude oil for many hours after treatment. This probably was due to the slow escape of confined air in the wood, which remained under a slight pressure for many hours after the release of external pressure.

REDWOOD (SEQUOIA SEMPERVIRENS).

In the redwood the summerwood was about one-third the width of the springwood. The latter was very open, with thin-walled tracheids. The resin cells were rather large, numerous, and scattered throughout the springwood.

Resin cysts, or aggregates of resin cells, were sometimes contiguous and coalescent and formed extended tangential series in the initial growth of the springwood of distant-growth rings. Often the cysts were separated longitudinally only by a wall of resin cells. Tyloses were sometimes present in the cysts.

The average oven-dry weight per cubic foot of four heart specimens was 20 pounds, and of seven sap specimens 19.3 pounds.

Penetration in general took place more readily in the springwood than in the summerwood, but the maximum penetrations were in the one to three last-formed summerwood tracheids and in the two or more first-formed springwood tracheids; that is, along the outer face of the summerwood in the zone of the resinous cells and cysts. In the portions treated most heavily the summerwood band was treated throughout, but usually it was penetrated very slightly.

The character of the penetrations in the cylinder treatments was very similar to that in the penetrance tests. Near the end of the stick the entire springwood of nearly every ring was penetrated, but near the center only the first-formed springwood tracheids were treated. The summerwood was usually treated for only a short distance from the ends.

In the sapwood penetration was somewhat quicker and absorption a trifle greater than in the heartwood. But these differences were so slight that they may be disregarded.

Radial and tangential penetrations were about equal. This indicated that tangentially extended series of resin cysts did not influence appreciably tangential penetration. The average longitudinal penetration was about 50 times greater than the average radial or tangential penetrations.

The influence of the resin structure was apparent in redwood. The creosote followed the resin zone more readily than the surrounding wood structure. A peculiarity of redwood was that the springwood was penetrated more easily than the summerwood, whereas with most other species the summerwood was more easily penetrated than the springwood.

WESTERN HEMLOCK (TSUGA HETEROPHYLLA).

The growth rings of western hemlock were narrow, with prominent summerwood bands usually about equal in width to the springwood, which consisted of large and thin-walled tracheids.

The average oven-dry weight per cubic foot of six heart specimens was 27 pounds, and of six sap specimens 28 pounds.

Resin cells were very prominent on the outer face of the summerwood. These sometimes united to form an imperfect resin passage. In other respects the western hemlock specimens were structurally similar to eastern hemlock.

Penetration took place more readily in the summerwood than in the springwood. In most cases the resinous portion (on the outer face of the summerwood) seemed to be penetrated first, the oil passing for a very short distance from this zone radially into both the summerwood and springwood. The summerwood band as a whole treated almost as easily as the resinous zone, and in many growth rings the summerwood was treated while the resin canals were untreated. The springwood was also uniformly penetrated, but not as far nor as heavily as the summerwood.

The character of penetration in cylinder-treated sticks was similar to that in sticks treated in the penetrance apparatus. The springwood treated longitudinally from 1 to 4 or 5 inches, while the summerwood was treated to the center of the stick in nearly every growth ring.

Practically no difference was noted either in penetration or absorption between the heartwood and sapwood. The average longitudinal penetration was about 90 or 100 times as great as the average radial or tangential penetrations.

WHITE FIR (ABIES GRANDIS).

The growth rings of white fir were usually very broad, with large and thin-walled springwood tracheids. Resin cells were few and scattering on the outer face of the springwood. Resin passages were not present. Structurally this species is very similar to eastern hemlock.

The average oven-dry weight per cubic foot of all heart specimens was 22 pounds, and of six sap specimens 22.7 pounds.

The greatest penetration took place in the last-formed summerwood tracheids, but the difference was not marked. Near the point of application of pressure both springwood and summerwood were equally treated, and at maximum penetrations even the springwood in many places was heavily treated. The heartwood was slightly easier to penetrate and absorbed somewhat more oil than the sapwood.

White fir contains no resin structures except simple resin cells, but it was nevertheless penetrated easily in both springwood and summerwood.

The average longitudinal penetration was about 50 times the average radial and 35 times the average tangential penetration.

NOBLE FIR (ABIES NOBILIS).

The summerwood of noble fir was about equal in width to the springwood. The spring tracheids were large and thin-walled. In distinct and widely separated growth rings, resin cells were localized to form imperfect resin canals, these occurring in somewhat continuous zones in the summerwood.

The average oven-dry weight per cubic foot of 10 heart specimens was 21.9 pounds, and of five sap specimens 23.6 pounds.

The maximum penetration took place along summerwood bands and more especially in the last-formed tracheids of the summerwood. In the most heavily treated zone, near the point of application of pressure, the entire summerwood was treated together with portions of the springwood.

The character of penetrations in the cylinder and in the penetrance treatments were very similar. The summerwood was nearly always treated to the center of the stick. Near the ends considerable springwood penetration was noted. In the sapwood more of the springwood was treated than in the heartwood.

The sapwood treated more quickly and absorbed more oil than the heartwood. Radial and tangential penetrations were of considerable importance, especially in the sapwood. The average longitudinal penetrations were about 40 times the average radial and tangential penetrations.

DOUGLAS FIR (PSEUDOTSUGA TAXIFOLIA).

The growth rings of Douglas fir were variable in width. The proportion of summerwood varied from almost nothing to nearly half of the growth ring. The spring tracheids were large and thin-walled. Resin cells were few and were scattered on the outer face of the summerwood. The resin passages were

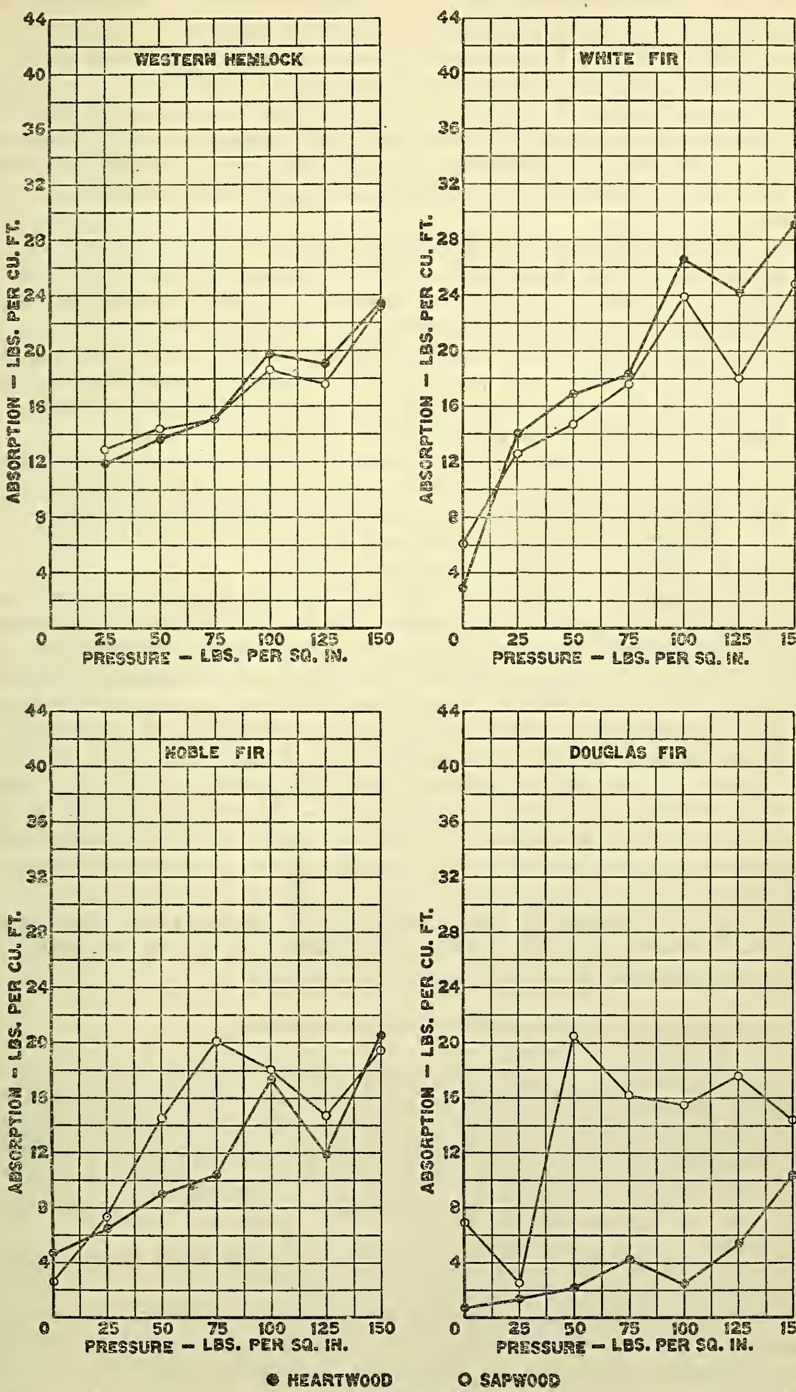


FIG. 6.—Absorption in the heartwood and sapwood of western hemlock, white fir, noble fir, and Douglas fir.

small, few, widely scattered and occurred chiefly in the summerwood; at frequent intervals they were partially obstructed by constrictions.

The average oven-dry weight per cubic foot of four heart specimens was 27.5 pounds, and of five sap specimens 27.7 pounds.

This species contained "fusiform rays"; that is, rays traversed by resin canals, these being smaller than the longitudinal ducts. The ray ducts frequently crossed the longitudinal ones at right angles, thereby forming junctions. This offered the possibility of a deep radial penetration through the radial ducts.

The penetration, especially in the sapwood, took place much more easily in the summerwood than in the springwood. Maximum penetrations took place along the resin ducts, chiefly in the summerwood; in the springwood the ducts were sometimes treated while the surrounding tracheids were not. The springwood was always treated near the point of pressure. In the heartwood both the springwood and summerwood were treated, sometimes equally but usually more heavily in the latter. The sapwood was easily treated, both radially and longitudinally along the two sets of ducts.

The character of penetration in the cylinder treatments was similar to that in the penetrance specimens. The summerwood was much the easier to treat, but the springwood was penetrated by prolonged application of pressure. In some cases springwood resin ducts were found that were not penetrated, whereas the adjacent summerwood was penetrated.

In this species there was a very great difference between penetrations and absorptions in the heartwood and in the sapwood. The former appeared to be almost impenetrable, while the latter was easily treated. This can be explained partially by the larger quantity and less soluble condition of the resin in the canals of the heartwood. In sapwood the radial ducts had a very great influence on penetrations, and it seems probable that this would be the case in the heartwood also for long-continued treatments. There is also a great difference between heartwood and sapwood in the penetrability of the nonresinous structure. Such penetrability is directly affected by the penetrability of the ducts themselves, since creosote in the latter quickly become saturated with resin which must escape to the surrounding wood before penetration can continue.

In heartwood the ratio of longitudinal to radial and tangential penetrations was about 10 or 12 to 1. In sapwood longitudinal penetration was about 12 times radial and 100 times the tangential penetrations.

SITKA SPRUCE (PICEA SITCHENSIS).

The growth rings of Sitka spruce were broad with summerwood equal to or exceeding the springwood. Resin cells were wholly wanting. Resin passages were few, small, and had thick-walled epithelium cells; they were well developed but frequently constricted. Tyloses were sometimes present in the resin canals. The canals in the fusiform rays had also thick-walled epithelium cells. The resin ducts running radially and longitudinally frequently intersected each other.

The average oven-dry weight per cubic foot of seven heart specimens was 19.2 pounds, and of four sap specimens 18.1 pounds.

While the heartwood of this species contained both radial and longitudinal ducts, they were not sufficiently numerous to have much influence on penetration. When present in the springwood the ducts were usually treated, but the oil did not spread to the surrounding structure. Penetration took place very rapidly in the summerwood, which treated almost as easily as the resin ducts themselves. Springwood was difficult to penetrate but was sometimes treated, especially in the zone where pressure was applied.

In the sapwood, resin ducts occurred frequently that were not well penetrated, while the summerwood band, a few tracheids distant, was heavily treated. The penetration appeared to follow first the very last-formed summerwood tracheids of each year's growth. Later the second and third rows of tracheids were penetrated and finally the entire summerwood band. Still later slight penetration occurred in some of the springwood tracheids, but this was comparatively rare.

In the medullary rays neither the intermediate cells nor the ray parenchyma were treated. The upper and lower ray cells, however, were very frequently penetrated from the longitudinal summerwood tracheids, and these ray cells extended through the longitudinal tracheids of the springwood without in any way penetrating them. This whole phenomenon was not noted in any of the species previously discussed.

The cylinder-treated wood was penetrated in much the same manner as the pieces treated in the penetrance apparatus. All summerwood was well treated, and in the sapwood a considerable amount also of springwood.

This wood, in common with most of the species previously discussed, becomes discolored in the springwood several weeks after treatment. On close examination it was found that most of the discoloration was localized in the bordered pits. It is not evident from present knowledge how this could be confined to the pits without the remainder of the tracheids also becoming discolored.

Resin ducts were not an important factor in the treatment of this species. The summerwood was penetrated very rapidly. The sapwood absorbed more oil than the heartwood, chiefly because the former was more heavily treated in the springwood.

The ratio of average longitudinal to average radial or tangential penetration can not be determined because the specimens were completely penetrated longitudinally, but it was at least 120 times as great.

WHITE SPRUCE (PICEA CANADENSIS).

The growth rings of white spruce were broad; the summerwood was about one-fourth the width of the springwood. Resin cells were never present. The resin passages were few, large, and sometimes contained tyloses. The ducts of the fusiform rays were surrounded by thick-walled epithelial cells.

The average oven-dry weight of five heart specimens was 24 pounds per cubic foot.

The penetrance tests were made on heartwood only. The penetration took place most quickly in the last-formed summer tracheids of the various growth rings, and in most cases the summerwood as a whole was treated more quickly than springwood. Near the point of pressure the springwood was partially treated. Resin ducts in the specimens were so infrequent that they had little effect upon penetration. Ray ducts were difficult to treat and appeared to aid little in radial penetrations.

The cylinder-treated sticks were penetrated similarly to those treated in the penetrance apparatus. Resin ducts when present were usually treated, but apparently they aided very little in the penetration of the tracheids surrounding them. Medullary ray tracheids were occasionally treated, but the penetration was limited and took place with difficulty. The summerwood was usually treated to the center of the stick. Often, however, zones occurred covering several growth rings in which the summerwood was not treated. When the summerwood failed to be penetrated the springwood was not treated. In some growth rings the springwood was treated to the center, but never as heavily as the summerwood. The treatment was, as a rule, not at all uniform, and considerable resistance was offered to penetration. While sapwood was more penetrable than heartwood, it was, nevertheless, very difficult to treat. The longitudinal penetration was from 35 to 40 times greater than the radial or tangential penetrations.

ENGELMANN SPRUCE (PICEA ENGELMANNI).

In Engelmann spruce the growth rings were broad; the summerwood was open, and one-third to one-half the width of the springwood. Resin cells are never present. The resin passages were large but few, and did not contain tyloses. The fusiform rays contained large radial ducts surrounded by thick-walled epithelial cells.

The average oven-dry weight per cubic foot of six heart specimens was 24.7 pounds, and of five sap specimens 25.9 pounds.

In the heartwood the penetration was chiefly in the summerwood, but a few springwood tracheids were treated near the point of pressure. Resin ducts seemed to be treated with difficulty and did not appear to assist greatly in the penetration. The rays were frequently treated, whether containing resin canals or not. The penetration of the rays most frequently extended over from one to three growth rings and seemed to start from summerwood bands.

Penetration in the sapwood seemed to be chiefly in the resin ducts. The summerwood bands and medullary rays were also treated, but penetration here took place much more slowly than through the resin ducts. Complete longitudinal and radial penetration occurred through the ducts only.

The cylinder tests showed that in heartwood the summerwood bands were all treated to the center of the stick. Resin ducts were sometimes treated, sometimes not. Most of the medullary rays were penetrated. In the sapwood the summerwood was treated as in the heartwood, and in places the springwood was equally well treated. Usually, however, the springwood was only partially treated, as was indicated by its golden-brown color; the treated summerwood was nearly black.

Radial penetration in this species seemed to be due largely to the rays. Apparently, creosote passed from the summerwood to the rays and thence to the next summerwood band, leaving the intervening springwood untreated. Resin ducts were very important factors in the sapwood penetration, but not in the heartwood. The sapwood treated almost instantly and absorbed more oil than the heartwood which was very difficult to penetrate. This difference was one existing chiefly in the springwood of the heart and of the sap respectively. In the latter the springwood was, as a rule, very heavily treated, but not so in the former.

The longitudinal penetration averaged about four times the radial in heartwood and 20 times the radial in sapwood. It was about 50 times the tangential penetrations in both heart and sap.

WESTERN LARCH (LARIX OCCIDENTALIS).

In the western larch specimens the summerwood was equal to about one-half the width of the springwood. The spring tracheids were large and very thin-walled. Resin cells were scattered on the outer face of the summerwood. Resin passages were large, not numerous, without tyloses, and surrounded by thick-walled epithelial cells. The radial canals were large and not very numerous.

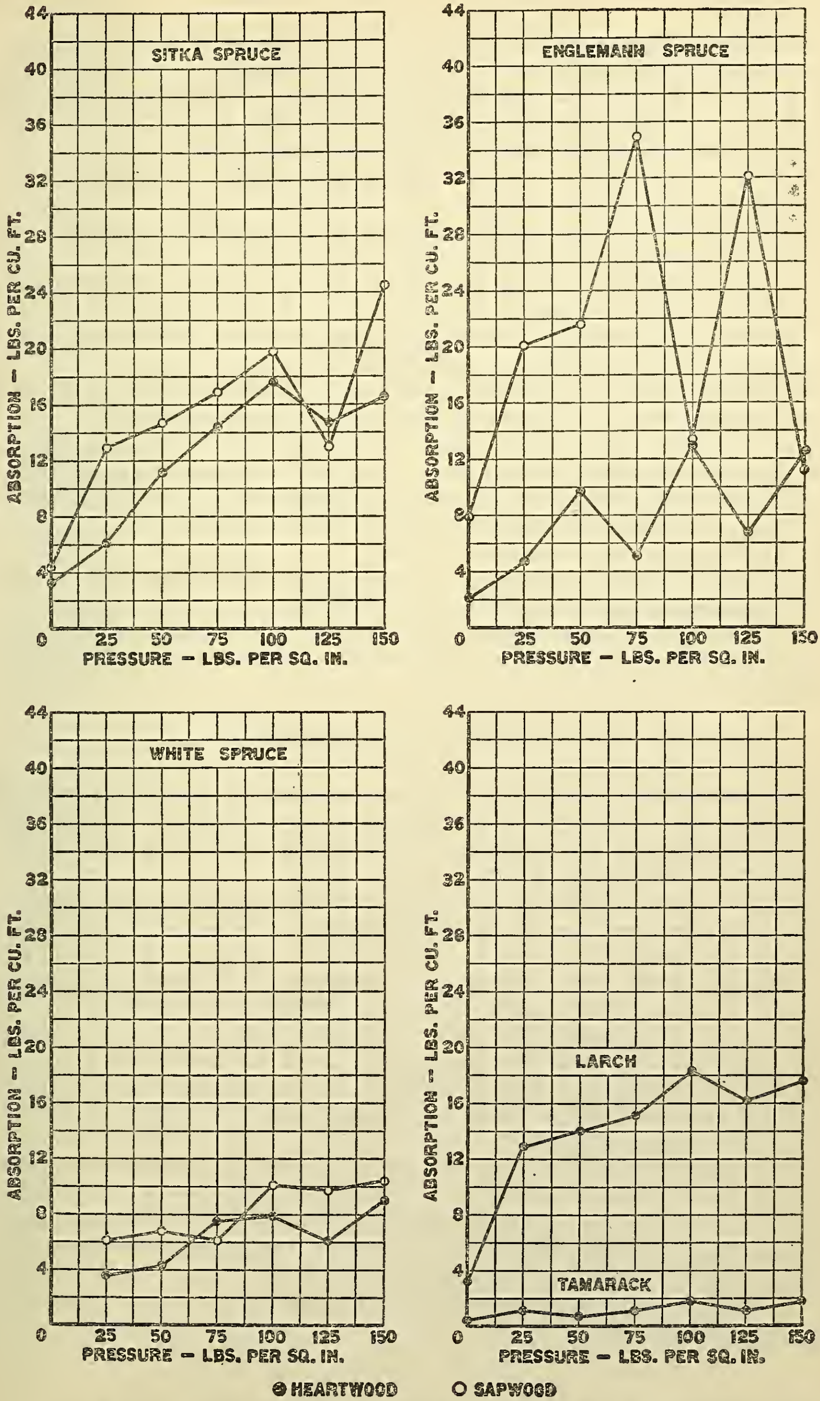


FIG. 7.—Absorption in the heartwood and sapwood of Sitka spruce, Engelmann spruce, white spruce, larch, and tamarack.

The average oven-dry weight per cubic foot of six heart specimens was 30.5 pounds.

Heartwood only of western larch was tested, as the sapwood is so thin that suitable pieces were not obtainable. The resin ducts were comparatively easy to penetrate, and isolated ones outside of the zone of longitudinal treatment were very frequently penetrated through intersecting radial ducts. Certain treated resin canals were closely examined and showed that:

1. Where fusiform rays crossed summerwood bands the latter were not treated.

2. The fusiform rays frequently intersected treated longitudinal ducts and usually contained creosote.

3. The summerwood on each side of longitudinal resin ducts was treated tangentially from one-eighth to one-fourth inch.

4. Resin and creosote appeared to be forced away from the resin canal into summerwood, but not often into springwood.

The summerwood was completely penetrated in most of the pieces, while, as a rule, the springwood was penetrated longitudinally about 1 inch only.

Cylinder treatments also showed that summerwood was much more penetrable than springwood. The relatively greater ease of penetration was probably due to the resin ducts, as in every case the greatest penetrations were found to be in the zone of a resin duct. Even without pressure the oil frequently penetrated the ducts longitudinally as much as 6 inches.

In heavily treated portions both springwood and summerwood were treated, but the latter much more heavily than the former.

It is known from other tests that the sapwood of this species is very easily treated, and may be completely penetrated in both springwood and summerwood.

TAMARACK (LARIX LARICINA).

The summerwood of tamarack was from one-fourth to one-half the width of the springwood. Resin cells were few, and widely scattering on the outer face of the summerwood. Resin passages were large and devoid of tyloses, and ran in radial and longitudinal directions.

The average oven-dry weight of six heart specimens was 32.5 pounds per cubic foot. Only heartwood specimens were treated as the sapwood was too thin to cut test specimens.

Tamarack offered great resistance to penetration. While similar to western larch in its microscopic structure, it was very different in its resistance to treatment. Most of the resin ducts were impenetrable under the conditions of the test. Longitudinally penetration occurred in 30 to 45 minutes, but only in a few isolated ducts, and then it did not spread to the surrounding cells, except near the point of pressure. The summerwood seemed to offer as much resistance as did the springwood.

Certain observations were made on treated sapwood of tamarack, which were aside from the regular experiments. These observations showed that the sapwood was very easy to penetrate. Both the springwood and summerwood (in the sap) were saturated with oil in a moderate treatment; the summerwood usually seemed to have the heavier absorption.

The average longitudinal penetration was 22 times the average radial and tangential penetrations.

LODGEPOLE PINE (PINUS MURRAYANA).

The growth rings of lodgepole pine were broad, with the summerwood about one-fourth the width of the springwood. The transition from one to the other was gradual. Resin cells were entirely absent. Resin canals were rather small; numerous, and mostly in the summerwood; radial ducts were few.

The average oven-dry weight per cubic foot of six heart specimens was 23.4 pounds, and of six sap specimens, 22.9 pounds.

The heartwood of lodgepole pine greatly resisted treatment, and resisted longitudinal penetration nearly as much as radial. What penetration occurred took place through the longitudinal and radial resin ducts. From these the summerwood was more or less treated, and occasionally a medullary ray (not fusiform) was found to be penetrated. In the tracheids, even when a pressure of 90 pounds was applied for one hour (piece 166), the penetration longitudinally was not deeper than the length of three cells, and tangentially not over six cells, and then very light. The treatment seemed to take place chiefly through the radial ducts, the oil passing to the longitudinal ducts wherever the two intersected.

In the cylinder most of the resin ducts appeared to be treated, and one split section showed creosote in the center of the piece. Cells surrounding the treated ducts in the summerwood appeared to be treated farther than equivalent cells in the springwood.

The sapwood was variable in its penetrability. Two of the pieces were penetrated radially in 30 to 45 seconds, the oil flowing copiously from the tangential surfaces almost as soon as pressure was applied, while the other piece required 20 minutes to be penetrated radially. The nonresin structure was very easily treated in both springwood and summerwood, but more quickly in the latter. The medullary ray cells also were usually treated.

In the cylinder the sapwood treated very easily, and even in the light treatments both springwood and summerwood were saturated. So easily was the sapwood treated that no difference in absorption was evident between pieces soaked in hot oil (run 7) and others treated at a pressure of 150 pounds (run 6).

It is evident that in a thorough treatment of large timbers of this species the sapwood will be completely treated while the heartwood will be penetrated radially from 1 to 2 inches. The average longitudinal penetration was about one and one-half times the radial; the tangential penetration could not be determined, but was probably negligible.

JACK PINE (PINUS DIVARICATA).

The summerwood of jack pine was dense, and about one-third the width of the springwood. Resin canals were small, numerous, chiefly in the summerwood, and contained tyloses. Radial ducts were not numerous.

The average oven-dry weight per cubic foot of five heart specimens was 25.4 pounds.

In the heartwood of jack pine longitudinal penetration took place first through the resin ducts, from which the oil passed into the surrounding cells. Summerwood was penetrated much more easily than springwood, and usually all summerwood bands were treated. The springwood was not, however, very difficult to penetrate, as this also contained many resin ducts. Treatment was comparatively rapid in the radial resin ducts; from these the penetration was diverted to the longitudinal ducts wherever the two sets crossed.

In the cylinder sapwood was treated first in the summerwood. The springwood also treated very quickly, and in the heavier treatments both springwood

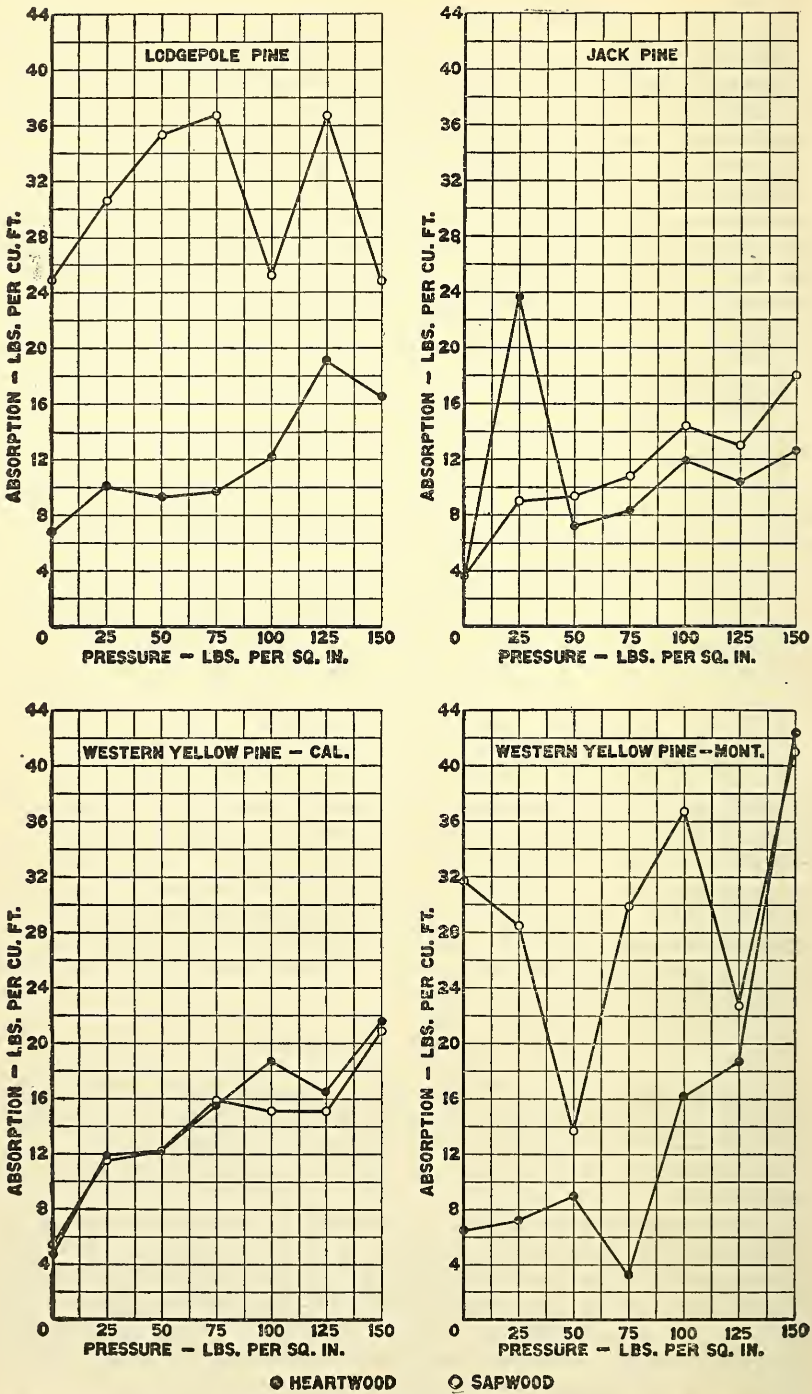


FIG. 8.—Absorption in the heartwood and sapwood of lodgepole pine, jack pine, and western yellow pine.

and summerwood were saturated, resulting in very heavy absorptions. These are not evident in the absorption data, because the sapwood specimens really contained at least 50 per cent of heartwood. This condition was unavoidable because of the very thin sapwood that was available.

Radial penetration was an important factor in this species. In the heartwood it averaged from one-eighth to one-fourth as great as the longitudinal penetration; the tangential was only about one-eightieth of the longitudinal.

WESTERN YELLOW PINE (PINUS PONDEROSA).

The summerwood of western yellow pine was variable, dense, and was from one-third to one-half the width of the springwood. The spring tracheids were rather thick-walled. Resin passages were of medium size, numerous, and located chiefly in the summerwood. Radial ducts were also numerous.

The average oven-dry weight per cubic foot of six heart specimens from California was 25 pounds, and of six sap specimens 23 pounds; of six heart specimens from Montana 25.4 pounds, and of five sap specimens 27.4 pounds.

In the heartwood of the western yellow-pine specimens from California the summerwood treated more easily than the springwood. Usually the entire summerwood band was penetrated, and often many of the springwood tracheids were heavily treated. The longitudinal and radial ducts were the channels through which the penetration first took place, and from these it passed into the summerwood. When springwood was treated, the oil seemed to come from radial ducts and usually did not penetrate far from them. In the specimens from Montana the summerwood treated first, as in the California specimens, but the outer summer tracheids had the heaviest absorptions and were treated for the greatest distances. The springwood was untreated except for isolated tracheids which were penetrated from the ray ducts.

In the sapwood of the California specimens penetration took place very rapidly in the resin ducts, but throughout the tracheids treatment required as much time as in the heartwood; and on microscopical examination both heartwood and sapwood were found to have the same appearance. In the radial ducts of the specimens from Montana sapwood penetration was much greater than in those from California. Immediately after pressure was applied oil flowed from these ducts, and the entire sapwood, both springwood and summerwood, was heavily treated within a few seconds.

In the cylinder-treated sticks of the California tree both heartwood and sapwood had the same appearance, and while in both the summerwood appeared to have the heavier absorptions, the springwood also was very heavily discolored. The Montana tree, however, was not penetrated quickly in the heart springwood, except in the case of certain pieces (Nos. 41–46) which treated like the sapwood. In these specimens the summerwood was treated throughout. In case of the lighter absorptions the springwood was practically untreated, but as the absorptions increased the proportion of springwood treated also increased.

In the California specimens longitudinal penetration averaged about 8 times the radial and 30 times the tangential penetration. In the Montana specimens the longitudinal penetration averaged about 4 times the radial and 50 times the tangential penetrations.

SPRUCE PINE (PINUS GLABRA).

The spruce-pine specimens were of extremely rapid growth. The summerwood was about one-half the width of the springwood. Resin ducts were very numerous and large, especially in the summerwood. Radial ducts were few. The sapwood was much lighter in weight than the heartwood.

The average oven-dry weight per cubic foot of seven heart specimens was 32.2 pounds, and of six sap specimens 26 pounds.

Two heartwood pieces of spruce pine (Nos. 225 and 240) treated like the sapwood. These pieces became saturated with oil almost as soon as pressure was applied, and on splitting both springwood and summerwood were found to be uniformly discolored with creosote. Examined microscopically, no difference appeared between these pieces and other heartwood directly adjacent that was very resistant to penetration.

Three heartwood pieces were found, however, that resisted penetration in the manner usually noted in the heartwood of pine. These pieces of spruce pine were, in fact, among the most impenetrable in the entire series of species tested. They were penetrated in the summerwood somewhat more quickly than in the springwood, and microscopic examination showed that the summerwood plainly was the most heavily treated portion. The medullary rays were frequently lightly treated. While radial and longitudinal ducts were often filled with what appeared to be a mixture of resin and creosote, they did not seem to aid materially in the penetration. The presence of a bright yellow substance in many of the tracheids of the heartwood, especially near resin ducts and in the springwood, seemed to indicate that resin had been forced from the ducts into the surrounding tracheids.

In the sapwood, while the summerwood treated more easily than the springwood, yet the latter was also very penetrable. Microscopic examination showed the summerwood to be saturated with oil and the springwood deeply colored. The medullary rays were usually treated. The resin ducts of the sapwood were usually heavily treated and seemed to be responsible for the quick penetrance of sapwood.

In the cylinder the heartwood piece treated in the nonpressure run showed that the greatest penetrance took place in the summerwood resin ducts. The springwood was treated for ½ to 1 inch, while summerwood was treated (around resin ducts only) from 1 to 6 inches. In some of the pressure treatments the springwood also was found to be heavily treated. The absorption, as indicated by the color of the treated sticks was very uneven.

The sapwood was very heavily treated in both springwood and summerwood; the latter, however, seemed to have taken the oil more quickly. Increasing the pressure did not seem to greatly increase the absorption in the sapwood, because it could be saturated without pressure. In general, spruce pine was extremely erratic in its penetrability and in its absorption of creosote. Some portions of heartwood were completely saturated with oil, while others directly adjacent were almost impenetrable. The average longitudinal penetration in heartwood was about 5 times the average radial and 16 times the average tangential penetrations.

LONGLEAF PINE (PINUS PALUSTRIS).

The growth rings of longleaf pine were usually narrow, with very dense summerwood. Resin cells were never present. Resin passages were numerous and large, chiefly in the summerwood, and contained tyloses. Ray ducts were few.

The average oven-dry weight in pounds per cubic foot of six heart specimens was 35.3 pounds, and of six sap specimens 22.8 pounds.[1]

In the heartwood while the summerwood was more penetrable than the springwood the latter was also easily treated. Both longitudinal and ray

---

[1] It should be noted that the dry weight of the sapwood was only two-thirds that of the heartwood. This was due to much thinner summerwood bands in the sapwood.

ducts were usually filled with creosote, from which isolated spring tracheids were frequently treated.

In the sapwood the resin ducts were always thoroughly penetrated by creosote. The summerwood was very heavily treated, and the springwood was evenly stained to a color much darker than the untreated wood, although creosote was not actually visible as such. Medullary rays were treated to about the same extent as the springwood.

In the cylinder the deepest penetrations and heaviest absorptions of the heart were in the summerwood. Here the treated wood was usually very dark, except in the farthest limits of summerwood penetration, where the color shaded so gradually to that of the natural wood that no line between treated and untreated wood could be detected. While more difficult to treat than summerwood, the springwood did not offer great resistance to penetration. Certain zones of springwood were often found that seemed to be filled with an oil much lighter in color than that in the adjacent summerwood. This may have been resin or creosote in which resin was dissolved. These zones were located between heavily treated summerwood bands; they were usually very close to resin ducts and were found only in the more heavily treated sections of the wood.

In sapwood the summerwood was in every case very heavily treated. Springwood was erratic in its absorption, some portions being black, others being only slightly discolored.

In general longleaf pine was found to be erratic in its penetrance and absorption of creosote. The sapwood was very easily penetrated and absorbed much oil without the aid of pressure. Merely dipping the sapwood was sufficient to penetrate it completely and to secure absorptions almost as heavy as those under the heaviest pressures. In heartwood the average longitudinal penetration was about 26 times the average radial and 100 times the average tangential penetrations.

SHORTLEAF PINE (PINUS ECHINATA).

The growth rings of shortleaf pine were broad, with summerwood which often exceeded the springwood in thickness. Resin cells were never present. Resin passages were large, numerous, scattering, and contained tyloses. Ray ducts were also numerous.

The average oven-dry weight per cubic foot of five heart specimens was 39 pounds, and of the five sap specimens, 31.8 pounds.

In the heart the summerwood was treated more thoroughly than the springwood, but penetration even in the summerwood was very difficult and took place only around the resin ducts. Very frequently penetration failed to occur in all of the summerwood tracheids, and often it occurred in only three or four of them, and these separated from one another. These tracheids were apparently reached from the medullary rays, which, in turn, were reached either from other longitudinal tracheids or from resin ducts. The medullary rays were frequently penetrated in one or more tracheids, and they may play an important part in the treatment of this species.

The heartwood in this species was one of the most impenetrable of the heartwood in any of the species tested; its longitudinal penetration was only 2.75 inches. In absorption shortleaf compares very favorably with other southern pines. All of these species were variable in the heartwood, and it is probable that if sufficient tests were made the penetration of shortleaf pine would show results similar to longleaf pine.

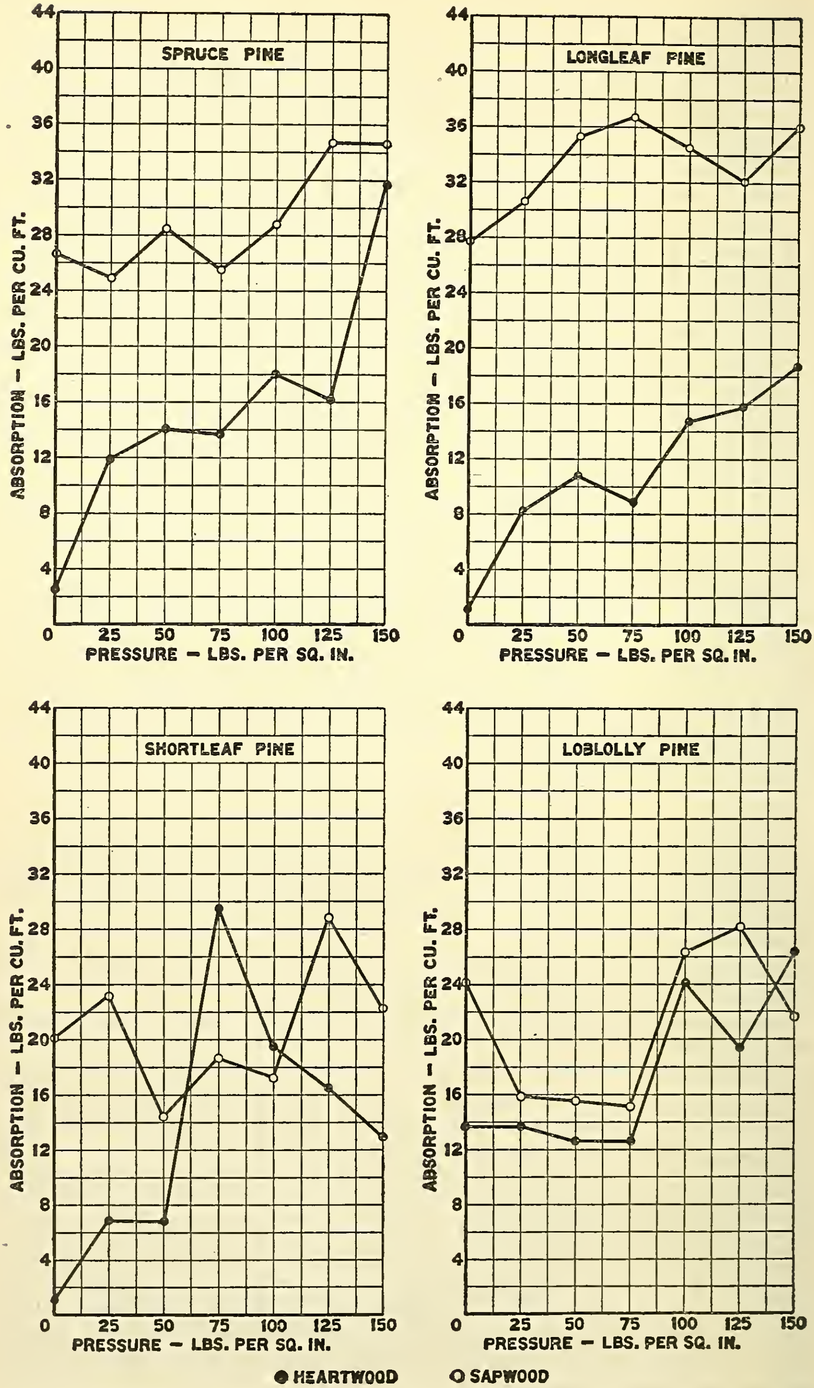


FIG. 9.—Absorption in the heartwood and sapwood of spruce pine, longleaf pine, shortleaf pine, and loblolly pine.

The sapwood was extremely easy to treat. The oil penetrated radially in from 5 to 10 seconds and ran from the tangential surfaces in streams. After removal the pieces were found to be saturated with creosote.

The heartwood pieces treated in the cylinder appeared to have been treated more thoroughly than those in the penetrance apparatus. Penetration took place probably through the radial ducts, but it was not accomplished without the use of pressure. The piece in the nonpressure run was treated in the summerwood only, and then only from 1 to 2 inches deep, longitudinally. The summerwood was in most cases more heavily treated than the springwood, but the latter was frequently treated at the ends of the tracheids near the rays, where masses of dark-colored oil would collect. In the sap the summerwood was in all cases heavily treated. The springwood treated erratically in some places as heavily as summerwood, in others only lightly. In this respect the species resembled longleaf pine. Much of the springwood contained golden-yellow oil as distinguished from the brownish-black oil filling the summerwood.

Except for the greater resistance, the general character of the penetrations in this species was similar to that in longleaf pine. The average longitudinal penetration was about 8 times the radial and 55 times the average tangential penetrations.

LOBLOLLY PINE (PINUS TÆDA).

In the specimens of loblolly pine the growth was very rapid, some of the rings being over one-half inch wide; the springwood usually was somewhat wider than the summerwood. Resin passages were numerous, very large, chiefly in the summerwood, and contained tyloses. Radial ducts were numerous. The length of tracheids varied from 40 to 100 times their width.

The average oven-dry weight per cubic foot of four heart specimens was 33.1 pounds, and of seven sap specimens 32.1 pounds.

In the heart the summerwood was more easily penetrated than the springwood, and resin ducts were an important factor in the penetrations. Springwood ducts were not treated as far as summerwood ducts, although the springwood itself was quite easily penetrated, and in heavily treated portions the absorption appeared to be nearly as heavy as in the summerwood. The medullary rays were treated about as heavily as the springwood.

The sapwood was penetrated very rapidly, and within a few seconds after applying pressure the oil ran from the tangential surfaces in streams through the resin ducts. The pieces were also penetrated longitudinally within a few seconds. The summerwood was in all cases heavily treated, but the springwood only partially. Had the latter been longer under pressure, however, it also would probably have been fully treated. Creosote collected in the rays and in the ends of the spring tracheids which frequently also were treated for their entire length. Most spring tracheids appeared to be stained when not filled with oil.

In the cylinder most heartwood pieces treated rapidly in both springwood and summerwood. In the piece treated without pressure some springwood bands were found where the resin ducts were penetrated, although the surrounding springwood remained untreated. Many of the medullary rays were treated lightly, and all of the ray ducts appeared to be filled with oil.

In sapwood both springwood and summerwood were heavily treated. The summerwood, however, appeared to be more heavily treated than the springwood. All of the latter was stained, and there was evidence of the presence of oil much lighter in color than that in the summerwood. Many spring tracheids were heavily treated, especially at the ends near the medullary rays.

In general, this species was very easy to penetrate in both heart and sap wood. There was no great differences between the appearance of this species after treatment and that of longleaf and shortleaf pines.

The average longitudinal penetration in the heartwood was about 20 times the average radial and 80 times the average tangential penetration.

TABLE 2.—*Order of species in respect to longitudinal and radial penetrations and absorptions.*

Species.	Character of wood.	Penetrance tests.					Impregnation tests, absorption per cubic foot.	Order of species in respect to—			Average dry weight per cubic foot.
		Number of specimens in average.	Average time of treatment.	Time required to penetrate 12 inches.	Average longitudinal penetration.	Average radial penetration.		Longitudinal penetration.	Radial penetration.	Absorption.	
			Min.	*Min.*	*In.*	*In.*	*Lbs.*				*Lbs.*
Douglas fir	Heart.	3	70	....	0.57	0.05	4.38	1	2	4	32.5
Tamarack	...do...	3	70	35	.87	.04	1.26	2	1	1	33.5
Lodgepole pine	...do...	3	52	....	.98	.63	12.84	3	25	12	25.1
Spruce pine	...do...	3	70	....	1.65	.30	17.58	4	20	26	34.4
Alpine fir	...do...	3	70	....	1.73	.11	3.66	5	7	2	25.2
Shortleaf pine	...do...	3	70	....	[1] 2.75	.35	15.36	6	21	17	39.7
Engelmann spruce	...do...	3	75	....	2.83	.83	8.64	7	27	7	27.2
Western larch	...do...	3	70	15	3.17	.09	15.72	8	11	18	34.1
White spruce	...do...	3	70	....	3.27	.09	6.42	9	9	5	25.6
Yew	...do...	3	70	....	3.42	.08	12.36	10	8	9	38.8
Western yellow pine, Montana	...do...	3	70	....	4.42	1.25	16.14	11	29	20	25.0
Jack pine	...do...	3	70	....	4.43	1.27	12.36	12	30	8	28.8
Redwood	...do...	3	77	....	4.58	..16	18.78	13	16	29	20.5
Alpine fir	Sap...	3	70	....	5.50	.07	4.14	14	6	3	22.7
Noble fir	Heart.	3	65	14	5.83	.12	12.60	15	14	11	24.1
Douglas fir	Sap...	3	70	20	6.10	.43	14.46	16	23	15	30.9
Eastern hemlock	Heart.	3	70	35	6.67	.07	17.28	17	5	25	23.4
Do	Sap...	2	45	....	6.75	.05	18.78	18	3	28	20.3
Redwood	...do...	3	70	....	6.87	.13	21.06	19	15	33	20.2
Western hemlock	Heart.	3	70	30	7.42	.06	17.16	20	4	24	30.8
Western yellow pine, California.	...do...	4	61	48	7.60	.72	16.08	21	26	19	28.9
Western hemlock	Sap...	3	70	30	8.27	.09	17.04	22	10	23	32.0
Loblolly pine	Heart.	3	60	½	8.33	.85	18.12	23	28	27	35.9
White fir	Sap...	3	65	15	9.00	.18	18.96	24	18	30	24.1
Sitka spruce	...do...	3	45	9	9.33	.10	16.98	25	13	22	19.7
Lodgepole pine	...do...	3	21	½ to 40	9.67	([2])	31.56	26	37	38	23.6
Longleaf pine	Heart.	3	70	16	9.83	.38	12.90	27	22	13	39.2
White fir	...do...	3	70	24	10.05	.20	21.54	28	19	34	23.4
Noble fir	Sap...	3	70	3	10.33	.18	16.20	29	17	21	24.8
Western yellow pine, California.	...do...	3	15	10	4.50	[3] .54	15.12	30	24	16	29.8
Sitka spruce	Heart.	2	70	23	12.00	.09	13.44	31	12	14	18.5
Spruce pine	Sap...	3	3	5	[4] 12.00	([2])	29.46	32	33	37	30.8
Engelmann spruce	...do...	3	2	½	6.83	.37	22.20	33	31	35	30.9
Shortleaf pine	...do...	3	2	½	[4] 12.00	([2])	20.76	34	32	32	35.3
Longleaf pine	...do...	3	1	1	[4] 12.00	([2])	34.20	35	35	39	25.2
Western yellow pine, Montana.	...do...	3	1½	½	[4] 12.00	([2])	28.74	36	34	36	25.9
Loblolly pine	...do...	3	½	½	[4] 12.00	([2])	20.40	37	36	31	37.3
White spruce	...do...	......	......	......	......	......	8.22	......	......	6	26.1
Jack pine	...do...	......	......	......	......	......	12.42	......	......	10	30.7

[1] See discussion on page 33 of Appendix.

[2] Complete. Since the radial penetration of lodgepole, spruce, shortleaf, longleaf, and western yellow (Montana), and loblolly pine was complete in each case, the relative order of these species is not significant.

[3] Treated for 15 minutes only and penetrated same distance as heartwood in an equal time.

[4] Complete.

NOTE.—When penetration was complete it was not more than 12 inches, as the specimens could be penetrated a total distance longitudinally of only 12 inches. Complete radial penetration varied in different specimens. The minimum for complete penetration radially was 1 inch, and the maximum 1.50 inches. This depended upon the direction of the annual rings in reference to the surface of the specimen.

TABLE 3.—*Proposed grouping of species for treatment.*

Class.	Species.	Penetration. Longitudinal.	Penetration. Radial.	Absorption per cubic foot.
		In.	*In.*	*Pounds.*
I	Alpine fir, heartwood	1.73	0.11	3.66
	Yew, heartwood[1]	3.42	.08	12.36
	Alpine fir, sapwood	5.50	.07	4.14
II	Douglas fir, heartwood	.57	.05	4.38
	Tamarack, heartwood[1]	.87	.04	1.26
	White spruce, heartwood[2]	3.27	.09	6.42
III	Western larch, heartwood	3.17	.09	15.72
	Redwood, heartwood	4.58	.16	18.78
	Noble fir, heartwood	6.07	.12	12.60
	Eastern hemlock, heartwood	6.66	.07	17.28
	Eastern hemlock, sapwood	6.75	.05	18.78
	Redwood, sapwood	6.83	.13	21.06
	Western hemlock, heartwood	7.42	.06	17.16
	Western hemlock, sapwood	8.27	.09	17.04
	White fir, sapwood	9.00	.18	18.96
	Sitka spruce, sapwood	9.33	.10	16.98
	White fir, heartwood	10.05	.20	21.54
	Noble fir, sapwood	10.33	.18	16.20
	Sitka spruce, heartwood	12.00	.09	13.44
IV	Lodgepole pine, heartwood	.98	.63	12.84
	Spruce pine, heartwood	1.65	.30	17.58
	Shortleaf pine, heartwood	2.75	.35	15.36
	Engelmann spruce, heartwood	2.83	.83	8.64
	Western yellow pine, heartwood	4.42	1.25	16.14
	Jack pine, heartwood	4.43	1.27	12.36
	Western yellow pine, California, heartwood	7.60	.72	16.08
	Longleaf pine, heartwood	9.83	.38	12.90
	Loblolly pine, heartwood	8.33	.85	18.12
V	Tamarack, sapwood	Penetration not determined. All except white spruce known to treat very easily.		
	Western larch, sapwood			
	Jack pine, sapwood			
	White spruce, sapwood			
	Western yellow pine, California, sapwood	4.50	0.54	15.12
	Douglas fir, sapwood	6.10	.43	14.46
	Engelmann spruce, sapwood	6.83	.37	22.20
	Lodgepole pine, sapwood	9.67	(3)	31.56
	Spruce pine, sapwood	(3)	(3)	29.46
	Western yellow pine, sapwood	(3)	(3)	28.74
	Longleaf pine, sapwood	(3)	(3)	34.20
	Shortleaf pine, sapwood	(3)	(3)	20.76
	Loblolly pine, sapwood	(3)	(3)	20.40

[1] Sapwood not available for either penetrance or impregnation tests.
[2] Sapwood not available for penetrance tests.
[3] Complete.

TABLE 4.—*Results of penetrance tests on individual pieces.*

YEW—HEARTWOOD.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches. First end.	Time required to penetrate 12 inches. Second end.	Penetrations. Longitudinal. Average.	Penetrations. Longitudinal. Maximum.	Penetrations. Radial. Average.	Penetrations. Radial. Maximum.	Penetrations. Tangential. Average.	Penetrations. Tangential. Maximum.
	Per ct.		*Lbs.*	*Min.*	*°F.*	*Lbs.*	*Min.*	*Min.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
3	10.4	21.0	38.0	30	145	89	(1)	(1)	2.50	5.00	0.08	0.10	0.06	0.08
2	15.3	16.0	35.8	60	145	87	(1)	(1)	3.50	6.60	.10	.10	.06	.08
1	16.6	26.0	40.7	120	145	90	(1)	(1)	4.25	9.20	.06	.10	.06	.10
Average	14.1	21.0	38.2	70	145	89	(1)	(1)	3.42	6.93	.08	.10	.06	.09

[1] Creosote did not penetrate to end of specimens.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches.		Penetrations.					
									Longitudinal.		Radial.		Tangential.	
							First end.	Second end.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
	Per ct.		Lbs.	Min.	°F.	Lbs.	Min.	Min.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
ALPINE FIR—HEARTWOOD.														
308	11.6	21.8	22.6	30	135	90	[1]	[1]	0.70	4.20	0.10	0.15	0.05	0.10
307	11.9	20.4	22.0	60	143	90	[1]	[1]	2.20	6.60	.08	.10	.08	.10
309	13.2	17.1	20.9	120	143	90	[1]	[1]	2.30	7.40	.15	.20	.10	.12
Average	12.2	19.8	21.8	70	140	90	[1]	[1]	1.73	6.07	.11	.15	.08	.11
ALPINE FIR—SAPWOOD.														
301	12.3	15.0	20.9	30	143	90	[1]	[1]	5.0	5.5	0.05	0.15	0.05	0.10
302	9.7	14.5	22.6	60	133	90	[1]	[1]	6.0	7.0	.10	.10	.15	.30
303	11.6	14.6	22.4	120	152	90	[1]	75	5.5	9.0	.05	.10	.15	.30
Average	11.2	14.7	22.0	70	143	90	[1]	[1]	5.5	7.2	.07	.12	.12	.23
REDWOOD—HEARTWOOD.														
118	13.6	19.3	19.9	60	140	88	[1]	[1]	4.20	10.4	0.20	0.25	0.18	0.25
117	9.5	18.7	20.2	68	130	85	[1]	[1]	3.80	10.9	.15	.18	.15	.30
121	18.1	18.6	19.5	102	136	82	[1]	[1]	5.75	12.0	.13	.16	.10	.32
Average	13.7	18.9	19.9	77	135	85	[1]	[1]	4.58	11.1	.16	.20	.14	.29
REDWOOD—SAPWOOD.														
85	......	26.2	20.1	31	138	88	[1]	[1]	5.75	12.0	0.14	0.16	0.10	0.35
88	13.2	27.3	27.2	60	142	78	[1]	[1]	9.25	12.0	.11	.13	.09	.11
86	12.7	29.7	28.0	120	140	85	[1]	[1]	5.60	8.1	.13	.15	.09	.16
Average	13.0	27.7	25.1	70	140	84	[1]	[1]	6.87	10.7	.13	.15	.09	.21
EASTERN HEMLOCK—HEARTWOOD.														
256	11.8	35.9	22.20	30	139	88	30	......	5.50	12.0	0.08	0.10	0.06	0.08
265	10.5	23.6	21.60	60	139	89	30	30	7.50	12.0	.09	.11	.10	.30
259	9.4	25.0	24.70	120	144	86	45	60	7.0	12.0	.05	.10	.10	.35
Average	10.6	28.2	22.83	70	141	88	......	......	6.67	12.0	.07	.10	.09	.24
EASTERN HEMLOCK—SAPWOOD.														
251	11.9	24.5	18.40	30	141	89	5	30	8.5	12.0	0.05	0.08	0.10	0.12
254	14.5	31.7	18.60	60	135	87	......	30	5.0	12.0	.05	.08	.10	.16
Average	13.2	28.1	18.50	45	138	88	......	......	6.75	12.0	.05	.08	.10	.14
WESTERN HEMLOCK—HEARTWOOD.														
92	12.6	10.8	25.6	30	142	87	[1]	[1]	8.50	12.0	0.06	0.15	0.09	0.13
95	10.4	12.6	27.9	60	137	88	30	[1]	5.00	12.0	.05	.10	.05	.10
91	7.8	13.1	27.9	120	133	85	30	[1]	8.75	12.0	.06	.15	.10	.15
Average	10.3	12.2	27.1	70	137	87	......	......	7.42	12.0	.06	.13	.08	.13

[1] Creosote did not penetrate to end of specimens.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches.		Penetrations.					
									Longitudinal.		Radial.		Tangential.	
							First end.	Second end.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
	Per ct.		*Lbs.*	*Min.*	°*F.*	*Lbs.*	*Min.*	*Min.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
WESTERN HEMLOCK—SAPWOOD.														
89	8.3	20.5	28.6	30	124	84	30	(1)	8.50	12.0	0.06	0.08	0.11	0.20
86	13.1	26.4	28.0	60	138	83	(1)	(1)	8.30	12.0	.08	.12	.12	.32
90	13.2	22.0	27.5	120	135	80	30	(1)	8.00	12.0	.12	.15	.13	.30
Average	11.5	23.0	28.0	70	132	82	......	......	8.27	12.0	.09	.12	.12	.27
ENGLEMANN SPRUCE—HEARTWOOD.														
172	9.4	24.5	23.82	45	128	89	(1)	(1)	2.50	3.50	0.50	1.10	0.05	0.05
178	10.5	12.2	25.28	60	151	90	(1)	(1)	4.0	6.50	1.00	1.30	.05	.05
157	8.0	10.9	25.89	120	151	88	(1)	(1)	2.0	6.0	1.00	1.00	.08	.08
Average	9.3	15.9	25.00	75	143	89	......	......	2.83	5.33	.83	1.13	.06	0.6
ENGLEMANN SPRUCE—SAPWOOD.														
134	7.3	44.4	26.85	1	115	89	½	½	6.0	12.0	0.50	0.80	0.30	0.50
148	13.6	21.8	26.88	2	118	89	1	1	2.50	12.0	.30	.90	.08	.10
190	21.0	42.0	25.60	2	120	89	Immediately.		12.0	12.0	.30	.60–1.6	.05	.05
Average	14.0	36.1	26.44	2	118	89	......	......	6.8	12.0	.36	.98	.14	.22
WESTERN LARCH—HEARTWOOD.														
226	10.3	55.0	30.78	30	141	76	(1)	(1)	1.00	3.4	0.06	0.30	0.07	0.10
211	11.2	58.0	29.13	60	151	89	15	30	5.00	12.0	.10	.80	.12	.30
210	8.9	60.0	30.70	120	140	80	15	30	3.50	12.0	.10	.10	.12	.30
Average	10.1	58	30.20	70	144	82	......	......	3.17	9.1	.09	.40	.10	.23
TAMARACK—HEARTWOOD.														
312	12.3	13.6	32.1	30	143	87	30	30	0.50	12.0	0.02	0.05	0.02	0.05
313	12.1	14.0	30.4	60	134	90	45	30	1.50	12.0	.05	.10	.05	.10
311	12.1	14.4	30.4	120	139	86	30	30	.60	12.0	.05	.10	.05	.10
Average	12.2	14.0	31.0	70	139	88	......	......	.87	12.0	.04	.08	.04	.08
LODGEPOLE PINE—HEARTWOOD.														
167	13.7	5.9	22.62	35	134	87	(1)	(1)	0.20	2.00	1.00	1.20	(2)	(2)
138	12.5	5.9	22.43	60	133	90	(1)	(1)	.50	2.50	.30	1.00	(2)	(2)
166	9.7	6.4	23.02	60	148	90	(1)	(1)	2.25	4.00	.60	1.20	(2)	(2)
Average	12.0	6.1	22.69	52	138	89	......	......	.98	2.83	.63	1.13	......	......

[1] Creosote did not penetrate to end of specimens.

[2] Could not be determined.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches.		Penetrations.					
									Longitudinal.		Radial.		Tangential.	
							First end.	Second end.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
	Per ct.		*Lbs.*	*Min.*	*°F.*	*Lbs.*	*Min.*	*Min.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
LODGEPOLE PINE—SAPWOOD.														
145	12.4	7.9	23.06	1	......	......	[1]	½–¾	10.00	12.0	[2]	[2]	[3]	[3]
149	39.3	7.8	22.18	1	......	......	40	40	10.0	12.0	[2]	[2]	[3]	[3]
150	16.1	6.5	22.41	60	......	......	[1]	20	9.0	12.0	[2]	[2]	[3]	[3]
Average	22.6	7.4	22.55	21	......	......	......	......	9.67	12.0	......	......	......	......
JACK PINE—HEARTWOOD.														
296	17.6	7.7	24.1	30	132	88	[4]	[4]	3.10	6.60	0.80	1.20	0.10	0.10
298	12.9	8.6	25.1	60	137	90	[4]	[4]	4.0	9.6	1.60	1.60	.10	.20
297	13.9	8.6	23.9	120	150	91	[4]	[4]	6.2	8.8	1.40	1.60	.10	.10
Average	14.8	8.3	24.4	70	140	90	......	......	4.43	8.33	1.26	1.47	.10	.13
BULL PINE—HEARTWOOD.														
98	17.3	8.6	24.7	30	77	140	18	[4]	4.0	5.0	0.40	0.50	0.15	0.20
99	10.1	15.0	25.1	80	77	145	80	[4]	10.0	12.0	1.12	1.25	.22	.30
97	19.2	13.0	24.7	115	80	154	45	[4]	12.0	12.0	1.25	1.37	.20	.50
101	37.0	......	25.2	17	76	148	[4]	[4]	4.40	5.60	.12	.25	.06	.10
Average	20.9	12.2	24.9	60	77	147	......	......	7.6	8.7	.72	.84	.16	.28
BULL PINE—SAPWOOD.														
103	13.6	21.3	27.1	15	80	150	15	[4]	3.50	12.0	0.50	1.00	1.12	0.20
104	9.6	......	26.5	15	76	143	2	4	4.0	12.0	.22	.30	.05	.10
107	16.2	......	29.4	15	74	140	12	[4]	6.00	12.0	.90	1.10	.35	.40
Average	13.1	21.3	27.7	15	77	144	......	......	4.50	12.0	.54	.80	.17	.23
WHITE FIR—HEARTWOOD.														
208	15.6	7.1	22.03	30	136	88	19	30	11.0	12.0	0.20	0.30	0.30	0.50
224	13.9	6.8	21.83	60	128	87	23	60	7.75	12.0	.20	.25	.20	.25
140	11.7	6.8	21.68	120	143	89	30	45	11.50	12.0	.20	.30	.25	.32
Average	13.7	6.9	21.85	70	136	88	......	......	10.08	12.0	.20	.28	.25	.36
WHITE FIR—SAPWOOD.														
162	18.3	10.7	21.84	15	129	85	15	[4]	12.0	12.0	0.30	0.60	0.50	0.90
158	8.9	8.5	23.62	60	135	87	16	26	8.00	12.0	.15	.18	.25	.37
197	9.7	7.7	23.09	120	131	88	15	60	7.00	12.0	.10	.25	.20	.43
Average	12.3	9.0	22.85	65	132	87	......	......	9.00	12.0	.19	.34	.32	.57
NOBLE FIR—HEARTWOOD.														
267	......	17.8	24.7	30	129	87	10	15	8.0	12.0	0.05	0.08	0.10	0.20
279	8.7	15.0	22.6	60	145	90	[4]	[4]	4.5	7.5	.10	.20	.15	.30
276A	......	14.1	......	105	137	90	18	25	5.0	12.0	.20	.30	.20	.25
Average	8.7	15.6	23.6	65	137	89	......	......	5.8	10.5	.12	.20	.15	.25

[1] Radially.
[2] Complete.
[3] Could not be determined.
[4] Creosote did not penetrate to end of specimens.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches. First end.	Time required to penetrate 12 inches. Second end.	Penetrations. Longitudinal. Average.	Penetrations. Longitudinal. Maximum.	Penetrations. Radial. Average.	Penetrations. Radial. Maximum.	Penetrations. Tangential. Average.	Penetrations. Tangential. Maximum.
	Per ct.		*Lbs.*	*Min.*	*°F.*	*Lbs.*	*Min.*	*Min.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
NOBLE FIR—SAPWOOD.														
272	10.8	27.3	22.2	30	144	90	5½	12	10.0	12.0	0.30	0.40	0.10	0.15
276	8.9	19.1	25.4	60	142	90	1	15	9.0	12.0	.10	.10	.30	.50
266	13.6	29.5	23.4	120	140	89	3	15	12.0	12.0	.15	.15	.90	.90
Average	11.1	25.3	23.7	70	142	90	......	......	10.3	12.0	.18	.22	.43	.52
DOUGLAS FIR—HEARTWOOD.														
110	12.9	13.9	28.3	30	137	88	(1)	(1)	0.30	5.0	0.03	0.08	0.04	0.09
111	7.5	12.2	27.0	60	138	88	(1)	(1)	.60	12.0	.05	.12	.05	.09
108	10.9	15.0	28.0	120	142	88	(1)	(1)	.80	9.0	.08	.10	.08	.10
Average	10.4	13.7	27.8	70	139	88	......	......	.57	8.6	.05	.10	.06	.09
DOUGLAS FIR—SAPWOOD.														
112	15.4	21.4	26.9	30	139	86	25	(1)	5.10	12.0	0.40	1.00	0.05	0.10
113	10.9	26.0	26.5	60	136	87	15	45	5.20	12.0	.40	1.00	.05	.10
115	15.3	21.7	27.3	120	141	87	(1)	(1)	8.00	12.0	.50	1.00	.07	.12
Average	13.9	23.0	26.9	70	139	87	......	......	6.10	12.0	.43	1.00	.06	.11
SITKA SPRUCE—HEARTWOOD.														
220	14.5	9.3	17.47	30	144	84	1/30	1/30	12.0	12.0	0.08	0.12	0.08	0.20
209	13.8	4.1	15.85	60	147	85	30	30	12.0	12.0	.10	.15	.06	.15
219	9.5	8.6	17.86	120	140	84	15	15	12.0	12.0	.10	.20	.20	.20
Average	12.6	7.3	17.06	70	144	84	......	......	12.0	12.0	.09	.16	.11	.17
SITKA SPRUCE—SAPWOOD.														
212	......	11.4	18.86	......	......	......	Instantly.		4.0	12.0	0.08	0.20	0.15	0.25
223	7.4	11.8	19.06	30	144	86	12	14	12.0	12.0	.10	.20	.12	.20
228	11.3	12.3	18.60	60	144	87	15	15	12.0	12.0	.10	.14	.18	.25
Average	9.3	11.8	18.84	45	144	86.5	......	......	9.3	12.0	.09	.18	.15	.22
WHITE SPRUCE—HEARTWOOD.														
285	10.3	10.9	24.7	30	150	85	(1)	(1)	3.30	8.30	0.05	0.10	0.05	0.15
289	14.7	18.2	22.6	60	146	86	(1)	(1)	2.00	7.50	.06	.08	.05	.10
290	9.5	10.0	23.9	120	146	86	(1)	(1)	4.50	8.75	.15	.20	.15	.20
Average	11.5	13.0	23.7	70	147	86	......	......	3.27	8.18	.09	.13	.08	.15
WESTERN YELLOW PINE—HEARTWOOD.														
187	12.0	8.2	23.93	30	145	87	(1)	(1)	5.25	6.30	1.25	1.25	0.05	0.10
245	......	10.5	24.81	60	143	87	(1)	(1)	6.50	8.00	(2)	1.30	......	.05
200	13.6	8.6	23.81	120	139	85	(1)	(1)	1.50	2.20	1.20	1.80	......	......
Average	12.8	9.1	24.18	70	142	86	......	......	4.42	5.50	1.23	1.45	......	......

[1] Creosote did not penetrate to end of specimens. [2] Complete.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

WESTERN YELLOW PINE—SAPWOOD.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches.		Penetrations.					
									Longitudinal.		Radial.		Tangential.	
							First end.	Second end.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
	Per ct.		Lbs.	Min.	°F.	Lbs.	Min.	Min.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
156	10.2	16.4	23.60	1	138	88	$\frac{1}{3}$	$\frac{1}{3}$	12	12	(1)	1.00	0.22	0.20
142	21.2	15.4	22.25	2	130	88	$\frac{1}{6}$	$\frac{1}{4}$	12	12	(1)	1.00	.25	.3
238	9.1	16.8	23.82	1	126	88	$\frac{5}{12}$	......	12	12	(1)	1.00	......	......
Average	13.5	16.2	23.22	1	131	88	......	......	12	12	1.00	1.00	.24	.29

SPRUCE PINE—HEARTWOOD.

231	12.3	3.4	33.24	30	137	86	(2)	(2)	2.00	3.50	0.30	0.40	0.10	0.10
186	9.4	3.7	32.78	60	138	88	(2)	(2)	1.45	2.60	.30	.95	.10	.15
206	11.4	3.6	32.16	120	133	87	(2)	(2)	1.50	3.10	.30	.70	.10	.10
240[1]	13.0	4.3	29.78	3	......	89	(3)	(3)	(1)	(1)	(1)	(1)	......	......
225[1]	......	......	30.50	3	......	85	(3)	(3)	(1)	(1)	(1)	(1)	......	......
Average	11.5	3.6	32.73	70	136	87	......	......	1.65	3.07	.30	.68	.10	.12

SPRUCE PINE—SAPWOOD.

141	10.5	7.7	25.48	2	130	87	2	2	(1)	(1)	(1)	(1)	......	......
164	15.2	8.2	25.01	2	114	89	2	2	(1)	(1)	(1)	(1)	......	......
141	13.0	8.6	23.33	15	120	87	11	13	(1)	(1)	(1)	(1)	......	......
Average	12.9	8.2	24.61	6	121	88	......	......	......	......	......	......	......	......

LONGLEAF PINE—HEARTWOOD.

248	10.4	9.3	35.05	30	143	86	(2)	10	8.0	12.0	0.25	0.45	0.10	0.10
135	7.2	17.1	35.04	60	133	82	(2)	25	10.50	12.0	.40	.55	.10	.10
242	1.9	10.0	39.31	120	141	80	(2)	12	11.0	12.0	.50	.70	.10	.10
Average	12.2	12.1	36.47	70	139	83	......	......	9.83	12.0	.38	.57	.10	.10

LONGLEAF PINE—SAPWOOD.

143	18.5	20.5	22.48	$\frac{3}{4}$	130	83	(2)	(2)	(1)	(1)	(1)	(1)	(1)	(1)
136	17.4	26.4	22.03	$\frac{3}{4}$	120	83	$\frac{3}{4}$	(2)	(1)	(1)	(1)	(1)	(1)	(1)
202	17.7	25.5	22.27	1	125	83	(2)	(2)	(1)	(1)	(1)	(1)	(1)	(1)
Average	17.9	24.1	22.26	$\frac{5}{6}$	125	83	......	......	......	......	......	......	......	......

SHORTLEAF PINE—HEARTWOOD.

181	6.2	15.4	39.77	30	137	86	(2)	(2)	2.00	3.00	0.30	0.50	0.05	0.05
153	11.5	14.1	36.87	60	133	88	(2)	(2)	2.50	4.50	.30	.60	.05	.10
230	8.77	16.8	40.12	120	148	89	(2)	(2)	3.75	5.50	.45	.60	.05	.05
Average	8.8	15.4	38.92	70	139	88	......	......	2.75	4.33	.35	.57	.05	.07

[1] Complete. [2] Creosote did not penetrate to end of specimens. [3] Not taken.

TABLE 4.—*Results of penetrance tests on individual pieces*—Continued.

Piece No.	Moisture.	Average number of rings per inch.	Oven-dry weight per cubic foot.	Total time of treatment.	Average temperature.	Average pressure per square inch.	Time required to penetrate 12 inches.		Penetrations.					
									Longitudinal.		Radial.		Tangential.	
							First end.	Second end.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
	Per ct.		*Lbs.*	*Min.*	*°F.*	*Lbs.*	*Min.*	*Min.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
SHORTLEAF PINE—SAPWOOD.														
207	12.3	13.6	31.96	1	154	88	[1]	[1]	[2]	[2]	[2]	[2]	......	......
203	14.6	13.5	30.10	2½	150	88	[1]	[1]	[2]	[2]	[2]	[2]	0.35	0.50
132	11.1	16.1	32.18	2½	146	86	1/12	1/6	[2]	[2]	[2]	[2]	.05	.10
Average	12.7	14.4	31.41	2	150	87	......	......	......	......	......	......	.20	.30
LOBLOLLY PINE—HEARTWOOD.														
213	9.7	3.5	32.49	1	132	87	[1]	[1]	2.50	8.50	0.20 .90	0.50 1.80	0.05	0.05
246	9.1	2.8	33.24	60	136	88	¾	[1]	[2]	[2]	.50 1.00	1.00 1.90	.20	.20
185	12.1	4.1	31.98	120	137	88	3	5	[2]	[2]	.75	1.00 1.50	.20	.20
Average	10.3	3.5	32.57	60	135	88	......	......	......	......	.35 .88	.83 1.73	.15	.15
LOBLOLLY PINE—SAPWOOD.														
241	7.9	8.7	30.15	½	130	87	[1]	[1]	[2]	[2]	[2]	[2]	0.50	1.00
299	7.5	7.7	34.0	¾	136	87	⅔	⅔	[2]	[2]	[2]	[2]	.25	.30
300	10.0	7.8	33.2	½	141	87	[1]	[1]	[2]	[2]	[2]	[2]	1.00	.50 1.50
Average	8.5	8.1	32.45	30	136	87	......	......	......	......	......	......	.58	.82

[1] Creosote did not penetrate to end of specimens. [2] Complete.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

▽

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 102

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 23, 1914.

(PROFESSIONAL PAPER.)

ACIDITY AS A FACTOR IN DETERMINING THE DEGREE OF SOUNDNESS OF CORN.

By H. J. Besley and G. H. Baston, *Assistants, Office of Grain Standardization.*

INTRODUCTION.

In January, 1910, the Office of Grain Standardization, Bureau of Plant Industry, undertook the investigation of corn (maize) acidity. At that time it was generally known that in all cases the amount of acid or the degree of acidity found in badly damaged or spoiled corn was far greater than the amount of acid or the degree of acidity found in corn which was sound and in good condition. This fact was well established by the researches of Black and Alsberg,[1] of the Department of Agriculture, and by the work of foreign chemists and other investigators [2] on the toxicity of spoiled corn.

It was for the purpose of ascertaining the range in the degree of acidity of commercial corn and to determine the reliability of the acid test as a criterion of quality and soundness of corn from the standpoint of commercial grading that the investigation herein described was undertaken.

METHOD, APPARATUS, AND REAGENTS.

DESCRIPTION OF METHOD.

Select a representative sample (about 100 grams) of corn to be tested and grind to such fineness that at least 80 per cent will pass through a 2-millimeter sieve. Weigh accurately duplicate samples of 10 grams and transfer each to a 300 c. c. wide-mouthed Erlen-

---

[1] Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 199, 36 p., 1910.

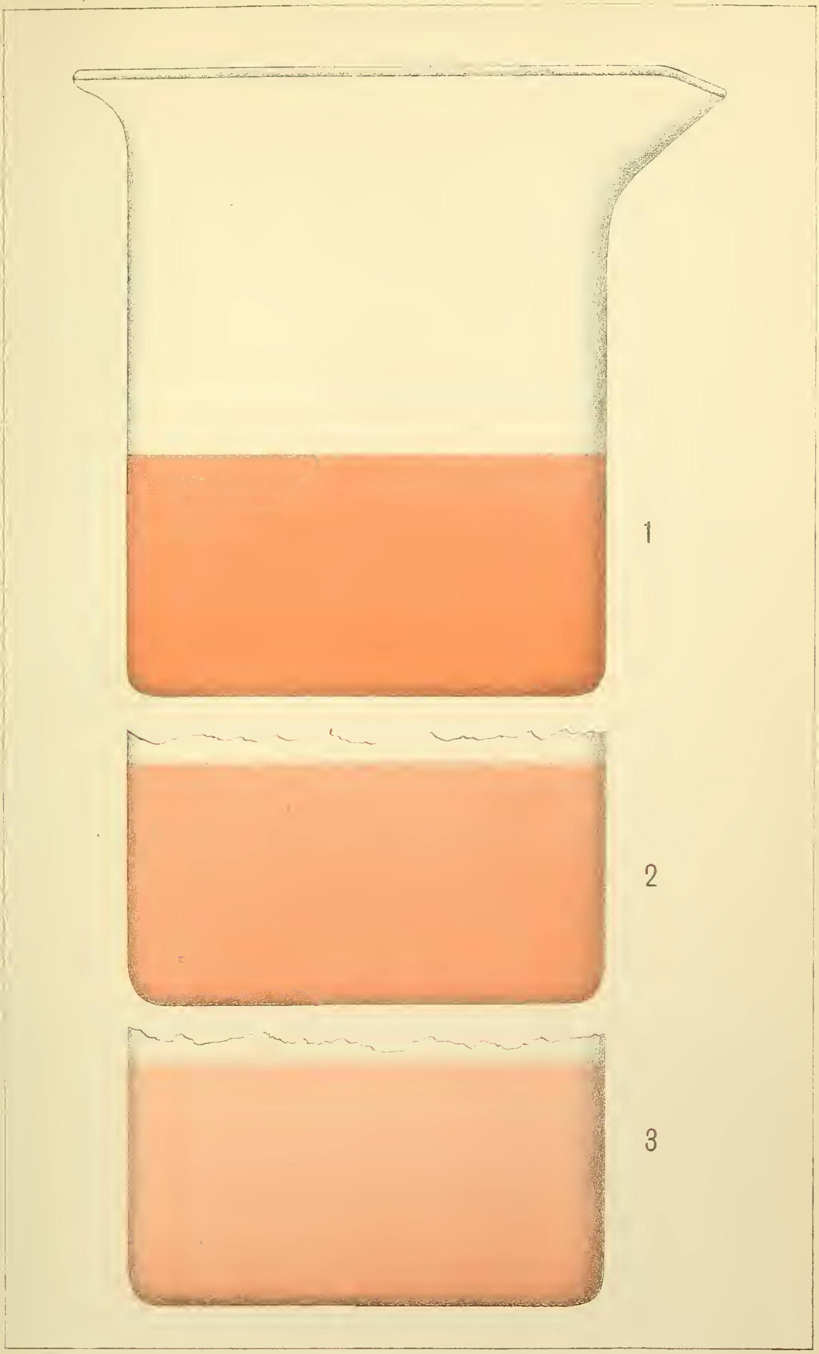
[2] Schindler, Josef. Anleitung zur Beurteilung des Maises und seiner Mahlprodukte mit Rücksicht auf ihre eignung als Nahrungsmittel. Innsbruck, 1909, 43 p., 1 pl.

Note.—This bulletin shows how the acid test may be used in the commercial grading of corn; it intended for chemists, grain buyers, and all who are interested in grading corn, more especially in the corn belt and at terminal markets.

42125°—14——1

meyer flask, then add 50 c. c. of 80 per cent alcohol, specific gravity 0.86, and stop the flask tight with a cork or rubber stopper. In order that the meal may be thoroughly and equally subjected to the action of the alcohol, carefully shake the flask with a whirling motion, avoiding a distribution of the meal on the sides of the flask. After shaking, let the meal digest in the alcohol over night (approximately 16 to 18 hours). After digestion filter through a dry filter paper. Place 25 c. c. of the clear filtrate in a 250 c. c. beaker and add 75 c. c. of distilled water and 1 c. c. of phenolphthalein solution and titrate with a one-hundredth normal alkali solution. The proteids dissolved in the alcohol are thrown out of solution when water is added, leaving a white precipitate, which makes it difficult to determine just what constitutes an end point in the titration. The end point that has been adopted is perhaps a slight degree over the point of neutrality, but it is necessary to carry the titration to a distinct color in order to get comparable results. This titration, as will be readily seen when making the determination, is different from most titrations, owing to the cloudy white precipitate formed on the addition of water to the alcoholic extract, which in a measure obscures the color. It will, however, be necessary to analyze corn ranging in color from pure white to deep yellow, where in each case the color of the extract is slightly different. One also has to deal with mixtures of white and yellow corn, where again another colored extract results, depending upon the relative quantity of white and yellow corn present in the sample. Plate I will help persons who perform this analysis for the first time to get the correct color. The colors shown represent titrations of yellow, mixed, and white corn, and it will be seen that the color of the liquid obtained at the end point is slightly different in each of the three cases. It is not expected that persons making this test shall match these colors exactly, but they are intended to give one as clear an idea of the color as can be shown on paper.

To correct the reading of the burette for the acid contained in the alcohol and phenolphthalein, make a blank by taking 25 c. c. of alcohol, 75 c. c. of distilled water, and 1 c. c. of phenolphthalein solution and titrate in the same manner as the corn extract. Subtract the reading thus obtained from the reading obtained by titrating the corn extract, and the result will represent the true acidity in 5 grams of corn. Multiply this result by 2, and it will represent the number of cubic centimeters of one-hundredth normal alkali required to neutralize the acid in 10 grams of corn, or the number of cubic centimeters of normal alkali required to neutralize the acid in 1,000 grams of corn. This result is termed the "degree of acidity" of the corn.



APPROXIMATE COLORS DETERMINING THE END POINT IN TITRATION OF CORN ACIDITY.
FIG. 1.—COLOR AT END POINT IN TITRATION OF YELLOW CORN. FIG. 2.—COLOR AT END POINT IN TITRATION OF MIXED CORN. FIG. 3.—COLOR AT END POINT IN TITRATION OF WHITE CORN.

APPARATUS.

A special apparatus is being perfected whereby the time of making acidity determinations can be reduced to approximately 30 minutes.

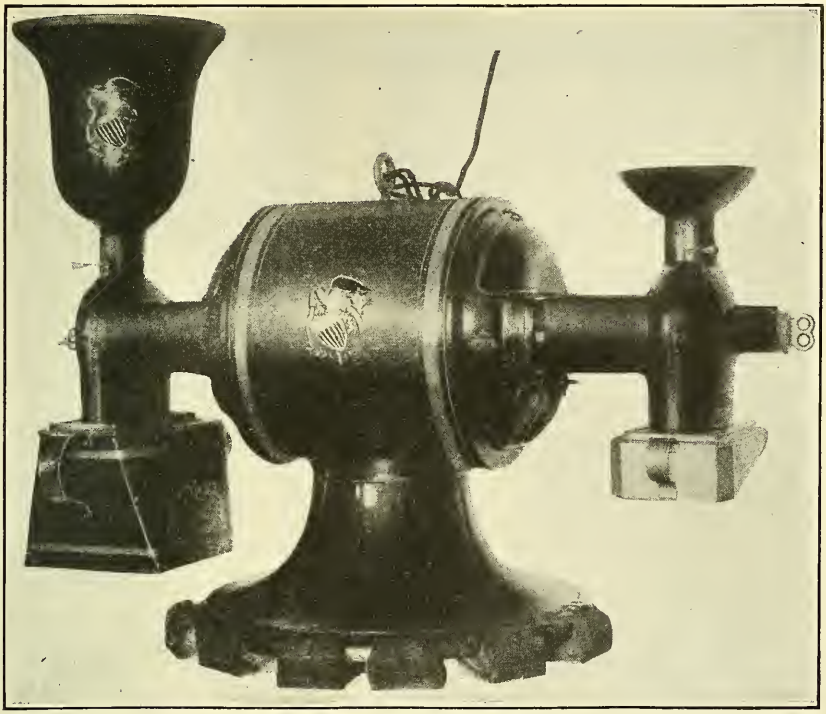


FIG. 1.—Power mill for grinding samples of corn.

Some mechanical defects have been found in the apparatus used in the preliminary investigations and further experimental work is

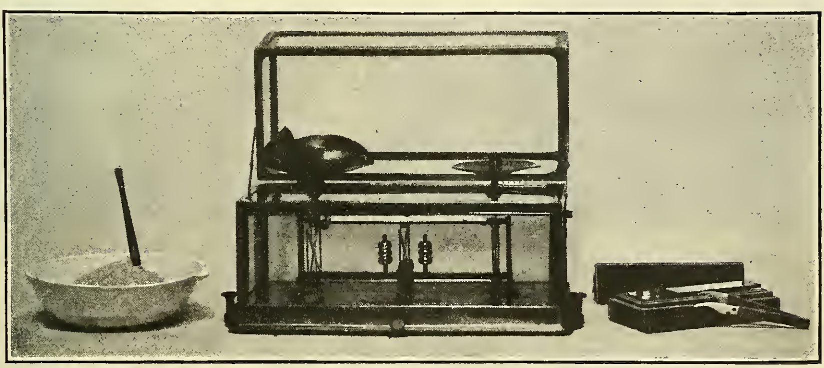


FIG. 2.—Balance, weights, and spatula.

necessary in order to correct these defects before the department would be justified in making a definite announcement.

LIST OF NECESSARY APPARATUS.

(1) Mill.
(2) Balance.
(3) Erlenmeyer flasks, cork or rubber stoppers to fit.
(4) Pipette, 50 c. c.
(5) Funnels, 3-inch.
(6) Graduates, 25 c. c.
(7) Beakers, 250 c. c.
(8) Burette, 50 c. c.
(9) Filter stand.
(10) Hydrometer, reading between 0.700 and 1,000.

DESCRIPTION OF APPARATUS.

Mill.—Any small hand mill can be used for grinding the samples, but where a large number of samples is to be handled, a power mill similar to the one shown in figure 1 is practically indispensable. Any make of power mill similar to the one illustrated will be found satisfactory.

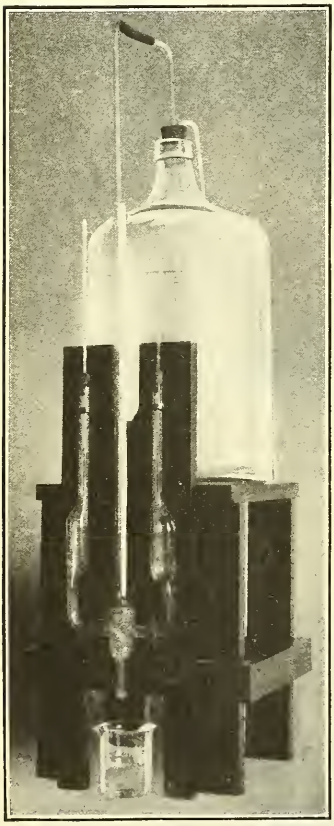


FIG. 3.—Bailey's automatic pipette (75 c. c.) connected with bottle of distilled water.

Balance.—Any chemical balance will answer for weighing the samples, but a balance like the one illustrated in figure 2 will greatly facilitate the work and will be found accurate and speedy and not as complicated as most chemical balances.

Pipettes.—Where only a few samples are to be analyzed, a 50 c. c. standardized pipette will serve for adding the alcohol, but where many samples are to be analyzed an automatic 50 c. c. burette, such as is illustrated in figure 4, will be a decided advantage. An ordinary standardized 75 c. c. pipette will suffice for measuring the water, but where many samples are to be handled an automatic 75 c. c. pipette (illustrated in fig. 3) will be a great help both in time and accuracy.

Burettes.—A 50 c. c. Squibbs burette will be found very satisfactory in titrating (fig. 5)

Filterstand.—A convenient filterstand is illustrated in figure 6. It accommodates 60 funnels and graduates and is a great space saver over many other types.

Drain stand.—A wooden stand like the one shown in figure 7 will be a great help in drying and protecting the glassware. This model can be easily moved about, enabling one to move many flasks or beakers at once, thus saving many steps and valuable time.

REAGENTS.

(1) Eighty per cent alcohol: The specific gravity of commercial 95 per cent alcohol is about 0.816. To make 80 per cent alcohol put

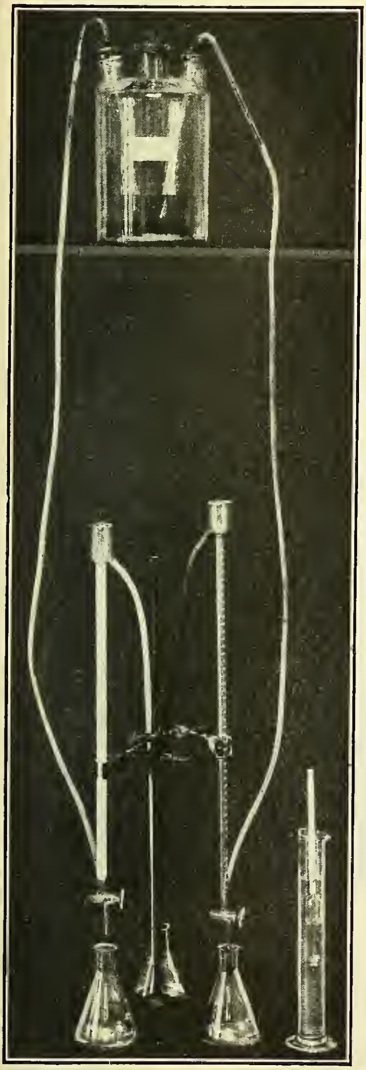


FIG. 4.—Automatic burette of 50 c. c. capacity used in adding 80 per cent alcohol. Hydrometer and cylinder used for preparing alcohol shown at the right.

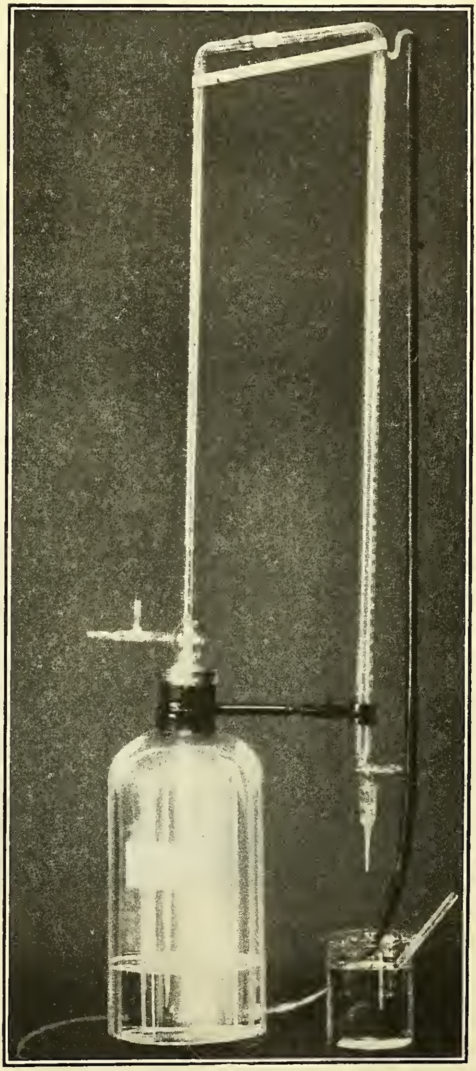


FIG. 5.—Squibb's automatic 50 c. c. burette.

the 95 per cent alcohol in any tall glass container, preferably a cylinder, and add water little by little until the hydrometer reads 0.86. Be careful to mix thoroughly after each addition of water.

(2) Standard alkali solution: Hundredth normal potassium hydroxid (KOH) solution has been found to be the solution best adapted for making this determination, but hundredth normal sodium hydroxid (NaOH) solution will be found satisfactory if potassium hydroxid is not obtainable. The standard alkali solution should be prepared from the fused KOH or NaOH sticks, purified by alcohol, or bought ready for use from a dealer in fine chemicals, as the one making the test desires. The solution is apt to deteriorate on standing for any considerable length of time, and for that reason it is best to buy or make up in small quantities.

(3) Phenolphthalein: A solution of phenolphthalein containing one gram of phenolphthalein in 300 c. c. of alcohol has been found to

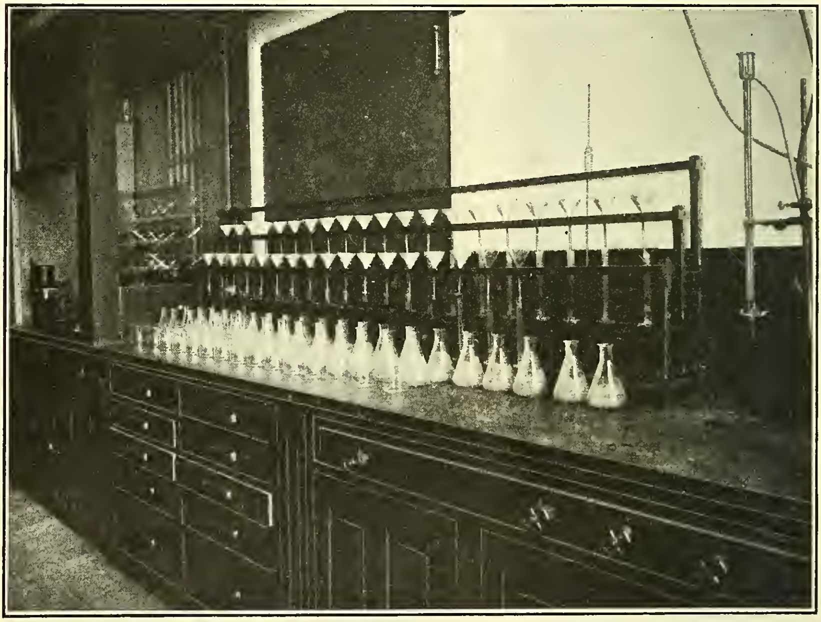


FIG. 6.—Filter stand, showing arrangement of funnels, graduates, flasks, and beakers.

be the most satisfactory indicator. Be careful to mix the solution thoroughly.

(4) Distilled water.

DEGREE OF ACIDITY OF CORN.

CORN SELECTED FOR SEED.

Table I shows the degree of acidity and the percentage of germination of corn selected for seed. The samples from the crop of 1912 represent Illinois corn selected by individual farmers. The samples from the crops preceding 1912 represent corn selected for seed by various State experiment stations, except that the samples from

Iowa were also selected by individual farmers throughout the State. All samples shown in Table I were tested for acidity and germination in the year 1912. The corn at the time of analysis was apparently of first-class quality and in excellent condition, although, as the results of the germination show, some of the samples were unfit for seed.

Analyses of approximately 10,000 samples of corn in this investigation showed a range in degree of acidity from 9 to over 100 c. c. In consideration of this wide range, Table I illustrates the uniform low degree of acidity found in corn selected for seed. Table I shows

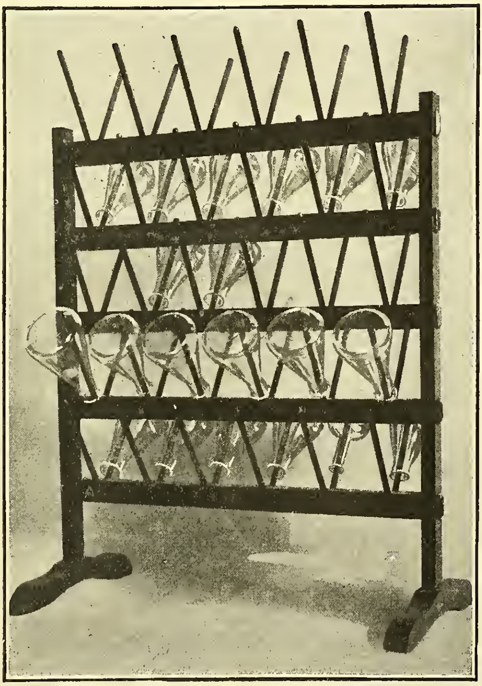


FIG. 7.—Drain stand.

further that, if properly harvested and carefully stored, corn can be kept for several years without suffering any great loss of viability or increasing abnormally in degree of acidity. Although this investigation shows that the degree of acidity is not an absolute criterion of the viability of corn, the results obtained firmly establish the direct relation of the degree of acidity to the percentage of germination.

A degree of acidity of 18 c. c. or below is evidence of a high percentage of germination, and the lower the degree of acidity is found to be the stronger is the evidence of high germinative power or strong viability in the seed.

TABLE I.—*Acidity and germination of corn selected for seed.*

Crop year and laboratory No.	Grown in State of—	Acidity.	Germination.	Crop year and laboratory No.	Grown in State of—	Acidity.	Germination.
Crop of 1906:		*C. c.*	*Per ct.*	Crop of 1912:		*C. c.*	*Per ct.*
38293 C...	Indiana..........	15.1	96	71990 W..	Illinois..........	14.6	95
Crop of 1908:				71991 W..	.....do..........	18.4	97
38133 C...	Ohio..........	20.5	96	71992 W..	.....do..........	15.0	100
38137 C...	Minnesota..........	21.5	100	71993 W..	.....do..........	15.8	94
Crop of 1909:				71994 W..	.....do..........	17.2	97
38445 C...	Missouri..........	23.8	56	72150 W..	.....do..........	15.0	99
38134 C...	Ohio..........	21.9	92	72151 W..	.....do..........	16.6	90
38138 C...	Minnesota..........	17.8	82	72152 W..	.....do..........	15.0	100
Crop of 1910:				72153 W..	.....do..........	15.0	100
39147 C...	Kansas..........	18.5	88	72154 W..	.....do..........	15.0	99
39148 C...	.....do..........	17.5	100	72155 W..	.....do..........	17.2	100
39149 C...	.....do..........	16.6	98	72156 W..	.....do..........	17.0	92
39150 C...	.....do..........	15.5	98	72157 W..	.....do..........	16.2	100
38446 C...	Missouri..........	23.2	42	72158 W..	.....do..........	16.6	97
38135 C...	Ohio..........	19.4	98	72159 W..	.....do..........	18.2	100
38139 C...	Minnesota..........	20.4	100	72160 W..	.....do..........	13.8	100
38294 C...	Indiana..........	22.5	[1] 34	72161 W..	.....do..........	16.6	96
38295 C...	.....do..........	20.6	88	72162 W..	.....do..........	14.8	98
38088 C...	Wisconsin..........	19.5	98	72163 W..	.....do..........	17.4	100
38090 C...	.....do..........	21.0	98	71563 W..	.....do..........	19.0	91
Crop of 1911:				71564 W..	.....do..........	16.8	99
38444 C...	Missouri..........	16.6	100	71565 W..	.....do..........	18.8	100
38447 C...	.....do..........	13.6	98	71566 W..	.....do..........	16.6	100
38136 C...	Ohio..........	18.2	96	71567 W..	.....do..........	17.4	100
38132 C...	Minnesota..........	19.5	98	71568 W..	.....do..........	16.4	100
38296 C...	Indiana..........	18.1	94	71569 W..	.....do..........	16.2	96
38087 C...	Wisconsin..........	18.7	100	71570 W..	.....do..........	18.4	100
38089 C...	.....do..........	15.9	100	71571 W..	.....do..........	16.4	99
38372 C...	Iowa..........	18.0	94	71572 W..	.....do..........	20.6	96
38373 C...	.....do..........	18.0	100	71573 W..	.....do..........	18.6	100
38374 C...	.....do..........	16.8	100	71574 W..	.....do..........	17.0	98
38375 C...	.....do..........	19.6	100	71575 W..	.....do..........	18.0	100
38376 C...	.....do..........	18.6	88	71754 W..	.....do..........	16.4	95
38377 C...	.....do..........	18.6	82	71755 W..	.....do..........	16.2	100
38378 C...	.....do..........	20.2	17	71756 W..	.....do..........	18.0	100
38379 C...	.....do..........	15.8	90	71757 W..	.....do..........	17.8	95
38380 C...	.....do..........	17.9	94	71758 W..	.....do..........	16.4	98
38381 C...	.....do..........	17.4	98	71759 W..	.....do..........	15.2	98
Crop of 1912:				71760 W..	.....do..........	15.6	100
71558 W..	Illinois..........	19.0	99	71799 W..	.....do..........	16.2	98
71559 W..	.....do..........	16.8	100	71800 W..	.....do..........	18.0	100
71560 W..	.....do..........	17.4	100	71801 W..	.....do..........	16.6	100
71561 W..	.....do..........	18.6	92	71802 W..	.....do..........	16.8	100
71562 W..	.....do..........	17.4	99	71803 W..	.....do..........	17.0	94
71820 W..	.....do..........	16.0	100	71804 W..	.....do..........	16.0	99
71913 W..	.....do..........	17.4	97	71805 W..	.....do..........	18.8	100
71914 W..	.....do..........	14.2	98	71806 W..	.....do..........	15.8	100
71915 W..	.....do..........	14.2	100	71807 W..	.....do..........	16.0	100
71916 W..	.....do..........	14.2	99	71808 W..	.....do..........	15.6	100
71917 W..	.....do..........	17.8	100	71809 W..	.....do..........	19.6	97
71918 W..	.....do..........	15.0	97	71810 W..	.....do..........	18.6	99
71919 W..	.....do..........	16.6	96	71811 W..	.....do..........	18.0	96
71920 W..	.....do..........	14.2	100	71812 W..	.....do..........	18.0	96
71921 W..	.....do..........	14.6	97	71813 W..	.....do..........	15.8	98
71922 W..	.....do..........	18.6	99	71814 W..	.....do..........	17.4	99
71979 W..	.....do..........	17.8	100	71815 W..	.....do..........	15.8	100
71980 W..	.....do..........	17.8	98	71816 W..	.....do..........	17.4	79
71981 W..	.....do..........	16.4	96	71817 W..	.....do..........	15.6	100
71982 W..	.....do..........	19.0	96	71818 W..	.....do..........	17.6	82
71983 W..	.....do..........	17.6	96	71819 W..	.....do..........	15.0	99
71984 W..	.....do..........	19.0	99	72186 W..	.....do..........	16.0	95
71985 W..	.....do..........	19.6	96	72187 W..	.....do..........	16.6	93
71986 W..	.....do..........	17.0	99	72188 W..	.....do..........	15.0	98
71987 W..	.....do..........	16.4	98	72189 W..	.....do..........	15.8	98
71988 W..	.....do..........	15.6	99	72195 W..	.....do..........	13.6	95
71989 W..	.....do..........	18.4	100	72196 W..	.....do..........	16.0	97

[1] Weak.

Table II shows a summary of the analyses of 127 samples of corn selected for seed, giving the average acidity and average germination for each year and all years combined. Attention is called to the fact of the low average degree of acidity of 17.2 c. c. in connection with the correspondingly high average percentage of germination 95.2. The results shown in this table were all determined in 1912.

TABLE II.—*Average acidity and average germination of corn selected for seed from the crops of six different years.*

Crop of—	Number of samples.	Average acidity.	Average germination.
		C. c.	*Per cent.*
1906	1	15.1	96
1908	2	21.0	98
1909	3	21.2	77
1910	11	19.5	86
1911	17	17.7	91
1912	93	16.7	98
Total	127		
General average (all crops)		17.2	95.2

CORN ON THE FARM.

Table III shows a comparison of the analyses of corn at the time of harvest and at different periods of storage both in the crib and in shocks. The shocks were well put up and afforded good protection to the corn. Attention is invited to the low degree of acidity and high moisture content of the corn on October 1 and to the decrease in moisture on the succeeding dates. It will be noted that on May 1 the corn was still low in degree of acidity, after having lost its excessive moisture during storage through the winter on the farm.

TABLE III.—*Acidity and moisture of corn kept from October 1, 1910, to May 1, 1911, inclusive, in shocks and in crib under country conditions at the Maryland station, College Park, Md.*

Sample.	Item of comparison.	Dates of sampling.		
		Oct. 1, 1910.	Feb. 13, 1911.	May 1, 1911.
Composite inside of shocks	Moisture, per cent	24.9	16.0	14.6
	Acidity, c. c.	11.0	17.0	17.0
Composite outside of shocks	Moisture, per cent	24.9	16.0	13.3
	Acidity, c. c.	13.5	19.0	17.0
Composite of shocks	Moisture, per cent	23.4	16.0	13.9
	Acidity, c. c.	12.6	18.0	17.0
Composite of crib	Moisture, per cent	(1)	16.9	14.0
	Acidity, c. c.	(1)	17.5	15.0

[1] No corn in crib.

Attention is called in Table IV to a comparison of the keeping qualities of corn stored in different cribs used throughout the Middle West. Corn was examined in January, February, March, April, and May, 1913, and it was found that very little change had taken place while stored in any of the several cribs. On the whole, the corn was in very good condition and the degree of acidity of the corn stored on the farm through the winter was uniformly low.

TABLE IV.—*Acidity and germination of corn stored over winter on Illinois farms in cribs of different type.*

Type of covered crib.	Location.	Item of comparison.	Dates of sampling, 1913.				
			January.	February.	March.	April.	May.
Rail crib	Turpin, Ill	Acidity ... c. c.	18.6	15.0	15.4	15.4	(1)
		Germination ... per cent	96.0	100.0	98.0	99.0	
Single crib	Cerro Gordo, Ill.	Acidity ... c. c.	14.0	13.4	14.6	12.6	13.4
		Germination ... per cent	98.0	97.0	97.0	98.0	90.0
Double crib	Long Creek, Ill	Acidity ... c. c.	18.4	15.2	16.8	15.3	15.4
		Germination ... per cent	98.0	96.0	94.0	85.0	90.0

[1] Crib shelled out.

Ears of corn were collected representing all parts of several cribs of corn in Illinois, and a uniformly low degree of acidity was found throughout the individual ears, as shown in Table V. In the sampling of these cribs, care was taken to secure ears which would represent the corn in the crib as a whole.

TABLE V.—*Average and range in degree of acidity of individual ears of corn sampled from farm cribs at Turpin, Long Creek, and Cerro Gordo, Ill.*

Total number of ears.	Acidity (c. c.).			Number of ears with acidity—			
	Average.	Minimum.	Maximum.	Below 20 c. c.	Between 20.1 and 25 c. c.	Between 25.1 and 30 c. c.	Above 30 c. c.
144	17.0	9.8	31.8	120	21	2	1

CORN IN COUNTRY, TERMINAL, AND EUROPEAN MARKETS.

Acidity determinations were made of several thousand samples representing corn selected for seed, country elevator receipts and shipments, terminal-market receipts, and corn as loaded at seaboard for export and as discharged at foreign ports. Corn selected for seed was taken as that best representing the average condition of corn on the farm. Table VI shows that there is a steady increase in the acidity as the corn passes through the different grain centers from the farm until it has reached a foreign port. While the average of all the corn except that which was received at foreign ports is below 22 c. c. in acidity, it will be seen from the range given in the right-hand column that there were some samples in all cases that could not be classed as sound corn, and on the other hand, while the corn as received at foreign ports had an average acidity of 30.4 c. c., indicating an inferior quality, it will be seen from the range that some arrived in practically as good condition as when it left the farm. This table represents an average of 7,124 samples.

TABLE VI.—*Average acidity and range in acidity of samples representing corn selected for seed, corn received at and shipped from country elevators, corn received at terminal markets, and corn as loaded at seaboard for export and as discharged at foreign ports.*

Kind of corn.	Number of samples.	Acidity (c. c.).	
		Average.	Range.
Corn selected for seed	127	17.2	13.6 to 23.8
Country elevator receipts and shipments	197	19.4	14.5 to 50.8
Terminal-market receipts	5,174	20.4	11.7 to 66.4
Loaded at seaboard for export	1,098	20.2	12.4 to 32.0
Discharged at foreign ports	528	30.4	16.0 to 110.8

A comparison was made of the graded and the rejected and sample-grade receipts as they were received at Baltimore, New Orleans, Chicago, and Kansas City, and it was found that the average acidity of the rejected and sample-grade corn as shown in Table VII was much higher in all markets than the acidity of the graded receipts. This table represents a total of 5,174 cars.

TABLE VII.—*General average degree of acidity of corn receipts at four of the principal terminal markets, showing the relation of the degree of acidity of the graded receipts to the degree of acidity of the rejected receipts and sample grade.*

Market.	All receipts.		Graded receipts.		Rejected and sample grade receipts.	
	Number of samples.	Average acidity.	Number of samples.	Average acidity.	Number of samples.	Average acidity.
		C. c.		C. c.		C. c.
Baltimore	1,737	20.6	1,659	20.3	78	26.8
New Orleans	755	22.9	573	20.6	182	30.6
Chicago	2,450	19.7	2,208	19.2	242	23.2
Kansas City	232	18.7	220	18.1	12	29.2

RELATION OF THE ACIDITY OF CORN TO CERTAIN CRITERIA OF SOUNDNESS AND QUALITY.

In order to determine whether or not the amount of acid found in corn may be considered a factor in judging its quality and soundness, the results of the acid test must be compared with all well-established and generally acknowledged criteria of soundness and quality.

Viability (or germinative power), temperature, and percentage of sound and damaged kernels as determined by mechanical analysis are criteria of the soundness and quality of corn.

Corn having attained a temperature higher than normal, through heating in storage or transit, is conceded to be unsound and of poorer quality than corn which has never been subjected to a temperature above normal.

Corn showing upon mechanical analysis a high percentage of sound kernels and a low percentage of damaged kernels must be conceded to more closely approximate sound corn and be of better quality than

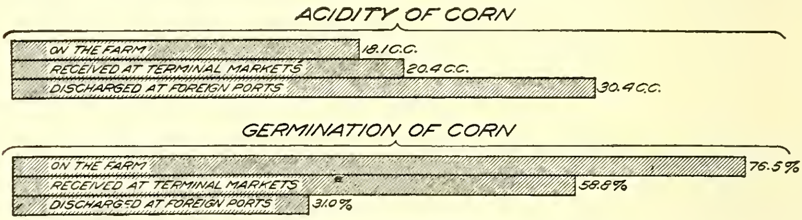


FIG. 8.—Graphic comparison of the degree of acidity and the percentage of germination of corn (1) as found on the farm, (2) as received at terminal markets, and (3) as discharged at foreign ports.

corn showing a lower percentage of sound kernels and higher percentage of damaged kernels.

VIABILITY, OR PERCENTAGE OF GERMINATION.

The results of the investigations show in a general way that the degree of acidity of corn increases as the viability, or percentage of germination, decreases.

Figure 8 is a graphic comparison of the degree of acidity and the percentage of germination of corn as found on the farm, as received at terminal markets, and as discharged at foreign ports.

FIG. 9.—Graphic comparison of the acidity of first-class country crib corn with the acidity of terminal-market graded and rejected receipts.

Figure 9 further summarizes the relation of the degree of acidity found in corn on the farm to the acidity found in corn arriving at terminal markets.

In figure 10 the samples represent corn saved for seed in several States and of various crop years. These samples were found to be uniformly low in degree of acidity. In the figure will be noted an acidity sound-corn line at 22 c. c. on the acidity scale. The investigation shows that this line most closely approximates the maximum degree of acidity found in corn which was sound and of good quality. It will be seen that three samples of corn selected for seed exceeded an acidity of 22 c. c., but it will be seen also that these three samples were exceptionally low in percentage of germination. A fourth sample very low in percentage of germination did not exceed an acidity of 22 c. c. The agent or agencies which destroyed the germinative power of this corn did not cause abnormal increase in degree of acidity. This is contrary to the general rule, because agencies which destroy germinative power are generally the same agencies which cause abnormal acidity. It is mainly through deterioration of the germ that the degree of acidity is increased, as shown in figures 32 and 33 (p. 44).

Table VIII summarizes the relationship of low germinative power to high acidity. Germination tests were made in connection with

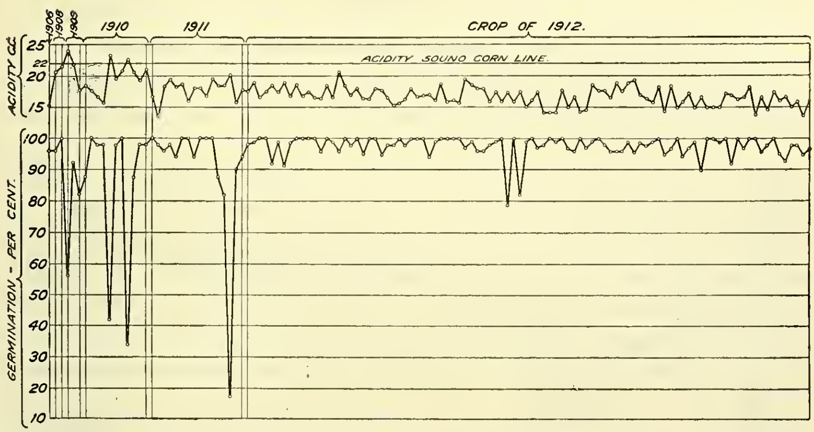


FIG. 10.—Curves showing the uniformly low degree of acidity in corn selected for seed in which there is a high percentage of germination.

acidity tests on all samples handled in this investigation. The samples in this table represent the widest possible range in quality and condition of corn, from first-class country crib corn in excellent condition through various conditions and stages of deterioration as found in corn shipped from country stations and arriving at terminal markets and European ports. The samples are grouped according to their source. The average degree of acidity of samples in each group which showed a percentage of germination less than 20 is compared with the average degree of acidity of samples which showed a percentage of germination ranging from 21 to 40, 41 to 60, 61 to 80, and 81 to 100. The table shows that corn with a low germinative power is higher in degree of acidity than corn of high germinative power, irrespective of the source of the sample.

TABLE VIII.—*Samples representing corn on the farm, at country shipping points, at terminal markets, and at foreign ports, showing the increase in degree of acidity in direct proportion to the decrease in percentage of germination.*

Source of samples.	Item of comparison.	Samples which showed a range in the percentage of germination from—				
		0 to 20	21 to 40	41 to 60	61 to 80	81 to 100
Individual ears from farm cribs.	Number of samples	....	2	2	9	131
	Average acidity ......c.c.	....	29.9	20.6	18.2	16.6
Country elevator receipts and shipments.	Number of samples	7	28	60	86	21
	Average acidity ......c.c.	29.8	21.1	18.9	19.3	19.6
Terminal market receipts.	Number of samples	598	657	968	1,830	1,058
	Average acidity ......c.c.	26.6	21.8	19.6	19.3	18.6
Corn discharged at foreign ports.	Number of samples	167	129	76	74	9
	Average acidity ......c.c.	39.9	25.5	25.5	21.5	18.0

EFFECT OF POOR CARS ON THE CONDITION OF CORN.

Corn often arrives at terminal markets in cars with leaky roofs, and not infrequently the grain directly under the leaky part becomes

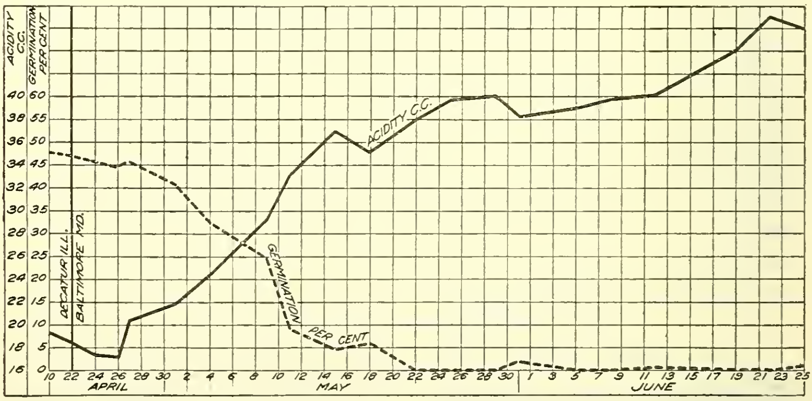


FIG. 11.—Curves showing the increase in degree of acidity and the decrease in percentage of germination through advancing stages of deterioration in a car of corn.

wet and reaches advanced stages of deterioration while the greater part of the corn in the car remains sound and in good condition.

Table IX shows the results of acidity and germination tests made on samples taken from both the good and bad parts of such cars.

TABLE IX.—*Comparison of the average acidity and the average germination of corn sampled in the good and the bad parts of cars received at a terminal market.*[1]

Source of samples.	Average acidity.	Average germination.
	C. c.	*Per cent.*
Good part of car	18.6	67.7
Bad part of car	23.4	49.0

[1] These results represent an average of 73 cars.

Figure 11 shows the direct and the proportional increase in the degree of acidity with the decrease in percentage of germination of samples taken from a car of corn which was shipped from Decatur, Ill., to Baltimore, Md., and allowed to stand on the track in Baltimore until it was in an advanced stage of deterioration.

RELATION TO TEMPERATURE.

Figure 12 shows the average condition of a cargo of corn loaded at a United States seaport compared with the average condition at the time of discharge of the cargo at a European port. The degree of acidity varies directly with the quality and soundness of the corn, as is indicated by the variation of the other factors graphically shown.

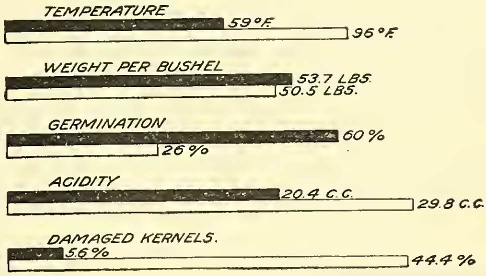


FIG. 12.—Graphic comparison of the average condition of a cargo of corn at the time of loading at a United States seaport compared with its average condition at the time of discharge at a European port, showing the effect of temperature through ocean transportation on various factors which determine the soundness and quality.

In figure 13 reference is again made to a car of corn shipped from Decatur, Ill., to Baltimore, Md. At the time of its arrival at Baltimore the corn contained an average moisture percentage of 18.60. Four days after its arrival at Baltimore the temperature began to

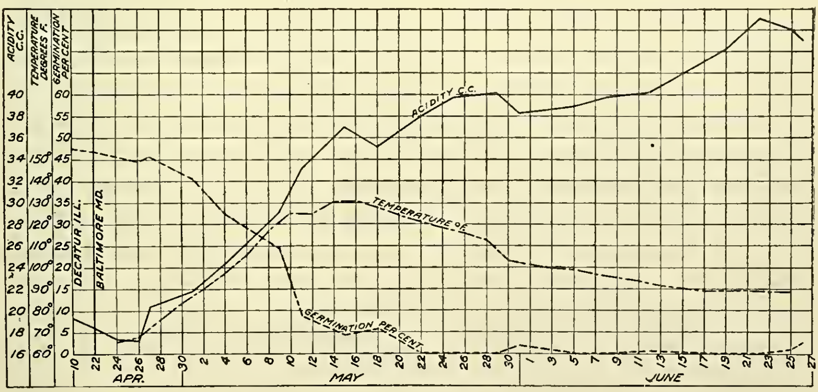


FIG. 13.—Curves showing the effect of temperature on the degree of acidity and the percentage of germination of a car of corn which was left on the railway track through advancing stages of deterioration.

increase rapidly, and with the increase in temperature there was a proportional increase in degree of acidity and a corresponding decrease in the percentage of germination.

Figure 14 shows the relation of the degree of acidity to the condition of corn before and after a storage experiment in a large elevator bin at a terminal market. During the course of the experiment the corn was allowed to go out of condition and underwent considerable deterioration. The degree of acidity is shown as a factor in comparison with other factors which determine the quality and soundness of corn.

Corn under certain conditions may attain a temperature of 100° F. or more before it becomes discolored or shows to the eye any effect of damage by heat. Table X shows the effect of the increase of temperature upon the degree of acidity, percentage of germination, and percentage of sound kernels as found in samples having undergone ocean transportation. The samples were taken at European ports at the time the vessels were unloaded. Nine cargoes are represented. The corn at the time of loading was cool, the greatest bulk of it being below 50° F. Through ocean transportation covering a period ranging from 14 to 30 or 35 days[1] a large part of the corn attained a temperature greater than it had at the time of loading. This increase varied from one or two to over a hundred degrees in the case of the badly damaged portions of the cargoes. In the table the degree of acidity and the percentages of germination and of sound kernels represent the average of all samples which showed temperatures below 50° F., between 51° and 60°, between 61° and 70°, between 71° and 80°, between 81° and 90°, between 91° and 100°, and above 100°, respectively, at the time of discharge of the cargoes. Samples which attained a temperature of 71° or more showed marked evidence of deterioration, and the higher the temperature the more advanced the stage of deterioration and the higher the degree of acidity.

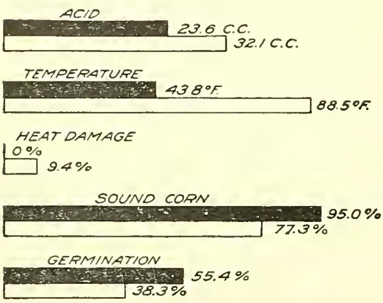


FIG. 14.—Graphic comparison of the condition of corn at the time an elevator storage bin was filled and at the time the bin was emptied, showing the degree of acidity as a factor in comparison with other factors which determine quality and soundness.

TABLE X.—*Degree of acidity, percentage of germination, and percentage of sound kernels of samples representing 9 cargoes of exported corn, showing the effect of the increase of temperature.*

Basis of comparison.	Temperature of samples at time of discharge (° F.).						
	Below 50°.	51° to 60°.	61° to 70°.	71° to 80°.	81° to 90°.	91° to 100°.	Above 100°.
Number of samples	106	65	70	44	29	20	109
Degree of acidity ....c. c.	21.0	24.4	26.8	31.9	33.5	33.7	42.5
Germination ....per cent.	50.2	39.4	42.1	36.0	21.7	18.8	4.2
Sound kernels as determined by mechanical analysis, per cent.	88.38	84.4	81.65	71.68	60.73	50.94	14.10

[1] In the case of one vessel a period of 50 days elapsed from the time of loading until the time of discharge.

RELATION TO THE PERCENTAGE OF SOUND KERNELS.

In Table XI the degree of acidity as found in approximately 2,400 samples is compared in a general way with the percentage of sound kernels found in the same samples by mechanical analysis. The results in section A of the table represent samples from all grades of car receipts at a principal terminal market from December, 1911, to November, 1912, inclusive. The samples represented in section B of the table were taken at the time the cargoes were discharged at European ports from nine vessels loaded at the United States seaboard.

TABLE XI.—*Comparison of the degree of acidity of samples of corn which were found upon mechanical analysis to contain a low percentage of sound kernels with the degree of acidity of samples which contained higher percentages of sound kernels.*

A.—REPRESENTATIVE OF ALL GRADES OF CAR RECEIPTS AT A TERMINAL MARKET.

Basis of comparison.	Sound kernels (per cent).					
	Less than 50.	51 to 60.	61 to 70.	71 to 80.	81 to 90.	91 to 100.
Number of samples	28	13	26	91	456	1,467
Average acidity ..... c. c.	34.8	32.0	27.4	25.9	22.5	18.6

B.—REPRESENTATIVE OF NINE CARGOES DISCHARGED AT EUROPEAN PORTS.

Basis of comparison.	Less than 50.	51 to 60.	61 to 70.	71 to 80.	81 to 90.	91 to 100.
Number of samples	58	18	17	25	91	92
Average acidity ..... c. c.	40.9	31.1	32 9	28.8	24 4	21 2
Average germination ..... per cent.	5.3	18.6	29.8	38.8	41.0	55.9

RELATION TO THE PERCENTAGE OF DAMAGED KERNELS.

In figure 15 is shown the relation of the percentage of damaged kernels to the degree of acidity found in samples of corn of all grades, representing 2,454 cars received at a principal terminal market (C) from December, 1911, to May, 1913, inclusive. These cars of corn ranged from 10 to 60 c. c. in degree of acidity. The percentage of cob-rotten kernels and the percentage of heat-damaged kernels, if any, was determined by the mechanical analysis of a representative sample from each car.

It is the purpose of figure 15 to illustrate the general way in which the acidity of corn increases with the amount of damaged kernels as detected by the eye in mechanical analysis. The point at which the curve intersects a perpendicular cross-section line denotes the average percentage of damaged kernels found in the samples, which ranged in degree of acidity as designated at the top of the perpendicular cross-section line. The average percentage of damaged kernels is shown at the left. The curve designated "cob rot" (solid line) represents the percentage of kernels damaged by agencies other than heat. The curve designated "cob rot plus heat damage" (broken line) represents the percentage of the total of the damaged kernels.

The curves show that the samples which were found by analysis to have a large percentage of damaged kernels were also found to have a high degree of acidity. It is shown further that the degree of acidity varies directly with the percentage of damaged kernels and that the presence of heat-damaged kernels in any large amount

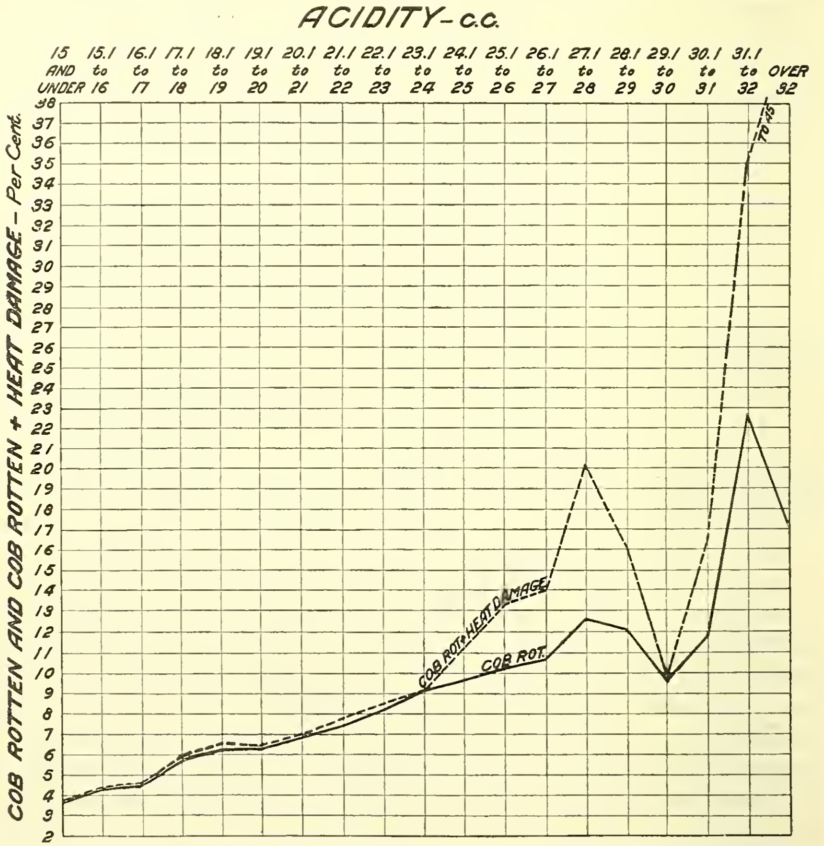


FIG. 15.—Curves showing the relation of damaged kernels to the degree of acidity found in samples of corn (all grades) representing 2,454 cars received at a principal terminal market (C) from December, 1911, to May, 1913, inclusive.

greatly increases the degree of acidity. When the percentage of heat-damaged kernels was small, the degree of acidity was only slightly increased. A break occurs in the continuity of the curves representing the percentages of damaged kernels at acidity ranges between 27.1 and 31 c. c. This break shows that a number of the samples, although having a slightly higher degree of acidity than certain other samples, contained a smaller percentage of damaged kernels. The difference, however, is small, being only 2.5 per cent, and this evidence should in no way discredit the merits of the acid test. It must be remembered that, theoretically, the degree of acidity of corn is a measure not only of the amount or quantity of damage but that it is also a measure of the quality or degree of damage in any given sample. Hence, it can be readily understood how a sample containing 10 per cent of damaged kernels might have a higher degree of acidity than a sample containing 15 per cent of damaged kernels, provided the degree of damage or the extent to which the kernels were damaged is taken into consideration. This factor of degree or state of damage, or stage of deterioration, while

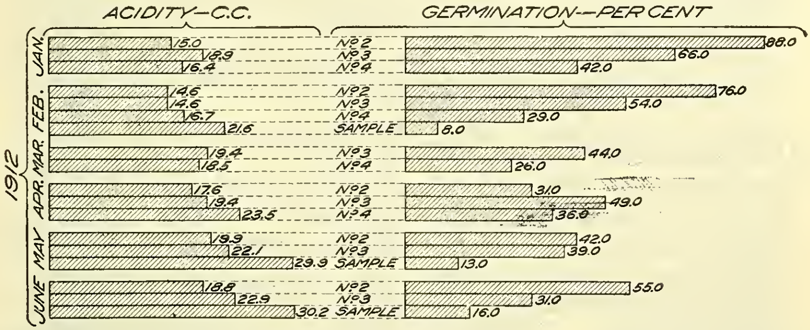


FIG. 16.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (A), by months, from January to June, 1912, inclusive.

immeasurable by the eye in any standard or definite way, is readily determined by the acidity test.

RELATION OF ACIDITY AND GERMINATION OF CORN TO COMMERCIAL GRADING AT TERMINAL MARKETS.

The purpose in presenting figures 16, 17, 18, 19*a*, and 19*b* is to correlate the average degree of acidity and the average percentage of germination of corn with the commercial grading at terminal markets by months. Attention is called to the increase in the degree of acidity and the decrease in the percentage of germination from the high to the lower grades. Attention is also called to the decrease in degree of acidity and the marked increase in the percentage of germination upon the arrival of the new crop in November, as shown in figures 17, 18, 19*a*, and 19*b*.

ACIDITY OF CORN AS A FACTOR IN COMMERCIAL GRADING.

ACIDITY OF COMMERCIAL GRADES.

Corn arriving at a terminal market is graded or classified according to its condition and quality. In this connection the words "condition" and "quality" are more or less synonymous. It is generally understood, however, in commercial grading that "condition of corn" refers to freedom from or presence of dirt, cob, broken ker-

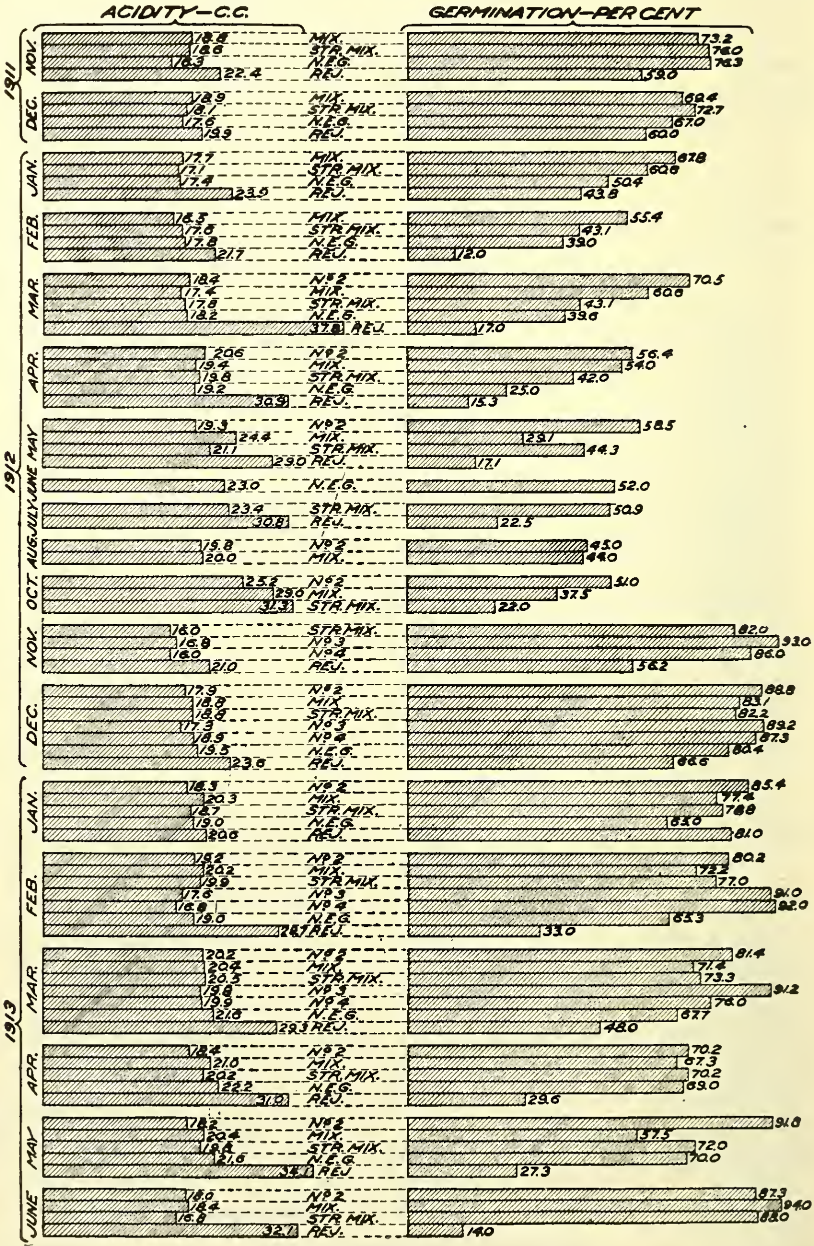


FIG. 17.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (B), by months, from November, 1911, to June, 1913, inclusive.

nels, other grains, unnatural odors, and excessive percentage of moisture—as corn is spoken of as being clean or dirty; mixed with oats or wheat; musty, sour, or sweet; damp, wet, or dry. The word "quality," then, in connection with grading of corn, must refer to soundness, meaning freedom from injury, defect, or decay, i. e., normally perfect of its kind.

Of the factors affecting the condition of corn, viz, dirt, cob, broken kernels, other grains, unnatural odor, and moisture, all with the

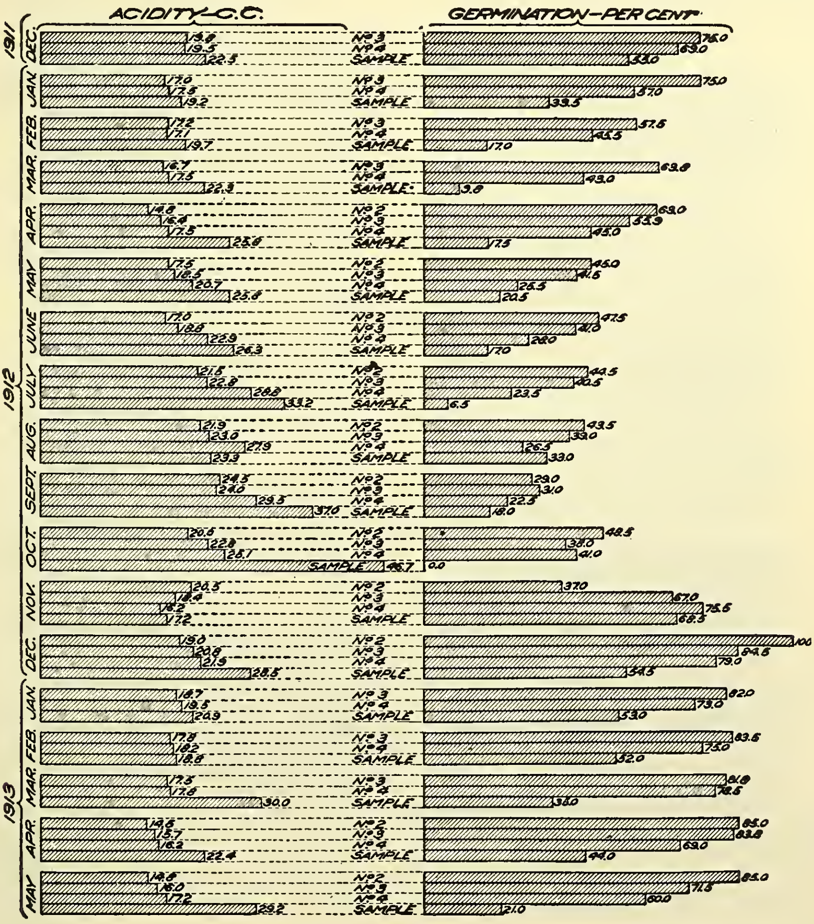


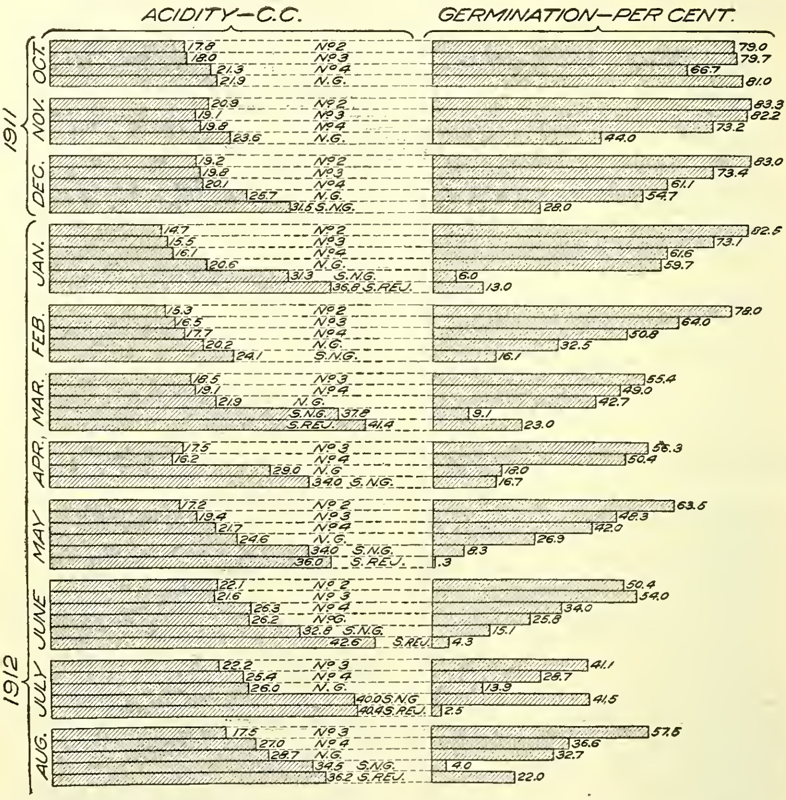
FIG. 18.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (C), by months, from December, 1911, to May, 1913, inclusive.

exception of odor can be definitely ascertained by practical and quantitative methods. The exact percentage of dirt, cob, broken kernels, and other grains can be readily determined by mechanical separations; the percentage of moisture can be as readily determined by the use of a moisture tester.[1]

[1] Duvel, J. W. T. A moisture tester for grain and other substances and how to use it. U. S. Department of Agriculture, Bureau of Plant Industry Circular 72, 15 p., 13 fig., 1910.

Heretofore in commercial grading, corn has been considered out f condition because of unnatural odor only when the odor is suffi-ently pronounced to be readily detected by the sense of smell, hich varies with different individuals and even with the same indi-idual under different conditions.

In the grading of corn from the standpoint of quality or soundness, owever, the methods are entirely arbitrary, inasmuch as there is



G. 19a.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (D), by months, from October, 1911, to August, 1912, inclusive.

lways considerable question as to just what constitutes cob-rotten, ecayed, or otherwise damaged and defective kernels in any given ample which may be under inspection.

It is the purpose of this section of this report to show the relation f degree of acidity in a detailed way to acknowledged criteria of oundness and quality of corn and to call to the attention of the rain trade and those of the general public who may be interested the possibilities of the acid test as an additional criterion in determining soundness and quality of corn from the standpoint of commercial grading.

The samples shown in Tables XII to XIX and figures 20 to 31 and 33 were graded by the Illinois State Grain Inspection Department

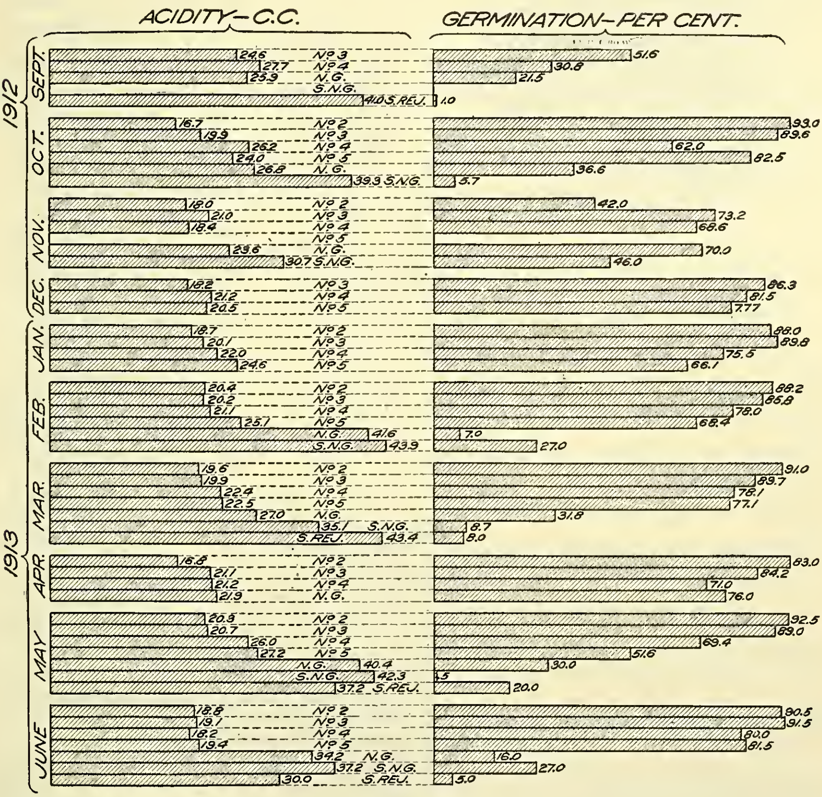


FIG. 19*b*.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (D), by months, from September, 1912, to June, 1913, inclusive.

according to the rules governing the grading of grain in the years 1912 and 1913.

Figure 20 shows the average degree of acidity of Nos. 2, 3, 4, and sample-grade corn as it was graded upon arrival at a principal terminal market (C), representing an average of approximately 2,000 cars received from December, 1911, to December, 1912, inclusive. Very little difference is shown between the grades 2, 3, and 4. This is due to the fact that the greater part of the corn that graded 3 and 4 was so graded because of excessive moisture, although sound and of quality good enough for No. 2. Figure 20 also shows the average degree of acidity of samples received from April 1, 1912, to October 31, 1912, inclusive. This is the time of the year during which corn arrives at terminal markets in a drier condition and is graded principally from the standpoint of quality and soundness. It will be seen that the degree of acidity increases directly with the lowering of the grades. Figure 20 further shows the average degree of acidity of samples received from January 1, 1913, to May 31, 1913, inclusive. Increase in acidity is shown through the lower grades, and uniformly lower acidity was found in Nos. 2, 3, and 4 corn of the crop of 1912 than was found in samples from the crop of 1911. This comparison by crop years will appeal to those who may recall the far superior quality and condition of the crop of 1912 as it was marketed over that of the crop of 1911.

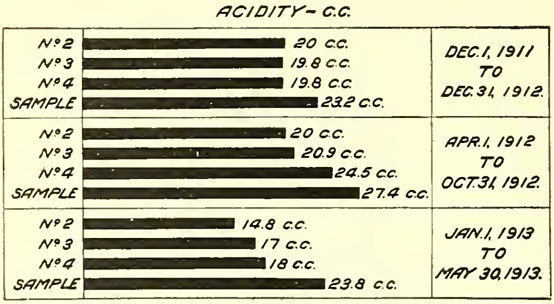


FIG. 20.—Graphic comparison of the average degree of acidity of corn, by grades, as received at a principal terminal market (C) through different seasons: (1) December, 1911, to December, 1912; (2) April, 1912, to October, 1912; (3) January, 1913, to May, 1913.

ACIDITY OF MECHANICAL SEPARATIONS OF CORN.

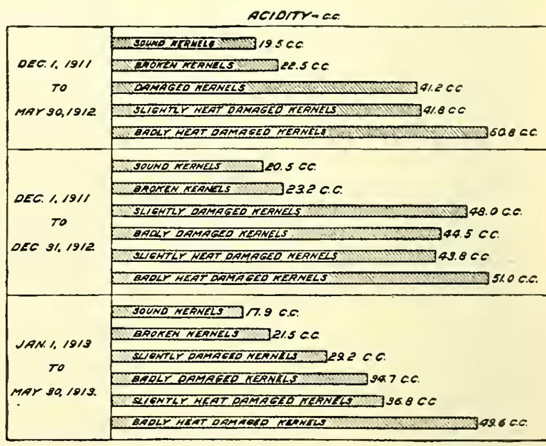


FIG. 21.—Graphic comparison of the average degree of acidity of mechanical separations of samples of corn as received at a principal terminal market (C) through different seasons: (1) December, 1911, to May, 1912; (2) December, 1911, to December, 1912; (3) January, 1913, to May, 1913.

Figure 21 shows the average degree of acidity of separations resulting from mechanical analyses of samples of corn representing approximately 3,000 cars received at a terminal market. It also represents the crop of 1911 and the crop of 1912, based on terminal-market receipts from January to May, 1913, inclusive, and represents the general average of both crops combined. By the degree of acidity of the mechanical separations the superior quality and condition of the crop of 1912 is also shown.

In one instance in figure 21 the acidity of the corn designated as "badly damaged" appears somewhat lower than the acidity of the corn designated as "slightly damaged." This is due to the fact that the corn designated as "badly damaged" had so far undergone deterioration as to be typical of rot and decay, which agencies tend to cause a state of alkalinity rather than a state of acidity. At one time, no doubt, before the corn reached that state of rot and decay, the degree of acidity was higher. Rot and decay serve to slightly reduce the maximum degree of acidity which the corn attains in the

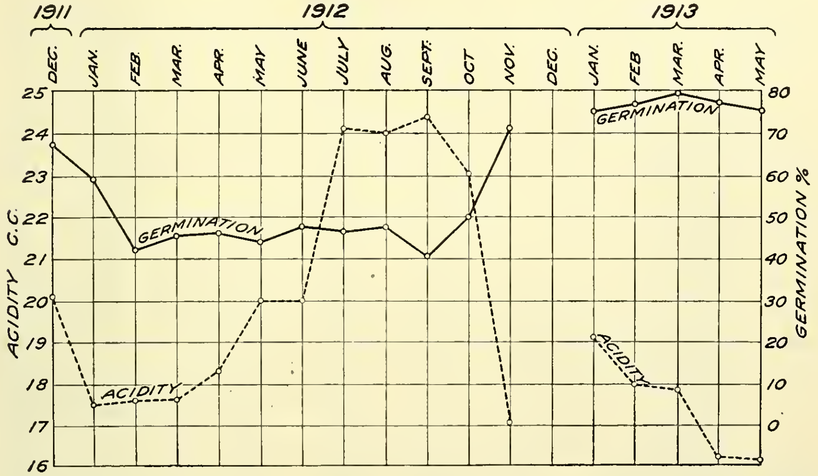


FIG. 22.—Curves showing the monthly average degree of acidity and percentage of germination of corn as received at a principal terminal market (C).

cycle of deterioration, but leaves the degree of acidity sufficiently high to stamp the corn as being wholly unsound.

The general relation of the degree of acidity to the germinative power of corn arriving at a terminal market is shown in figure 22 by curves which represent monthly averages. Attention is called (1) to the marked increase in the degree of acidity and decrease in the percentage of germination starting in the spring with the approach of warm weather and continuing throughout the summer months and again (2) to the very marked decrease in the degree of acidity and increase in the percentage of germination commencing in October, upon the arrival of the new crop. Through germination and acidity the superior quality and condition of the crop of 1912 over the crop of 1911 is again shown by these curves.

RELATION TO GERMINATION AND SOUND KERNELS.

Table XII shows a comparison of the degree of acidity with the percentage of germination and the percentage of sound corn (exclusive of broken kernels). The monthly averages of these three factors are shown for each grade. Examination of this table will also reveal a consistent decrease in the percentage of sound corn and the percentage of germination from the high to the lower grades and a corresponding consistent increase in the degree of acidity.

TABLE XII.—*Relation of the percentage of sound corn, the percentage of germination, and the degree of acidity to the commercial grades, by months, from December, 1911, to May, 1913, inclusive.*

Year and month.	Grade.	Number of samples.			Sound corn.	Germination.	Acidity.
		Sound corn.	Germination.	Acidity.			
1911.					*Per cent.*	*Per cent.*	*C. c.*
December	No. 3	18	16	12	93.8	76.1	19.7
	No. 4	120	112	110	91.2	68.8	19.7
	Sample	38	28	27	89.6	56.3	22.3
1912.							
January	No. 3	68	62	65	91.9	75.3	17.0
	No. 4	145	133	134	90.8	64.4	17.6
	Sample	22	21	21	86.6	39.5	19.2
February	No. 3	34	31	31	91.4	57.9	17.8
	No. 4	123	108	111	91.3	46.7	17.2
	Sample	28	28	28	83.4	18.5	19.9
March	No. 3	59	56	59	90.8	62.0	16.9
	No. 4	112	108	112	90.1	41.1	17.5
	Sample	15	13	14	77.6	9.7	22.3
April	No. 2	6	6	6	91.9	63.3	14.8
	No. 3	43	43	43	89.3	54.8	16.4
	No. 4	99	99	99	87.2	45.5	17.5
	Sample	26	26	26	55.0	17.5	25.9
May	No. 2	39	39	39	89.8	45.4	17.5
	No. 3	117	116	117	86.3	41.3	18.4
	No. 4	78	75	78	78.9	25.1	20.7
	Sample	43	41	43	56.3	20.6	26.1
June	No. 2	38	37	38	90.6	47.6	17.1
	No. 3	116	111	114	88.4	41.3	18.8
	No. 4	67	65	67	82.8	28.2	22.8
	Sample	10	10	10	68.6	17.4	26.3
July	No. 2	59	59	59	90.4	44.4	21.5
	No. 3	66	64	66	87.0	40.5	22.9
	No. 4	34	34	34	80.1	20.8	28.8
	Sample	8	8	8	78.9	6.5	33.2
August	No. 2	34	34	34	90.1	43.7	21.9
	No. 3	65	60	65	88.4	40.2	23.4
	No. 4	34	32	34	82.2	26.8	27.9
	Sample	3	3	3	83.4	33.3	23.2
September	No. 2	20	20	20	91.8	29.2	24.4
	No. 3	41	40	41	88.3	31.2	24.0
	No. 4	35	34	35	81.4	22.6	29.5
	Sample	2	2	2	70.0	18.0	37.0
October	No. 2	17	17	17	92.1	48.5	20.0
	No. 3	61	60	61	87.5	38.0	22.9
	No. 4	18	18	18	81.7	41.1	25.0
	Sample	1	1	1	6.0	0	46.7
November	No. 2	5	5	5	91.0	37.2	20.6
	No. 3	43	43	43	91.1	67.4	18.3
	No. 4	97	97	97	90.8	75.4	16.2
	Sample	34	34	34	86.1	68.4	17.1

TABLE XII.—*Relation of the percentage of sound corn, the percentage of germination, and the degree of acidity to the commercial grades, by months, from December, 1911, to May, 1913, inclusive*—Continued.

Year and month.	Grade.	Number of samples.			Sound corn.	Germination.	Acidity.
		Sound corn.	Germination.	Acidity.			
1912.					*Per cent.*	*Per cent.*	*C. c.*
December	No. 2	1	1	1	96.8	100.0	19.0
	No. 3	25	25	25	91.9	84.6	20.8
	No. 4	34	34	33	90.2	78.7	21.9
	Sample	9	9	9	72.2	54.4	28.5
1913.							
January	No. 3	26	26	24	92.5	82.0	18.6
	No. 4	33	33	29	90.1	73.0	19.4
	Sample	5	4	2	84.8	51.7	20.9
February	No. 3	19	19	19	92.7	83.8	17.7
	No. 4	19	17	19	89.2	74.9	18.1
	Sample	3	3	3	90.2	52.0	18.7
March	No. 3	39	39	39	90.9	81.9	17.4
	No. 4	23	23	23	89.4	78.2	17.7
	Sample	2	2	2	60.8	35.0	30.0
April	No. 2	11	11	11	92.3	85.4	14.6
	No. 3	36	36	36	91.5	83.8	15.7
	No. 4	14	14	14	86.5	69.4	16.1
	Sample	6	6	6	70.3	44.0	22.3
May	No. 2	41	41	41	91.9	85.0	14.8
	No. 3	24	24	24	88.7	71.5	16.0
	No. 4	7	7	7	84.5	60.0	17.2
	Sample	3	3	3	27.4	21.0	29.2

Figure 23 represents the data compiled in Table XII. The curves denoting monthly average degree of acidity bear the same relation to each other as do the curves denoting monthly average percentage of germination and sound corn.

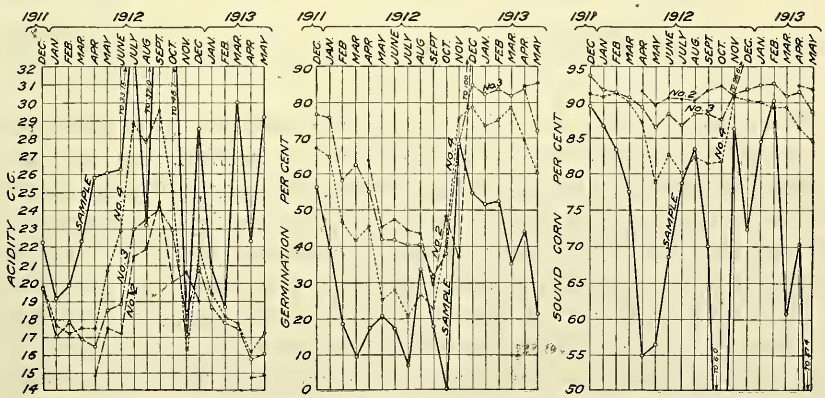


FIG. 23.—Curves showing, by grades, the monthly average degree of acidity, the percentage of germination, and the percentage of sound corn in representative samples of corn received at a principal terminal market (C).

While there is considerable variation between the grades in all the factors throughout the greater part of the year, confusion of the lines denoting little variation and an overlapping of the grades occurs at points indicated as October and November. This is due to the arrival upon the market of the new crop, when practically all of the corn is graded down because of its excessive moisture and not because of inferior quality.

As already stated, these investigations have shown that 22 c. c. most closely approximates the maximum degree of acidity found to be contained in sound or normally perfect corn.

Table XIII shows the average percentage of sound corn, the average percentage of germination, and the average degree of acidity of each commercial grade. In comparison with these general averages there is likewise shown the relation of the amount of sound corn and the percentage of germination found in samples having a degree of acidity greater than 22 c. c. to the amount of sound corn and the percentage of germination found in samples showing a degree of acidity less than 22 c. c.

TABLE XIII.—*Relation of the percentage of germination and the percentage of sound corn to the degree of acidity found in samples above and below 22 c. c. acidity, by grades, for a year.*

Grade.	Item of comparison.	Number of samples.	Sound corn.	Germination.	Acidity.
			Per cent.	*Per cent.*	*C. c.*
No. 2	General average of all samples	218	90.61	44.40	20.11
	Average of samples above 22 c. c. acidity	63	91.20	28.23	24.21
	Average of samples below 22 c. c. acidity	155	90.60	51.23	18.48
No. 3	General average of all samples	731	88.60	48.80	19.63
	Average of samples above 22 c. c. acidity	171	87.10	30.28	24.84
	Average of samples below 22 c. c. acidity	546	89.38	54.45	18.00
No. 4	General average of all samples	962	87.72	48.60	19.64
	Average of samples above 22 c. c. acidity	185	81.25	25.94	27.44
	Average of samples below 22 c. c. acidity	744	88.15	53.57	17.70
Sample	General average of all samples	230	75.20	32.50	22.42
	Average of samples above 22 c. c. acidity	85	53.58	13.60	30.47
	Average of samples below 22 c. c. acidity	133	87.23	44.90	18.00

Table XIV further establishes the same relationship between the percentage of sound corn, the percentage of germination, and the degree of acidity. In this table, which represents No. 2, No. 3, No. 4, and sample-grade corn, respectively, the samples are grouped by months and the amount of sound corn and the percentage of germination of samples above and below 22 c. c. acidity is compared.

This table shows that less sound corn and lower germinative power were found in the samples which ranged above 22 c. c. acidity. In the lower grades the decrease is more marked in both the percentage of sound corn and the percentage of germination. In the case of No. 2 corn the percentage of sound corn remains quite constant whether the sample showed acidity greater or less than 22 c. c., but the percentage of germination decreases with the increase in degree of acidity. The acid test detects deterioration of the germ where the eye does not, and it discriminates against the kernels of low germinative power.

TABLE XIV.—*Relation of the percentages of sound corn and of germination of samples above 22 c. c. acidity to the same factors of samples below 22 c. c. acidity, by months, from December, 1911, to May, 1913, inclusive, for grades Nos. 2, 3, 4, and sample.*

Year and month.	Acidity above or below 22 c. c.	Grade No. 2 corn.				Grade No. 3 corn.				Grade No. 4 corn.				Sample grade.			
		Number of samples.	Average. Sound corn.	Average. Germination.	Average. Acidity.	Number of samples.	Average. Sound corn.	Average. Germination.	Average. Acidity.	Number of samples.	Average. Sound corn.	Average. Germination.	Average. Acidity.	Number of samples.	Average. Sound corn.	Average. Germination.	Average. Acidity.
			Per cent.	Per cent.	C. c.		Per cent.	Per cent.	C. c.		Per cent.	Per cent.	C. c.		Per cent.	Per cent.	C. c.
1911.																	
December	Above	0	.....	.....	.....	1	91.2	58.0	26.0	10	89.1	62.4	23.1	8	84.4	45.8	28.5
	Below	0	.....	.....	.....	11	93.8	77.3	19.1	100	91.1	69.4	19.4	19	90.8	60.4	19.6
1912.																	
January	Above	0	.....	.....	.....	0	.....	.....	.....	3	87.0	67.3	22.9	1	51.4	22.0	37.4
	Below	0	.....	.....	.....	65	91.9	75.3	17.0	131	91.1	64.3	17.4	20	90.2	36.6	18.2
February	Above	0	.....	.....	.....	1	95.1	2.0	22.2	1	89.6	12.0	24.2	7	60.6	11.1	27.5
	Below	0	.....	.....	.....	30	91.3	59.8	17.7	110	91.6	47.0	17.1	22	91.2	20.9	17.4
March	Above	0	.....	.....	.....	0	.....	.....	.....	1	76.4	60.0	23.0	5	54.8	11.1	27.2
	Below	0	.....	.....	.....	59	90.8	62.0	16.9	111	91.0	40.9	17.4	9	89.5	8.2	19.4
April	Above	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	14	32.0	5.7	31.5
	Below	6	91.6	63.3	14.8	43	89.3	54.8	16.4	99	87.2	45.5	17.5	12	81.8	31.2	19.3
May	Above	1	91.7	20.0	23.9	5	78.6	24.8	25.1	19	67.3	18.3	24.8	27	43.6	11.7	30.4
	Below	38	89.8	46.0	17.3	112	86.7	42.0	18.1	59	82.7	27.4	19.4	16	72.3	37.7	18.8
June	Above	1	91.7	12.0	23.2	9	83.7	28.5	23.3	38	80.7	24.0	25.4	8	65.1	10.3	28.9
	Below	37	90.6	48.3	16.9	105	88.8	42.2	18.4	20	85.4	33.9	19.4	2	82.7	51.0	16.0
July	Above	25	90.9	30.9	23.8	38	86.6	31.7	24.5	30	79.9	17.7	29.8	8	78.9	6.5	33.2
	Below	34	90.0	54.4	19.8	28	87.5	53.3	20.8	4	81.6	44.0	21.3	0	.....	.....	.....
August	Above	15	88.8	30.8	24.2	38	87.8	27.4	25.6	30	81.8	24.6	28.5	1	76.5	28.0	28.5
	Below	19	91.1	53.9	20.1	27	89.1	62.3	20.3	4	85.4	42.0	21.5	2	86.8	40.0	21.0
September	Above	16	91.7	23.6	25.3	32	88.5	25.8	25.1	34	81.1	22.6	29.5	2	70.0	18.0	37.5
	Below	4	92.2	51.5	20.6	9	87.6	52.8	20.1	1	89.3	.....	18.7	0	.....	.....	.....
October	Above	3	91.5	25.6	23.4	38	87.3	22.5	24.5	13	77.3	27.8	28.2	1	6.0	0	46.7
	Below	14	92.2	54.1	19.3	23	87.8	64.9	20.2	5	93.1	75.6	16.9	0	.....	.....	.....
November	Above	1	91.8	8.0	25.1	9	87.3	33.5	24.2	6	82.4	20.7	28.8	3	43.4	16.0	29.1
	Below	4	90.8	44.5	19.5	34	92.1	76.3	16.7	91	91.3	79.0	15.4	30	90.2	73.4	15.9
December	Above	0	.....	.....	.....	6	96.2	77.7	23.6	15	95.1	80.2	23.7	9	76.8	54.0	28.5
	Below	1	96.8	100	19.0	19	95.1	85.5	19.9	19	92.5	77.0	20.3	0	.....	.....	.....
1913.																	
January	Above	0	.....	.....	.....	1	94.9	76.0	23.6	3	93.9	58.7	22.3	1	82.2	60.0	25.0
	Below	0	.....	.....	.....	23	95.8	82.0	18.5	26	93.6	74.7	19.2	1	96.9	62.0	16.8
February	Above	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....
	Below	0	.....	.....	.....	19	95.4	83.5	17.8	19	93.6	75.0	18.2	3	93.9	52.0	18.8
March	Above	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	1	34.6	24.0	39.9
	Below	0	.....	.....	.....	36	93.9	81.8	17.5	23	92.5	78.5	17.8	1	91.7	46.0	20.1
April	Above	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	3	64.5	43.3	28.2
	Below	11	95.4	85.4	14.6	36	94.6	83.8	15.7	15	90.3	69.0	16.2	3	83.2	45.0	16.6
May	Above	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	2	0	4.0	34.8
	Below	41	94.5	85.0	14.8	24	91.5	71.5	16.0	7	87.7	60.0	17.2	1	83.8	54.0	18.0

Table XV further shows the relation of the degree of acidity of corn to the percentage of germination. Although a test of germinative power could never be used in a practical way in grading corn commercially, except, possibly, in cases of appeal, its value and reliability as a criterion of soundness and quality are, nevertheless, generally acknowledged.

TABLE XV.—*Relation of the degree of acidity to the percentage of germination of samples of corn which arrived at a terminal market from December, 1911, to May, 1913, inclusive.*

Item.	Germination (per cent).				
	0 to 20.	21 to 40.	41 to 60.	61 to 80.	81 to 100.
Number of samples	419	427	560	696	330
Average acidity .... c. c.	24.5	21.1	19.2	18.2	16.7

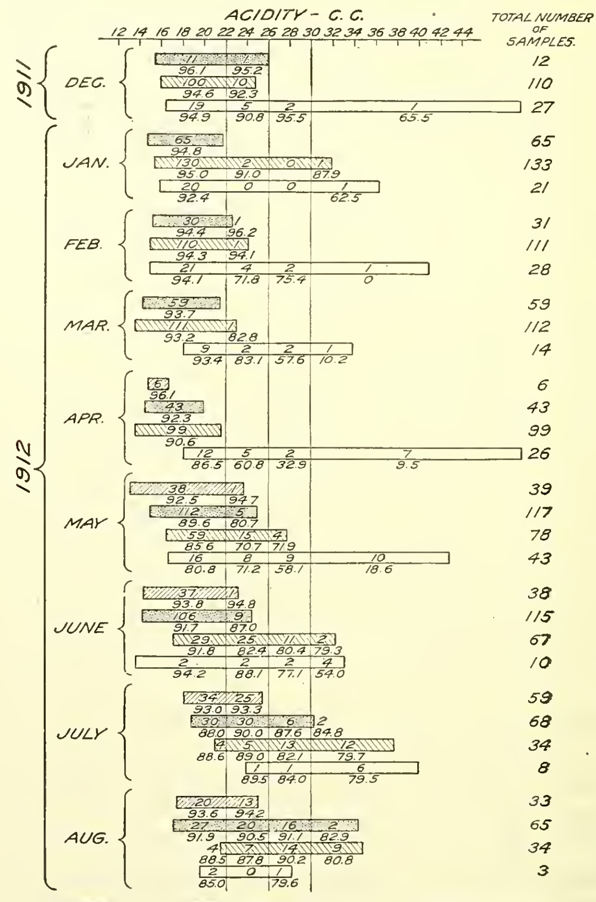


FIG. 24a.—Graphic comparison of the increase in degree of acidity with the decrease in percentage of sound kernels found in representative samples of corn as received at a principal terminal market from December, 1911, to August, 1912, inclusive. The individual bars represent the maximum and the minimum degrees of acidity found in each grade. The figures on the bars refer to the number of samples in each grade which fell within the acidity ranges of below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c. The number just below the bar refers to the average percentage of sound kernels found in the samples which fell within the acidity range designated.

In the foregoing illustrations and tables the relation of sound corn and germination has been compared with the degree of acidity by showing the average percentage of sound corn and average percentage of germination found in samples with acidity greater than 22 c. c. and in samples with acidity less than 22 c. c.

Figures 24*a* and 24*b* serve the purpose of showing the range in the degree of acidity found in each grade, by months. They show, further, by months, the number of samples in each grade with a

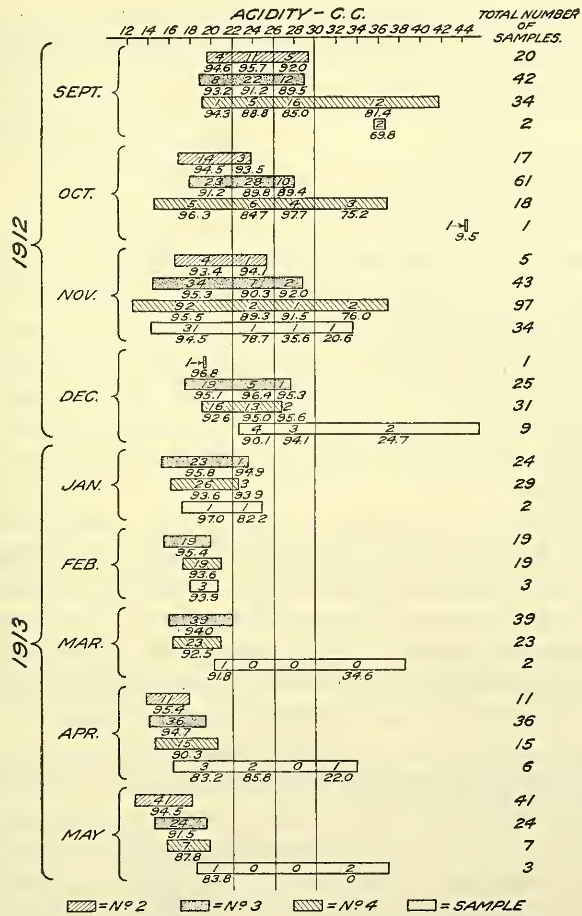


FIG. 24*b*.—Graphic comparison of the increase in degree of acidity with the decrease in percentage of sound kernels found in representative samples of corn as received at a principal terminal market from September, 1912, to May, 1913, inclusive. The individual bars represent the maximum and the minimum degrees of acidity found in each grade. The figures on the bars refer to the number of samples in each grade which fell within the acidity ranges of below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c. The number just below the bar refers to the average percentage of sound kernels found in the samples which fell within the acidity range designated.

degree of acidity below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c., and also the average percentage of sound corn (including sound broken kernels) found in the samples which fell within these ranges in degree of acidity. Attention is called in these figures to the low percentage of sound corn found in samples within the higher ranges of acidity, to the small range in the degree of acidity found in samples of the high grades compared with the greater range in degree of acidity of samples in the lower grades, and also to the uniform low degree of acidity of the corn marketed in 1913 as compared to the acidity of the 1912 receipts (crop of 1911). Table XVI represents a summary of figures 24*a* and 24*b*.

TABLE XVI.—*Samples of corn analyzed for acidity at a principal terminal market from December, 1911, to May, 1913, inclusive, showing the average percentage of sound corn and the percentage of the total number of samples falling within stated acidity ranges.*

Samples.	Range of acidity (c. c.).			
	Below 22.	22.1 to 26.	26.1 to 30.	Above 30.
Number of samples	1,909	314	142	87
Percentage of total number of samples	77.9	12.8	5.8	3.5
Average percentage of sound corn found in samples	92.9	88.0	84.4	57.9

RELATION OF COMMERCIAL GRADES TO DAMAGED KERNELS.

By comparing the degree of acidity found in samples with the percentage of damaged kernels found in the same samples by critical mechanical analysis it will be seen that the acid test is a factor in the commercial grading of corn. This fact is clearly brought out in Tables XVII, XVIII, and XIX, and in figures 25 to 33, covering samples representing approximately 2,500 cars received at a principal terminal market.

Table XVII shows the results of acid tests and mechanical analyses for damaged kernels made with samples representing grades No. 2, No. 3, No. 4, and sample, respectively. Attention is called to the increase in the percentage of damaged kernels with the increase in the range of degree of acidity in each grade, and to the uniformly low percentage of damaged kernels found in samples which showed a degree of acidity below 22 c. c., irrespective of the grade.

TABLE XVII.—*Samples of corn analyzed for acidity, showing the percentage which fell within stated ranges, the average heat damage, and the average damage other than from heat of samples in each range.*

Samples and acidity range.	Total samples.		Average damage other than from heat (per cent).	Heat-damaged samples.		
	Number.	Per cent.		Number.	Per cent.	Average (per cent).
No. 2 corn:						
Below 22 c. c.	209	77.1	4.82	2	0.95	2.0
Between 22.1 and 26 c. c.	56	20.6	4.90	0		
Between 26.1 and 30 c. c.	5	1.9	6.13	0		
Above 30 c. c.	0	0				
No. 3 corn:						
Below 22 c. c.	704	79.6	5.9	1	.14	10.2
Between 22.1 and 26 c. c.	131	14.8	7.37	0		
Between 26.1 and 30 c. c.	44	4.9	8.72	0		
Above 30 c. c.	6	.67	13.47	0		
No. 4 corn:						
Below 22 c. c.	853	81.0	5.31		.35	21.3
Between 22.1 and 26 c. c.	95	9.05	12.04	1	1.05	6.45
Between 26.1 and 30 c. c.	65	6.1	17.57	3	4.61	19.0
Above 30 c. c.	40	3.81	18.52	0		
Sample grade:						
Below 22 c. c.	141	58.3	5.21	6	4.25	17.9
Between 22.1 and 26 c. c.	37	15.4	10.66	11	29.72	26.9
Between 26.1 and 30 c. c.	23	9.6	10.91	12	52.17	36.9
Above 30 c. c.	41	16.7	14.94	28	68.29	72.4

The results of the analyses of samples given in Table XVIII show that the degree of acidity of corn increases with the percentage of damaged kernels. Attention is called to the fact that of the samples showing a low percentage of damaged kernels a very small percentage is found in the higher ranges of acidity, while of the samples showing a high percentage of damaged kernels a large percentage is high in degree of acidity.

TABLE XVIII.—*Relation of degree of acidity to the percentage of damaged kernels (exclusive of heat damaged) in samples of corn, as received at a terminal market from April 1, 1912, to October 31, 1912, inclusive.*

Samples.	Damaged kernels of No. 2 corn samples.		Damaged kernels of No. 3 corn samples.			Damaged kernels of No. 4 corn samples.		Damaged kernels of sample-grade corn.	
	With less than 5 per cent.	With more than 5 per cent.	With less than 5 per cent.	With between 5 and 10 per cent.	With more than 10 per cent.	With less than 10 per cent.	With more than 10 per cent.	With less than 10 per cent.	With more than 10 per cent.
Below 22 c. c. acidity, per cent	69.9	71.0	76.2	67.8	60.8	77.1	36.6	85.0	23.0
Above 22 c. c. acidity, per cent	30.1	29.0	23.8	32.2	39.2	22.9	63.4	15.0	77.0
Above 28 c. c. acidity, per cent	0	3.2	1.5	2.8	7.0	7.2	27.9	5.0	44.5
Above 32 c. c. acidity, per cent	0	1.0	0	0	2.1	.6	13.1	5.0	31.1
Average of damaged kernels, per cent	3.13	8.03	3.6	7.22	13.87	6.12	23.7	5.79	27.1
Average acidity, cubic centimeters	19.8	20.2	19.6	20.6	21.4	19.8	26.1	19.4	26.1
Number of samples	126	93	130	242	143	166	197	20	74

Figure 25 summarizes by grades the general relationship that the percentage of damaged kernels bears to the range in the degree of acidity of corn arriving at a principal terminal market. The relationship of the moisture content to these factors is also shown.

To summarize in words, it may be said that corn arriving at terminal markets from country points decreases in moisture content with the advance of the season from harvest to harvest, and likewise there is an increase of damaged kernels and a corresponding increase in degree of acidity, the increase in damaged kernels being due to the deterioration that takes place in the corn while in the crib or in the country elevator, primarily as a result of excessive moisture.

Figures 26 and 27 summarize by grades and by combination of all grades the general relationship that the degree of acidity bears to the percentage of damaged kernels found in samples of corn arriving at a principal terminal market. The relationship of the moisture content and percentage of germination to these factors is also shown. By these curves all factors which determine the quality, soundness, and condition of corn may be compared with the commercial grading of corn arriving at a principal terminal market.

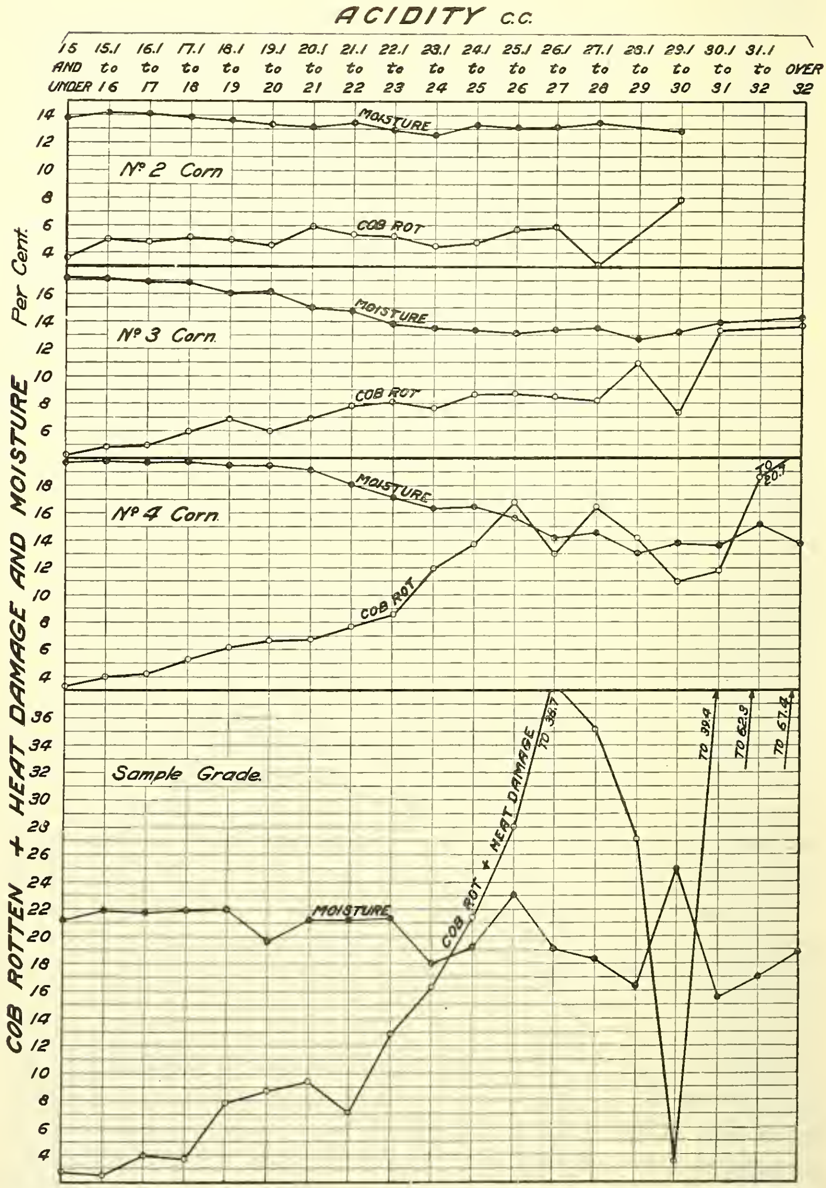


FIG. 25.—Curves showing the relation of the percentages of moisture and of cob-rotten kernels to the degree of acidity in samples of No. 2, No. 3, No. 4, and sample-grade corn as received at a principal terminal market (C).

GENERAL CONSIDERATIONS.

The percentage of moisture in corn is and should be the primary factor in commercial grading. This is due to the fact that the quality of corn from the standpoint of storage and transportation is directly dependent upon the moisture content above certain limits. From the time of harvest until spring (usually April or May, depending upon the season and section of the country) the corn arrives at terminal markets with an excessive percentage of moisture. But after a certain time in the year the great bulk of the corn arriving at terminal markets is without excessive percentage of moisture and the moisture content ceases to be a factor in the grading. Quality and soundness, or the percentage of damaged kernels, then become the primary factors in determining the grade.

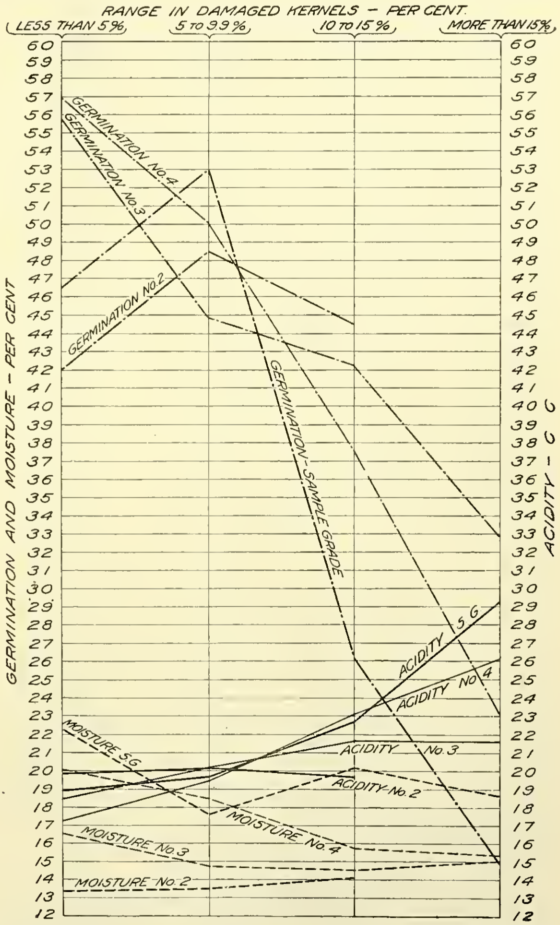


FIG. 26.—Curves showing the relation of the degree of acidity and the percentages of germination and of moisture to the range in percentage of damaged kernels as found in samples representing No. 2, No. 3, No. 4, and sample-grade corn arriving at a principal terminal market (C) from December, 1911, to November, 1912, inclusive.

The degree of acidity of corn, a factor heretofore never used in commercial grading, is nevertheless found to be in direct relation to the degree of quality and soundness as applied to the commercial grades in connection with the range in percentage of damaged kernels found in corn arriving at terminal markets, as shown in figure 28.

The degree of acidity of corn should not necessarily be considered a measure of the percentage of individual kernels that are visibly damaged. It is the soundness and quality of the corn which is indicated by the acidity test, and the results of this investigation suggest the acidity test as a method to be used in determining accurately the soundness and quality of corn.

Let us consider, for example, that a sample of seed corn showed upon test a degree of acidity of 15 c. c. This represents approximately the acidity of the average corn selected for seed. Now, let us consider that a sample of corn consisting entirely of cob-rotten or otherwise damaged kernels showed upon test a degree of acidity of 45 c. c. This represents the degree of acidity of corn selected by the Office of Grain Standardization as being most typical of damaged kernels found in commercial corn arriving at terminal markets throughout the country. Suppose the two samples be mixed in the proportion of 90 per cent seed corn and 10 per cent damaged corn. The degree of acidity of this sample would be theoretically 90 per cent of 15 c. c. plus 10 per cent of 45 c. c., or 18 c. c. This would stamp the sample as being commercially sound corn.

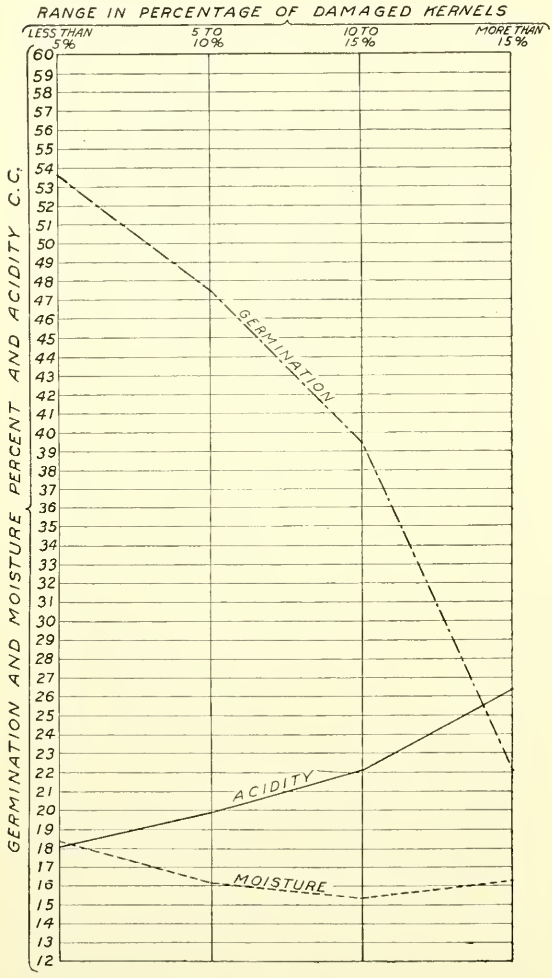


FIG. 27.—Curves showing the relation of the degree of acidity and the percentages of germination and moisture to the range in percentage of damaged kernels as found in samples of corn (average of all grades) arriving at a principal terminal market (C) from December, 1911, to November, 1912, inclusive.

Let us consider further a sample of average sound corn as determined by mechanical separations of samples from several thousand cars of corn arriving at terminal markets. The acidity of such corn is shown by this investigation to be approximately 19.5 c. c. If a sample be made consisting of 90 per cent of this sound corn and 10 per cent of the damaged corn showing an acidity of 45 c. c., the sample so prepared would show theoretically a degree of acidity of 22.05 (90 per cent of 19.5 c. c. plus 10 per cent of 45 c. c.). This sample would be stamped as being "unsound corn" according to the acid test. The percentage of damaged kernels may vary considerably in corn regarded as sound by the acid test. This is dependent upon the degree of soundness or quality of the kernels judged by the eye as being not damaged.

As a result of this investigation, 22 c. c. is recommended as approximately expressing the maximum degree of acidity found to be contained in corn considered commercially sound. Corn showing a degree of acidity exceeding 22 c. c. indicates the development of excessive acidity through the deterioration of the germ, and is discriminated against as being of poorer quality than corn showing a degree of acidity less than 22 c. c.

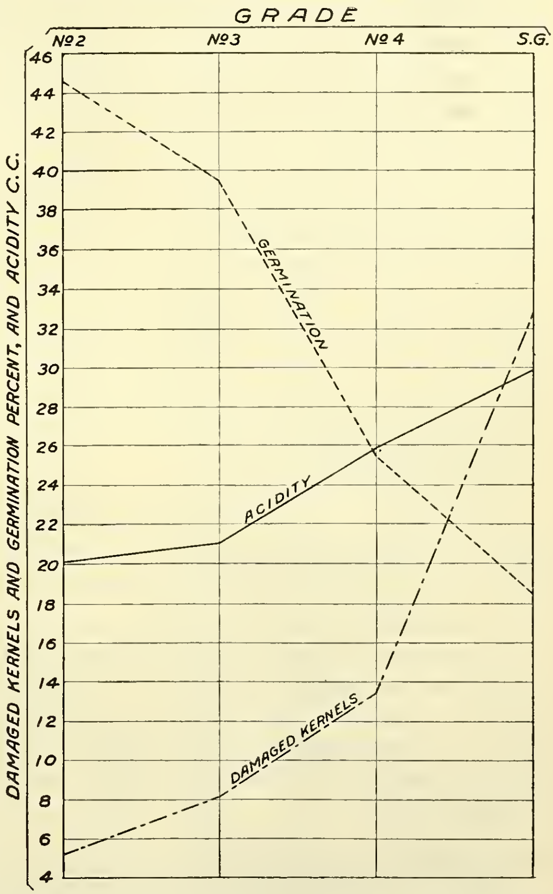


FIG. 28.—Curves showing the increase in the degree of acidity of samples of corn from the high to the low grades where there is also a corresponding increase in percentage of damaged kernels and decrease in percentage of germination, as found to represent approximately 900 cars of corn received at a principal terminal market (C) throughout a year, all of which corn contained less than 16 per cent of moisture and was graded according to quality and amount of damage.

In the determination of soundness and quality of corn by means of the acid test, it is the large bulk of the corn which must be considered rather than the 10 or 15 per cent of damaged kernels which the sample under analysis may contain. The acid test measures definitely the quality and soundness of the 85 or 90 per cent of the so-called "sound kernels," as recognized by the analyst or inspector in his determination of 10 or 15 per cent of damaged kernels by means of a mechanical analysis. Directed only by his judgment in a mechanical separation of "damaged kernels" from "sound kernels" in any given sample, the analyst is entirely without means of expressing in any standard way the quality and soundness of the sample as a whole. He is, furthermore, entirely without means of confirming his judgment or opinion in his discrimination between sound and damaged kernels by any standard test or criterion.

The results of these corn-acidity investigations indicate that the acid test is such a criterion, and it is offered as an aid to any analyst or inspector who desires to determine in a uniform, standard, and scientific way the quality and soundness of corn.

In order to classify corn as to quality and soundness by means of the acid test, it is necessary to fix certain limits in the degree of acidity, above which limits the corn may be said to be unsound as compared to corn below such limits. It is only in a general, broad way that these limits are suggested. Corn which is to the eye unquestionably of poor quality and unsound shows invariably a high degree of acidity between limits of 30 and 50 c. c. Corn showing above 50 c. c. in degree of acidity is in a very advanced stage of deterioration, and its quality does not need to be tested in any other way than by inspection.

As a result of these and other investigations of the acidity of corn in this country [1] and abroad, a limit of 30 c. c. seems most appropriate in discriminating against wholly bad or unsound corn. Any corn with a degree of acidity more than 30 c. c. is unquestionably unsound and of very poor quality.

Of samples representing approximately 2,450 cars of corn received at a principal terminal market from December, 1911, to May, 1913, inclusive, 87 were found to have a degree of acidity greater than 30 c. c. The results of analyses, together with the commercial grade and the remarks of the inspector who graded the samples, are shown in Table XIX.

TABLE XIX.—*Quality and condition of corn which showed a degree of acidity greater than 30 c. c., as found in representative samples at a principal terminal market.*

Laboratory No.	Month.	Grade.	Moisture.	Cob rot.	Heat damaged.	Germination.	Acidity.	Inspector's remarks.[2]
			Per cent.	Per cent.	Per cent.	Per cent.	C. c.	
38496	July	3	13.0	4.00	0	8	30.1	Too much damage.
38665	do	3	14.7	22.60	0	2	30.3	
38498	do	Sample	15.2	0	15.10	4	37.6	Subject; heating.
38520	do	do	15.7	11.00	0	6	33.0	Heating; one end hot.
38531	do	do	14.6	22.25	0	2	35.7	Heating.
38572	do	do	14.6	1.85	5.70	0	33.4	Slightly heating.
38619	do	do	14.8	15.85	0	0	32.8	Heating.
38748	do	do	14.4	44.00	0	0	41.5	Do.
38495	do	4	14.0	15.65	0	0	38.7	Subject; too much damage for 3.

[1] Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 199, 36 p., 1910.

[2] Explanation of terms: Subject=grade subject to change upon reinspection; mahogany=badly heat damaged.

TABLE XIX.—*Quality and condition of corn which showed a degree of acidity greater than 30 c. c., as found in representative samples at a principal terminal market*—Contd.

Laboratory No.	Month.	Grade.	Moisture.	Cob rot.	Heat damaged.	Germination.	Acidity.	Inspector's remarks.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*	
38497	July	4	14.6	17.00	0	16	31.4	Subject; damaged and musty.
38500	do	4	15.0	27.50	0	4	38.3	
38519	do	4	14.7	24.10	0	10	32.3	Too much damage for 3.
38526	do	4	13.3	9.45	0	14	32.1	Do.
38537	do	4	13.1	12.85	0	2	32.9	Do.
38622	do	4	13.3	24.00	0	2	34.4	Damaged and musty.
38662	do	4	14.7	17.30	0	8	32.0	
38689	do	4	13.6	14.40	0	8	33.9	
38749	do	4	13.2	19.75	0	2	35.2	Too much damage for 3.
38757	do	4	14.9	24.10	0	34	35.3	
38760	do	4	14.3	26.25	0	22	32.7	
38977	August	3	13.6	16.50	0	0	32.2	Too much damage.
38998	do	4	13.6	16.25	......	......	35.0	Do.
38818	do	4	14.3	17.15	0	......	35.5	Too much damage for 3; subject.
38855	do	4	15.4	24.30	0	34	31.5	Damaged and musty.
38858	do	4	13.0	25.80	0	8	35.2	
38861	do	4	12.9	10.25	0	......	30.5	Too much damage for 3.
38873	do	4	14.3	15.75	0	6	31.3	Do.
38902	do	4	12.2	10.50	0	4	33.2	Do.
38926	do	4	13.9	17.05	0	20	32.7	Do.
38927	do	4	13.6	18.35	0	38	31.6	Do.
38979	do	4	13.4	21.00	0	......	34.2	
39064	September	4	13.7	10.00	0	32	30.7	Do.
39067	do	4	13.4	14.00	0	18	35.0	Do.
39057	do	4	13.4	26.50	0	14	42.3	Dirty and musty.
39069	do	4	14.2	35.00	0	20	39.5	Too much damage for 3.
39096	do	4	13.6	11.15	0	4	30.8	Do.
39115	do	4	13.5	29.70	0	6	43.3	Dirty and musty.
39131	do	4	13.1	12.00	0	10	30.6	Too much damage for 3.
39132	do	4	13.7	15.85	0	4	35.0	Subject; too much damage for 3.
39155	do	4	14.3	10.75	0	18	30.3	Too much damage for 3.
39157	do	4	12.8	9.25	0	2	30.7	Do.
39162	do	4	13.1	19.35	0	36	32.2	Do.
39163	do	4	13.7	14.25	0	6	32.8	Subject; too much damage for 3.
39028	do	Sample	13.0	22.35	......	14	36.4	Bottom mahogany.
39114	do	do	12.6	26.75	0	22	37.6	Damaged and dirty.
39191	October	4	14.1	13.50	0	......	34.9	
39192	do	4	14.5	27.75	......	2	37.8	Too much damage for 3.
39213	do	4	12.9	24.85	......	32	36.7	Do.
39212	do	Sample	12.7	......	89.15	......	46.7	Badly damaged.
39368	November	4	13.6	26.50	......	4	38.0	Too much damage for 3.
39389	do	4	13.3	16.50	......	16	30.7	Do.
39409	do	Sample	12.2	27.05	48.80	10	33.8	Badly damaged.
35336	December	do	23.0	34.05	0	32	52.0	Rotten end half.
35875	January	4	20.0	6.70	0	72	32.4	Damp and damaged.
35732	do	Sample	26.3	0	42.40	22	37.4	Wet, hot.
36240	February	do	33.9	0	95.70	0	42.6	Germination wet.
36684	March	do	26.9	0	86.80	0	34.4	Badly damaged.
37406	April	do	21.5	0	97.60	2	33.1	Hot.
37504	do	do	20.0	0	71.80	0	37.7	Do.
37505	do	do	21.5	0	98.70	0	32.9	Do.
37506	do	do	24.1	0	99.00	0	52.0	Do.
37521	do	do	16.2	0	94.15	0	39.8	Heated, sour, and mahogany.
37533	do	do	16.8	89.50	0	2	39.8	Subject; soft, badly damaged, sour.
37536	do	do	14.5	0	53.75	6	33.1	Soft, badly damaged, sour.
37632	May	do	19.0	68.80	0	12	42.4	Subject; soft.
37652	do	do	21.3	......	98.75	0	44.3	Hot.
37656	do	do	20.0	34.50	0	0	31.9	Do.
37747	do	do	17.9	......	74.65	6	40.3	Do.
37764	do	do	21.1	......	97.40	0	37.4	Do.
37785	do	do	20.0	......	95.15	0	43.1	Subject; too much damage for 3.
37819	do	do	19.1	......	95.80	......	37.5	Hot.
37871	do	do	18.6	......	95.20	......	39.0	Do.
37905	do	do	17.9	......	77.65	2	35.3	Do.
37945	do	do	20.6	......	63.00	4	33.7	Do.
38185	June	4	15.8	22.95	0	2	32.5	Damaged and musty.
38426	do	4	14.6	13.55	0	8	31.0	Too much damage for 3.
38122	do	Sample	14.6	53.75	0	8	31.4	Badly damaged; mahogany.
38242	do	do	15.1	......	47.25	2	30.8	Badly damaged and musty.
38304	do	do	15.9	19.70	12.00	36	30.3	Heating.
38425	do	do	15.4	17.15	15.22	2	33.5	Do.
39711	December	do	20.4	0	54.10	22	47.7	Hot.
39813	do	do	22.7	......	93.50	......	38.0	Subject; hot.
40535	March	do	......	65.40	......	24	39.9	
40870	April	do	22.3	78.00	......	20	34.6	
41119	May	do	......	......	......	4	31.6	
41152	do	do	......	......	......	4	38.0	

Assuming that 30 c. c. correctly discriminates in a general way between good and bad corn, it becomes necessary, in order to make the acid test a test of value, to establish limits below 30 c. c. which will relatively classify the good corn according to its degree of quality and soundness.

Results of corn-acidity investigations show that theoretically quality and soundness vary directly in proportion to the degree of acidity of the corn. All corn shows acidity of a certain degree. The minimum degree of acidity is represented in the corn at the time of harvest, and is found to vary between the limits of 9 or 10 and 15 or 16 c. c., having never been found to exceed 20 c. c.

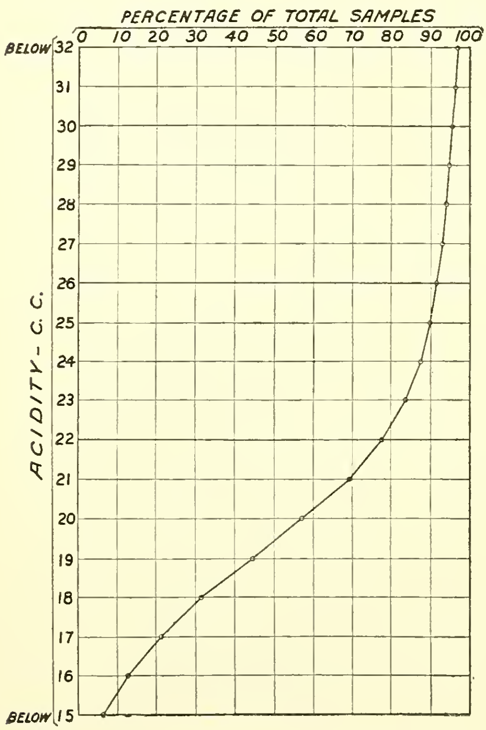


FIG. 29.—Curve showing the percentage of samples of corn tested for degree of acidity which fell below 15, below 16, below 17, and so on up to and including 32 c. c., representing approximately 8,000 cars received at four principal terminal markets.

Covering a period of three years, approximately 10,000 samples were tested for degree of acidity. These samples included seed corn as well as corn from the harvest field, corn as stored on the farm and as found through all stages of commercial handling, including transportation and storage, and showed ranges in the degree of acidity from 9 to 10 c. c. to over 100 c. c. Of the corn arriving at terminal markets throughout the country, between 75 and 80 per cent of the cars as sampled showed acidity below 22 c. c., about 90 per cent was below 26 c. c., and approximately 4 or 5 per cent was above 30 c. c. (Figs. 29 and 30.)

From the results of mechanical analyses of samples representing cars arriving at terminal markets (fig. 21) the average degree of acidity of the separations shows as follows:

	C. c.
Sound kernels	19.5
Broken kernels	22.5
Damaged kernels, exclusive of heat damage	41.2
Slightly heat-damaged kernels	41.8
Badly heat-damaged kernels	50.8

The monthly average acidity of corn considered damaged and the monthly average acidity of corn considered sound, as separated from samples representing approximately 3,000 cars received at a terminal market, compare with the relation of the degree of acidity of corn to its general appearance. (Fig. 31.) It will be seen that the corn appearing sound to the eye was uniformly low in degree of acidity, exceeding the limit of 22 c. c. only slightly in any of the months. Attention is also called to the increase of acidity in both the sound and damaged corn through the summer months, until the arrival upon the market of the new crop.

Of 127 samples of corn selected for seed, only three showed a degree of acidity above 22 c. c., and these samples showed evidence of deterioration through their low germinative power. (Fig. 10.)

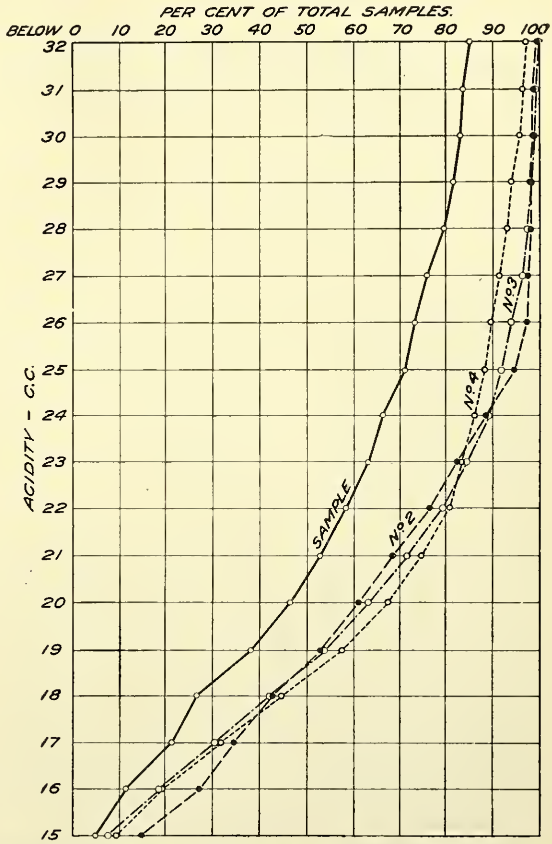


FIG. 30.—Curves showing the percentage of samples of corn in each commercial grade tested for degree of acidity which fell below 15, below 16, below 17, and so on up to and including 32 c. c., representing approximately 2,500 cars received at a principal terminal market from December, 1911, to May, 1913, inclusive.

With a knowledge of the fact that as corn deteriorates the degree of acidity increases and from the results of investigations as described in the preceding paragraphs, it is believed that 22 c. c. most closely denotes the first stages in deterioration and that any corn showing a degree of acidity greater than 22 c. c. is, by comparison, of lower quality and lacking in normal qualities of soundness which it at one time possessed.

From the theoretical standpoint it is undoubtedly true that corn with a degree of acidity of 15 c. c. more closely approximates ideal quality and soundness than corn with an acidity of 20 c. c. It has been the aim, however, in fixing the initial limit at 22 c. c. to choose a limit which would be practical from the standpoint of commercial grading. In the same sense that corn with an acidity of 20 c. c. is of poorer quality than corn with an acidity of 15 c. c., an acidity of 27 c. c. denotes poorer quality and a further advance toward wholly bad corn than an acidity of 25 c. c.

In the commercial classifying of corn according to quality and soundness by means of the acid test, this investigation would recommend but one limit between the limits of 22 and 30 c. c., and that it be placed at 26 c. c.

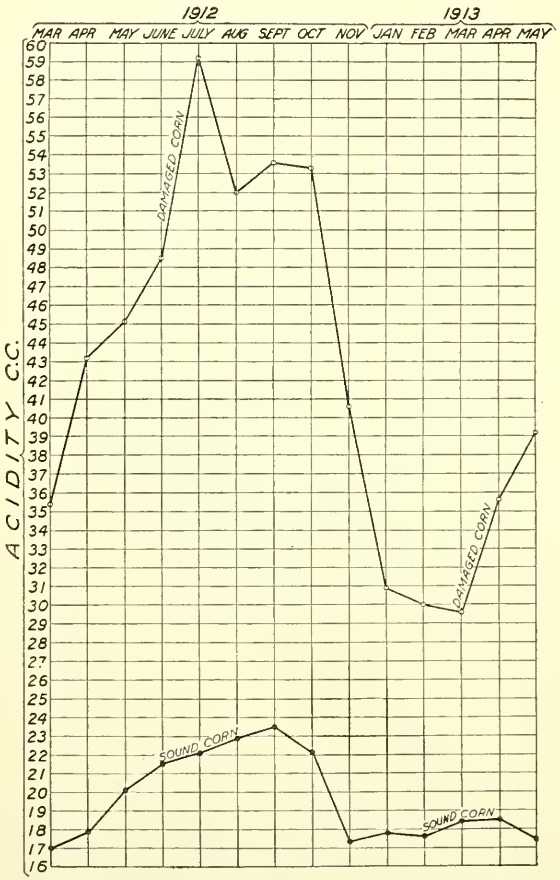


FIG. 31.—Curves comparing the monthly average degree of acidity of sound corn with the monthly average degree of acidity of damaged corn as determined by mechanical analyses of corn arriving at a principal terminal market.

The results of this investigation show that corn with a degree of acidity below 22 c. c. is normally sound and of first-class quality from the commercial standpoint; that corn with a degree of acidity between 22 and 26 c. c. is inferior in quality and soundness, due to deterioration of the germ; that corn with a degree of acidity between 26 and 30 c. c. has deteriorated sufficiently to be considered unsound; and that corn with a degree of acidity greater than 30 c. c. is badly damaged and of a very low quality. It must be remembered in the application of the acid test that the sample as a whole must be considered and not individual kernels.

The question will perhaps arise in the minds of some why the degree of acidity of corn was taken as the one important chemical factor in establishing its condition or quality. The answer to this question will be found in carefully studying Table XX, comparing the change in the different factors throughout the experiment. This table represents the chemical analysis of a car of corn sampled at various intervals from April 10 to June 26, inclusive, while it was standing on the track at Baltimore. The corn was allowed to heat and go out of condition. For a comparison of the acidity, temperature, and germination during the storage period, see figure 13 (p. 15), which shows that on April 26 the corn was in a badly damaged condition.

TABLE XX.—*Chemical analyses at different stages of deterioration of corn used in a feeding test.*[1]

[The results in columns marked with an asterisk (*) are calculated on a moisture-free basis.]

Date, 1912.	Lab. No.	Moisture.	Ash.*	Ether extract.*	Protein.*	Crude fiber.*	Pentosans.*	Invert sugar.*	Sucrose.*	Undetermined.*	Acidity.	Germination.
April:		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*C. c.*	*P. ct.*
10	63083	8.99	1.44	4.52	10.23	2.54	6.29	0.15	1.40	73.43	21.3	57.0
10	63084	9.72	1.46	3.98	9.69	2.64	6.42	.23	1.25	74.33	21.9	55.4
10	63085	9.67	1.41	4.35	10.21	2.58	6.70	.24	1.16	73.35	24.3	53.1
10	63086	9.98	1.39	4.50	10.14	2.27	5.94	.23	1.29	74.24	22.7	58.9
24	63181	10.40	1.48	4.58	10.39	2.30	6.34	.22	1.23	73.46	19.6	40.2
24	63182	10.30	1.44	4.33	9.51	2.12	5.95	.20	1.17	75.28	20.9	61.3
24	63183	10.31	1.49	4.36	9.97	2.37	6.45	.07	1.38	73.91	20.3	56.9
26	63254	9.40	1.43	4.45	9.87	2.48	6.78	.34	.95	73.70	19.0	33.1
26	63255	10.20	1.41	4.49	9.50	2.42	6.54	.26	1.12	74.26	19.4	59.2
26	63256	10.42	1.52	4.34	9.52	2.34	6.64	.22	1.17	74.25	19.6	60.3
27	63689	10.54	1.42	4.05	9.71	2.35	6.10	.30	.95	75.12	23.7	38.0
27	63690	10.45	1.44	4.36	9.64	2.22	5.88	.24	1.36	74.86	21.0	52.5
27	63691	11.06	1.47	4.38	9.59	2.24	6.12	.27	1.34	74.59	20.5	51.7
May:												
1	63825	10.12	1.52	3.89	10.05	2.29	5.59	.48	.40	75.78	36.9	11.3
1	63830	10.83	1.49	4.31	9.81	2.22	5.85	.10	1.20	75.02	24.0	65.0
1	63831	11.20	1.51	3.91	10.38	2.33	6.09	.26	1.09	74.43	24.1	54.0
4	63832	11.32	1.45	3.59	9.87	2.76	6.53	.16	1.24	74.40	21.0	54.1
4	63833	10.68	1.47	4.35	10.01	2.41	6.37	.24	1.10	74.05	26.4	44.8
4	63924	10.30	1.35	4.56	9.97	2.37	6.35	.17	.98	74.25	26.3	42.4
10	63923	9.87	1.45	4.15	10.13	2.20	6.27	.23	.90	74.67	29.5	18.9
10	64592	10.74	1.32	4.34	10.02	2.49	6.98	.40	.39	74.06	36.5	10.8
18	64591	10.75	1.47	4.04	10.02	2.66	7.23	.57	.17	73.84	42.4	3.4
22	65113	11.29	1.47	4.02	10.29	2.51	7.06	.47	.17	74.01	41.7	0
22	65114	11.35	1.44	4.18	10.50	2.49	7.39	.49	.19	73.32	44.0	0
25	65191	9.20	1.40	4.24	10.25	2.53	6.39	.39	.06	74.74	40.8	0
25	65192	8.67	1.42	3.87	10.40	2.46	6.02	.35	.08	75.40	46.0	0
29	65209	9.84	1.41	3.75	10.33	2.53	6.25	.26	0	75.47	45.2	0
29	65210	9.82	1.36	4.15	10.32	2.63	6.33	.47	.10	74.64	44.6	0
31	65341	9.59	1.45	3.96	10.30	2.58	6.50	.42	.32	74.47	47.6	4.4
31	65342	9.98	1.49	3.96	9.72	3.69	6.56	.46	.08	74.04	44.4	0
31	65346	10.40	1.50	3.83	9.98	2.51	6.58	.22	.42	74.96	37.5	7.8
31	65347	10.15	1.47	4.06	10.57	2.36	6.44	.38	.35	74.37	40.9	10.0
June:												
1	65352	10.67	1.44	4.00	9.79	2.62	6.66	.36	.29	74.84	40.5	7.8
5	65398	10.41	1.52	3.69	10.60	2.47	6.67	.36	.19	74.50	43.5	0
8	65461	11.14	1.52	3.76	10.28	2.35	6.37	.38	.12	75.22	44.8	0
12	65525	10.79	1.49	3.84	9.81	2.51	6.74	.42	.07	75.12	45.5	1.1
12	65542	11.53	1.61	3.80	10.11	2.19	5.82	0	.35	76.14	46.5	0
19	65593	10.94	1.52	3.63	10.45	2.61	6.66	.30	.09	74.74	50.8	0
25	65639	10.58	1.48	3.67	10.21	2.67	6.34	.40	.21	75.02	57.9	2.2
25	65640	11.03	1.51	3.62	11.66	2.53	6.63	.43	.01	73.61	48.1	0
26	65644	10.75	1.50	3.79	10.43	2.62	6.38	.33	.13	74.82	55.6	3.3
26	65650	9.47	1.47	3.88	10.28	2.50	5.79	.29	.18	75.61	49.0	0
Average	......	10.35	1.46	4.08	10.11	2.48	6.40	.30	.63	74.54	34.7	24.3

[1] The writers wish to express their appreciation to Mr. G. L. Bidwell, Chief of the Cattle Food Laboratory, Bureau of Chemistry, for making many of the chemical analyses here shown.

Now, compare the factors in Table XX from April 10 to June 26, 1912, and it will be found that the only factors showing a perceptible change are the acidity and sucrose, while the ether extract has a

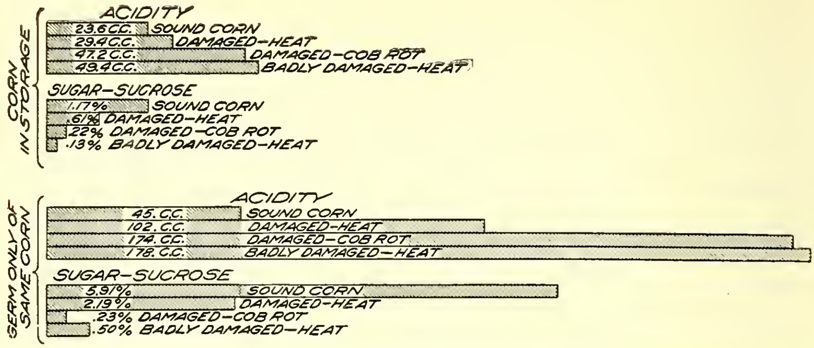


FIG. 32.—Graphic comparison of corn under various stages of deterioration, showing (1) that the degree of acidity is proportional to the degree of deterioration, (2) that where there is an increase in the degree of acidity there is a corresponding decrease in the amount of sugar, and (3) that the source of the increase in the degree of acidity is mostly in the germ.

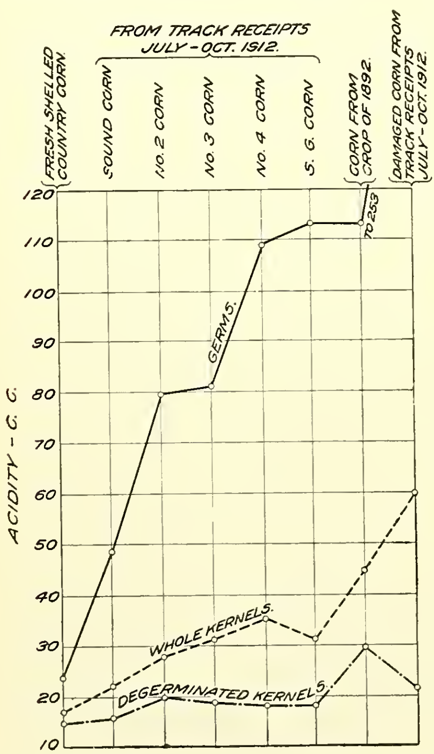


FIG. 33.—Curves comparing the degree of acidity of the germs of corn with that of the degerminated kernels and with that of the whole kernels, showing that the cause of the high degree of acidity in unsound corn is due to the development of abnormal acidity in the germ.

general tendency to become lower. This is as one would expect, because it is through the decomposition of these constituents, ether extract (fats and oils) and sugars, that acids are formed. All the analyses in columns 4 to 11 of the table have been calculated on a moisture-free basis.

Figure 32 represents corn under various stages of deterioration made from the results of a special storage experiment. It shows that the amount of acid is proportional to the degree of deterioration and that where there is an increase in the amount of acid there is a corresponding decrease in the amount of sugar, and it also shows that the source of the increase in the amount of acid is mostly in the germ.

Figure 33 represents the acid determinations of some of the component parts of the corn kernel and again shows that the seat of most of the acid, and especially the increase in acid, is in the germ.

SUMMARY.

As a result of these corn-acidity investigations, the following facts are well established:

(1) All corn, unless in a state of putrefaction, contains acid-reacting substances which impart to the corn a certain degree of acidity.

(2) There is a great variation in the degree of acidity of corn, ranging from 9 or 10 c. c. to over 100 c. c. The degree of acidity can be determined by the acid test to within 0.5 c. c.

(3) The source of corn acidity is mostly in the germ. The source of increase in the degree of acidity is almost entirely in the germ.

(4) All corn judged damaged by the eye is higher in degree of acidity than corn judged sound by the eye.

(5) In a general way the degree of acidity of corn varies inversely with the germinative power.

(6) The degree of acidity of corn increases directly with the percentage of damaged kernels as determined by mechanical analyses.

(7) The degree of acidity of corn is greatly increased by the action of fermentation and high temperature.

(8) Throughout the year, from harvest to harvest, there is a gradual increase in the degree of acidity and a corresponding decrease in the percentage of germination of corn arriving at terminal markets.

(9) With respect to quality and soundness, the degree of acidity of corn is commensurate with the commercial grading at terminal markets.

(10) The degree of acidity of corn is a criterion of soundness and quality.

(11) From the standpoint of commercial grading, corn with a degree of acidity less than 22 c. c. is normally sound and of good commercial quality; corn with a degree of acidity between 22 and 26 c. c. is somewhat inferior in quality and soundness, due to deterioration of the germ; corn with a degree of acidity between 26 and 30 c. c. evidences marked deterioration and is unsound; and corn with a degree of acidity greater than 30 c. c. is badly damaged and should be considered from a commercial standpoint as sample-grade corn.

O

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 103

Contribution from the Referee Board of Consulting Scientific Experts, Ira Remsen, Chairman. April 29, 1914.

(PROFESSIONAL PAPER.)

ALUM IN FOODS.

EXPLANATORY STATEMENT.

A report on the influence of aluminum compounds on the nutrition and health of man has been submitted by the Referee Board of Consulting Scientific Experts, in answer to questions put to it by the department. The report of the board itself, signed by each member, is brief, but it is accompanied by three elaborate reports giving the results of three sets of extensive experiments on human subjects conducted independently by three members of the board. To get the board's conclusions before the public at this time, it is considered advisable to publish its findings, but to omit the extensive reports of the three experimenters, giving only their final conclusions.

QUESTIONS SUBMITTED TO REFEREE BOARD.

The questions submitted to the board were as follows:

1. Do aluminum [1] compounds, when used in foods, affect injuriously the nutritive value of such foods or render them injurious to health?

2. Does a food to which aluminum compounds have been added contain any added poisonous or other added deleterious ingredient which may render the said food injurious to health? (*a*) In large quantities? (*b*) In small quantities?

3. If aluminum compounds be mixed or packed with a food, is the quality or strength of said food thereby reduced, lowered, or injuriously affected? (*a*) In large quantities? (*b*) In small quantities?

CHARACTER OF EXPERIMENTS CONDUCTED.

In order to base their report upon first-hand knowledge, the board instituted three sets of experiments, each independent of the others. One set of experiments was conducted by Dr. Russell H. Chittenden, of the Sheffield Scientific School, Yale University, New Haven; another by Dr. Alonzo E. Taylor, of the Medical School of the University of Pennsylvania, Philadelphia; and the third by Dr. John H. Long, of the Northwestern University Medical School, Chicago. In

[1] Aluminum is a synonym for aluminium, the metal used for cooking utensils and other implements. Alum or sodium aluminum sulphate is a salt of this metal.

41042°—14

each case tests were made on healthy young men by including aluminum in some form in their food. The food was all carefully measured and weighed and the amounts of its principal ingredients were determined by analysis. The excretions of the men's bodies (both urine and feces) were carefully collected, examined, and analyzed. Daily records of body weight, temperature, respiration, and pulse were kept for each man, and notes were made of any unusual symptoms. Any disturbance in health or physiological processes was thus detected.

Each experiment included three periods, in the first and last of which no aluminum was administered. During the middle period aluminum compounds were administered, the "dose" increasing as the experiment progressed. In this way the effect of large quantities was compared with that of small quantities. In Dr. Chittenden's and Dr. Taylor's experiments some of the men who served as "control" subjects received no aluminum at any time, so that any disturbances due to other causes might be checked up.

Dr. Chittenden's experiments included 12 men and continued from January 15 to June 22, 1912. During 130 days the diet contained bread raised with an alum baking powder made in the laboratory.[1] The dose of aluminum compound was increased from time to time, at first by increasing the quantity of bread and later by increasing the quantity of the baking powder used in making the bread. In this way the alum[2] used per man per day was increased from 0.578 gram[3] (8.920 grains) at the beginning to 2.287 grams[4] (35.295 grains) at the close of the dosage period; the actual aluminum contained in this dosage ranged from 0.065 gram (1.003 grains) to 0.257 gram (3.966 grains) per man per day. Eight men used the alum bread, while four had no aluminum in their food.

Dr. Long's experiments ran from February 8 to June 7, 1911, and included six men, all of whom received the dosage. Baking powder bread was not used, but instead for 40 days a mixture of the same composition as the residue left in such bread by alum baking powder was administered in the form of a powder in water or milk. For 30

[1] This bread was made fresh every day and contained in one baking of two loaves approximately:

Sifted flour	quarts..	2
Baking powder (25 per cent calcined alum)	heaping teaspoonfuls..	4
Salt (approximately one rounded teaspoonful)	ounce..	$\frac{1}{3}$
Butter	do....	1
Water, sufficient quantity.		

Later in the experiment a greater proportion of alum baking powder was used in the making of the bread in order to facilitate administering larger amounts of alum.

[2] The term "alum" as used under the heading "Character of experiments conducted" refers to the calcined sodic aluminic sulphate commonly used in alum baking powders and not to the ordinary crystallized alum.

[3] Equivalent to approximately two-thirds of a level teaspoonful of baking powder containing 25 per cent of alum. All the figures in this and succeeding footnotes must of necessity be approximate, since teaspoons vary in size and baking powders in composition.

[4] Approximately equivalent to $2\frac{2}{3}$ level teaspoonfuls of alum baking powder.

days the quantity of alum used was 2 grams[1] (30.866 grains) a day for each man; in the next 10 days the dose was doubled. Afterwards for 30 days the baking powder residue was treated so as to wash out everything except the compounds of aluminum with hydrogen and oxygen (aluminum hydroxide), the dose at first being the amount obtained from 4 grams[2] (61.732 grains) of alum per man per day, which was increased in the second 10 days to 6 grams[3] (92.598 grains) and in the third 10 days to 10 grams (154.330 grains) of alum. Finally, in a period of 10 days, the dose was the sodium sulphate consumed when 4 grams of alum were used, this compound being the cathartic ingredient which is left in bread by alum baking powder.[4]

Dr. Taylor conducted experiments with a squad of eight men from October 8, 1911, to May 10, 1912, with an intermission from December 16 to January 14. In this case also the powder was not used in bread, but was administered in wafers or dissolved in water. Six of the subjects took the aluminum compounds, while the other two took milk sugar, the men themselves not knowing which they were taking. There were two groups of experiments in which the whole squad took part. In the experiments of the first group, which ran from October 8 to December 16, tests were made with alum alone. The dose at first was such as to give each man 0.1 gram[5] (1.5433 grains) of aluminum a day and was increased from time to time until the daily dose was 0.298 gram[6] (4.599 grains) of aluminum for each man. The second group ran from January 14 to May 10. Tests were made with the residue from alum baking powder; tests were also made with certain aluminum compounds (aluminum hydroxide and aluminum chloride) which may be found in the residues from alum baking powders of different kinds, and with sodium sulphate, the purgative salt left in bread by alum baking powders. The smallest dose of the compounds containing aluminum gave each man 0.227 gram[7] (3.503 grains) of aluminum a day, while the largest dose gave 0.969 gram[8] (14.954 grains) of aluminum a day. The dose of the purgative salt (sodium sulphate), in which there is no aluminum,

---

[1] Approximately equivalent to $2\frac{1}{3}$ level teaspoonfuls of alum baking powder. Equlvalent to about 0.223 gram (3.44 grains) of aluminum.

[2] Approximately equivalent to $4\frac{1}{2}$ level teaspoonfuls of alum baking powder.

[3] Approximately equivalent to $6\frac{8}{10}$ level teaspoonfuls of alum baking powder. These amounts of alum are equivalent to about 0.44 gram (6.86 grains), 0.67 gram (10.29 grains), and 1.11 grams (17.15 grains) of aluminum.

[4] Editorial note: Sodium sulphate or Glauber's salt is a substance derived from the interaction of alum and baking soda in making bread with alum baking powders and is of itself a cathartic, formerly much used medicinally. Cream of tartar baking powder, when used in bread, by a similar interaction produces a cathartic substance known as sodium tartrate. Phosphate baking powders when used in making bread produce a cathartic substance known as sodium phosphate. Cream of tartar and phosphate baking powders produce catharsis, similar to that produced by alum baking powders, when used in quantities.

[5] Approximately equlvalent to a level teaspoonful of alum baking powder.

[6] Approximately equivalent to 3 level teaspoonfuls of alum baking powder.

[7] Approximately equivalent to $2\frac{1}{4}$ level teaspoonfuls of alum baking powder.

[8] Approximately equivalent to 10 level teaspoonfuls of alum baking powder.

was 5.23 grams [1] (80.714 grains) per man per day. Following these experiments four men took 1 gram (15.433 grains) of aluminum a day each for several days,[2] and then their blood was tested to detect any aluminum that might be present in it. No aluminum was found in the blood. As a further indirect test to determine whether aluminum was resorbed, one man took for five days enough aluminum hydroxide to furnish 0.660 gram (10.186 grains) of aluminum a day and another took enough to give 0.540 gram (8.334 grains) a day for five days. The men were fed a diet of low and known phosphorus content and the excrementa analyzed for phosphorus, in order to detect, if possible, signs of abstraction of this element from the tissues by resorbed aluminum. This test failed to demonstrate resorption of aluminum.

CONCLUSIONS OF INDIVIDUAL INVESTIGATORS.

Dr. Chittenden concludes from his experiments that small quantities of aluminum compounds, and even comparatively large quantities, when taken daily with the food, have no effect upon the general health and nutrition of the body. "In other words," as he sums up his conclusions, "aluminum compounds when used in foods—as in bread—in such quantities as were employed in our experiments do not affect injuriously the nutritive value of such foods or render them injurious to health, so far as any evidence obtained in our experimental work indicates."

Dr. Long, in concluding his report, calls attention to the fact that alum is rather generally used in the manufacture of cucumber pickles. This is an old practice which had its origin in the household rather than in the factory and is still common in the household. The hardening effect of the alum is believed to help in keeping the pickles. In the factory the cucumbers are first soaked for several weeks in strong brine, then in fresh water overnight, this process being sometimes repeated. Then the cucumbers are put into an alum liquor in which the weight of alum used is about one-fourth of 1 per cent of the weight of the cucumbers. The cucumbers and liquor are heated up to 120° or 140° F., then cooled and allowed to stand for from 6 to 24 hours. Then comes a bath in fresh water and afterwards the final treatment with vinegar. The vinegar takes out some of the alum from the pickles, so that usually the alum left in them amounts to less than two-tenths of 1 per cent.

Alum is also used in the preparation of maraschino cherries, and perhaps some other fruits. But the quantities of aluminum that might be consumed either in pickles or in the fruits referred to are so small, compared with the quantities actually consumed in baking powders, that the study of alum baking powders may be taken to cover the entire field.

---

[1] About one-fifth ounce of Glauber's salt. (See footnote, p. 3.)

[2] This corresponds to approximately 10 level teaspoonfuls of alum baking powder.

Alum, as such, is not present in the food when eaten. In the process of baking, the alum and soda in baking powder break up and recombine into several compounds. One product is the carbonic acid gas, which does the work of leavening. This gas passes off, leaving in the bread an aluminum compound and a compound called sodium sulphate. Dr. Long concludes that the cathartic action of large residues from the alum and soda combination—for instance, the residue left when the large dose of alum, 4 grams [1] (61.732 grains), was used—must be considered objectionable when administered daily. But this is much above the consumption in actual practice, and amounts of alum not above 2 grams [2] (30.866 grains) a day—a liberal allowance—do not appear to be harmful in any practical sense. Since the quantities of aluminum compounds consumed with other foods are insignificant compared with the quantities consumed in foods prepared with baking powder, the findings from the study of baking powder residues must be held to cover all cases. Keeping in mind that the aluminum compounds actually in the food when consumed are comparatively inert, Dr. Long declares that "it can not be said that, when mixed with foods in the small quantities actually considered necessary, they add a poisonous or deleterious substance, or injuriously affect the quality of the food with which they are used."

Dr. Taylor's conclusions agree in effect with those of his associates. He says, "We have had, unquestionably, evidences of the catharsis caused by the administration of large doses of baking powder." With the large doses used in his experiments, the stools are increased in weight and frequency, the movements are loose, and colic is apt to attend the evacuations. This condition is the result of sodium sulphate, which, though not an aluminum compound, is a residue of the alum baking powder. But with very large doses of aluminum compounds occasional dry colic may also be noted.

"I personally," says Dr. Taylor, "do not believe that it would be healthful for anyone, in camp or out of camp, to live upon a diet of baking powder biscuits. I do not believe that the regular ingestion of sodium sulphate in doses of from 3.5 to 5 grams [3] (54 to 77 grains) per day, with the normal diet, resulting in distinct looseness of the bowels, is a procedure to be recommended. Prolonged administration of saline cathartics even in small dose tends to leave behind a condition of constipation; and it is certainly the experience of the medical profession that the practice of the regular administration of saline cathartics is not to be recommended. This aspect of the question is of course not peculiar to aluminum baking powder, but applies to all baking powders, since to a greater or less extent a saline cathartic remains as the residue of the reactions of all known baking powders,

---

[1] Approximately equivalent to 4½ level teaspoonfuls of alum baking powder.
[2] Approximately equivalent to 2¼ level teaspoonfuls of alum baking powder.
[3] One-eighth to one-sixth ounce of Glauber's salt.

as demonstrated in direct tests with different baking powders on human subjects.[1] There is no evidence in our results to indicate that the occasional and ordinary use of bread, biscuits, or cake prepared with aluminum baking powder tends to injure the digestion. The amount of saline cathartic that would be ingested under conditions of normal diet would be very small and would provoke no catharsis or symptoms of any kind."

One other effect of the administration of compounds of aluminum is noted by Dr. Taylor, namely, a distinct decrease of phosphates in the urine and a corresponding increase of phosphates in the stools. But the extent of this change is too slight for it to have any material meaning or effect.

CONCLUSIONS OF THE REFEREE BOARD.

With the results of these independent experiments agreeing so well, the Referee Board were enabled to draw up a unanimous report, signed by all the members, namely: Ira Remsen, president of Johns Hopkins University, chairman; Russell H. Chittenden, professor of physiological chemistry in Yale University and director of the Sheffield Scientific School; John H. Long, professor of chemistry in the Northwestern University Medical School; Alonzo E. Taylor, Benjamin Rush professor of physiological chemistry in the University of Pennsylvania; and Theobald Smith, professor of comparative pathology in Harvard University.

In their report the board first define their understanding of the terms "small quantity" and "large quantity," as applied to alum baking powders, as follows:

> By the term "small quantity" we understand such an amount as may be ingested in the normal use of biscuits, pastry, or other articles leavened with baking powder, as these foods are practically used in the ordinary American family. This amount will not average more than 25 to 75 milligrams[2] (0.39 to 1.16 grains) of aluminum daily for the days of consumption of such articles.

---

[1] "We must not, however, be oblivious to the fact," says Dr. Taylor, who conducted part of these investigations, "that a saline cathartic residue results from the reaction of every form of known baking powder now commonly employed. The use of cream of tartar or tartaric acid baking powder leaves in the alimentary tract a residue of tartrates which exhibit the action of a saline cathartic and of diuresis [excessive excretion of urine] as well. The so-called phosphate baking powder leaves as a residue of reaction sodium phosphate, again a saline cathartic. And aluminum baking powder leaves as a residue of reaction sodium sulphate, a saline cathartic. Apparently therefore, at present at least, the use of baking powder is associated with the introduction into the alimentary tract of a certain amount of saline cathartic, the salt differing with the use of the particular type of baking powder."

[2] This is approximately equivalent to one-quarter to three-quarters of a level teaspoonful of alum baking powder.

By the term "large quantity" we understand such an amount of aluminum as would be ingested only under very unusual conditions, as for example, where the flour consumption is mainly in the form of biscuits or other articles leavened with aluminum baking powders. This amount may reach 150 to 200 milligrams [1] (2.31 to 3.09 grains) of aluminum per day. A person subsisting mainly on baking-powder biscuits, as may happen in camp life, might ingest an amount in excess of 200 milligrams per day. With this possibility in mind, we have also studied the effects of amounts up to and exceeding 1,000 milligrams [2] (15.4 grains) of aluminum per day.

With this understanding of the terms, the board give the following answers to the questions submitted to them:

Aluminum compounds when used in the form of baking powders in foods have not been found to affect injuriously the nutritive value of such foods.

Aluminum compounds when added to foods in the form of baking powders, in small quantities, have not been found to contribute any poisonous or other deleterious effect which may render the said food injurious to health. The same holds true for the amount of aluminum which may be included in the ordinary consumption of aluminum baking powders furnishing up to 150 milligrams (2.31 grains) of aluminum daily.

Aluminum compounds when added to foods, in the form of baking powders, in large quantities, up to 200 milligrams (3.09 grains) or more per day, may provoke mild catharsis.

Very large quantities of aluminum taken with foods in the form of baking powders usually provoke catharsis. This action of aluminum baking powders is due to the sodium sulphate which results from the reaction.

The aluminum itself has not been found to exert any deleterious action injurious to health, beyond the production of occasional colic when very large amounts have been ingested.

When aluminum compounds are mixed or packed with a food, the quality or strength of said food has not been found to be thereby reduced, lowered, or injuriously affected.

In short, the board conclude that alum baking powders are no more harmful than any other baking powders, but that it is wise to be moderate in the use of foods that are leavened with baking powder.[3]

---

[1] This is approximately equivalent to $1\frac{1}{2}$ to 2 level teaspoonfuls alum baking powder.

[2] Approximately equivalent to 10 level teaspoonfuls alum baking powder.

[3] See footnotes, pages 3 and 6.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 104

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 10, 1914.

THRIPS AS POLLINATORS OF BEET FLOWERS.

By Harry B. Shaw,
Assistant Pathologist, Office of Cotton and Truck Diseases and Sugar-Plant Investigations.

INTRODUCTION.

While conducting breeding experiments with sugar beets during a period of more than five years, it could never be observed that the beet flower, despite the pungent fragrance of its nectar and the remarkable abundance of its pollen, attracted nearly as many insect visitors as numerous blooms offering less pronounced attractions. Especially significant was the rarity of the visits of the honeybee and other common species of Hymenoptera. It appeared as though nature had vainly provided powerful insect lures, excepting only those of conspicuous size and color. It is true that insects, some of them capable of transferring pollen from flower to flower, do visit beet flowers, but relatively their numbers are small and their visits few.

These breeding experiments necessitated the isolation and hand pollination of numerous beet flowers. Not infrequently, in spite of careful technic, it was found that single flowers which had been emasculated and protected by paper bags from pollination became fertilized and produced seed in a manner at the time inexplicable. Although the actual percentage of such cases was small, it was sufficient to attract attention and to cast doubt upon the thoroughness of the protection afforded by the bags. Not only is the beet flower protandrous, but numerous attempts of the writer to effect close fertilization by preserving the pollen until the stigma of the same flower should become receptive, then applying the pollen, have failed. The above-mentioned fertilization, therefore, could not have been accomplished by pollen from any one of the single flowers operated on, even had such pollen reached the stigma; in other words, the beet flower can not be self-fertilized. The most probable explanation for the fertilization of these isolated flowers was the

Note.—The investigations and experiments reported in this bulletin are of interest to horticulturists and plant breeders.

42131°—14

unobserved access of minute pollen-bearing insects. None of the common visiting insects other than thrips is minute enough to gain entrance through the interstices between the mouth of the paper bag and the stem when the bag is tied closely about the beet spike. Thrips, however, are so tiny as scarcely to be visible to the naked eye, the mature larvæ being about $\frac{1}{27}$ inch long and only about $\frac{1}{70}$ inch long immediately after hatching; hence it seemed probable that some of these insects might have crawled up within the mouth of the tied bags and dropped on the stigmata of the isolated flowers some of the pollen they were carrying.

OCCURRENCE OF THRIPS ON BEET FLOWERS.

Besides several other species not identified, the Bureau of Entomology determined the following among specimens of thrips col-

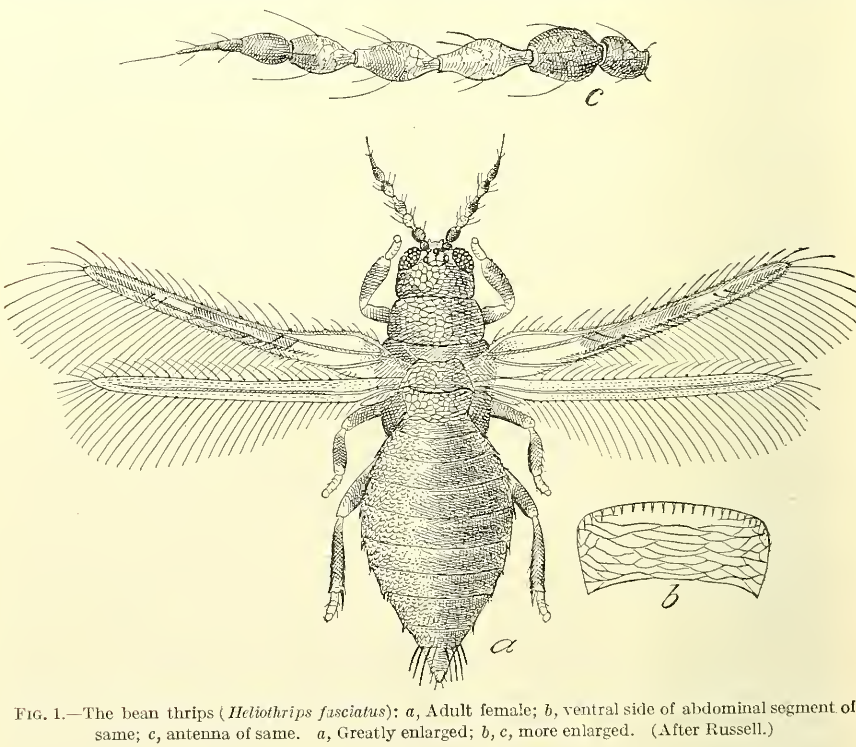


Fig. 1.—The bean thrips (*Heliothrips fasciatus*): *a*, Adult female; *b*, ventral side of abdominal segment of same; *c*, antenna of same. *a*, Greatly enlarged; *b*, *c*, more enlarged. (After Russell.)

lected from beet flowers at Garland, Utah, in 1909 and 1910: *Heliothrips fasciatus* L. (fig. 1), *Frankliniella fusca* Hinds, and *Frankliniella tritici* Fitch. The species most abundant during the seasons of 1911 and 1912 at Ogden, Utah, was *Thrips tabaci*, the onion thrips. The few observed at Jerome, Idaho, during the summer of 1913 have not yet been determined.

At Garland the seed beets were grown near fields of alfalfa, whence many of the thrips found on beets doubtless migrated, the same species

THRIPS TABACI DISLODGED FROM THE BEET FLOWERS SHOWN IN PLATE II.
NATURAL SIZE. (ORIGINAL.)

BRANCHED SPIKE OF BEET FLOWERS FROM WHICH THE THRIPS SHOWN IN PLATE I WERE DISLODGED. NATURAL SIZE. (ORIGINAL.)

being exceedingly abundant in alfalfa blossoms. In Ogden the experimental plats were located in the heart of a trucking district, where many onions and other general truck crops are grown. At Jerome the beet plats were surrounded by alfalfa fields. At Garland these insects were fairly abundant. At Ogden in 1911 they were very abundant. This may be better appreciated by a glance at Plate I, which shows the thrips that were dislodged from the small branched spike depicted in Plate II after the spike of flowers had been exposed for a short time to the fumes of chloroform. Before the thrips had recovered from anesthesia the spike and its branches were distinctly outlined by the stupefied insects. Notes taken at the time read as follows:

August 7, 1912.—After treatment with chloroform, 85 thrips fell from a spike possessing 80 open flowers; from another branched spike 190 thrips were dislodged.

Inspection of beet flowers sometimes revealed as many as five or six thrips in a single perianth.

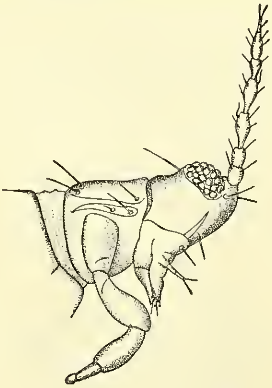


FIG. 2.—Side view of the head of a thrips, showing the mouth parts. Much enlarged. (After Moulton.)

In 1912, on the site of an old Chinese truck garden at Odgen, thrips became extraordinarily numerous during the late blooming period, when they fairly swarmed in and about the beet flowers. It was then ascertained that in addition to drinking the nectar and devouring the pollen they may also injure the floral organs.

Earlier studies of the injurious effects of various sucking insects, including aphides, red spiders, and thrips, on sugar beets, had established the fact that the last-named insects sustain their unenviable character on sugar beets also; they cause on young sugar beets a great diversity of leaf curls and distortions. On the spikes and bractlets of seed beets small silvery scars may be found as a result of their attacks. The thrips is more destructive than most sucking insects, because, not satisfied with merely puncturing, it tears and grubs up the surface tissues of its food plants with its powerful mouth cones, or proboscis (fig. 2), in order to release a more copious flow of the plant juices.[1] It reminds one of the actions of a hog.

These studies were extended to the observation of thrips on the inflorescence of sugar beets. The spikes and spikelets of the sugar beet, with their closely arranged spirals of flower clusters, are very numerous and afford excellent hiding places for these insects. It was found that as the period of most abundant bloom approached, thrips became increasingly numerous, partly through migration from

[1] Moulton, Dudley. The pear thrips and its control. United States Department of Agriculture, Bureau of Entomology, Bulletin 80, pt. 4, p. 54, 1912.

other plants, but more especially through breeding. Eggs are deposited and hatched on the spikes themselves. On hatching, the young larvæ quickly seek the flowers, doubtless attracted by the pungent fragrance of the nectar, and literally wallow in the nectar and pollen, avidly drinking the one and voraciously devouring the other.

Observations covering five seasons have shown that several species of Thysanoptera visit beet flowers and that the number of individuals varies greatly with the locality and general environments, notably with the crops in the vicinity. At Jerome, Idaho, in 1913, on land only recently cleared from sagebrush, thrips were rather scarce, although somewhat abundant in alfalfa in near-by fields. These insects have also been seen in moderate abundance on seed beets in Indiana and Michigan.

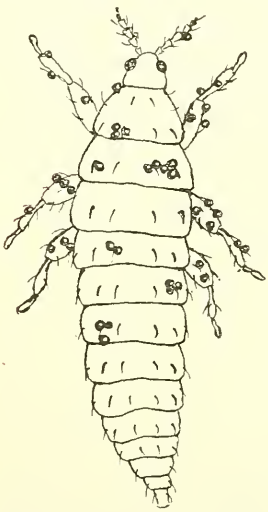


FIG. 3.—Larva of *Thrips tabaci* (second stage) taken from a sugar-beet flower. The insect carries numerous beet-pollen grains on its body. × 50. (Sketch of the larva after Russell.)

THRIPS AS POLLEN BEARERS.

The writer has been able to discover in the literature very little reference to thrips as a pollen bearer and no proof of its ability to bring about the fertilization of flowers.

Darwin was familiar with the visits of thrips and kept in mind the possibility that they might gain entrance through his nets.

Hermann Müller [1] records their occurrence in the flowers of several genera and species, but does not mention beets. In a paragraph on Thysanoptera he says that "probably few flowers, if any, are altogether exempt from their visits, and though they have seldom been detected in the conveyance of pollen, yet from their great abundance, their value as fertilizers must not be overlooked. It is almost impossible to exclude these tiny insects by means of nets. The Thysanoptera seek both pollen and honey. They seize a single pollen grain in their mandibles and convey it to the mouth."

Uzel,[2] in Bohemia, has noted the visits of several species of Thysanoptera among sugar and stock beets, but adduces no evidence in proof of the actual pollination of those flowers by thrips.

On August 3, 1911, at the experimental plats in Ogden, Utah, spikes of beet flowers were exposed to the fumes of chloroform to

[1] Müller, Hermann. The fertilisation of flowers. Tr. and ed. by D'Arcy W. Thompson, London, 1883, p. 44–45.

[2] Uzel, Heinrich. Über die Insekten, welche die Blüten der Zucker- und Futterrübe besuchen. Zeitschrift für Zuckerindustrie in Böhmen, Jahrg. 37, p. 182–197, 1913.

dislodge insects that might be harboring in them. As already stated, thrips in unsuspected number were thus removed. (Pls. I and II.) A microscopic examination of many of these—larvæ and adults—showed that without exception beet pollen grains were present on their bodies (fig. 3).

The original notes under this date are as follows:

August 3, 1911.—Discovered that *Thrips* sp. [later determined as *Thrips tabaci*] are exceedingly numerous on and among beet flowers. Some spikes were collected, and absorbent cotton sprinkled with chloroform was held over them to stupefy any insects that might be present. Thrips fell off and were microscopically examined. Without exception, each bore among its body hairs numerous sugar-beet pollen grains. Some open flowers were then examined, and thrips, as they recovered from their stupor, were observed to enter the perianth, where they moved about quite actively, traveling over every part. Many pollen grains were picked up by the insects' body hairs, others were dropped; pollen was also transferred from one insect to another when they came in contact one with another.

Almost at the close of the blooming period of beets, counts were made of the pollen grains borne by a number of thrips dislodged with chloroform from beet spikes, as shown in Table I.

TABLE I.—*Beet pollen grains on thrips, near the close of the blooming period.*

Stage of development of the insect.	Number of grains found on surface indicated.		
	Dorsal.	Abdominal.	Total.
Nymph	30	10	40
Adult	62	78	140
Do	53	82	135

These pollen grains were distributed over every part of their bodies, even along the antennæ. Nor do these figures represent unusual individuals. The blooming period was practically over at this time; pollen was therefore not very abundant. Both larval and adult thrips have since been seen to be literally covered with beet pollen.

EXPERIMENTS IN THE POLLINATION OF BEET FLOWERS.

The foregoing results were both interesting and surprising, and at once suggested, among others, the following queries:

(1) Do the thrips in this instance redeem themselves from their hitherto wholly evil reputation by playing an essential, or even an important, rôle in the fertilization of beet flowers? Or, do they simply convey pollen from one flower to another on the same plant and thus effect close pollination only?[1]

[1] Other experiments have shown close pollination of beet flowers to be almost absolutely ineffective in bringing about fertilization, which is undesirable even when successful. Self-fertilization is not possible. The term "self-fertilization" is here used to mean that resulting from the pollen of the same flower; "close pollination," or "close fertilization," that effected by the application of pollen from one flower to another on the same plant; "cross-pollination," that between any two plants.

(2) Inasmuch as they consume large quantities of pollen, do they thus work injury to beets?

(3) Do they injure the floral organs of beet flowers?

To be effective agents in the fertilization of beet flowers, they must do more than convey pollen from one flower to another on the same spike, stem, or plant; they must bring about true cross-pollination.

Although already late in the season when the foregoing observations were made, experiments were at once planned to ascertain whether pollination and fertilization might be effected through the agency of thrips. To this end several vigorous seed beets, still in bloom, were selected. On August 7 and 8, 1911, the largest buds on a number of spikes were emasculated, the smaller and more immature buds being trimmed off. This work was done at the stage when the sepals were just about to separate at the tips and disclose a tiny yellow spot of the anthers, and it was performed under a pollinating tent in order to exclude flying insects and wind-carried pollen (fig. 4). As each set of buds was emasculated it was at once covered with a white manila paper bag, 4 by 6 inches in size. A tuft of absorbent cotton was first wrapped carefully about the spike some inches below the buds. The bag was then drawn over the spike until the emasculated buds were situated inside the bag near the top, while the mouth of the bag reached well below the buds and came in contact with the wrapping of cotton. The mouth of the bag was then folded diagonally in such a manner as to pinch the cotton-wrapped stem in one corner; then it was folded a second time to make tight contact. Metal clips were finally set along the edge of the double fold to secure it (fig. 5). The stems bearing these spikes were tied to stakes to prevent too much movement and to keep them in an upright position. Before covering the spikes a close search was made for thrips or other small insects, any such being removed. The stigmata of these flowers became receptive three days later. Thrips were then collected from other beet flowers into small vials. As each lot was collected it was immediately transferred to one of the bagged spikes.

FIG. 4.—Pollinating tent of white sheeting, which may be completely closed and secured with hooks and eyes or buttons. (Original.)

FIG. 1.—FLOWERS OF SUGAR BEETS TO WHICH THRIPS HAD ACCESS. NATURAL SIZE. (ORIGINAL.)

FIG. 2.—SPIKES OF SUGAR-BEET FLOWERS ON CHECK PLANTS, WHICH REMAINED STERILE. NATURAL SIZE. (ORIGINAL.)

To accomplish this a slit was made in one side of the bag at least 2 inches below the buds of the inclosed spike, so that no pollen or thrips might fall upon the flowers when the vial was inverted over the slit, and the pollen-bearing thrips were jarred downward into the bag. This being done, the slit was closed with adhesive plaster, leaving the inclosed thrips free to seek the nectar and distribute the pollen they carried. About 25 thrips were put in each bag.

Three forms of control or checks were employed at this time:

(1) Spikes of emasculated buds were isolated, as above described, and left undisturbed.

(2) Similar spikes were isolated, and when the inclosed flowers had become receptive, slits were made in the bag and at once closed without introducing thrips.

(3) Spikes of buds were prepared as for emasculation and isolated without that operation being performed. These also were then left undisturbed.

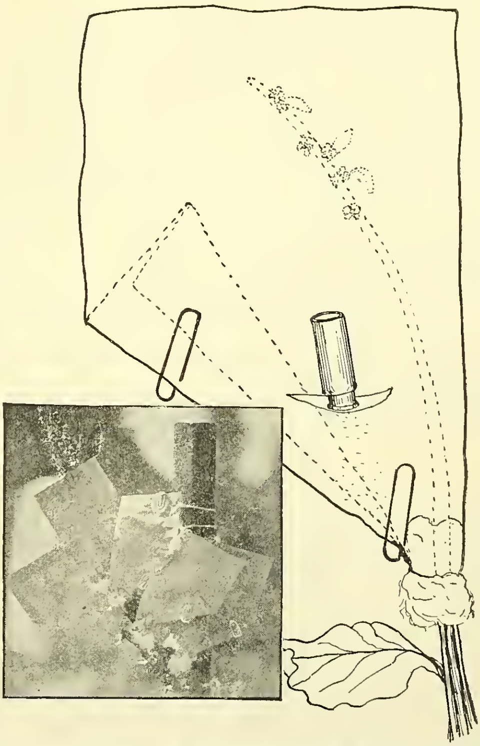


FIG. 5.—Spikes of beet flowers isolated by means of paper bags, showing the method of admitting pollen-bearing thrips through an opening. (Original.)

One month later, all the bags were opened to examine the inclosed flowers. The time had been too brief for the maturation of seed, but it was ample for fertilization and for the development of seed to the milky stage. The results were as follows:

Every flower on the checks remained sterile, the sepals of some remaining green. In other cases the entire flower had withered (Pl. III, fig. 2). Among those to which thrips had been introduced, one set of flowers was lost; of a second set, 16.66 per cent of the flowers became fertilized and produced seed; a third showed 20 per cent of fertilization; and a fourth, 28.6 per cent. For the entire set, the percentage of effective pollination by thrips was 20.37 (Pl. III, fig. 1).

On August 26, 1911, eight spikes of wild-beet flowers were similarly treated. Three of these were used as checks. Thrips were placed with the others in the manner above described. Some of these spikes were afterwards broken off, but of those remaining none of the checks became fertilized; of those to which thrips had been admitted only one remained, and 20.5 per cent of its flowers had been fertilized and produced seed.

The flowers of a beet spike open successively; therefore, few at any one time attain the same stage of development. This fact not only limits the number of available buds on each spike, but also may reduce the percentage of effective hand pollination as much as 50 per cent. The above results may therefore be considered not only positive, but surprising. The complete notes of the results of this experiment are shown in Table II.

TABLE II.—*Pollination of beet flowers—experiment of August 26, 1911.*

Spike.	Description.	Flowers.		Seeds.		Remarks.
		On spike.	Sterile.	Number.	Per cent.	
No. 1a	Check	22	22	0	0	Not emasculated; spike dry and brown.
No. 2a	do	14	14	0	0	Do.
No. 2b	do	36	36	0	0	Emasculated.
No. 2c	do	22	22	0	0	Do.
No. 3a	do	10	10	0	0	Emasculated; stems and flowers green.
	Total	104	104	0	0	
No. 3b	Thrips admitted	7	5	2	28.6	
No. 3c	Missing					
No. 4a	Thrips admitted	12	10	2	16.66	
No. 4b	do	35	28	7	20.00	
	Total	54	43	11	20.37	For the entire set.
	Wild beets.					
No. 1	Check					
No. 2	do					
No. 4	do		All.	0	0	Broken off.
No. 3	Thrips admitted					Do.
No. 5	do					Do.
No. 6	do					Do.
No. 7	do					Do.
No. 8	do	24	19	5	20.83	

During the following season two similar experiments were carried out. The first experiment was made on June 26, 1912, when the plants were flowering abundantly. On this date two spikes were prepared as already described, except that the additional precaution was taken to spray thoroughly all parts of the flowers and spikes with water from an atomizer to remove any thrips that might be hidden there. Three days later thrips were collected and transferred to the bags. A month later complete notes were made, with the results shown in Table III.

On July 12, 1912, the second experiment was started in the same manner with three spikes, and a month later the data shown in Table III were secured.

These experiments demonstrate that thrips transferred from one flowering beet to another may carry sufficient pollen on their bodies to effect fertilization.

TABLE III.—*Pollination of beet flowers—experiments of June 26 and July 12, 1912.*

Experiment of June 26, 1912.						Experiment of July 12, 1912.					
Spike.	Description.	Flowers.		Seeds.		Spike.	Description.[1]	Flowers.		Seeds.	
		On spike.	Sterile.	Number.	Per cent.			On spike.	Sterile.	Number.	Per cent.
No. 1	Thrips admitted	18	6	12	66.66	No. 1	Thrips admitted	13	8	5	38.46
No. 2	do	14	4	10	71.14	No. 2	do	20	17	3	15
	Total[2]	32	10	22	68.75	No. 3	Check	20	20	0	0

[1] Of the 33 flowers to which thrips were admitted in this experiment, 24.24 per cent are shown to have been fertilized, while all the checks remained sterile.
[2] For entire set.

CROSS-POLLINATION BY THRIPS.

As already stated, other studies have shown that close pollination of beets rarely results in fertilization and that self-fertilization does not take place. To be of service to beets, thrips must therefore bring about cross-pollination. The writer has found the impression rather general that thrips do not travel from plant to plant to any great extent. On this point the following evidence from the writer's notes is available:

July 19, 1912.—A great number of thrips had been shaken from seed beets in full bloom into a large pan. In the slanting rays of the evening sun many of the adults, which are winged, could be seen to fly from the collecting pan and alight on adjacent plants. Their flight was sustained and fairly steady, though not nearly so rapid as that of gnats.

July 21, 1912.—Since attention was attracted to the flight of thrips, careful watching, when their wings glitter in the evening sunshine, revealed the fact that their flight from plant to plant is voluntary and frequent; this flight is well sustained, though very slow. They were seen to travel not only from one plant to the next, 4 feet away, but to more distant ones. The flight of many of these thrips was intercepted by a sheet of white paper, upon which they alighted. Some of them were chloroformed and examined. Pollen at this time was not very abundant, because the plants were long past the time of maximum bloom. Counts were made showing that 5 different thrips carried grains of pollen, as follows: No. 1, 5 grains; No. 2, 44 grains; No. 3, 3 grains; No. 4, 38 grains; No. 5, 4 grains.

July 23, 1912.—An examination of the seed beets in plat 2, where seed is almost ripe, showed an absence of thrips. The number of these insects on the plants now in bloom in plat 1 is immense. [Plat 1 lies about 50 feet north of plat 2. Many beets in plat 1 were planted later than those in plat 2 and were therefore still in bloom.] Thrips were fairly numerous in plat 2 when the plants there were in bloom; therefore it would appear that thrips migrate some distance in pursuit of pollen and nectar. An examination of plants in plat 1, some of which had been planted earlier than others, showed the earlier planted ones, now without bloom, to be devoid of thrips.

This study established the fact that not only are thrips capable of collecting and carrying pollen on their bodies and of effecting cross-pollination and subsequent fertilization when transferred from one flowering beet to another, but that they voluntarily travel from plant to plant and carry pollen throughout a sustained flight.

From this evidence there can remain no doubt that these insects are capable of playing an important rôle in the pollination of beet flowers. May it not be a very significant one? It is known that in certain parts of Europe and the United States beets have sometimes, perhaps frequently, failed to produce seed, although an abundance of bloom appeared. It seemed possible that the presence or absence of thrips in great number might in part be responsible for this phenomenon. Subsequent observations, however, afford evidence in disproof of this theory. It is safe to say that thrips undoubtedly assist in the pollination of beet flowers, perhaps to a greater extent than any other species of insect. It can scarcely be doubted that they perform a like service for many other plants.

INJURY TO SEED BEETS.

Thrips feed avidly upon the nectar and pollen of beets, but beet pollen is so abundant that unless thrips be present in enormous numbers they apparently do no damage to the floral organs, preferring as food the nectar and pollen. However, should they become extraordinarily numerous, as was the case at Ogden in 1912 during the latter part of the season, it would seem that the nectar and pollen are not sufficiently abundant to supply their truly voracious appetites. They then attack the more delicate and succulent parts of the flowers. Sometimes the styles are cut through at the base, but more frequently the papillæ, with which the lobes of the stigma are thickly studded, are torn to pieces. Furthermore, they may devour so much pollen as to interfere with both wind and insect pollination by too greatly diminishing the supply. Thrips move actively from flower to flower of the same spike, from spike to spike and stem to stem of the same plant, and in this way bring about much more close pollination than cross-pollination, and in fact effect all the close pollination and fertilization of which the plant is susceptible. This in itself is undesirable and even harmful. Close fertilization has been shown to cause degeneration among beets, even in the sense of pollination and fertilization between different individuals of the same progeny.

TROUBLE TO PLANT BREEDERS.

The writer has experimentally shown that the larvæ of thrips in all stages readily pass through the meshes of fine silk chiffon and much more readily through the net, cloth, and sheeting frequently used by horticulturists and plant breeders to isolate flowers designed to be hand-pollinated. He has also been able to demonstrate that they actually do effect pollination and fertilization after passing through such covers.

The following is an instance of what might be expected to occur through the agency of thrips: The horticulturist of a well-known firm of seedsmen in the United States noted that his asters became fertilized although covered with cloth bags. The writer suggested that thrips might be responsible for this. The horticulturist replied in part that "the aster flowers were merely covered with coarse-meshed cloth to see if they were self-fertile. Insects as small as thrips would not have been excluded. We merely learned that the fertilization of asters is not dependent on the insects—mostly beetles—that one ordinarily sees on the flowers."

The horticulturist and plant breeder may not disregard these insects. They introduce an element of uncertainty to be guarded against with the utmost care and circumspection. Their minute size, inconspicuous color, great numbers, and the fact that they are almost ubiquitous make them a factor to be reckoned with by every worker along these lines and necessitate the development of special precautions and technic.

Covers of net, cloth, and sheeting afford no real protection against them; even paper bags must be applied with great care. The writer found the method described and illustrated in connection with these experiments to be simple and efficacious.

It is as necessary to rid the isolated portion of plant and flower of thrips already present as to prevent the access of others after isolation. In these experiments the practice was made of carefully scrutinizing each spike of buds or flowers before covering it and brushing off any thrips that might be present with a camel's-hair or sable brush, sometimes also spraying the spike thoroughly with water. In the summer of 1912 the use of nicotine sulphate also was tried, as shown in the following notes:

July 24, 1912.—At this late blooming period, thrips have become exceedingly numerous on all spikes in bloom; they interfere seriously with pollination work. To ascertain whether a simple, practical method might be available to rid the individual spikes completely of these pests, the following experiment was carried out: Some spikes, badly infested with thrips, were selected. Before operating on the spikes, they were immersed in the following solution: Water, 2 pints; nicofume (nicotine sulphate), 1 tablespoonful.

Spikes 1, 2, and 3 (in their normal condition, i. e., bearing flowers of all stages—buds, flowers just opening, and flowers already fertilized) were immersed in the above solution 10 seconds; then they were at once isolated with manila paper bags in the manner previously described.

Spike 4, with selected buds emasculated, was treated with nicofume like the preceding, bagged, and (when stigmata had become receptive) pollinated.

Spikes 5 and 6 were treated like No. 4, but not pollinated.

Spike 7 was merely shaken and flowers blown upon to dislodge thrips; flowers emasculated.

August 19, 1912.—All spikes examined.

Nos. 1, 2, and 3 in good condition; no signs of thrips or other insects; no injury from nicofume; good seed formed.

No. 4. No injury from nicofume apparent; no evidence of thrips or other insects; emasculated July 24, 1912; pollinated July 27, 1912; of 10 flowers pollinated 8 produced seed.

No. 5. General condition similar to No. 4; emasculated July 24, 1912; not pollinated; 13 flowers emasculated; all remained sterile.

No. 6. Similar to No. 5; all flowers remained sterile.

No. 7. Check; spike dead.

This experiment shows that the treatment with nicotine solution did not perceptibly injure beet flowers and that it at the same time removed thrips from them.

CONCLUSION.

From these experiments it is seen that these minute insects, the numerous species of Thysanoptera, some of which more or less injuriously infest practically all our plants, are also active agents in pollination. Among beet flowers they are frequently very numerous indeed, effecting both close pollination and cross-pollination upon them. However, after taking into account the various forms of injury they do, it is doubtful whether the balance remains in their favor in regard even to beets. Under ordinary conditions, in fields of commercial seed beets, it is believed that on the whole their work is beneficial; but should they become excessively numerous, they sustain their reputation as one of our really destructive pests. To the horticulturist and plant breeder they are pests of the worst type, necessitating constant watchfulness and a refined technic in all pollination work.

The suggestion is ventured that certain supposed mutations may really have been the result of unsuspected cross-pollination by means of one or another species of thrips, whether in cereals supposedly not susceptible to cross-pollination without the intervention of man or in flowers which were thought to have been isolated against cross-pollination.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 105

Contribution from the Office of Public Roads, Logan Waller Page, Director.
July 10, 1914.

(PROFESSIONAL PAPER.)

PROGRESS REPORTS OF EXPERIMENTS IN DUST PREVENTION AND ROAD PRESERVATION, 1913.

EXPERIMENTS AT CHEVY CHASE, MD.

(Completion of 1912 project.)

CEMENT CONCRETE, OIL-CEMENT CONCRETE, VITRIFIED BRICK, AND BITUMINOUS SURFACE TREATMENTS ON CONCRETE.

The 1912 experimental project is located upon a section of Kensington Road (Connecticut Avenue extended), extending north from Bradley Lane to the loop of the Capital Traction Co. tracks at Chevy Chase Lake. This total length of 6,195 feet was covered by six experimental sections, as follows:

Experiment No. 1, bituminous concrete (Topeka specification).

Experiment No. 2, bituminous concrete (District of Columbia specification).

Experiment No. 3, cement and oil-cement concrete surface treated with bituminous materials.

Experiment No. 4, oil-cement concrete.

Experiment No. 5, cement concrete.

Experiment No. 6, vitrified brick.

The work was begun September 9, 1912, and was continued until December 13, 1912, when, owing to unfavorable weather conditions, it was discontinued, after 4,561 feet had been partially completed. A complete report of the work accomplished in 1912, with approximate cost data, was published in Office of Public Roads Circular No. 99. The following report covers the completion of the project with such repetition as may appear necessary to a better understanding of the methods pursued.

NOTE.—This bulletin gives the details of construction of several sample roads constructed under the supervision of the Office of Public Roads. It is of interest to all sections where improvement of roads is contemplated or necessary.

41701°—14——1

EXPERIMENT NO. 3.—CEMENT CONCRETE AND OIL-CEMENT CONCRETE (SURFACES TREATED WITH BITUMINOUS MATERIALS).

Location:
- Cement concrete—
  - Station 12+50 to station 15+84, gravel aggregate.
  - Station 15+84 to station 21+60, limestone aggregate.
  - Station 21+60 to station 25+03, gravel aggregate.
- Oil-cement concrete—
  - Station 25+03 to station 27+29, limestone aggregate.
  - Station 27+29 to station 30+90, limestone aggregate.

Total length:
- Cement concrete section—1,253 feet.
- Oil-cement concrete section—587 feet.

Total area:
- Cement concrete section—2,837 square yards.
- Oil-cement concrete section—1,341 square yards.

The details regarding the construction of both types of concrete are fully described in Circular No. 99, and repeated in this report under experiments Nos. 4 and 5.

As noted in Circular No. 99, the concrete for these experiments was completed in the fall of 1912, but owing to cold weather it was necessary to postpone the application of surface treatments until 1913. The surface of the concrete was then washed, thoroughly swept, and allowed to dry off, after which a number of bituminous materials, singly and in combination, was applied. Where a paint coat is indicated, it signifies a thin surface application of a material for the purpose of possibly securing better adhesion than might otherwise be obtained for the wearing or carpet coat. The paint coats were broomed over the surface without heating. The heavier products were heated in three-barrel kettles, and spread over the surface by means of a hand-drawn distributor of about 30 gallons capacity, so designed as to permit the material to flow out in a thin sheet about 18 inches wide.

The applications were then covered with pea gravel or limestone grits applied by a spreading machine and the road was immediately opened to traffic.

The locations selected for the various sections are indicated by lettered markers along the roadside. The following is a tabular description of these sections:

TABLE 1.—*Description of various sections of experiment No. 3.*

Section.	Location (stations).		Paint coat.	Carpet coat.
	From—	To—		
A	12+50	15+00	None	Refined coal tar.
B	15+00	17+50	...do	Water-gas tar preparation No. 2.
C	17+50	20+00	...do	Fluxed native asphalt No. 2.
D	20+00	21+25	Water-gas tar preparation No. 1.	Do.
E	21+25	22+50	Native asphalt emulsion	Fluxed native asphalt No. 1.
F	22+50	25+00	Water-gas tar preparation No. 1.	Oil-asphalt No. 1.
G	25+00	26+50	None	Refined coal tar.
H	26+50	28+00	...do	Water-gas tar preparation No. 2.
I	28+00	29+50	...do	Fluxed native asphalt No. 2.
J	29+50	30+90	...do	Oil-asphalt No. 2.

Analyses of the various materials used are given in Tables Nos. 2 and 3. A sample of the asphaltic emulsion was not obtained, but it was the same product as was used on section No. 11 of the 1911 project and reported in Circular No. 99. For a paint coat the emulsion was diluted with an equal volume of water.

From station 33+60 to station 34+15 the concrete was given a paint coat of the crude water-gas tar, the analysis of which is given in Table 2. The application was made at the rate of approximately 0.1 gallon per square yard. It was absorbed to a slight extent and soon dried, and was distinctly evident as a brown stain on the surface when last inspected.

TABLE 2.—*Analyses of tar products used in surface treatment of concrete.*

Materials.	Crude water-gas tar.		Refined coal tar.		Water-gas tar preparation.			
					No. 1.		No. 2.	
Sections			A and G.		D and F.		B and H.	
Specific gravity 25°/25° C	1.082		1.219		1.108		1.144	
Viscosity, Engler, 50° C., 50 c. c. specific					14.0			
Float test 32° C			1′ 23″				3′ 27″	
Float test 50° C			40″				1′ 15″	
Per cent of free carbon	0.32		16.29		0.25		0.95	
	By volume.	By weight.	By volume.	By weight.	By volume.	By weight.	By volume.	By weight.
Distillation:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Water	[1] 7.5	6.9	0.0	0.0	0.0	0.0	0.0	0.0
First light oils to 110° C	[1] 6.3	5.1	[2] .8	.5	[1] 1.7	1.4	[1] .2	.1
Second light oils 110° to 170° C	[1] 1.1	.8	[3] .3	.2	[1] .6	.4	[1] .2	.2
Heavy oils 170° to 270° C	[4] 25.1	23.4	[5] 16.4	14.7	[1] 18.5	16.3	[1] 7.5	6.4
Heavy oils 270° to 315° C	[6] 16.4	15.5	[7] 10.0	8.7	[8] 18.4	17.0	[9] 11.8	10.4
Pitch	43.6	47.8	72.5	75.8	60.8	64.8	80.3	82.8
	100.0	99.5	100.0	99.9	100.0	99.9	100.0	99.9

[1] Clear. [2] One-half solid. [3] Cloudy. [4] Three-fourths solid. [5] Two-thirds solid. [6] Two-fifths solid. [7] Solid.
[8] Clear. Showed 7.5 per cent insoluble in dimethyl sulphate. A 315°–350° C. fraction showed 7.5 per cent, and a 350°–375° C. fraction showed 17.5 per cent insoluble in dimethyl sulphate.
[9] Clear. This fraction, and also a 315°–350° C. fraction and a 350°–375° C. fraction each showed 7.5 per cent insoluble in dimethyl sulphate.

TABLE 3.—*Analyses of native and oil-asphalt products used in the surface treatment of concrete.*

Materials.	Fluxed native asphalt.		Oil asphalt.	
	No. 1.	No. 2.	No. 1.	No. 2.
Sections	E.	C, D, and I.	F.	J.
Specific gravity 25°/25° C.	1.045	1.043	1.031	1.012
Melting point ° C.	39	48	92	52
Penetration (25° C., 100 grams, 5 seconds [mm.])	18.4	14.8	[1] 2.6	14.7
Per cent of loss at 163° C., 5 hours (20 grams)	3.50	2.73	.32	.59
Penetration of residue (mm.)	6.3	6.4	1.8	10.3
Per cent of total bitumen insoluble in 86° B. naphtha	19.60	21.87	34.84	21.72
Per cent of fixed carbon	9.83	11.17	15.62	10.92
Per cent soluble in CS_2 (total bitumen)	94.70	96.56	99.74	99.72
Per cent of organic matter insoluble	1.23	1.35	.17	.17
Per cent of inorganic matter insoluble	4.07	2.09	.09	.11
	100.00	100.00	100.00	100.00

[1] Penetration (0° C., 200 grams, 1 minute) 1.4 mm.; penetration (46° C., 50 grams, 5 seconds) 5.8 mm.

EXPERIMENT NO. 4.—OIL-CEMENT CONCRETE.

Location:

Station 30+90 to station 33+60, gravel aggregate.

Station 42+50 to station 44+61, limestone aggregate.

Station 46+10 to station 49+00, trap rock aggregate.

Total length: 771 feet.

Total area: 1,744 square yards.

Methods and materials.—Owing to irregularity in the delivery of the materials, it became necessary to build experiments Nos. 4 and 5 in separated sections. The first two sections in the order above given were completed in 1912, while the third was built in the spring of 1913.

The concrete was mixed in a mechanical mixer of the self-propelled rotary-distributor type. The proportions were 1 part of Portland cement to 1¾ parts of sand and 3 parts of coarse aggregate, with enough water to produce a concrete of quaky consistency. A light residual petroleum having the characteristics given below in Table No. 5 was mixed with the concrete to the amount of 5 pints per bag of cement. This mixture was accomplished by delaying the introduction of the oil until after the cement, sand, coarse aggregate, and water had been partially mixed. The concrete was spread evenly over the subgrade to a depth slightly greater than the finished thickness of 6 inches and the surface was then "struck off" by means of a well-designed "strike board." After this the surface was finished to true grade and cross-section with a wooden float. The floating was done from a bridge which rested upon the side forms and the concrete gutter. Expansion joints were purposely omitted and no joints of any other kind were constructed except those between the days' work, and these were formed at an angle of 80 degrees to the center line of the road. Before continuing the work of laying the concrete the faces of such joints were washed with a 10 per cent solution of muriatic acid and then with water.

Protection of concrete after laying.—As soon as practicable after laying the pavement it was covered with canvas and was so protected until the concrete had set hard enough for it not to be injured by a man walking upon it. The canvas was then removed and the concrete was covered with a layer of loam or sand about 2 inches in depth. This was kept wet for a period of 8 days. The covering was allowed to remain on the pavement for a period of 15 days, after which it was removed whenever it was convenient to do so.

Typical mechanical analyses of all the coarse aggregates used are given in Table 4.

TABLE 4.—*Mechanical analyses of coarse aggregates used in all concrete experiments.*

	Gravel.	Limestone.	Trap.
Passing 2-inch, retained on 1½-inch screen	2.3		
Passing 1½-inch, retained on 1¼-inch screen	10.8		
Passing 1¼-inch, retained on 1-inch screen	24.0	13.2	6.6
Passing 1-inch, retained on ¾-inch screen	25.8		19.5
Passing ¾-inch, retained on ½-inch screen	26.4	34.2	40.6
Passing ½-inch, retained on ¼-inch screen	9.8	47.4	24.9
Passing ¼-inch screen	.9	5.2	8.4
	100.0	100.0	100.0

TABLE 5.—*Analyses of fluid residual petroleum used in oil-cement concrete for experiment No. 4.*

Specific gravity 25°/25° C	0.933
Viscosity, Engler, 50° C., 100 c. c. specific	27.8
Per cent of loss at 163° C., 5 hours (20 grams)	2.67
Float test of residue, 32° C. (time)	1′ 35″
Per cent of total bitumen insoluble in 86° B. naphtha	2.31
Per cent of fixed carbon	3.01
Per cent soluble in CS_2 (total bitumen)	99.90
Per cent of organic matter insoluble	.08
Per cent of inorganic matter insoluble	.02
Total	100.00

Hydrated lime experiment.—Between stations 47+90 and 49+00 hydrated lime was also added to the concrete. The proportioning of the mixture for this section of the experiment was as follows: Hydrated lime, 20 pounds; cement, 188 pounds; sand, 4 cubic feet; coarse aggregate, 7½ cubic feet; and oil, 10 pints.

EXPERIMENT NO. 5.—CEMENT CONCRETE.

Location:

Station 33+60 to station 37+85, gravel aggregate.
Station 37+85 to station 42+50 } limestone aggregate.
Station 44+61 to station 46+10 }
Station 46+10 to station 52+00, trap rock aggregate.

Total length: 1,339 feet.
Total area: 3,013 square yards.

Methods and materials.—The same procedure was followed as in the construction of experiment No. 4, excepting for the omission of the oil from the mixture. From station 33+60 to station 42+50 this section was completed in 1912, but the remainder of the construction was carried out in the spring of 1913.

Hydrated lime experiment.—Between station 49+00 and station 50+50, and joining the same experiment in the oil-cement concrete, hydrated lime was added to the concrete. The proportions were the same as given in experiment No. 4, except the omission of the oil.

Experiment No. 6.—Vitrified brick.

Location: Station 52+00 to station 61+80.
Area: 2,055 square yards.

Concrete base and shoulder.—The concrete base was similar in character and construction to that used in experiments Nos. 1 and 2, and described in Circular No. 99. The concrete was made up of 1 part by volume of Portland cement, 3 parts of sand, and 7 parts of gravel. A bag of cement was considered as having a volume of 1 cubic foot. The concrete was mixed in a mechanical concrete mixer of the self-propelled, rotary-distributor type, the flow from which was practically continuous, and the distributor was swung across the road and the mixer moved ahead in such manner as to place the concrete upon the subgrade in approximately the position desired. It was then shoveled into place in such an amount as to form when compacted with concrete tampers a uniform layer 6 inches in thickness.

Before the concrete base had taken initial set, a concrete shoulder 8 inches wide and 6 inches high, mixed in the proportions of 1 part of cement, $1\frac{3}{4}$ parts of sand, and 3 parts of gravel was placed upon all the edges of the base except those which abut against the concrete gutter.

Sand cushion.—The cushion sand was spread over the base to an approximate depth of 2 inches and struck off to a true depth of 2 inches by the use of a "strike board," the ends of which rested upon the concrete curbs. The cushion was then rolled with a lawn roller weighing 300 pounds. After the first rolling, sand was spread over the rolled surface to a depth of about one-fourth inch, and again struck off and thoroughly rolled. A mechanical analysis of the sand used is given in Table 6.

Table 6.—*Mechanical analysis of the cushion sand.*

	Per cent.
Passing $\frac{1}{8}$-inch, retained on 10-mesh screen	7.1
Passing 10-mesh, retained on 20-mesh screen	13.7
Passing 20-mesh, retained on 30-mesh screen	18.9
Passing 30-mesh, retained on 40-mesh screen	20.5
Passing 40-mesh, retained on 50-mesh screen	16.8
Passing 50-mesh, retained on 80-mesh screen	13.7
Passing 80-mesh, retained on 100-mesh screen	1.4
Passing 100-mesh screen	1.1

The brick.—Fourteen varieties of paving block were laid, and Table 7 shows their different descriptions and locations.

TABLE 7.—*Brick used in experiment No. 6.*

Section.	Location (stations).		Description.
	From—	To—	
A	52+00	52+51.5	Shale (wire-cut lug).
B	52+51.5	53+19.0	Do.
C	53+19.0	54+27.7	Shale, repressed.
D	54+27.7	55+32.7	Do.
E	55+32.7	56+44.1	Do.
F	56+44.1	57+13.5	Do.
G	57+13.5	57+74.0	Do.
H	57+74.0	58+41.9	Do.
I	58+41.9	58+91.9	Do.
J	58+91.9	59+53.2	Fire clay, repressed.
K	59+53.2	60+ 7.9	Do.
L	60+ 7.9	60+66.7	Shale, repressed.
M	60+66.7	61+26.8	Fire clay, repressed.
N	61+26.8	61+78.1	Fire clay (wire-cut lug).

The report of tests on samples of these brick is given in Table 8.

TABLE 8.—*Rattler, sand-blast, and absorption tests on vitrified brick used at Chevy Chase, Md.*

Section.	Brick.	Rattler loss.[1]	Sand-blast loss.[1]	Water of absorption—5 brick.
		Per cent.	*Grams.*	*Per cent.*
A	Shale (wire-cut lug)[2]	21.12	27.0	1.39
B	do.[3]	16.36	23.3	1.31
C	Shale, repressed [4]	25.57	27.1	.88
D	do.[5]	17.67	32.1	1.65
E	do.[6]	22.04	20.6	1.10
F	do.[7]	18.80	41.5	1.81
G	do.[8]	27.92	35.1	2.29
H	do.[9]	22.68	35.8	3.74
I	do.[10]	22.59	32.5	2.86
J	Fire clay, repressed [11]	19.11	37.1	1.56
K	do.[12]	37.68	50.5	2.38
L	Shale, repressed [13]	38.89	84.5	4.04
M	Fire clay, repressed [14]	24.31	44.0	3.73
N	Fire clay (wire-cut lug)[15]	31.19	28.5	3.68

[1] Average of three tests.
[2] Hard-burned brick having a good structure.
[3] Medium hard-burned brick having a very good structure.
[4] Brick well vitrified; losses in rattler mainly due to chipping.
[5] Brick molded from coarsely ground shale; had a fairly good structure and was hard burned.
[6] Brick very hard burned; losses in rattler due to chipping.
[7] Brick molded from coarsely ground clay; had a good structure.
[8] Medium hard-burned brick which wear evenly, though excessively, in the rattler test.
[9] Medium hard-burned brick made from finely ground clay and having a fairly good structure.
[10] Medium hard brick made from coarsely ground clay and wearing down uniformly in rattler.
[11] Brick made from coarsely ground fire clay; had an excellent structure, free from laminations; not burned very hard.
[12] Comparatively soft-burned brick made from coarsely ground fire clay; wear in rattler excessive though uniform.
[13] Comparatively soft-burned brick made from coarsely ground clay; wear in rattler excessive though uniform.
[14] Fairly soft-burned brick made from medium finely ground clay; worn down evenly by rattler.
[15] Losses in rattler due mainly to open laminations; brick hard burned.

Laying and grouting brick.—The brick were laid in straight courses at right angles to the curb. No driving was permitted to straighten the courses. After the brick were laid and all the spalls and imperfect bricks removed, the brick were rolled with a 5-ton tandem roller until they were firmly bedded in the sand cushion. The joints were then filled with a cement grout composed of one part of Portland cement and one part of sand. Table 9 contains the mechanical analysis of the sand used.

TABLE 9.—*Mechanical analysis of sand for grout.*

	Per cent.
Passing $\frac{1}{8}$-inch, retained on 10-mesh screen	0.4
Passing 10-mesh, retained on 20-mesh screen	1.5
Passing 20-mesh, retained on 30-mesh screen	2.8
Passing 30-mesh, retained on 40-mesh screen	6.0
Passing 40-mesh, retained on 50-mesh screen	30.6
Passing 50-mesh, retained on 80-mesh screen	41.1
Passing 80-mesh, retained on 100-mesh screen	4.1
Passing 100-mesh, retained on 200-mesh screen	11.2
Passing 200-mesh screen	2.3

The grout was applied in two courses, the first of which was thin enough to run freely. This was swept into the joints by means of rattan hand brooms. After the first course had settled well into the joints and before any of it had dried, grout of the consistency of thick cream was squeegeed over the pavement, leaving all the joints completely filled.

Protection of the pavement.—Immediately after the completion of the grouting, sand was spread over the pavement to a depth of one-half inch and kept wet for seven days.

Expansion joints.—No transverse expansion joints were constructed and the ends of the pavement are practically fixed. A longitudinal expansion joint was constructed along each curb line. From station 52 + 00 to station 54 + 00 it is 1 inch wide and was filled with a mixture of equal parts, by volume, of coal-tar pitch and Portland cement. From station 54 + 00 to station 56 + 00 the expansion joint is one-half inch wide and is filled with asphaltic felt, while from station 56 + 00 to station 61 + 00 the expansion joint is 1 inch wide and is filled with an oil asphalt having a penetration at 25° C. of 3 mm. and a melting point of 94° C.

Measured bricks.—The thickness of a sufficient number of bricks of each variety to lay two courses across the pavement was measured. These bricks were then laid in the same manner as the other brick, and their location was carefully recorded, so that at any future time they may be taken from the pavement, measured, and the amount of wear determined.

Cost data.—The cost data given in Circular No. 99 were necessarily subject to revision when the project was completed. Table 10 shows the cost of the entire work by experiments, together with a statement of the unit costs of material and labor prevailing on the work.

TABLE 10.—*Unit costs.*

Labor (per day of 8 hours):		
Superintendent		$10.00
Foreman		$4.50
Rollerman		$3.50
Engineer for mixer		$4.00
Carpenter		$3.50
Laborer		$1.60
Team		$5.00
Materials f. o. b. nearest siding:		
Sand	per ton	$0.70
Gravel (for use in concrete gutter and base)	do	$0.85
Gravel (for use in concrete pavement)	do	$0.95
Crushed limestone	do	$1.10
Crushed trap rock	do	$1.35
Cement	per barrel	$1.51
Vitrified brick	per M	$20.00
Oil asphalts (cents)	per gallon	10.13
Fluxed native asphalts (cents)	do	14.10
Refined coal tar (cents)	do	10.92
Water-gas tar preparation No. 2 (cents)	do	8.42
Water-gas tar preparation No. 1 (cents)	do	7.22
Native asphalt emulsion (cents)	do	13.00
Residual petroleum (cents)	do	10.70
4-inch vitrified clay tile (delivered on work) (cents)	per foot	6.69
Contract price for unloading and hauling materials from siding to work (average haul 3,100 feet):		
Sand and gravel (cents)	per ton	40
Crushed stone (cents)	do	45
Cement (cents)	per barrel	10
Machinery (per day):		
Concrete mixer		$10.00
Roller		$5.00

TABLE 11.—*Concrete gutter.*

Total length	feet	5,631
Quantities of materials per linear foot of gutter:		
Cement	barrel	0.101
Sand	cubic yard	.029
Gravel	do	.050
Cost data (cents per linear foot):		
Cement		16.06
Sand		4.38
Gravel		8.44
Forms		1.81
Foreman		2.05
Carpenter and helper		2.05
Finisher and helper		3.24
Labor		16.49
Total		54.52
Total cost of gutter		$3,070.02

TABLE 12.—*Cost of miscellaneous work.*

Building catch basin		$19.02
Removing 10 trees		95.87
Removing old cobble gutter, 3,310 linear feet		79.61
Labor on broken stone shoulder (from station 58+50 to station 62+00)		[1] 62.50
		257.00
FRENCH DRAIN.		
Length ... feet		8,648
Labor:		
Foreman	$140.87	
Men	846.87	
Teams	108.56	
		$1,096.30
Materials:		
Tile, 8,648 feet, at 6.7 cents per foot	579.42	
Stone for filling trench [2]	369.52	
		948.94
		2,045.24
Cost per linear foot (cents)		23.65

[1] Stone secured from excavation.

[2] A considerable quantity of stone for filling the trench was secured from the old macadam road. The labor necessary to secure this stone was so much that the drain would have cost but little more had fresh stone been purchased.

TABLE 13.—*Materials and cost data for bituminous-concrete experiments at Chevy Chase, Md.*

Experiment No.	Section.	Description: Pavement material.	Length of section.	Area of section.	Base: Gravel.	Base: Sand.	Base: Cement.	Pavement: Coarse aggregate.	Pavement: Sand.	Pavement: Limestone dust.	Pavement: Bituminous material.	Pavement: Bituminous seal coat.	Pavement: Cement on surface.	Pavement: Chips.
			Feet.	*Sq. yds.*	*Cu. yds.*	*Cu. yds.*	*Barrels.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Gals.*	*Gals.*	*Barrels.*	*Cu. yds.*
1	A	Topeka specification, limestone aggregate	334	762	0.150	0.065	0.145	0.0644	....	0.005	1.89	....	0.003	....
1	B	Topeka specification, trap aggregate	301	736	.150	.065	.145	.0668	....	.0066	2.09	....	.003	....
2	A	District of Columbia specification, limestone aggregate	284	631	.150	.065	.145	.0464	0.0244	.005	1.34	0.51	....	0.005
2	B	District of Columbia specification trap aggregate	346	769	.150	.065	.145	.0462	.0244	.005	1.52	.51	....	.005

Experiment No.	Section.	Pavement material.	Cost per square yard: Base: Gravel.	Base: Sand.	Base: Cement.	Base: Mixing and laying.	Pavement: Bituminous concrete at plant (estimated).	Pavement: Hauling to road.	Pavement: Laying and rolling.	Pavement: Bitumen in seal coat.	Pavement: Chips in seal coat.	Pavement: Labor applying seal coat.	Pavement: Cement on surface.	General: Preparing subgrade.	General: Superintendence.	General: General expense.	General: Miscellaneous.	Total cost: Per square yard.	Total cost: Entire section.
			Cents.	*Cts.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cents.*	*Cts.*	*Cts.*	*Cts.*	*Cents.*	
1	A	Topeka specification, limestone aggregate	27.30	9.30	23.40	17.45	43.00	19.00	5.89	......	......	......	0.48	21.44	8.01	4.54	6.81	186.62	$1,422.04
1	B	Topeka specification, trap aggregate	27.30	9.30	23.40	17.45	43.00	19.00	5.89	......	......	......	.48	21.44	8.01	4.54	6.81	186.62	1,373.52
2	A	District of Columbia specification, limestone aggregate	27.30	9.30	23.40	17.45	43.00	19.00	5.89	7.19	1.21	1.11	......	21.44	8.01	4.54	6.81	195.65	1,234.55
2	B	District of Columbia specification, trap aggregate	27.30	9.30	23.40	17.45	43.00	19.00	5.89	7.19	1.21	1.11	......	21.44	8.01	4.54	6.81	195.65	1,504.55
		Total cost	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	[1] 5,580.74

[1] Includes also $46.08, the cost of a mortar shoulder 2 inches by 6 inches and 1,315 feet long, costing at the rate of 4.26 cents per linear foot.

TABLE 14.—*Materials and cost data for cement concrete in experiment at Chevy Chase, Md.* [1]

Description.			Quantities of materials (per square yard).			Cost per square yard.									Total cost.	
Coarse aggregate.	Length of section.	Area of section.	Coarse aggregate.	Sand.	Cement.	Preparing subgrade.	Coarse aggregate.	Sand.	Cement.	Mixing and laying.	Protection after laying.	Superintendence.	General expense.	Miscellaneous.	Per square yard.	Entire section.
	Feet.	*Sq. yds.*	*Cu. yds.*	*Cu. yds.*	*Barrels.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	
Gravel	1,102	2,488	0.123	0.069	0.255	21.44	25.10	9.87	41.15	21.31	1.62	8.01	4.54	6.81	139.85	$3,479.47
Limestone	1,190	2,729	.123	.069	.255	21.44	28.10	9.87	41.15	21.31	1.62	8.01	4.54	6.81	142.85	3,898.37
Trap	300	633	.123	.069	.255	21.44	29.89	9.87	41.15	21.31	1.62	8.01	4.54	6.81	144.64	915.57
Total																8,293.41

[1] The data for the cement-concrete surface coated with bituminous materials in experiment No. 3 are included in this table.

TABLE 15.—*Materials and cost data for oil-cement concrete experiment at Chevy Chase, Md.* [1]

Description.			Quantities of materials (per square yard).				Cost per square yard.										Total cost.	
Coarse aggregate.	Length of section.	Area of section.	Coarse aggregate.	Sand.	Cement.	Oil.	Preparing subgrade.	Coarse aggregate	Sand.	Cement.	Oil.	Mixing and laying.	Protection after laying.	Superintendence.	General expense.	Miscellaneous.	Per square yard.	Entire section.
	Feet.	*Sq. yds.*	*Cu. yds.*	*Cu. yds.*	*Barrels.*	*Gallons.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	
Gravel	631	1,438	0.123	0.069	0.255	0.638	21.44	25.10	9.87	41.15	7.06	22.06	1.62	8.01	4.54	6.81	147.66	$2,123.35
Limestone	437	992	.123	.069	.255	.638	21.44	28.10	9.87	41.15	7.06	22.06	1.62	8.01	4.54	6.81	150.66	1,494.45
Trap	290	655	.123	.069	.255	.638	21.44	29.89	9.87	41.15	7.06	22.06	1.62	8.01	4.54	6.81	152.45	998.55
Total																		4,616.35

[1] The data for the oil-cement concrete surface coated with bituminous materials in experiment No. 3 are included in this table.

TABLE 16.—*Materials and cost data for bituminous surface treatment on concrete at Chevy Chase, Md.*

Section.	Bituminous material.		Length of section.	Area of section.	Rate of application.			Cost per square yard.					Cost of entire section.
	Paint coat.	Carpet coat.			Bituminous materials (per square yard).		Chips (per square yard).	Bituminous material.		Chips.	Labor of application.	Total.	
					Paint coat.	Carpet coat.		Paint coat.	Carpet coat.				
			Feet.	*Sq. yds.*	*Gallons.*	*Gallons.*	*Cu. yds.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	
A and G	None	Refined coal tar	404	912	....	0.33	0.01	....	4.09	2.43	3.07	9.59	$87.46
B and H	do	Water-gas tar preparation No. 2	396	903	....	.33	.01	....	3.27	2.43	3.07	8.77	79.19
C and I	do	Fluxed native asphalt No. 2	398	907	....	.50	.01	....	7.05	2.43	3.07	12.55	113.83
D	Water-gas tar preparation No. 1	do	127	289	0.20	.50	.01	1.74	7.05	2.43	3.79	15.01	43.38
E	Native asphalt emulsion	Fluxed native asphalt No. 1	123	281	.10	.50	.01	1.30	7.05	2.43	3.79	14.57	40.94
F	Water-gas tar preparation No. 1	Oil-asphalt No. 1	251	571	.20	.40	.01	1.74	4.60	2.43	3.79	12.56	71.72
J	None	Oil-asphalt No. 2	138	315	....	.50	.01	....	5.75	2.43	3.07	11.25	35.43
	Total		....	....	....	....	....	....	....	....	....	....	471.95

TABLE 17.—*Materials and cost data for brick pavement at Chevy Chase, Md.*

Description:	
Length of section .... feet..	980
Area of section .... square yards..	2,055
Quantities of materials (per square yard):	
Base—	
Gravel .... cubic yard..	0.150
Sand .... do....	0.065
Cement .... barrel..	0.145
Pavement—	
Sand cushion .... cubic yard..	0.061
Brick .... number..	40
Sand in grout .... cubic yard..	0.005
Cement in grout .... barrel..	0.031
Cost per square yard:	
Base—	
Gravel .... cents..	27.30
Sand .... do....	9.30
Cement .... do....	23.40
Mixing and placing .... do....	17.45
Pavement—	
Sand in sand cushion .... do....	10.10
Preparing sand cushion .... do....	3.66
Brick .... do....	80.00
Unloading and piling brick from car .... do....	15.23
Hauling and piling brick by roadside .... do....	11.18
Laying brick .... do....	5.20
Rolling brick .... do....	1.76
Sand in grout .... do....	0.80
Cement in grout .... do....	5.08
Grouting .... do....	2.96
Protection .... do....	1.57
General—	
Preparing subgrade .... do....	21.44
Superintendence .... do....	10.43
General expense .... do....	4.54
Miscellaneous .... do....	6.81
Total cost:	
Per square yard .... do....	258.21
Total section	[1] $5,515.86

COMPLETE SUMMARY OF 1912 PROJECT AT CHEVY CHASE, MD.

On January 29, 1914, a careful inspection of all the experiments was made, and their condition was reported as follows:

Experiments Nos. 1 and 2, the bituminous concretes, are both in excellent condition. The section laid under the Topeka specification has a slightly wavy surface as compared with the District of Columbia pavement, and has compressed in a few places below the top of the

[1] Includes also $136.59, the cost of a concrete shoulder, 6 inches by 8 inches, 1,350 linear feet at 10.12 cents per linear foot; and $73.05, the cost of an expansion joint, 1,900 linear feet, at 3.84 cents per linear foot.

adjoining curb. The seal coat on the District of Columbia pavement began to bleed badly with the advent of warm weather, and in July it was necessary to make an application of pea gravel to the extent of 0.011 cubic yard per square yard. This is regarded as supplementary construction and charged accordingly. A smooth and excellent wearing surface has resulted.

The results of expansion in concrete during hot weather were noted at the joint between experiments Nos. 2 and 3, where the roadway buckled across its entire width, and to a small extent sheared off some of the concrete base of the District of Columbia pavement. The defect was repaired by cutting out a narrow strip of concrete. The pavement settled to its original grade, and the slot was filled by three double courses of vitrified brick, the joints of which were filled with hot coal-tar pitch.

An inspection of the several bituminous surface treatments applied to concrete did not seem to indicate any noticeable difference between the adaptability of cement concrete and oil-cement concrete to this form of treatment. The condition of the various sections at the time of inspection was noted as follows:

A (Refined coal tar): The adhesion was fairly good, but the bitumen had become quite hard and had worn off in a number of small spots.

B (Water-gas tar preparation No. 2): The adhesion was about the same as the coal tar, but much fewer places had worn through.

C (Fluxed native asphalt No. 2): The adhesion was not particularly good. There were no failures in the east half of the road, but for one-third of the width on the west side the treatment was about 30 per cent gone.

D (Fluxed native asphalt No. 2 over water-gas tar preparation No. 1): There were but few failures on the north two-thirds of the section; the bitumen was flexible and the adhesion good. There was extensive patching in the south third, but a large part of this was due to damage done by a traction engine shortly after the section was completed.

E (Fluxed native asphalt No. 1 over a native asphalt emulsion): The adhesion was poor. There were few small failures on the east half of the roadway, and about 40 per cent of the treatment was gone on the west half.

F (Oil asphalt No. 1 over water-gas tar preparation No. 1): The adhesion was poor, and the treatment was about 50 per cent gone throughout. One very good piece was left on the east half at the south end.

G (Refined coal tar): The condition was about the same as section A.

H (Water-gas tar preparation No. 2): This section was in very good condition. The adhesion was good and there were only two or three very small bare places.

I (Fluxed native asphalt No. 2): The north half was good, but there were a few large bare places in the south half on the east side of the road.

J (Oil asphalt No. 2): This section was generally good on the east half of the road, with several fairly large bare places along the west side.

In connection with the above report, it should be said that practically all of the sections suffered to a greater or less extent from the passage of a traction engine over them. This occurred during a rather warm spell shortly after the completion of the work, when the bitumen showed a slight tendency to bleed. The necessary repairs were rapidly made by the patrolman, but as section markers had not then been placed, his costs could not be distributed. When the sections had once been put in thorough repair they were permitted to wear without further attention, with the results above given.

The exposed concrete surfaces as a whole presented a smooth, uniform texture, and there was apparently no difference in wear between the plain cement and oil-cement concrete. The addition of hydrated lime has had no noticeable effect on the concrete. This section can not be distinguished from the others and has developed four cracks in a total length of 260 feet. Transverse cracks developed at varying intervals throughout the sections, and the average distance between cracks is shown in Table 18, which is based on observations made November 5, 1913. It should be noted that the cracks in the sections which had been surface-treated with bituminous materials include those which were noted before the surface treatment was applied as well as those which have since been noted through cracking of the bituminous surface.

TABLE 18.—*Average distance between cracks in concrete road of Chevy Chase, Md.*

Character of pavement.		Length.	Average distance between cracks.
Concrete.	Aggregate.		
Surface coated with bituminous materials:		*Feet.*	*Feet.*
Cement	Gravel	660	45
Do	Limestone	580	145
Oil-cement	do	230	115
Do	Gravel	370	50
Surface exposed:			
Cement	do	425	61
Do	Limestone	600	100
Do	Trap	300	40
Oil-cement	Limestone	210	105
Do	Gravel	260	45
Do	Trap	290	60

It will be noted from the foregoing table that cracks have developed at a greater average distance where a limestone aggregate was used, and at the last inspection there were still two sections of the limestone concrete each 140 feet in length without a crack. When the edges of any cracks began to wear excessively, the cracks were filled with the water-gas tar preparation No. 1 and sand. The results of this treatment have thus far proved entirely satisfactory.

The measurements referred to in Circular No. 99 are being continued, and it is probable that interesting results will be reported in the near future.

No difference was noted in the character of the various sections of brick pavement. The grouted surface had practically all worn off, and it was observed at a few places throughout the length of the section that small transverse cracks had developed where the grout had broken loose from a course of brick.

Beginning with March 4, 1912, regular counts of traffic on the Connecticut Avenue sections were made. The census is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the second one-year period, or 28 counts, for the period March 10, 1913, to February 24, 1914, is given in Table 19. The east side of the road carries outgoing traffic and the west side incoming traffic.

TABLE 19.—*Volume and character of traffic on Connecticut Avenue north and south of Bradley Lane and west on Bradley Lane.*

Vehicle.	North.				South.				West on Bradley Lane.			
	Maximum.		Average.		Maximum.		Average.		Maximum.		Average.	
	East side.	West side.	East side.	West side.	East side.	West side.	East side.	West side.	East-bound.	West-bound.	East-bound.	West-bound.
1. Loaded one-horse wagon	22	17	10	9	22	19	12	11	15	17	8	7
2. Unloaded one-horse wagon	17	24	6	8	29	29	10	11	13	14	6	6
3. Loaded two-horse wagon	22	80	11	23	28	85	13	26	24	22	8	8
4. Unloaded two-horse wagon	83	26	14	8	81	25	17	8	29	22	4	6
5. Loaded four-horse wagon	4	3	0	0	4	3	1	1	2	2	0	0
6. Unloaded four-horse wagon	2	2	0	0	3	4	0	0	2	2	0	0
7. One-horse pleasure vehicle	14	14	6	7	29	26	9	9	16	19	6	6
8. Two-horse pleasure vehicle	2	2	0	0	5	6	1	1	3	5	0	1
9. Rubber-tired horse vehicle	2	3	0	0	3	4	0	0	4	2	0	0
10. Saddle horse	5	8	1	1	11	7	2	2	7	9	1	2
11. Motor cycle	21	18	5	4	20	20	7	6	21	21	4	5
12. Excessively heavy vehicle	4	22	0	2	3	22	0	2	2	2	0	0
13. Motor runabout	37	35	14	15	50	51	25	22	26	29	11	12
14. Motor touring car	154	151	71	71	226	229	130	106	67	89	33	43
15. Loaded motor dray	17	32	8	9	19	31	10	10	20	18	6	7
16. Unloaded motor dray	5	7	2	3	10	14	2	3	5	12	1	2

EXPERIMENTS ON ROCKVILLE PIKE, MARYLAND.

TARS AND OILS—SURFACE TREATMENT.

The principal purpose of these experiments was to demonstrate the relative value of several bituminous products commonly used for surface treatment, and to ascertain, by comparative service tests, the relative economy from a maintenance standpoint of cold treatment with the lighter products as compared with hot treatment in which some of the heavier products were used. Incidentally, the relative wearing qualities of trap-rock screenings and fine gravel will be practically tested, and on some of the sections where oil was applied, an attempt was made to learn what difference, if any, would result from making the application to a wet and dry road surface.

The road selected for the experiments is commonly known as the Rockville Pike and extends from the District of Columbia line to the corporate limits of Rockville, Md., a distance of approximately 9 miles. It was a macadam road originally constructed with quartzite and patched with limestone from time to time. At the time of these experiments it had become rough and badly worn, and was therefore resurfaced before any surface treatments were applied. This work was done on three contracts, the first two of which, including the portion from station 0 + 15 at the District line to station 210, were completed in July, 1913, and the third, extending from station 210 to the corporate limits of Rockville, in October, 1913. The old surface was loosened with spikes in the roller wheels and further broken up with a 3-ton scarifier. The surface was then reshaped and rolled, after which from 3 to 3½ inches of new limestone was added and the surface was finished as water-bound macadam. The road was graded 25 feet wide in both cuts and fills, and the surface of the finished macadam had a width of 15 feet and a crown of 0.6 inch per foot. The cost of this work averaged 52 cents per square yard or $4,676 per mile of 15-foot road. A section of 10-foot road on Bradley Lane, 1,500 feet in length, was also scarified and resurfaced with limestone as water-bound macadam on a separate contract. This was a limestone road which had become badly worn and rutted. The total cost for resurfacing was $1,285.72, or 75.6 cents per square yard.

Surface treatment was started on September 5 at the District line on the macadam which had been longest completed. The surface was thoroughly swept with a horse-drawn street sweeper, and any hard cakes of dust were removed with shovels. As the work progressed over macadam which had been more recently completed, these cakes of dust became more numerous, and were removed with considerable difficulty. The advisability of permitting traffic to consolidate and wear a new macadam surface to a reasonable extent before surface treating was thereby demonstrated. All the bituminous materials were delivered in tank-car lots of from 5,600 to 5,800 gallons with an average haul of 1⅛ miles from the road. The material was heated at first by a small portable boiler, but as colder weather developed it was found necessary to engage a 40-horsepower traction engine in order to heat the heavier materials properly.

The application was made by means of two 600-gallon distributors which were each drawn by one team. They were equipped with a gasoline pump developing about 40 pounds pressure at the nozzles. The material was ejected from slotted nozzles in fan-shaped sprays so spaced as to cover half the width of the road on each passage of the machine.

The specification required that the bituminous material should be allowed to lie on the road surface for from one to three hours before being covered. It was soon noted, however, that on warm days a part of the material was lost by drainage over the shoulders and the practice of immediately covering the application with screenings or gravel was therefore adopted. Approximately the south half of each experiment was covered with trap rock screenings, while the north half was covered with fine river gravel. The latter material, used in the first three experiments, tended to run somewhat coarser than that obtained later, but no appreciable difference in results was noted after the road had been subjected to traffic for a short time.

The mechanical analyses of the average run of trap rock and gravel are given in Table 20.

TABLE 20.—*Mechanical analyses of covering materials used in Rockville Pike experiments.*

Material.	Trap rock.	Gravel.
	Per cent.	*Per cent.*
Passing ¾-inch, retained on ½-inch screen	30.5	5.2
Passing ½-inch, retained on ¼-inch screen	65.3	62.0
Passing ¼-inch, retained on ⅛-inch screen	3.7	29.0
Passing ⅛-inch screen	.5	3.8
Total	100.0	100.0

EXPERIMENT NO. 1.—REFINED COAL TAR—HOT APPLICATION.

Location: Station 0+15 to station 61+20.
Length: 6,105 feet.

Bradley Lane was also treated for a width of 10 feet and a length of 665 feet east from Rockville Pike.

Date of application: From September 9 to September 22.
Temperature of tar: From 165° to 200° F.

TABLE 21.—*Analysis of refined coal tar used in experiment No. 1.*

Specific gravity 25°/25° C			1.204
Float test at 32° C. (time)			1′32″
Per cent of free carbon			14.93
Distillation:		By volume.	By weight.
Water	per cent..	[1] 1.6	1.3
First light oils to 110° C		Trace.	Trace.
Second light oils 110°–170° C	per cent..	.5	.4
Heavy oils 170°–270° C	do....	[2] 13.7	11.9
Heavy oils 270°–315° C	do....	[3] 7.2	6.3
Pitch residue	do....	[4] 77.0	79.8
Total	do....	100.0	99.7

[1] From leaky coils in tank car. [2] Four-fifths solid. [3] One-fourth solid. [4] Fairly glossy; brittle.

EXPERIMENT NO. 2.—REFINED WATER-GAS TAR—COLD APPLICATION.

Location: From station 61+20 to station 135+00.
Length: 7,380 feet.

Bradley Lane was also treated for a width of 10 feet and a length of 835 feet east from the end of the preceding experiment.

Date of application: September 23 and 24.
Temperature of tar: From 80° to 100° F.

TABLE 22.—*Analysis of refined water-gas tar used in experiment No. 2.*

Specific gravity 25°/25° C	1.121	
Viscosity, Engler, 50° C., 50 c. c. specific	17.5	
Per cent of free carbon	3.33	
Distillation:	By volume.	By weight.
Water	Trace.	Trace.
First light oils to 110° C. per cent	[1] 0.2	0.2
Second light oils 110°–170° C. do	[2] 3.3	2.4
Heavy oils 170°–270° C. do	[1] 28.0	24.3
Heavy oils 270°–315° C. do	[1] 13.5	12.4
Pitch residue do	55.0	60.2
Total do	100.0	99.5

EXPERIMENT NO. 3.—ASPHALTIC PETROLEUM—COLD APPLICATION.

Location: From station 135+00 to station 209+00.
Length: 7,400 feet.
Date of application: From September 25 to September 30.
Temperature of oil: About 80° F.

TABLE 23.—*Analysis of asphaltic petroleum* [3] *used in experiment No. 3.*

Specific gravity 25°/25° C	0.935
Flash point °C	22
Burning point °C	30
Viscosity, Engler, 25° C., 50 c. c. specific	67.0
Per cent of loss at 163° C., 5 hours (20 grams)	27.01
Float test of residue (50° C.) (time) [4]	2'21"
Per cent of total bitumen insoluble in 86° B. naphtha	14.22
Per cent of fixed carbon	7.90
Per cent soluble in CS_2 (total bitumen)	99.89
Per cent of organic matter insoluble	.11
Per cent of inorganic matter insoluble	.00
Total	100.00

Details.—The oil was distributed in one application from station 135+00 to station 175+00, but on the remainder of this section about 0.25 gallon was applied on one day and another 0.25 gallon was applied the next day, after which the screenings or gravel were thrown on and the surface was rolled. From station 196+00 to station 206+00 the macadam was first well sprinkled with water and the oil was applied while the road surface was still moist.

[1] Clear. [2] Turbid. [3] Fairly viscous, slightly sticky, fluid. [4] Soft, sticky, glossy.

EXPERIMENT NO. 4.—RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION.

Location: From station 209+00 to station 280+00.
Length: 7,100 feet.
Date of application: From October 9 to October 15.
Temperature of oil: Maximum 210° F., minimum 165° F., average 188° F.

TABLE 24.—*Analysis of residual asphaltic petroleum* [1] *used in experiment No. 4.*

Specific gravity 25°/25° C	1.002
Flash point ° C	86
Burning point ° C	175
Viscosity, Engler, 100° C., 50 c. c. specific	21.0
Per cent of loss at 163° C., 5 hours (20 grams)	9.23
Float test of residue (50° C.) (time) [2]	2′42″
Per cent of bitumen insoluble in 86° B. naphtha	10.55
Per cent of fixed carbon	5.63
Per cent soluble in CS_2 (total bitumen)	99.93
Per cent of organic matter insoluble	.06
Per cent of inorganic matter insoluble	.01
Total	100.00

Details.—From station 241 + 50 to station 251 + 07 the macadam was first well sprinkled with water and the oil was applied while the road surface was still moist. Owing to the viscosity of the oil and the cool weather, some difficulty was experienced in starting the distributor pump. This resulted in the formation of pools of thick oil at the beginning of each trip before the nozzles worked uniformly enough to have the team start. After a few experiences with this trouble, the distributor nozzles were allowed to discharge into the ditch until a uniform distribution began.

EXPERIMENT NO. 5.—RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION.

Location: From station 280+00 to station 347+75.
Length: 6,775 feet.
Date of application: From October 21 to November 21.
Temperature of oil: Maximum 221° F., minimum 167° F., average 200° F.

TABLE 25.—*Analysis of residual asphaltic petroleum* [1] *used in experiment No. 5.*

	Car No. 1.	Car No. 2.
Specific gravity 25°/25° C	0.990	0.998
Viscosity, Engler, 100° C., 50 c. c. specific	26.0	37.5
Float test at 50° C. (time)	1′28″	1′26″
Per cent of loss at 163° C., 5 hours (20 grams)	3.03	2.63
Float test of residue (50° C.) (time) [3]	2′50″	2′45″
Per cent of total bitumen insoluble in 86° B. naphtha	19.29	18.83
Per cent of fixed carbon	10.47	10.64
Per cent soluble in CS_2 (total bitumen)	99.97	99.90
Per cent of organic matter insoluble	.02	.10
Per cent of inorganic matter insoluble	.01	.00
Total	100.00	100.00

[1] Sticky, viscous fluid. [2] Sticky, semisolid. [3] Soft, sticky.

Details.—Car No. 1 began to foam badly from water contamination after the first two loads had been applied. About 2,000 gallons were used, when, owing to the difficulty of handling the material, the remainder of the shipment was rejected and replaced by car No. 2. From station 314 + 10 to station 320 + 70 and from station 294 to station 308 the oil was applied soon after a rain while the surface of the macadam was still moist.

Experiment No. 6.—Water-gas tar preparation—Hot application.

Location: From station 347+75 to station 411+00.
Length: 6,325 feet.
Date of application: November 24 and November 26.
Temperature of tar: Maximum 248° F.; minimum 180° F.; average 214° F.

Table 26.—*Analysis of water-gas tar preparation [1] used in experiment No. 6.*

Specific gravity 25°/25° C			1.15
Float test at 32° C. (time)			2′9″
Per cent of free carbon			1.29
Distillation:		By volume.	By weight.
Water	per cent..	0.0	0.0
First light oils to 110° C	do....	[2].2	.1
Second light oils 110°–170° C	do....	[2].2	.2
Heavy oils 170°–270° C	do....	[2]16.7	14.9
Heavy oils 270°–315° C. [3]	do....	[4]7.5	6.6
Pitch residue	do....	75.4	78.1
Total	do....	100.0	99.9

Details.—The east half of the road from station 393 + 60 to station 397 + 60 was treated by means of hand-pouring pots.

Experiment No. 7.—Asphaltic petroleum—Cold application.

Location: From station 411+00 to station 477+89.
Length: 6,689 feet.
Date of application: December 4 and 5.
Temperature of oil: From 80° to 100° F.

Table 27.—*Analysis of asphaltic petroleum [5] used in experiment No. 7.*

Specific gravity 25°/25° C	0.959
Flash point ° C	32
Burning point ° C	41
Viscosity, Engler, 25° C., 50 c. c. specific	114.5
Per cent of loss at 163° C., 5 hours (20 grams)	27.44
Float test of residue (50° C.) [1]	1′53″
Per cent of total bitumen insoluble in 86° B. naphtha	7.38
Per cent of fixed carbon	4.28
Per cent soluble in CS_2 (total bitumen)	99.91
Per cent of organic matter insoluble	.08
Per cent of inorganic matter insoluble	.01
Total	100.00

[1] Sticky, very viscous fluid.
[2] Clear.
[3] A 315°–350° C. fraction showed 5 per cent and a 350°–375° C. fraction showed 10 per cent insoluble in dimethyl sulphate.
[4] Clear; showed 5 per cent insoluble in dimethyl sulphate.
[5] Sticky, fluid, with strong naphtha odor.

The cost data given in Table 28 are based upon the following unit prices for labor and materials:

Foreman (per 8-hour day)	$4.00
Distributor operator (per 8-hour day)	4.00
Fireman (per 8-hour day)	2.00
Laborers (per 8-hour day)	1.60
Teams (per 8-hour day)	4.00
Traction engine (per day)	10.00
Gravel, on siding (per ton)	1.75
Trap rock, on siding (per ton)	3.35

No charge was made for distributor or other implements.

TABLE 28.—*Materials and cost data for surface treatment experiments on Rockville Pike.*

Experiment No.	Description.			Quantity of materials (per square yard).		Cost per square yard.								Total cost.	
	Bituminous material.	Length of section.	Area of section.	Bituminous material.	Gravel.	Bituminous material.	Gravel.[1]	Cleaning surface.	Heating bituminous material.	Applying hot material.	Spreading gravel.	Rolling.	Miscellaneous.	Per square yard.	Per mile 15-foot road.
		Feet.	*Sq. yds.*	*Gallons.*	*Cu. yds.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	
1	Refined coal tar (hot)	6,105	10,175	0.531	0.0138	4.35	3.01	0.30	1.22	0.53	0.55	0.05	0.92	10.93	$961.84
2	Refined water-gas tar (cold)	7,380	12,300	.438	.0138	2.85	3.01	.30	.09	.37	.55	.05	.92	8.14	716.32
3	Asphaltic petroleum (cold)	7,400	12,333	.470	.0138	2.35	3.01	.30	.09	.37	.55	.05	.92	7.64	672.32
4	Residual asphaltic petroleum (hot)	7,100	11,833	.473	.0138	3.29	3.01	.30	1.22	.53	.55	.05	.92	9.87	868.56
5	Do	6,775	11,292	.496	.0138	3.31	3.01	.30	1.22	.53	.55	.05	.92	9.89	870.32
6	Water-gas tar preparation (hot)	6,325	10,542	.531	.0138	3.72	3.01	.30	1.22	.53	.55	.05	.92	10.30	906.40
7	Asphaltic petroleum (cold)	6,689	11,148	.502	.0138	3.33	3.01	.30	.09	.37	.55	.05	.92	8.62	758.56

[1] The costs in this table are based on finishing with gravel. The trap-rock screenings were applied at the rate of 0.0132 cubic yard per square yard at an additional cost of 2.82 cents per square yard, or $248.16 per mile of 15-foot road.

SUMMARY OF EXPERIMENTS ON ROCKVILLE PIKE.

These experiments were carefully inspected on January 7 and again on April 2, 1914. It is, of course, too early to draw any conclusions regarding the relative value of the several treatments. From a consideration of the present condition of all the sections, it would appear that the trap rock and gravel have given equally good results. Experiment No. 1, which has been under traffic the longest, has developed a smooth, firm surface with but few defects, and these are slight. There has been, however, a decided settlement of the road along the west shoulder in the vicinity of station 12+00, and this has resulted in the surface breaking along the edge. Experiment No. 2 has also developed a generally smooth surface. Toward the north end of this experiment, the surface treatment has worn off to some extent, yielding a mosaic appearance, but, owing to a fair penetration obtained with the material used, the stones are held firmly in place by a matrix of fine stone and bitumen. Experiment No. 3 has a more rubbery or corky character than any of the others, and shows some tendency to become muddy during long periods of rain or snow. This tendency is still more pronounced on experiment No. 7, but the surfaces of both experiments soon become smooth and perfect with the advent of dry weather. Evidences of frost action and a consequent heaving of the surface were noted between station 164+00 and station 167+00. Between station 156+50 and station 157+50 a 24-inch culvert running diagonally under the road broke through. This has been replaced with new pipe, and the road will necessarily be resurfaced over the area involved. The surfaces of experiments Nos. 4, 5, and 6 are in general smooth and firm throughout. There is, perhaps, more unevenness throughout experiment No. 5, owing largely to the fact that the treatment was so interrupted because of the difficulties incident to handling the tank car of foaming material. The surface of experiment No. 6 has picked off in a number of small areas throughout the crown of the road, and will require immediate repair at these points. These defects evidently developed through insufficient protection of the bituminous surface with screenings or gravel. There has apparently been some settlement in the wheel tracks throughout experiment No. 7 and to some extent on experiment No. 6.

Beginning with June 28, 1913, regular counts of traffic on Rockville Pike were made every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for 22 counts, covering the period from June 28, 1913, to March 28, 1914, is given in Table 29.

TABLE 29.—*Volume and character of traffic on Rockville Pike at its intersection with Bradley Lane.*

Vehicle.	Maximum.		Average.	
	North-bound.	South-bound.	North-bound.	South-bound.
1. Loaded one-horse wagon	27	24	14	14
2. Unloaded one-horse wagon	26	26	10	10
3. Loaded two-horse wagon	25	57	14	23
4. Unloaded two-horse wagon	65	28	15	7
5. Loaded four-horse wagon	4	5	1	1
6. Unloaded four-horse wagon	4	3	1	1
7. One-horse pleasure vehicle	22	29	13	16
8. Two-horse pleasure vehicle	4	5	2	1
9. Rubber-tired horse vehicle	6	6	2	1
10. Saddle horse	18	21	6	7
11. Motor cycle	43	35	15	15
12. Excessively heavy vehicle	5	18	2	2
13. Motor runabout	44	72	20	20
14. Motor touring car	209	225	81	86
15. Loaded motor dray	15	14	7	8
16. Unloaded motor dray	7	9	2	3

EXPERIMENTS AT MIAMI, FLA.

OILS-CORALLINE ROCK.

These experiments are located on the Biscayne Drive about 2 miles north of Miami, Fla. This road is the principal highway connecting Miami with Fort Lauderdale, Palm Beach, and other cities along the Florida east coast and is subjected to a fairly heavy mixed traffic, with numbers of automobiles during the winter season. Like most of the roads in Dade County, it is surfaced with a soft oolitic limestone formed from coral remains and known locally as marl or coralline rock. Deposits of this material are found in abundance throughout the county, and it comes from the pit in a soft, usually moist condition somewhat resembling coarse gravel with a large proportion of fine material. It varies from pure white to rusty yellow in color. Upon exposure to the atmosphere and traffic on the road, it shows remarkable cementing qualities, becoming fairly hard, dense, and impervious, and, when used in newly constructed roads, it yields a smooth excellent surface at a comparatively low cost. These roads, however, wear rapidly and very unevenly, and potholes develop to such an extent and size as to make the surface rough and unsatisfactory for travel. To avoid this condition persistent maintenance by patching or the frequent resurfacing of the road is necessary and this is accomplished by scarifying the surface, recrowning, and rolling. The intense white color of the road surface also offers some objection on account of its trying effect on the eyes, and several unsuccessful efforts at surface treatment with bituminous materials have been tried for the double purpose of preserving the road and producing a more satisfactory color. A study of the general nature of the coralline rock led to the belief that a more satisfactory and permanent surfacing might be obtained in construction with a properly selected bituminous binder, and the following experiments were instituted in cooperation with the commissioners of Dade County, beginning with station 0 at the Miami end of the work. The experiments were begun on June 9, 1913, and completed on June 28, 1913.

The equipment consisted of a 10-ton gasoline roller, scarifier, grader, two 1-barrel heating kettles, and hand-pouring pots. The oil was in all cases applied by pouring pots. The sand used in finishing the surface was a very fine, white siliceous pit sand, which was screened for the purpose of removing twigs, leaves, and other foreign matter. Two asphaltic oils, one light and the other heavy, were used, and the characteristics of each are shown in the following table. The light oil was used without heating and the heavy oil was applied at a temperature of about 200° F.

TABLE 30.—*Analysis of asphaltic petroleums used in experiments at Miami, Fla.*

Character.	Light.	Heavy.
	Experiments 1, 2, 4.	Experiments 3, 5, 6.
Specific gravity 25°/25° C.	0.960	0.992
Flash point °C	42	105
Burning point °C	67	145
Viscosity, Engler, specific	[1] 152.4	[2] 9.0
Per cent of loss at 163° C.	27.53	16.33
Float test on residue (50° C.)	[3] 2′19″	[3] 2′40″
Per cent of total bitumen insoluble in 86° B. naphtha	10.40	10.83
Per cent of fixed carbon	5.01	5.82
Per cent soluble in CS_2 (total bitumen)	99.94	99.94
Per cent of organic matter insoluble	.06	.04
Per cent of inorganic matter insoluble	.00	.02
Total	100.00	100.00

[1] At 25° C., 50 c. c. [2] At 100° C., 100 c. c. [3] Soft, sticky, with slight flow.

EXPERIMENT NO. 1.—SEMIPENETRATION METHOD—COLD, LIGHT OIL.

Location: From station 0+00 to station 0+96.
Length: 96 feet.

Method.—The old surface was scarified, regraded, and left loose to a depth of about 2 inches. Rain during the night previous to oiling caused the surface to rebond, and it was again broken to a depth of 2 inches and smoothed with rakes. The light oil was applied at the rate of 0.9 gallon per square yard and allowed to soak in for two hours before sanding, after which the surface was rolled. Owing to the quantity of fine material in the scarified surface, very little penetration was accomplished, but the oil was absorbed to a considerable extent. On rolling, the surface cracked and waved badly. Several rains with a light rolling after each improved its condition to a great extent, but the promise of ultimate success was not great.

EXPERIMENT NO. 2.—SURFACE TREATMENT—COLD, LIGHT OIL.

Location: From station 0+96 to station 5+49.
Length: 453 feet.

Method.—The old surface was scarified, regraded, and water-bound. It was then swept clean and the oil was applied at the rate of 0.5 gallon per square yard by means of pouring pots. After vigorously brooming the oil, the surface was sanded and rolled.

From station 0 + 96 to station 2 + 85 the surface was very damp from rain the previous night. The oil was allowed to stand from two hours at station 0 + 96 to six hours at station 2 + 85. It was sanded late in the afternoon and rolled the following morning. From station 2 + 85 to station 3 + 90 the sand was spread immediately after the oil was applied. From station 3 + 90 to station 5 + 49 the oil stood from three to six hours before sanding. The sanding was barely completed when a heavy rain fell and on the following morning the sand mat was found washed into ridges and to a large extent carried off the road entirely. The portion of the experiment on which the oil had stood the shorter time became rather mushy and uneven, while the remainder of the section was fairly smooth and hard. The section was resanded but the same condition was evident two weeks later.

EXPERIMENT No. 3.—PENETRATION METHOD—HOT, HEAVY OIL.

Location: From station 5+49 to station 7+49.
Length: 200 feet.

Method.—In this experiment, after the old surface had been regraded, a course of new unscreened rock was spread to a loose depth of 2½ inches. This course was brought to the required shape with a very light rolling in an effort to permit penetration by leaving the crust as open as possible. Light rains previous to the application of oil caused the surface to become slightly water-bound. The hot oil was applied at the rate of approximately 0.6 gallon per square yard, but owing to the varying texture of the surface it readily penetrated on some areas and remained almost entirely on the surface of others. The surface was sanded and rolled as in the previous experiments.

EXPERIMENT No. 4.—PENETRATION METHOD—COLD, LIGHT OIL.

Location: From station 7+49 to station 9+16.
Length: 167 feet.

Method.—This experiment was quite similar to No. 3, in that the application was made on a 2½-inch course of new, unscreened rock. The rock was, however, heavily rolled in an effort to tighten the surface sufficiently for brooming the oil. This was partially effected and the penetration seemed to be as good as in the more lightly rolled section. Oil was applied at the rate of 0.7 gallon per square yard and allowed to stand for three hours before sanding, and at the end of this time it was practically all absorbed.

EXPERIMENT No. 5.—PENETRATION METHOD—HOT, HEAVY OIL.

Location: From station 9+16 to station 11+55.
Length: 239 feet.

Method.—This experiment was essentially the same as experiment No. 4 except for the reason that the course of new, unscreened rock was reduced to a loose thickness of 1½ inches in an effort to reduce the cost of this type of experiment. From station 9 + 16 to station 10 + 87 sand was used for a top dressing. The surface cracked and lifted under rolling, and required patching in several spots a few days later. From station 10 + 87 to station 11 + 55 new rock screenings were used for the top dressing.

EXPERIMENT NO. 6.—PENETRATION METHOD—HOT, HEAVY OIL.

Location: From station 11+55 to station 12+62.
Length: 107 feet.

Method.—Owing to the difficulty in securing a surface of uniform texture with unscreened rock, it was decided to lay a section with new, screened material. The rock furnished from the pit was passed over a ⅜-inch screen and the material retained was spread to a loose depth of 3 inches on the regraded road surface. Oil was applied at the rate of about 1 gallon per square yard, and this was sufficient to flush the voids. The penetration was evidently about 2 inches in depth over the entire surface of the section. From station 11+55 to station 11+80 new rock screenings were used as a top dressing, and over the remainder of the section sand was used for this purpose.

SUMMARY OF EXPERIMENTS AT MIAMI, FLA.

An inspection of these experiments in December, 1913, showed Nos. 1 and 2 to be in very bad condition and demonstrated the impracticability of treating the original coralline rock roadway either by attempted penetration or strictly surface application of bitumen. Experiments Nos. 3 and 4 presented a very satisfactory appearance and there was little difference between them. No real failures were evident. Experiment No. 5 was not as satisfactory, although only two or three small holes had developed in it. Experiment No. 6, where new, unscreened rock was used, was in excellent condition and showed no indication of weakness anywhere on its surface. The cross section was true throughout and it had not worn perceptibly, although the untreated road immediately north of it had worn fully an inch during the preceding six months.

The cost data are based upon the following unit prices for labor and materials:

Foreman (per 10-hour day)	$3.50	Screened rock	$1.75
Rollerman (per 10-hour day)	4.00	Sand, on work	1.06
Pit boss (per 10-hour day)	3.00	Light asphaltic petroleum (per gallon)	.162
Labor (per 10-hour day)	1.50	Heavy asphaltic petroleum (per gallon)	.182
Teams (per 10-hour day)	6.00		
Rock, in pit (per cubic yard)	.15		

No charge was made for heating kettles, pouring pots, or other necessary equipment.

TABLE 31.—*Materials and cost data for experiments at Miami, Fla.*

Experiment No.	Description.				Quantities of materials (per square yard).			Cost per square yard.							
	Material and method.	Character of application.	Length of section.	Area of section.	New rock.	Bitumen.	Sand.	Preparing surface.	New rock in place.	Bitumen.	Sand.	Applying bitumen.	Rolling and finishing.	General expense.	Total cost.
			Feet.	*Sq. yds.*	*Cu. yds.*	*Gallons.*	*Cu. yds.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
1	Light asphaltic petroleum (semi-penetration).	Cold..	96	213	.....	0.92	0.012	2.34	.....	14.90	1.33	2.23	1.01	0.98	22.79
2	Light asphaltic petroleum (surface treatment).	...do...	453	1,006	.....	.41	.012	2.34	.....	6.66	1.33	1.01	1.01	.98	13.33
3	Heavy asphaltic petroleum (penetration method).	Hot...	199	443	0.069	.625	.012	2.34	11.01	11.37	1.33	1.52	1.01	.98	29.56
4	Light asphaltic petroleum (penetration method).	Cold..	168	371	.069	.705	.012	2.34	11.01	11.42	1.33	1.71	1.01	.98	29.80
5	Heavy asphaltic petroleum (penetration method).	Hot...	239	531	.041	.62	.012	2.34	6.61	11.28	1.33	1.51	1.01	.98	25.06
6	.....do..............	...do...	197	240	.087	.99	.012	2.34	16.67	18.02	1.33	2.42	1.01	.98	42.77

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT WASHINGTON, D. C., 1912.

TAR PREPARATION AND OILS—SURFACE TREATMENT.

The original report of these experiments is to be found in Circular No. 99, and the following covers the repairs to date, and the condition of the various sections in January, 1914.

SECTION NO. 1.—REFINED WATER-GAS TAR PREPARATION.

This section presents a smooth, hard, mosaic surface and has not required any repairs. In a few places along the sides of the road the treatment has cracked off for a few inches back from the edge, exposing the underlying macadam.

SECTION NO. 2.—ASPHALTIC PETROLEUM.

This treatment showed some tendency to push into slight waves and a few small humps, particularly along the south edge of the roadway. Several worn depressions in the middle of the road also developed during the winter, and apparently had their initial cause in the fact that small dust patches had been overlooked in cleaning the surface, and the treatment had not adhered properly. At the east end of the section, a number of steam pipes pass under the road, and the heat from these gives rise to conditions under which it has always been difficult to maintain a satisfactory road surface. Three distinct displacements of the surface have taken place at this point, resulting in the formation of depressions and corresponding humps. On July 11 the section was repaired and given a light surface treatment with the material originally applied. The larger depressions were filled with 1-inch limestone and the water-gas tar preparation which had been used on section No. 1. The small depressions were filled with fine screenings and the oil originally used on this section. All humps were removed with a mattock. When such repairs had been made, oil was applied at the rate of 0.10 gallon per square yard throughout the most traveled area by allowing it to run from the bung of the barrel and distributing it with hand push brooms. The application was covered with a thin layer of torpedo sand.

The total cost of maintenance for the year was $25.49, or 2.33 cents per square yard for the entire section.

When inspected in January, the general appearance of the surface was satisfactory, but the wearing carpet appeared to be developing numerous fine cracks throughout the entire length. The portion over the steam pipes required further repair in the early winter, and a change in the form of construction at this point will probably be made.

Section No. 3.—Residual petroleum.

As noted in Circular No. 99, this section showed a tendency to become muddy in wet weather, and after periods of continued rain the surface was covered with a deep oily mud, which traffic gradually worked into low ridges along the edges of the road. By summer the surface of the macadam began to be exposed throughout the traveled way, and a light treatment with the oil originally used was made on July 9, 1913. The oil was applied at the rate of about 0.10 gallon per square yard throughout the most traveled area in the same manner as on section No. 2 and was covered with torpedo sand.

The total cost of this work was $20.65, or 2.92 cents per square yard, for the entire section.

The section now presents a generally satisfactory appearance excepting for a small area on the grade at the west end. The treatment is largely worn off here, but this is almost entirely due to the condition of the adjoining pavement and gutter, where water is held for some time after a storm and continually carried on the oiled section by traffic.

Section No. 4.—Asphaltic petroleum.

This surface gave excellent service in both wet and dry weather, but, owing to the light treatment which had been given, it gradually wore off until the underlying macadam was exposed in places throughout the traveled way. A second application of about 0.10 gallon per square yard of the oil originally used was made in July, 1913, throughout the most traveled area. The oil was applied in the same manner as on the two previous sections and covered with torpedo sand.

The east arm of the fork at the north end of the section was not treated at this time, owing to the fact that traffic through there had not been sufficient to crush the gravel covering completely. The surface treatment, however, had by winter disappeared over an area of about 4 square yards, and in December this place was patched with a surface application of oil and fine gravel.

The total cost of maintaining this section was $27.45, or 2.08 cents per square yard, for the entire section. When last inspected it presented a smooth, uniform surface throughout.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD., 1911 PROJECT.

BITUMINOUS CONSTRUCTION AND SURFACE TREATMENT.

The original reports of these experiments are given in Circulars Nos. 98 and 99. The following report is based upon an inspection made January 29, 1914:

SECTION NO. 1.—REFINED COAL TAR—PENETRATION METHOD.

The surface of this section is well bound and presents as a whole a satisfactory appearance, but the seal coat is worn off to the extent of about 75 per cent and a few shallow, worn depressions can be noted. It was decided that a new seal coat was not necessary at the beginning of the past season, but an application of a light tar and screenings will very likely be made in the spring.

SECTION NO. 2.—REFINED COAL TAR—MODIFIED GLADWELL METHOD.

The surface of this section is well bound and its general appearance is good excepting for a slight unevenness. This is to be expected from the excessive bleeding which originally took place and the necessary irregularity in the distribution of chips to take up the bitumen.

SECTION NO. 3.—FLUXED NATIVE ASPHALT—PENETRATION METHOD.

This section continues to present an excellent appearance. The seal coat as a whole is intact excepting for a few small areas which present a somewhat mosaic appearance. No holes or depressions are in evidence and the section has had no repairs to date.

SECTION NO. 4.—GILSONITE OIL ASPHALT—PENETRATION METHOD.

As a whole this section continues in good condition and, excepting for a slight unevenness, the surface presents a satisfactory appearance. There are, however, a few places where the coarse stone shows up rather unevenly, and this condition led to the formation of a number of worn depressions toward the north end of the section, where patching became advisable. The shallower places were cared for by a thin paint coat of oil asphalt with screenings, but a few of the deeper ones were cut out clean and filled with new stone, and a patch was made by the penetration method.

The total cost of patching during the past year was $4.05.

Section No. 5.—Oil asphalt—Penetration method.

During the past summer it became necessary to repair four small worn depressions in which the stones were working loose. Three were on the east side and one was on the west side of the road, and all were close to the gutter. At the time of the inspection the surface presented a somewhat uneven and worn appearance; coarse surface stones were in evidence throughout, and the binder apparently did not retain much life. There were, however, no signs of raveling and no necessity for any repairs.

The total cost of patching during the past year was $2.31.

Section No. 6.—Oil asphalt—Penetration method.

This section presents about the same general appearance as No. 5. The depressions mentioned in the previous inspection report raveled badly in a few months and were finally repaired with new stone and oil asphalt applied by the penetration method. Four patches were made along the west side close to the gutter and one at the north end of the east side.

The total cost of these repairs was $3.47.

Section No. 7, A and B.—Oil asphalt—Penetration method.

The bitumen used in this section was without doubt too hard and had too high a melting point for this class of construction. In A, where two coats were applied, the binder lacks life, and it became necessary to patch another loose depression during the past season. B offers an excellent demonstration of what prompt and efficient maintenance can accomplish when the failure of bituminous construction is imminent. The simple cold-surface treatment described in Circular No. 99 undoubtedly prevented the loss of this section, and it now presents a good surface. It has had no further attention and, with the exception of one or two very small worn places which were evidently not properly cared for when repairs were made, it will probably not require any expenditure upon it during the coming season.

SECTION NO. 8.—REFINED WATER-GAS TAR PREPARATION—SURFACE TREATMENT.

During the spring of 1913 the first surface treatment began to lose its efficiency on this section and a number of small, shallow chug holes developed, particularly toward the north end. In order to prevent further deterioration, these were repaired with a light application of heavy refined coal tar and fine gravel. On September 12, 1913, the section was given a surface treatment of the same trade product which was originally used, the analysis of which is shown in the following table:

TABLE 32.—*Analysis of refined water-gas tar [1] used in second surface treatment of section No. 8.*

Specific gravity 25°/25° C			1.120
Viscosity, Engler, 50° C., 50 c.c. specific			12.8
Per cent of free carbon			0.95
Distillation:		By volume.	By weight.
Water	per cent..	0.2	0.2
First light oils to 110° C	do	.2	.2
Second light oils 110°–170° C	do	[2] 1.3	1.0
Heavy oils 170°–270° C	do	[2] 23.0	20.5
Heavy oils 270°–315° C	do	[2] 17.8	16.2
Pitch residue	do	57.5	61.8
Total	do	100.0	99.9

The surface was swept and the material was applied by an automobile distributor and was charged at 9 cents per gallon distributed on the cleaned road. The application was immediately covered with clean limestone screenings of a size that would pass a 1-inch screen, and lightly rolled. The cost data for this treatment are given in Table 34. The section now offers a fairly uniform, attractive surface, well bound and comparatively free from ruts or depressions.

SECTION NO. 9.—ASPHALTIC PETROLEUM—SURFACE TREATMENT.

This section, like section No. 8, began to lose the effect of its first treatment in the spring of 1913. The deterioration was most marked on the outer third of the road adjacent to the gutter, where traffic was lightest. This was evidently due to the fact that the surface lacked the ironing action of traffic and, lying somewhat open and porous, was rutted by the combined action of water and detritus which worked over upon it. A number of shallow, worn depressions developed, principally at the south end of the section. These were filled by applying a hot paint coat of the oil asphalt used in section No. 5 and then filling the depression with clean 1-inch limestone screenings.

On July 30 and 31, immediately after these patches had been made, the entire section was given a surface treatment of the same trade

[1] Sticky, fluid. [2] Clear.

product originally used and was then covered with a layer of clean limestone screenings which would pass a 1-inch screen. The surface was first swept by hand push brooms, and the oil was applied by allowing it to run from the bungs of the barrels and distributing it with brooms. The surface was not rolled. A torrential rain interrupted the work when the south half of the section had been completed. Some of the oil was washed into the gutters and this is no doubt responsible for the fact that the southern end of the section now presents a rougher appearance than the north half.

Table 33 shows the characteristics of the bituminous material used.

TABLE 33.—*Analysis of asphaltic petroleum*[1] *used in second surface treatment of section No. 9.*

Specific gravity 25°/25° C	0.959
Flash point ° C	38
Burning point ° C	80
Viscosity, Engler, 25° C., 50 c. c. specific	153.3
Per cent of loss at 163° C., 5 hours (20 grams)	25.05
Float test of residue (50° C.)[2]	1′29″
Per cent of total bitumen insoluble in 86° B. naphtha	7.84
Per cent of fixed carbon	4.96
Per cent soluble in CS_2 (total bitumen)	99.92
Per cent of organic matter insoluble	.08
Per cent of inorganic matter insoluble	.00
Total	100.00

The materials and cost data for the second surface treatment of sections Nos. 8 and 9 are given in Table 34, as follows:

TABLE 34.—*Materials and cost data for second treatment of sections Nos. 8 and 9.*

	Section 8.	Section 9.
Area treated (square yards)	1,447	761
Materials per square yard:		
Bitumen (gallons)	.25	.204
Screenings (cubic yards)	.012	.012
Cost data (cents per square yard):		
Sweeping and cleaning	(3)	.210
Bitumen	2.25	1.426
Application of bitumen	(3)	.364
Screenings	2.54	2.684
Spreading screenings	.37	.526
Rolling	.30	....
Total cost	5.46	5.210

SECTION NO. 10.—RESIDUAL PETROLEUM—SURFACE TREATMENT.

As had been anticipated, this section began to bleed excessively with the advent of warm weather and required the application of approximately 4 cubic yards of limestone screenings to prevent the surface from picking up. The surface also began to wave badly,

[1] Thin, fluid, with strong naphtha odor.
[2] Soft, sticky, with slight flow.
[3] Automobile distributor used; cost charged in price of bitumen.

developing irregular humps throughout the entire length of the section, which in places were easily 3 inches above the actual cross section of the road. To remedy this condition the humps were either trimmed off or entirely removed with a shovel until the clean macadam stone was exposed. The material thus removed was generally quite rich in bitumen and was distributed where required in order to improve the cross section of the surface. These fresh patches were protected by a thin covering of screenings, and they held in place well, so that at the time of inspection the section presented a much improved and fairly uniform appearance.

The cost of maintenance on this section for the year amounted to $19.05, or 1.88 cents per square yard for the entire section.

SECTION NO. 11.—NATIVE ASPHALT EMULSION—MACADAM RESURFACING.

No further treatment has been given to this section, and it presents a smooth, firm, and satisfactory appearance. Owing to the omission of any finishing coat of bituminous material, there were two small areas on the east side near the north end in which the coarse stone could be seen. These did not ravel or wear appreciably, but in conjunction with other repairs they were recently painted with a thin coat of cold refined water-gas tar preparation and covered with a light scattering of screenings.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE ON BRADLEY LANE, CHEVY CHASE, MD., 1911.

REFINED SEMIASPHALTIC OIL.

The original report of these experiments was published in Circular No. 98, and the report of an inspection at the end of a year's service may be found in Circular No. 99. The following report covers the condition of the experiment at the end of 1913, and the repairs up to date.

The surface treatment of Bradley Lane was originally treated as three distinct experiments, but owing to the fact that the conditions on all three sections have become, in general, the same, they will be considered as a unit. The formation of a thick mat or hump on the outer edges of the roadway where the heavier treatment had been applied was noted in Circular No. 99. The wear throughout the entire traveled way became more pronounced during the past year; the surface was exposed in long shallow depressions of varying length; and a number of depressions ranging in depth from 1 to 2 inches developed. It was found that the mat along the sides was rich in bitumen which still possessed good adhesive qualities, and the mixture was therefore used for filling the worst depressions. When tamped into place and covered with a thin layer of screenings, a satisfactory and firm patch soon resulted through compression by traffic. By thus trimming off the humps and filling depressions the general contour of the road was greatly improved. In December all bare places were covered with a light application of the water-gas tar preparation No. 1 the analysis of which is given in Table 2, and screenings.

The total cost of maintaining and repairing the surface during the year was $40.41, or 1.19 cents per square yard for the entire area.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT JAMAICA, N. Y., 1911.

OIL-CEMENT CONCRETE, OIL ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

The original report of these experiments was published in Circular No. 98, and the report of an inspection made December 19, 1912, with repairs to date, was given in Circular No. 99. The experiments were again inspected and repaired in June, 1913, and the following report covers the work done at that time and the condition of the sections when again inspected on December 16, 1913.

Experiment No. 1.—Oil-cement concrete.

When inspected in June it was found that practically all of the various carpet coats which were applied to this section in 1912 were gone with the exception of the refined coal-tar section. About 75 per cent of the carpet coat on this section was in fair condition.

The surface of the pavement showed the effect of the wear of traffic and contained many shallow depressions among which the following were so deep as to be practically through the concrete: Station 0 + 98, 4 feet by 5 feet, against the south side of the pavement; station 0 + 75, 2½ feet by 3 feet, 8 feet from the south edge of the pavement; station 0 + 77, 1 foot by 1½ feet, 13 feet from the south edge of the pavement; station 0 + 77, 1½ feet by 1½ feet, 16 feet from the south edge of the pavement; station 0 + 03, 2½ feet by 4 feet, 18 feet from the south edge of the pavement.

The expansion joint at station 0 + 97 was in perfect condition and had completely protected the abutting ends of the concrete.

Repairs were made as follows: The entire section was gone over and all the old flush coat that could be loosened readily with pick and shovel was removed. The shallow depressions, 1 to 1½ inches in depth, were filled to grade with ¾-inch stone. The deep depressions were cut out to the subgrade to the size above stated and filled with 1½-inch stone, the voids of which were filled with sand and refined coal tar. The depression at station 0 + 03 was repaired with paving brick. The entire section was then surface-treated with bituminous materials as follows: From station 0 + 00 to station 0 + 57, refined coal tar, 0.30 gallon per square yard; from station 0 + 57 to station 0 + 97, water-gas tar preparation No. 1, 0.44 gallon per square yard; and from station 0 + 97 to the east end of the section, water-gas tar preparation No. 2, 0.41 gallon per square yard. Sand was spread over the flush coat at the rate of 0.016 cubic yard per square yard. The joints in the paving brick patch were filled with sand. Table 35 gives the analyses of the bituminous materials used.

TABLE 35.—*Analyses of tar products used in surface treatment of oil-cement concrete at Jamaica, N. Y.*

Materials.	Refined coal tar.		Water-gas tar preparation No. 1.		Water-gas tar preparation No. 2.	
Specific gravity 25°/25° C.	1.209		1.172		1.154	
Float test, 32° C. (time)	1′ 3″		16′ 28″		3′ 20″	
Float test, 50° C. (time)	....		2′ 18″		1′ 2″	
Per cent of free carbon	17.08		1.35		1.45	
	By volume.	By weight.	By volume.	By weight.	By volume.	By weight.
Distillation:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water	0.0	0.0	0.0	0.0	Trace.	Trace.
First light oils to 110° C.	[1] .4	.3	[2] .5	.4	[2] 1.2	0.9
Second light oils 110°–170° C.	[1] .5	.3	[2] .3	.2	[2] .3	.2
Heavy oils 170°–270° C.	[3] 17.9	14.7	[2] 2.3	1.8	[2] 5.4	4.0
Heavy oils 270°–315° C.	[4] 11.7	9.7	[5] 11.8	10.1	[6] 18.5	16.2
Pitch	69.5	74.7	85.1	87.4	74.6	78.5
Total	100.0	99.7	100.0	99.9	100.0	99.8

[1] Trace solid. [2] Clear. [3] One-third solid. [4] One-sixth solid.
[5] Clear, showed 7.5 per cent insoluble in dimethyl sulphate.
[6] Clear, showed 2.5 per cent insoluble in dimethyl sulphate.

When inspected in December, it was found that the part treated with refined coal tar was in slightly better condition than that treated with the water-gas tar preparation. Both sections showed similar bare spots, about the size of one's hand, where the tar carpet had been removed from the traveled way. The penetration patch in the center of the roadway west of the wood blocks was a trifle low, and tended to hold sand and dust, but the long patch just east of it on the south side of the roadway was in good condition.

EXPERIMENT NO. 2.—CUT-BACK OIL ASPHALT—MIXING METHOD.

In June this experiment was in very fair condition for a width of about 12 feet through the center and for its entire width from station 4 + 50 to the east end of the section. The sides of the road from station 1 + 98 to station 4 + 50 were rough, wavy, and badly worn, as noted in circular No. 99.

Repairs were made as follows: The entire surface of the section was broken up with a scarifier from the west end to station 4 + 50. No particular difficulty was experienced in the scarifying, and the bituminous wearing course broke up into fairly small pieces. The bitumen seemed to have about the same consistency as when originally put into the road. After the road was scarified, the bituminous wearing course was further broken up with picks and shovels and spread to a uniform grade. The road was then well rolled. A seal coat of refined coal tar, the analysis of which is given in Table 35, was then applied at the rate of 0.53 gallon per square yard, covered immediately with $\frac{3}{4}$-inch stone at the rate of 0.024 cubic yard per square yard, and thoroughly rolled. The $\frac{3}{4}$-inch stone used was rather dirty, owing to having been handled from the ground several times.

When inspected in December, this section was found to be in worse condition than before it had been scarified. Short, choppy waves had developed, from 3 to 4 feet in length and from 4 to 5 inches deep, from crest to trough. A somewhat wavy condition had also developed on the north side from station 4 + 50 to station 5 + 00.

EXPERIMENT NO. 3.—FLUXED NATIVE ASPHALT—MIXING METHOD.

No repairs were made to this section and when inspected in December it was still found to be in very good condition. There was a slight indication of waviness, but the undulations were long and shallow, and not sufficiently pronounced to inconvenience automobile traffic.

EXPERIMENT NO. 4.—REFINED COAL TAR—MIXING METHOD.

No repairs were made to this section and when inspected in December it was reported as being generally in good condition. The surface from station 8 + 00 to station 8 + 70 was very smooth, but some waviness had developed along the outer one-third of the roadway. On the south side this was apparently due to bleeding, and the excess material had been worked outward into waves which were in no place, however, more than 2 inches in depth. The earth shoulders along the brick gutters throughout this portion of the pavement had been much eroded, and the water from the road surface and cross streets does not flow in the gutter but along the shoulder of this section. From station 8 + 70 to station 9 + 50 the surface condition is very good and presents a somewhat mottled appearance, with about one-half mosaic and one-half covered with bitumen. From station 9 + 50 to the end of the section, where the oil-asphalt seal coat was applied, the surface resembled sheet asphalt. This portion was becoming a trifle wavy about midway between the sides and crown of the roadway.

EXPERIMENT NO. 5.—CUT-BACK OIL ASPHALT—MIXING METHOD.

In June the general surface of this section was good except that it had waved slightly on the sides and holes had been worn through as follows: Station 11 + 65, $2\frac{1}{2}$ [1] feet by $2\frac{1}{2}$ feet at the north edge of the pavement; station 11 + 68, 2 feet by $2\frac{1}{2}$ feet, 5 feet from the south edge

[1] Size of hole after it was trimmed out for repairing.

of the pavement; station 11 + 80, 1½ feet by 2 feet, 7 feet from the south edge of the pavement; station 12 + 20, 2 feet by 2 feet, 7 feet from the south edge of the pavement; station 12 + 48, 3 feet by 3 feet, 17 feet from the south edge of the pavement; and station 13 + 67, 1½ feet by 1½ feet, 17 feet from the south edge of the pavement.

These holes were repaired by first digging out the wearing course and base to a depth of 4 inches. They were then filled with 1½-inch stone, and the voids of the stone were partially filled with sand and tamped by hand. The refined coal tar referred to in Table 35 was then applied, covered with ¾-inch stone, tamped by hand, and rolled with a steam roller.

When inspected in December it was found that two holes about 18 inches in diameter had worn almost through the thickness of the wearing surface. These were located on the north side of the road at station 11 + 6 and station 11 + 22, respectively. Between station 11 + 00 and station 11 + 50 a bad wavy condition had developed on the north side of the road, but only to a slight extent on the south side. The center of the roadway was in very good condition. Several of the patches were low and all were in need of a seal coat, but the patch made with Topeka mixture was in excellent condition.

At Hardenbrook Avenue the south side of the intersection was more wavy than any other section of the experiments, excepting experiment No. 2, but the north side of the intersection was in very fair condition.

EXPERIMENT NO. 6.—OIL ASPHALT—PENETRATION METHOD.

No repairs were made to this section and it continues in excellent condition. Two grades of oil asphalt were originally used for a seal coat on this experiment, and the relative wearing qualities can now be noted. Where the heavier grade of material was used, the seal coat remains practically intact and only an occasional stone is visible. Many more stones of the wearing course can be seen where the lighter grade of the oil-asphalt seal coat was used.

EXPERIMENT NO. 7.—REFINED COAL TAR—PENETRATION METHOD.

In June this section was in good condition excepting that the following holes had worn through: Station 15 + 51, 3½ feet by 3½ feet, at the north edge of the pavement; station 16 + 90, 1 foot by 4 feet, 1 foot from the south edge of the pavement; and station 16 + 95, 1 foot by 1½ feet, 1 foot from the north edge of the pavement. These holes were repaired in the same manner as those in section No. 5.

In December the section was reported as in good condition excepting for a raveled spot at station 16 + 50.

EXPERIMENT NO. 8.—FLUXED NATIVE ASPHALT—PENETRATION METHOD.

No repairs were made on this section, and at the December inspection it was in good condition.

EXPERIMENT No. 9.—OIL ASPHALT—PENETRATION METHOD.

In June this section was in good condition with the exception of one hole 1½ feet by 1½ feet in size in the center of the road at station 18 + 50. This hole was repaired in the same manner as the holes in section No. 5.

This section was in good condition in December, excepting for some bleeding and a slight waviness on the last 75 feet. This was, however, not sufficient to be noticeable to traffic.

TABLE 36.—*Cost data of repairs at Jamaica, N. Y., 1913.*

Section.	Patches.			Carpet coat.			Cost per square yard.
	Material.	Labor.	Total.	Material.	Labor.	Total.	
1	$17.72	$4.50	$22.22	$28.39	$28.73	$57.17	$0.139
2	82.55	69.45	152.00				.183
3							.000
4							.000
5	2.16	4.93	7.09				.0085
6							.000
7	1.26	3.06	4.32				.0103
8							.000
9	.16	.51	.67				.0016

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEW YORK, N. Y., AND RIDGEWOOD, N. J., 1910.

OIL-CEMENT CONCRETE.

The original report of these experiments was published in Circular No. 94, and the reports of annual inspections appeared in Circulars Nos. 98 and 99. The following report covers inspections made December 17 and 18, respectively.

EXPERIMENTS AT NEW YORK, N. Y.

The general condition of the surface of the road shows gradual deterioration. The edges of the various cracks previously noted have widened and a few minor ones have formed. A new cut has been made in the center of the street from station 3 + 74 to station 3 + 82, and another from station 3 + 92 to station 4 + 35. The greatest wear has taken place between station 0 and station 0 + 15, where a series of potholes has formed. Otherwise the wear has been uniform.

EXPERIMENTS AT RIDGEWOOD, N. J.

The floor of the bridge over Saddle River has been covered with a bituminous surfacing and has therefore not been subjected to wear during the past year. The floor of the bridge over Hohokus River was in good condition and no appreciable wear has taken place since the last inspection.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT BOISE, IDAHO, 1910.

OIL-GRAVEL MACADAM.

The original report of this experiment was published in Circular No. 94 and reports of annual inspections were given in Circulars Nos. 98 and 99. The following report covers an inspection made on April 25, 1914:

The south or wide section of the road, which is the portion described in Circular No. 94, was practically all in the same condition and contained a number of potholes. There was, however, no indication of surface disintegration at any point throughout the entire construction. The narrower portion contained a few ruts, but generally speaking it was in fairly good condition. A new flush coat of bituminous material would undoubtedly prove beneficial on some stretches. From the cemetery eastward for a distance of about 1,900 feet the road had just been given a flush coat of a fairly heavy asphaltic petroleum product and had been covered with good coarse sand and fine gravel. Such ruts and depressions as had developed from time to time are in all probability due to the poor foundation, which was noted in the original description of the experiment.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT AMES, IOWA, 1910.

OIL-ASPHALT GRAVEL.

The original report of this experiment was published in Circular No. 94, and reports of annual inspections were given in Circulars Nos. 98 and 99. The following report covers an inspection made on January 7, 1914:

The general condition of the section is good, although it was covered with a layer of dust from one-fourth inch to three-fourths inch in thickness. The shape is well preserved, excepting for two or three depressions, and the wear has not been excessive. The surface in general resembled a brown layer of packed gravel and old bituminous material which is "short" and friable.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT KNOXVILLE, TENN., 1910.

TAR AND OIL PREPARATIONS.

The original report of these experiments was published in Circular No. 94, and reports of annual inspections are given in Circulars Nos. 98 and 99. The following report is based upon an inspection made on December 17, 1913, during a period of cold, damp weather:

SECTION NO. 1.—REFINED COAL TAR—PENETRATION METHOD.

The section was not resurfaced since last inspected, and the surface while not generally loose presented the appearance of a plain macadam road which had been bonded largely by traffic. All of the seal coat, with the exception of two small areas totaling approximately 24 square feet, has been worn off.

SECTION NO. 2.—REFINED TAR PREPARATION—PENETRATION METHOD.

Approximately one-half of the seal coat has been worn off and this section showed a rather uneven surface. A number of small raveled places are in evidence, extending generally from the outside of the main traveled way to the edges. The surface of this section has been broken for numerous water connections and the stone replaced in a loose manner without even tamping, and this is thought to be largely responsible for the general appearance of the surface.

SECTION NO. 3.—OIL ASPHALT—PENETRATION METHOD.

With the exception of the two small depressions noted in the inspection of November 22, 1911, this section presented a smooth, well-bonded surface, slightly mosaic in appearance. It could not be dug into with a knife and gave a hard metallic ring under horses' hoofs. The depressions were evidently due to settlement, and no raveling has taken place.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT YOUNGSTOWN, OHIO, 1909.

SLAG, SLAG AND LIME, SLAG AND WASTE SULPHITE LIQUOR PREPARATION, AND SLAG AND TAR.

The original report of these experiments was published in Circular No. 92, and reports of annual inspections are given in Circulars Nos. 94, 98, and 99. The inspection on which the following report is based was made on September 1, 1913, and the sections are discussed in the order of their *section* numbers, beginning at Mahoning Avenue.

SECTION NO. 1.—BLAST-FURNACE SLAG; SECTION NO. 2.—BLAST-FURNACE SLAG AND LIME; SECTION NO. 3.—BLAST-FURNACE SLAG AND WASTE SULPHITE LIQUOR PREPARATION.

The wear on these three sections has been quite uniform. The surfaces are well bonded and firm, and the crown is practically the same as when the road was originally constructed. The only difference noted in any of these sections was that on sections Nos. 2 and 3 the No. 1 stone was more in evidence on the surface than in section No. 1, and there were also very slight ruts in the traveled way.

Section No. 4.—Blast-furnace slag and refined coke-oven tar.

The surface of this section is distinctly mosaic and it is rather rough and uneven, particularly over the fill at the south end of the section. The surface is, as a whole, firm, and about 80 per cent of it is well bonded with tar which still shows considerable life. The section has worn much less than those adjoining it and is now from 1½ to 2 inches above them.

Sections Nos. 5 and 6.—Blast-furnace slag.

In general the surfaces of these two sections are about the same. They are slightly dusty, with the No. 1 stone showing frequently, and there were shallow ruts in the traveled way. In section No. 6 some very large pieces of slag, apparently from 4 to 5 inches in diameter, projected slightly above the surface and there were five shallow worn places on the east quarter.

Section No. 7.—Blast-furnace slag and open-hearth slag.

This section presented the same general surface as sections Nos. 5 and 6. About 100 feet from the south end of the section the road has sunk from 3 to 4 inches over a tile cross drain.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEWTON, MASS., 1908.

ASPHALTIC PREPARATIONS, TAR PREPARATIONS, RESIDUAL OIL, AND MOLASSES-OIL-LIME.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections were given in Circulars Nos. 92, 94, 98, and 99. No repairs have been made during the past year and the following report covers an inspection made on December 13, 1913.

Experiments Nos. 1, 2, 3, 4, 5, 6, and 7.—Asphaltic preparation—Mixing method.

The surfacing of experiments Nos. 1 to 4, inclusive, was gradually disappearing, and the west half of experiment No. 5 had deteriorated seriously during the past year. There had been little change in the condition of experiments Nos. 6 and 7, excepting for the fact that the holes reported at the last inspection had slightly increased in area during the year. In experiment No. 7 two additional holes, each about 1 square foot in area, had developed. These are in the wheel tracks and will continue to enlarge.

Experiment No. 8.—Residual petroleum—Mixing method.

This section had not changed appreciably since it was inspected a year ago, excepting for the fact that eight small pits were developing.

A surface treatment of the entire section is recommended to prevent further disintegration.

EXPERIMENTS NOS. 9 AND 10.—REFINED WATER-GAS TAR—MIXING METHOD.

These sections were in excellent condition. The west end of section No. 10 had been treated with an asphaltic oil for a distance of about 35 feet where the street beyond the experiment was repaired.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT GARDEN CITY, DODGE CITY, BUCKLIN, AND FORD, KANS., 1908.

SAND CLAY.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections are given in Circulars Nos. 92, 94, 98, and 99. The following are reports of inspections made in 1913.

EXPERIMENT AT GARDEN CITY.

The Santa Fe Road at Garden City, Kans., 12 by 765 feet, was inspected on December 19, and found to be in poor condition. The recent rains have had a damaging effect upon the gypsum clay surfacing, and have softened it into a muck-like condition varying from 2 to 4 inches in depth. This is more noticeable at the north end where some new gypsum has been added without sand, but the mud is in evidence throughout the entire course. The road has recently been worked with a small 2-horse grader, and the material has been pushed to the center in such a way as to give a uniform slope and crown. The road is reported to have been in excellent condition all last summer and will be so again as soon as it is dried out.

EXPERIMENT AT DODGE CITY.

The Mineola Road, improved by a clay and sand composition 14 by 9,750 feet, was inspected on December 19, 1913, and found to be generally in good condition throughout the whole course, with one exception, where a chuck hole of minor importance was in evidence. The ditches were in good order, the cross section uniform, and the edges of surfacing not broken by the attacks of traffic. It has been well maintained by dragging done by a near-by farmer whenever necessary, but, owing to recent and continuous rains for two weeks, the surface of the roadway had softened to the extent of being deformed by traffic, showing slight hoof marks and incipient ruts. At the extreme north end, for a distance of 75 feet, some new material has been added and left in an unfinished condition.

EXPERIMENT AT BUCKLIN.

The Spearville Road, at Bucklin, Kans., was inspected on December 20, 1913, and the clayed surfacing, which was 14 by 4,271 feet, was found to be in fairly good condition. The part at the north end, and especially the high part that forms the approach to the bridge over the Arkansas River, was smooth and free from ruts, owing to more rapid drainage. The balance of the course was rutted to some extent, because of an unusual amount of rain and traffic, and had frozen solid the night before inspection. The width, grade, cross section, and slope were uniform. No new material has been added this year and proper attention to maintenance has been accomplished by dragging.

Experiment at Ford.

The Spearville Road at Ford, Kans., was inspected on December 20, and found to be in good condition with the exceptions noted. The 16-foot width of surfacing was uniform as to slope, grade, and crown throughout the entire length of 350 feet, and showed no evidence of failure to carry the traffic, except slight ruts and hoof marks, which were due to the fact that recent rains had softened the surface of the roadway to a depth of about 1 inch. The road is high and well drained in every way, and gave evidence of "standing up" very well under climatic conditions and traffic. It has been maintained at a very low cost by the use of the split-log drag.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT INDEPENDENCE, KANS., 1908.

OIL-ASPHALT EARTH ROAD.

The original report of this experiment was published in Circular No. 90, and reports of annual inspections are given in Circulars Nos. 92, 94, 98, and 99. The following report is based upon an inspection made December 22, 1913.

The inspection was made under unfavorable conditions, as the ground was covered with snow from 2 to 3 inches deep and conclusions are largely based on information received in the light of reports. The part known as Tonopah Drive is now really an earth road, and was worked into condition about two months ago. It carries a mixed traffic with a maximum load of 6,000 pounds, and has developed ruts along the center, while the sides are fairly smooth. The ditches are well cleaned out and in good order, and the road has a good crown and uniform cross section. The part known as Minnehaha Street was also worked over along with Tonopah Drive and is in good condition with the exception of incipient ruts. The foundation, material, and drainage are much better than on Tonopah Drive and show very few signs of failure from climatic conditions or traffic. No attempt has been made to add more asphalt binder and to bring the road into its original condition as first constructed.

SUPPLEMENTARY REPORT OF AN EXPERIMENT MADE AT BOWLING GREEN, KY., 1907.

KENTUCKY ROCK ASPHALT.

The original report of this experiment was published in Circular No. 89 and reports of annual inspections are given in Circulars Nos. 90, 92, 94, 98, and 99. The inspection on which the following report is based was made on January 5, 1914:

For a distance of 50 feet from the west end of the section the north half of the road is badly worn and more than 50 per cent of the asphaltic surface is gone. The south half of the road is in fair condition.

In the remaining length of the section there are 33 depressions from 1 to 3 feet in diameter and from 1 to 3 inches in depth, which indicate partial or complete failure of the asphaltic surface. However, as a whole, this portion of the road is in a very fair condition, but it would appear that unless the surface is soon repaired the entire experiment will materially fail within the next year. Disintegration has been quite rapid since a mid-year inspection made on July 8, 1913.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 106

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
September 12, 1914.

(PROFESSIONAL PAPER.)

THE GRANULAR VENEREAL DISEASE AND ABORTION IN CATTLE.

By W. L. Williams,[1] *Professor of Surgery, Veterinary Department, Cornell University.*

INTRODUCTION.

Early in 1909 the writer had publicly announced the existence in a dairy herd in New York of the granular venereal disease, nodular vaginitis, or vaginitis folliculorum chronica contagiosa. Later observations showed that it was general, if not universal, among the herds of the State. This disease having been held responsible by many continental European veterinarians of high authority for the abortion and sterility of cows, it was deemed important that first of all it should be determined how widely and extensively this malady exists among the cattle of the United States. In order to accomplish this, it was decided to make post-mortem observations upon the genitalia of cows, heifers, and heifer calves on the killing floors of abattoirs at some of the principal slaughtering centers. The inspectors in charge of the Federal meat inspection at these stations, under instructions from the Chief of the Bureau of Animal Industry, United States Department of Agriculture, cooperated most heartily, and a large volume of most interesting material was furnished in the most convenient manner possible for inspection.

The importance of abortion and sterility in cows is rapidly becoming more acutely felt by breeders, and is each year playing a more serious part in the national economy. By interfering more and more with the reproductive powers of cows, these diseases exert an unfavorable influence upon the production of meat, milk, and dairy products, decreasing the supply and increasing the cost.

---

[1] In conjunction with the Pathological Division, Bureau of Animal Industry, United States Department of Agriculture.

NOTE.—This bulletin describes a very common affection of breeding cattle, as to which there is a wide diversity of opinion. The paper is the result of extensive study, and is of interest to veterinarians and cattle raisers generally.

43378°—14——1

The loss to the dairy industry is very great, although difficult to estimate. In those cases where fairly good records have been placed at our disposal pertaining to herds where it is aimed to raise and breed all or nearly all heifer calves, as is the case in pedigreed herds of private owners and in the herds of experiment stations, the losses from abortion and sterility fluctuate between 5 and 50 per cent per annum, with an average of perhaps 15 to 20 per cent. But these statistics are deceptive, and not safe for general deductions. These herds consist too largely of heifers, in which abortion and sterility are most common.

As nearly as we have been able to estimate, an estimate which is admittedly insecure, the annual losses in the dairies of New York from abortion and sterility are approximately 10 per cent, which probably exceeds $5 per cow for the total number in the State, or an approximate economic loss of perhaps $10,000,000 annually. Our inquiries regarding losses in other States, in beef as well as in dairy herds, indicate that there are no material differences in the ratio of losses in the various regions.

Innumerable reasons have been assigned to account for abortion and sterility in cows. Abortion has been regarded as the result of blows, goring, kicks, slips, falls, various feeds, waters, drugs, etc., and finally, when the abortions are numerous, to contagion. Sterility has been attributed also to a great variety of causes—to the character of the feed or water, to poverty, and overfatness, and, as with abortion, when the cases are numerous, to contagion.

Veterinarians who have investigated abortion in cows in recent years have agreed that in a very large percentage of cases it is due solely to contagion. The British Royal Commission for the investigation of this malady believes that more than 90 per cent of the abortions among cows in England are due to contagion, while Bang in Denmark, Hess and Zschokke in Switzerland, and other veterinarians of Europe hold similar views. Similar views are also held regarding sterility in cows by Hess of Switzerland, Albrechtsen of Denmark, and other leading investigators.

The basis of diagnosis relied upon in this report for determining the presence or absence of the granular venereal disease was the visible presence or absence in the mucosa of the vulva of the granular or nodular elevations generally regarded as a result of the infection. The number or size of the nodules visible to the naked eye was not taken into account as determining whether the animal was affected or not. If the nodules were visibly present the animal was classed as affected; if nodules were absent or were not to be detected the animal was marked negative or free.

THE GRANULAR VENEREAL DISEASE.

DISTRIBUTION AND PREVALENCE.

Table 1 presents concisely the results of the observations regarding the distribution and prevalence of the granular venereal disease throughout the territory covered.

TABLE 1.—*Prevalence and geographical distribution of the granular venereal disease in cattle.*

Place.	Animals observed.		Veal calves.				Spayed heifers.			
	Recorded.	Not recorded.	Nodules or granules present.		Nodules or granules not present.		Nodules or granules present.		Nodules or granules not present.	
	Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
Chicago	1,578	91	....	....	....	....	13	50	13	50
Omaha	552	23	6	40	9	60	12	92	1	8
Kansas City	599	6	8	33	16	67	74	70	32	30
Denver	193	....	....	....	....	....				
Fort Worth	328	8	60	72	23	28	....	....	....	....
Total	3,250	128	74	61	48	39	99	68	46	32

Place.	Cows under 4 years old.				Cows 4 years old or over.			
	Nodules or granules present.		Nodules or granules not present.		Nodules or granules present.		Nodules or granules not present.	
	Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
Chicago	273	90	29	10	1,078	86	172	14
Omaha	140	95	7	5	298	79	79	21
Kansas City	427	98	9	2	26	79	7	21
Denver	47	90	5	10	124	88	17	12
Fort Worth	19	100	....	....	201	89	25	11
Total	906	95	50	5	1,727	85	300	15

Table 1 shows a total of 2,806 cases where nodules or granules in the vulvar mucosa were macroscopically visible, as against 444 cases where they were not visible. This makes the average visible infection in all classes of animals 86 per cent.

Viewing the malady as one fundamentally venereal in character, though readily and abundantly transmitted otherwise, we observe the lowest ratio of infection, 61 per cent, in heifer calves slaughtered for veal and ranging between 6 weeks and 1 year in age, presumably because they had not copulated and hence had escaped the basic mode of infection. The next lowest ratio of infection, 68 per cent, is that of spayed heifers, where again, when spaying had been properly done, copulation was excluded as a factor in transmission. In the next class, comprising entire females from 1 to 4 years of age, essentially all of which had presumably been bred, the number of affected advances to 95 per cent, to fall again to 85 per cent in cows over 4 years of age.

The average percentage of infection in the slaughtered animals, as shown in this table, is lower than observed generally in herds in New York and other States. The observations here recorded were largely upon cattle of the beef breeds, which are not regularly kept in as close contact as dairy animals. In Chicago there were, however, a considerable number of dairy cows. In dairy animals it is rare to find, at least in the State of New York, a heifer calf 3 months old without the malady, except she has been early removed from her dam and grown in isolation. The table accordingly teaches that the granular venereal disease is essentially universal in its distribution over the area involved. In our abattoir observations no lot was found free, but merely individuals in various lots, which together amounted to 14 per cent.

Our investigations in herds have revealed no one, however small, free from the infection, though we have examined many in New York and a number in Pennsylvania, Ohio, Illinois, Missouri, Minnesota, Nebraska, Arkansas, and in some European countries. In our search for a herd without the infection, it was believed that in Arkansas or some other southern State, where, on account of tick fever, little interchange of cattle had occurred, and where the herds are kept mostly out of doors in a very primitive manner, it would be possible to find cattle free from the malady. Accordingly several herds in central Arkansas were visited, but these showed the evidences of the disease as uniformly, though not as severely, as herds in other States.

DESCRIPTION.

The granular venereal disease, infectious vaginal catarrh, vaginitis verrucosa, etc., was first described by Isepponi in 1887, since which time it has been recognized and investigated by a great number of writers, chiefly in Switzerland at first, then in Austria, Germany, France, and other continental European countries.

When or where the disease began no one knows. It has been stated by numerous writers that the disease has spread during recent years over a province or community or from one region to another, but this recorded spreading of the malady may well be accepted with caution. A knowledge of the existence or the recognition of the presence of a disease may circulate in such a manner as to become confused with the extension of the malady itself, and this is unquestionably true in a large measure of the granular venereal disease. We may well say that this disease is the most universal infection known in any species of domestic animal.

The granular venereal disease may be defined as a chronic infection of the genital tract of cattle, expressing itself clinically in the form of granular or nodular elevations in the genital mucosa, chiefly of the vulva, less frequently of the vagina.

SYMPTOMS.

The essential clinical symptom of the granular venereal disease consists of the appearance in the vulvar mucosa, protruding above its surface, of nodular, conical, spheroidal, or flat elevations, usually 1 to 2 millimeters in diameter. They are best observed clinically by holding the vulvar lips apart and causing a strong light to enter the vulva obliquely. The examination may be conducted advantageously in a well-lighted stable, by having the animal placed with her posterior parts presenting toward a window somewhat above the level of her back. The examiner then grasps each vulvar lip between the thumb and fingers, and, drawing the lips backward and outward, exposes the interior of the vulva to vision. The light, falling obliquely into the vulvar cavity illuminates it well, and, by refraction, the nodules are brought clearly into view.

In order to examine every part, the examiner should shift his position again and again, that he may view such area at the proper angle. In order to examine satisfactorily the roof of the vulva, the eye of the examiner should be on an approximately horizontal line with the mucosa. Highly satisfactory examinations may also be made in dark stables or at night with the aid of a good reflecting lamp.

The nodules are also recognizable upon digital palpation, the elevations being very evident to the sense of touch. At times digital palpation may have an advantage over vision because, as related below, even when the nodules are abundant, the mucosa may be edematous to such a degree that the nodules are rendered invisible, the thickened, edematous mucosa serving to cover them from view, though still palpable.

Under the prevailing conditions in American dairy herds, and so far as we know in the dairy herds of the world, heifer calves usually develop clinical signs of the disease at from 4 to 12 weeks of age, and from that time through adult life to old age present a series of interesting vacillations of intensity so great that various writers have designated these manifestations as acute, subacute, chronic, cured, sound, etc.

If the newborn heifer calf is kept in the same stable with dairy cows, perhaps in contact for two or three days with her dam, is fed and handled by persons who are in close contact with the cows, and placed in a common inclosure with older infected calves, the vulvar mucosa usually appears normal, smooth, moist, pale rose-colored for a period varying from 4 to 12 weeks, or even longer, when visual inspection reveals the presence of several or many spheroido-conical nodules in the vulvar mucosa 1 to 2 millimeters in diameter. They are usually solitary until they become very numerous, when they tend to become arranged in rows. They are most frequently colorless or faintly yellowish in the center and present the appearance of small, tense vesicles, but upon close examination they are hard to the touch and contain no fluid. Encircling the base of each nodule there usually appears a pale or bright vascular area, apparently due to increased vascularity (which a histological examination proves correct), thus giving the lesion the appearance of a minute vesicle surrounded by a vascular girdle. The nodules are scattered here and there, frequently along the floor of the vulva in the clitoral region, but quite as often on the sides or the roof of the vulva. Except for the nodules and the vascular girdle about the base of each, the surface of the mucosa in the early stage is smooth, pale rose-colored, and normal. There is no swelling, no inflammation, no discoloration of the vulvar mucosa, and no mucous or muco-purulent discharge.

Slowly and insidiously the disease spreads to individuals which have hitherto escaped, so that the older the heifers in a herd the larger the percentage which shows the evidences of the disease. The rapidity and uniformity in the spread of the malady rests largely upon environment. In the closely housed and much-handled heifer calves in dairies usually more than 90 per cent show the disease at 4 months of age, and before they reach one year the visible infection generally reaches 100 per cent, but if by any chance an individual escapes infection until breeding age the first service by the bull conveys the disease. In heifer calves not kept in close or prolonged contact with their dams or with older infected heifers, and not much if at all handled by persons who are habitually in contact with diseased animals, the infection spreads much more slowly. Thus we have observed in a herd of pedigreed Herefords approximately but 50 per cent of infection in virgin heifers and heifer calves. After birth these calves were allowed to go with their dams for a day or two and were then permitted to suck twice daily, but otherwise were kept separate from their dams or other older cattle.

In experimental heifer calves we have kept individuals up to 6 months, and even to one year old, without any trace of the infection.

The influence of environment upon the spread of the infection in heifer calves is further exemplified by Table 1, wherein the 122 veal heifers observed showed an average infection of 61 per cent. The percentage of infection among these calves is markedly below the average infection among heifer calves in eastern dairy herds of corresponding ages. Western veal calves largely run at liberty in the open, exposed to the infection from their dams but not from personal handling or close crowding in stables.

The number of the nodules generally increases slowly with the age of the virgin heifer from the date of infection up to puberty or estrum, when the increased vascularity and functional activity of the genital tract apparently favors a more rapid multiplication of the nodules and intensifies generally the symptoms of the malady, but these in the virgin heifer rarely if ever attain that intensity commonly seen after copulation.

When the nodules have become quite numerous they tend to become arranged in longitudinal, parallel rows corresponding to the longitudinal folds of the vulvar mucosa, the nodules being located upon the summits of the rugæ, emphasized and rendered more distinct by the inflammation of the mucosa, which causes it to swell, harden, and thicken, and forces it into marked folds. The individual nodules change in appearance. They increase little in size and projection. The vascular areas about their bases become more deeply injected and the vascularity may extend more or less completely over the surface of the nodules, so that some of them appear as bright-red elevations or as petechiæ on the vulvar mucosa.

The mucosa itself, between the nodules, becomes involved in the disease, is injected, red, and swollen. With the advent of definite irritation of the vulvar mucosa, a slight muco-purulent vulvar discharge ensues. It is not at first marked. Many say it is not present, or rather that the discharge noted is normal. There is, however, a visible discharge which so mats together the vulvar tuft and surrounding hairs in the heifer calf that in opening the vulva for inspection the examiner must frequently break down the adhesions between the surrounding hairs before the vulvar lips may be parted. Some contend that this is normal, but in experiment heifer calves observed by us such vulvar discharge has not appeared until infection had ensued. Herbivorous females of other species do not ordinarily present muco-purulent or other vulvar discharges. It would accordingly appear that mucous secretions normally occurring in the genital tube of heifer calves, heifers, and cows should be disposed of by the organs in a manner which would prevent their becoming conspicuous externally.

Up to the date of puberty or estrum the nodular venereal disease of heifer calves generally behaves essentially as a dormant malady, without material significance for the immediate welfare of the animal. Various observers may and do hold divergent views. Numerous cases are viewed by many veterinarians as sound because of the mildness of the symptoms, but the nodules are there, and so long as these are admitted as the deciding lesion of the malady the heifer must be regarded as infected.

Copulation is the signal for the awakening of the dormant infection, which behaves like other venereal disorders in animals and man under the stimulus of sexual contact. Within 24 hours after copulation the evidences of sexual irritation are marked. The mucosa becomes scarlet, swollen, tender, and in a large proportion of cases there is a very notable muco-purulent discharge which adheres to the vulvar tuft and soils the under surface of the tail and the skin of the buttocks and the perineum.

The vulvar lips frequently become markedly swollen and edematous. If the vulvar lips be parted, the vulvar mucosa is seen to be covered with masses of stringy, semiopaque mucus, or there may be seen small opaque flakes of muco-pus resting upon the mucosa.

The nodules now multiply with astonishing rapidity. Their arrangement in parallel longitudinal rows becomes well marked, the nodules being crowded into close contact with each other upon the summits of the swollen, hypertrophied mucous rugæ. The nodules frequently lose their transparency and assume a deep-red color, and the malady assumes in every way a more decisive clinical aspect of important disease. Even then, however, it is not noticeable in so far as the general health of the heifer is concerned.

The intensity of the symptoms increases for a few days, remains static for a time, and then tends to recede slightly, but the betterment makes no appreciable approach to the status which had been maintained prior to copulation—a fact which emphasizes strongly its essentially venereal character.

Should the heifer become pregnant at the first service, the irritation may abate slightly and slowly for a time, but the nodules remain prominent and approximately as numerous as ever, and the clinical evidences of disease remain essentially static, at one period apparently improved, at another worse, until near the time for parturition, when the vulvar mucosa becomes more reddened. A marked edema (parturient edema) then appears, the nodules are covered over and are no longer visible. Usually they may still be felt upon careful palpation. In many cases of abortion the edema of the vulvar mucosa is essentially the same as if parturition had occurred. Should parturition or abortion be followed by retained placenta and chronic metritis or pyometra, the nodules continue masked by the persisting edema so long as serious uterine disease continues. Otherwise, with the gradual disappearance of the edema of the mucosa the nodules slowly come again into view.

If the heifer fails to conceive at the first copulation, when the next estrual period arrives and copulation occurs, should the sterility be refractory, the symptoms tend to increase, so that sterile heifers are quite generally among the worst clinical cases of the disease in a herd. The symptoms of the disease retain approximately the average intensity acquired during the first pregnancy through the second and third pregnancies, when the severity of the malady gradually abates.

When the cow reaches 8 to 9 years of age, and her sixth or seventh pregnancy, the decrease in the intensity of the disease generally becomes quite marked, the nodules are fewer, less prominent, and more transparent, the irritation and injection of the vaginal mucosa is definitely decreased, and the muco-purulent discharge has largely abated. With advancing age, the vulvar mucosa becomes pale yellowish, or bluish-yellow, the nodules disappear, and the clinical evidences of the disease commonly vanish when the cow has reached the age of 12 to 15 years.

Such is a brief outline of the course of the malady as observed in a majority of cases, but the course is vacillating and erratic in individuals and in herds. Copulation always intensifies the symptoms, and one can generally identify by clinical examination nearly all cows recently bred.

The use of antiseptics in the vulvo-vaginal tract alters the clinical appearances profoundly. Daily washing of the vagina with non-irritant warm antiseptic solutions causes the symptoms of the malady to decrease rapidly in intensity, and in a few weeks the nodules may almost wholly disappear, the mucosa becomes smoother and softer, the color changes to a pale rose-red, and it looks as if the continuance of the handling would soon eliminate the disease, but in the end some nodules remain, and with a cessation of handling unaccompanied by copulation the symptoms remain static. On the other hand, when powerful antiseptics are introduced into the vagina the mucosa becomes irritated, swollen, and edematous, and the nodules become veiled.

Thus the clinical signs of the malady appear insidiously, usually when the heifer is but a few weeks old; the disease then pursues a comparatively uneventful course up to breeding age, then becomes suddenly intensified, and quickly reaches its zenith, where it maintains, with certain vacillations, an approximately horizontal course for three or four years, when it begins to abate slowly in intensity, to more or less completely disappear clinically with the advent of old age.

TABLE 2.—*Influence of pregnancy and other conditions upon the visibility of the granular venereal disease.*

Place.	Total animals.	Total pregnant.	Total nonpregnant.	Total cases where granules were not visible.	Pregnant cases where granules were not visible.				
					Total.	Per cent.	Fetus under 12 inches.	Fetus 12 to 24 inches.	Fetus 24 inches or over.
	Number.	*Number.*	*Number.*	*Number.*	*Number.*		*Number.*	*Number.*	*Number.*
Chicago	1,669	965	704	214	106	11	31	18	57
Omaha	575	366	209	96	59	16	11	18	30
Kansas City	601	123	478	64	4	3	4	0	0
Denver	193	127	66	22	14	11	6	2	6
Fort Worth	336	155	181	48	13	8	6	3	4
Grand total	3,374	1,736	1,638	444	196	11	58	41	97

Place.	Nonpregnant cases where granules were not visible.					Spayed.	Veal calves.
	Total.	Per cent.	Two years old or under.	Pyometra.	Recent parturition.		
	Number.		*Number.*	*Number.*	*Number.*	*Number.*	*Number.*
Chicago	95	13	3	12	10	13	....
Omaha	27	13	0	8	2	1	9
Kansas City	12	25	0	2	0	32	16
Denver	8	12	0	4	0	0	0
Fort Worth	12	7	0	0	0	0	23
Grand total	154	9	3	26	12	46	48

A study of Table 2 illustrates some of the influences which modify the visual signs of the malady. Among the pregnant animals in which the granules were not apparent macroscopically, the fetus exceeded 24 inches in length in about 50 per cent of the cases, while in the earlier stages of pregnancy the granules were more generally present. Among nonpregnant females the influence of pyometra and recent parturition is very marked.

Table 1 shows that many young heifers sold as veals escape the infection, while spayed heifers, usually free upon the range, quite generally escape. But the tables tell only a part. It was a very notable phenomenon that the probability of both the presence and intensity of the disease rested vary largely upon the question of copulation.

The spaying of range heifers is not generally well done. The operation is very carelessly and hastily performed, usually by the flank method, the operator thrusting his hand through the wound, grasping the ovaries and stripping them from the broad ligament between the thumb and fingers. The result is that 50 to 60 per cent of them are only partly spayed, some ovarian tissues are left which develop ovisacs and cysts, the heifers come in estrum or are nymphomaniac, and copulate freely with range bulls. The lesions of the granular venereal disease are uniformly seen in such imperfectly spayed animals, and show considerable intensity. In the perfectly spayed heifers the vulvar mucosa is generally normal, smooth, and pale rose-red, with but few if any visible nodules.

Another striking illustration of the influence of coitus upon the intensity of the disease was observed in a lot of 270 two-year-old range Hereford heifers which had evidently been kept away from the bull, except in the case of one individual which had, perhaps accidentally, become pregnant. In the 269 nonpregnant animals the disease was quite uniformly present, but only a few nodules were seen in each individual. Careful inspection was required lest they be passed over. The vulvar mucosa of the one pregnant heifer, however, bore more of the granules than the other 269 collectively. The entire mucosa was swollen and red, and dense masses of granules crowded thickly upon each other.

Throughout its long course the intensity of the infection rises and falls, sometimes in obedience to known causes, as copulation, sometimes in a manner not yet understood. During the period at which the disease is at its zenith few animals fail to show the clinical evidences of its presence, as is shown by Table 1, according to which the evidences of the disease were apparent in 95 per cent of cases. This is no higher than regularly observed at this age in dairy herds.

HISTOLOGY.

The histology of the disease has not been extensively studied. Isepponi speaks of the nodular elevations as granuloma; Ostertag views them as swellings of the lymph follicles normally present in the vulvar mucosa, and Martens also regards them as swellings or hypertrophy of normal papillary bodies.

Thoms has investigated the histology of the malady most fully. As a basis for his study of the normal vulvar mucosa he selected a cow about 7 years old and a calf 10 weeks old. The normality of the mucosa of these two animals may well be questioned. While in Table 1 there has been recorded a total of 300 cows over 4 years old in which nodules were not recognized, I would be wholly unwilling to select one of these as sound. The examination was merely negative as to their presence, not positive as to their absence. Thoms concludes that animals of any age may be infected, that with an exudate bearing the diplococci and short streptococci the disease may be induced experimentally in 16 hours by inoculation, that in four or five days nodules appear which consist mostly of the hypertrophy of the existing papillæ in the vulvar mucosa, but are largely the result of the formation of entirely new follicles by the accumulation of round cells in clumps, and that after healing the follicles atrophy gradually, but fail to return completely to their former size. Hence he concludes recovery is not wholly dependent upon the resumption by the follicles of their normal size.

BACTERIOLOGY.

The bacteriology of the granular venereal disease has been but little studied, and the conclusions reached may well be modified by future investigations. Ostertag concludes that the disease is due to a diplococcus or short streptococcus, which he recognized in the muco-purulent exudate in the vagina and vulva, and in one case in the uterus. He introduced the organism into the vaginæ of cows, sheep, goats, swine, and horses, causing in cows a chronic purulent vaginal catarrh, which agreed perfectly in its symptoms and course with catarrhal vaginitis, and from the diseased exudates of these animals pure cultures of the streptococcus were recovered. In sheep, goats, swine, horses, guinea pigs, and rabbits the results were negative.

In investigating the granular venereal disease we need as a basis an animal with unquestionably sound genital mucosa. This Ostertag believes he has secured. Details of the basis upon which he declares them sound are wanting. So with the transmission experiments of Ostertag. Were the animals to which he believed he transmitted the affection actually and wholly free from the disease at the beginning of his experiments? There is every reason to believe that a calf in passing through the infected birth canal of its dam may become infected at the time of birth, or if not then it surely often becomes infected within a few days when kept in the same stall or stable or fed and handled by persons who come in contact with the diseased mother. If a new-born calf be removed from its dam at once and kept in strict isolation, I find that it will possibly escape infection for a time, but not probably, and that it will be several weeks before the macroscopic lesions appear.

Further and more serious doubt is thrown upon the recorded experiments of Ostertag in the symptoms and course of the experimental granular venereal disease from the fact that the recorded symptoms are in conflict with the present writer's clinical experience with the beginnings of the disease. This has been gained by observing hundreds of heifer calves from 2 to 6 months old affected with the disease, as well as a number of experimental calves under immediate observation, which must necessarily have evidenced the disease over and over again in its incipiency.

Ostertag says:

> The first symptoms of infectious catarrh are swelling of the vulva, redness, swelling and sensitiveness of the vaginal mucosa, and a muco-purulent deposit upon the vaginal mucosa.

In the earlier stages of the malady, as we have observed it, there are present none of the symptoms emphasized by Ostertag. On the contrary, the disease comes on insidiously, and the first sign of the malady is the appearance of a few nodules in the vulvar mucosa, sharply defined above the surrounding epithelium, as pale yellow or colorless transparent elevations having a vascular girdle about their bases. Some would call these heifer calves sound, but if two or three typical nodules do not indicate granular venereal disease it would be difficult to understand by what line of reasoning 200 or 300 nodules can assure us of the existence of the malady.

In other words, Ostertag describes, not the beginning of the disease, but an "explosion" of the existing malady under profound irritation. It is not strange that virulent streptococci induced the symptoms he describes, nor that he was able to recover pure cultures of the microorganism from his experimental animals, but he has failed to reproduce the insidious, exceedingly mild early stages of the disease, which anyone who cares to do so may watch in heifer calves in any dairy. Neither need anyone fail to find cases, especially in recently bred heifers or young cows, in which all the symptoms described by Ostertag are present in their most impressive form, but that is not the beginning or end of the malady; it is its zenith. In a muco-purulent vaginal discharge streptococci are usually present, and, if sufficiently virulent cultures are introduced into the vagina of an animal of the same species from which the culture was procured there need be little surprise if it cause irritation. Ostertag states that the vaginal discharge comes from the formation of nodules and that the discharge is at first purulent or muco-purulent.

The granular venereal disease does not behave clinically like a malady dependent upon streptococci or other pyogenic organisms. It is not fundamentally pyogenic. The investigations of Thoms and others have failed to show the formation of papules, ulcers, or necrosis of tissues. The granules or nodules do not suppurate. When the granules become highly numerous, the vulvo-vaginal mucosa is swollen and rough, the rugæ overlap and strike against each other, the epithelium at the apices of the granules becomes abraded by compression and attrition, and, as Thoms relates, the result is a partial denudation of the epithelium, naturally leading to streptococcic infection and catarrh.

The granules behave unlike the product of streptococcic infection in their appearance and disappearance. They arise too suddenly and with too slight signs of irritation. In the heifer calf they appear as transparent or translucent granules or nodules, the body of the granule showing little or no color, while the base has a yellowish or red girdle or areola. They are not observed to grow. One day they are unseen, the next they are full size. In their mode of disappearance they behave very similarly. Their disappearance is chiefly noted numerically and not by volume.

PROGNOSIS.

If we omit from our consideration such alleged consequences of the nodular venereal disease as abortion, retained placenta, cystic degeneration of the ovaries, pyometra, and other serious affections of the genital organs, the prognosis as to the life of the patient is excellent, and the prospect for the amelioration and repression of the malady is highly favorable. But the outlook for recovery, in the present state of our knowledge, is very poor, if not hopeless. There is necessarily quite as wide variation in the prognosis as there is concerning the essential symptoms and diagnosis. If one holds, as many do, that the disease is present only when the nodules are very numerous (each party having his own conception of that definition) and there is a marked muco-purulent vaginal discharge (the degree of which each must define for himself) and these conditions shall be accompanied by sterility and abortion, the prognosis may be good. With such a conception, however, there can never be a clear line of demarcation between sound and diseased. Different observers can not hope to agree upon the number of the nodules which warrant a diagnosis of infection—whether there need be present 1,000 or 10 nodules. Neither can there be agreement as to what constitutes muco-purulent vaginal discharge, if the amount is to decide the question. Unlike other females among our domestic animals, there is a well-nigh universal vulvar discharge of mucus or muco-pus from cattle, which varies quite as widely as the number of nodules present. There is a somewhat close harmony between the number of nodules present and the amount of vaginal discharge.

If it is held that the presence of nodules in the vulvar mucosa, be they few or many and accompanied by little or much irritation or discharge, indicates the granular venereal disease, the prognosis as to complete cure of the disease is hopeless in the present state of our knowledge. It attacks the heifer and calf ordinarily when a few weeks old, and, except at times near to parturition or abortion or under the influence of serious disease of the uterus (pyometra, etc.), the disease is still clinically recognizable in most aged cows. No more typically chronic malady is known, so that the terms acute, subcute, and chronic are mere expressions of the vacillations in intensity dependent upon a great variety of causes.

From another standpoint we may regard the prognosis with some favor. Viewing it as the possible cause of abortion and sterility, we know that during its zenith, when the animal is from 2 to 5 years of age, the economic losses from these causes are greatest, and that after this period has passed the intensity of the disease abates, and with it the losses from abortion and sterility decline. So also we may regard as favorable the fact that we may repress the disease in its intensity and at the same time may decrease the losses from abortion and sterility.

Ostertag relates that one 6-year-old cow recovered spontaneously in 8 weeks, but he does not define what he means by recovery. Thoms holds that after recovery from the disease the follicles slowly decrease in size, but only in small degree, and then remain, and emphasizes his opinion that the cure of the disease is not necessarily followed by a disappearance of the nodules. Hess (in a personal communication) holds that when the redness and swelling of the vagina and the muco-purulent discharge therefrom have abated the disease is cured; that is, it is no longer present, sterility fails, abortion does not occur.

When necrotic or other tissues become encapsuled, when inorganic salts are deposited in the tissues, when dense sclerotic tissues have formed as a result of disease, and in many other cases, it is readily understood that the effects of the disease may persist indefinitely after the cessation of the malady. In the granular venereal disease investigators agree that the nodules consist essentially of masses of what appear to be round or lymph cells, cells of a very primitive character, with rarely a trace of skeletal stroma or of blood vessels among them. Such structures, it would seem, would be rapidly and completely dissipated by physiologically active tissues as soon as the irritant which has caused them had abated. This view is fully borne out clinically. Under varying conditions the numbers of nodules decrease rapidly. If the vagina is merely kept well douched with warm water and a mild antiseptic, a large percentage of the nodules disappear. If the nodules constitute the basic clinical phenomenon of the malady, it is difficult, considering their structure, to understand why, if the disease disappears, the basic symptom of it should not promptly follow

It is upon the partial disappearance of the nodules, muco-purulent vulvar discharge, etc., that the allegations of cure appear generally to be based. In other cases, however, the allegation of cure rests upon the swelling and edema caused in the vulvar mucosa by the application of an alleged remedy, by which the nodules are hidden. It is analogous to certain cures for exostoses on the legs of horses, wherein the neighboring soft tissues become so swollen and edematous from the application of the remedy that the exostosis is no longer apparent.

Referring to Table 1, in the group of cows 4 years old and over it may be assumed with safety that these animals had had an opportunity to recover spontaneously during a period of probably six years on an average, with the result that 85 per cent still showed the evidences of the disease. If we turn to Table 2, it will be found that, of the 13 per cent marked negative, nearly 40 per cent may have been masked by advanced pregnancy, recent parturition, or pyometra. Considering that other diseases and conditions at times cause the symptoms to be temporarily masked, it is apparent that this group of animals had made no marked advancement toward spontaneous recovery.

Although continental European veterinary periodicals are well filled with contributions by leading veterinarians recounting the cure of the disease by various remedies, in many cases in the phenomenal time of 10 to 20 days, we have faithfully applied many of these over prolonged periods and have as yet not observed a single cure, evidently, again, because of a variation in the definition of a cure.

SIGNIFICANCE OF THE GRANULAR VENEREAL DISEASE.

The importance of the granular venereal disease has been variously estimated by different investigators. As shown by Table 1, the disease is so universal that its presence may be made to afford an explanation for a great variety of ailments. When there is added to this the fact stated above of the wide divergence of opinion as to the clinical diagnosis of the disease, it naturally follows that different investigators assert, while others deny, that it causes any, few, or many losses, due to an extensive list of complications.

Some there are who vehemently assert that no such disease exists and hence can not cause losses. They believe the granules or nodules to be normal structures, else, they say, they would not be so universal. Such granules or nodules, however, are not ordinarily observed in the vulvar mucosa of other animal species. They do not appear in the vulvæ of new-born heifer calves, and may not appear for months if the calf is kept in isolation. After coition they multiply by leaps and bounds.

Some urge that the disease can be of no material importance because it is so common and so few animals appear to suffer unfavorable consequences. The same argument has been applied to tuberculosis of cattle and glanders of horses. We have come now to know that a very large percentage of each of these diseases goes unseen by the clinician and are detected only by biologic search. We have yet better analogies upon which tentative conclusions may be based. We have pointed out the fact that the disease is largely venereal in character. Though quite generally transmitted by other means, as is to some extent the case with all venereal affections, yet its intense arousal is brought about chiefly if not solely by coition.

In man and in each species of domestic animal there is one or more venereal disease, and each and every one is of material consequence. In woman, syphilis and gonorrhea are responsible for much abortion, sterility, and chronic diseases of the ovaries, oviducts, and other organs. In dourine in mares, aside from the high mortality, abortion or sterility is practically constant and no viable foals are born. There appears no good reason for assuming that the granular venereal disease of cows should form any marked exception to the general rule that a chronic venereal infection of the genital tract is a serious peril, especially from the standpoint of reproduction in the affected animals.

ABORTION.

Among the various complications alleged to accompany the granular venereal disease, stoutly asserted by some and as vigorously denied by others, is abortion. Here two views as yet unreconciled clash—that of Bang and his supporters that abortion is due to the abortion bacillus on the one hand, and that of Zschokke, Hess, and others that it is largely due to the granular venereal disease. At the outset it is well to bear in mind that the granular venereal disease and abortion are essentially universal. We hear now and then of the so-called breaking out of the granular venereal disease or of abortion in a herd, by which is ordinarily meant, not that the breaking out is the beginning of either malady, but simply that it has become so severe that it has attracted the attention of owners or veterinarians. If abortion is not playing havoc in a herd, the granular venereal disease may not be seen. No effort is made to see it. As soon as a large proportion of the cows begin to abort and an explanation is desired, search may be made for the granular venereal disease, and at once it is declared to have broken out, but all the time it was there. So with abortion itself. In small herds an actually visible abortion may not occur for years, or occur so rarely that the owner forgets the fact and he is ready to state that his herd has long been abortion-free. In large herds, however, of 50 to 100 cows and over abortion is recognized as being essentially universal. Of course its contagiousness is often denied and a plausible explanation for the accident is given. The heifer (nearly always a heifer) has drunk too much cold water, has slipped and fallen, has been gored or kicked, crowded in a door, or suffered from some error in feeding, or from other causes too numerous to mention and to which all cows are inevitably subjected.

Contagious abortion is too often confounded with the death and expulsion of the immature fetus. It is not at all essential that a pregnant cow affected with contagious abortion must abort or that a fetus affected with the malady shall die. It is no proof that the infection or disease of contagious abortion is absent from a herd when no dead fetuses are expelled, and it is far from proof that the contagion is absent when but one or two animals in a dairy of 25 to 40 cows abort in a given year. We would better define contagious abortion of cattle as a chronic infection of the genital tract which may imperil the health or life of the fetus. The affection has been all too scantily investigated to permit of a conclusion as to what percentage of pregnant cows having in their genital tracts the organism of contagious abortion actually abort. It is with certainty known that many of them do not abort. It is not at all rare to see cows giving birth to living, apparently healthy calves at full term, though at the commencement of labor they expel large volumes of typical abortion exudate. A yet more familiar example is premature births, essentially all of which may be referred to the infection of contagious abortion. The infection may reside in any part of the genital tract, so far as now known, but can affect the fetus unfavorably only when within the uterine cavity. Even within this cavity it does not necessarily destroy the life of the fetus or even cause premature birth, but the birth may be apparently normal and the calf well developed and vigorous.

Our entire view of the differentiation between accidental and contagious abortion needs revision. The belief in frequent accidental abortion in the cow is so deep-rooted in the minds of veterinarians and cattle breeders that the question is one difficult of approach.

If we study the gravid uterus of the cow (or other ruminant) critically, the provisions against accidental injury to the fetus impresses the observer as one of the most perfect physiologic arrangements to be found in animal life. The fetus of the ruminant is elaborately protected during intrauterine life. The pregnant uterus lies on a gently inclined plane, the abdominal floor, partly suspended by the vagina and broad ligaments. The fetus gets its nutrient supply, not ordinarily from a diffuse placenta as in the mare, or zonular placenta as in carnivora, where violence may cause placental detachment and entail fetal death, but instead procures its food supply through 100 or more cotyledons, complex multiple placentæ, each usually having a distinct neck, thus leaving an empty space between the uterus and chorion, permitting a to-and-fro movement between the uterine walls and fetal sac in every direction. The fetal security is further insured by its floating free within one and partly within a second sac of fluid.

As indicated by Table 2, the uteri of over 1,700 pregnant cows and heifers were inspected. Probably very few of them had been shipped less than 100 miles by railroad, many of them hundreds of miles. They had been driven some distance to a railway station, huddled into shipping pens, forced into cars, crowded and jammed, and not rarely got down and were trampled. At every turn opportunity was offered for crowding and jamming. Finally they were goaded into the killing pens, felled with a hammer, and tumbled out on the floor. Certainly they had been subjected to the dangers of mechanical and fright abortion. Yet, in all these cases, no trace of injury to the fetus, fetal membranes, or uterus which might possibly have caused abortion had the animal been allowed to live were seen. While such evidence does not prove the impossibility of accidental abortion in cows, it does indicate that it is not, after all, very readily induced.

In further search for lesions of accidental abortion in stock-yard cows, two animals were purchased which had aborted in the car or yards and another had expelled a live fetus prematurely. These were killed within a few hours after the occurrence. In none of the three was there a trace of mechanical injury, but lesions were found which are described elsewhere, showing conclusively that the abortion was due, not to mechanical injury, fright, or other accidental causes, but to an infection within the uterine cavity, the evidences of which could not have accumulated in a day or a week.

All other post-mortem examinations upon recently aborted cows, so far as found recorded, have uniformly shown, beyond question, that infection, not accident, was the essential cause of the death and expulsion of the fetus. No case of alleged accidental abortion in cattle, so far as we can find, has ever been verified by post-mortem examination.

Generally it may be said that the evidence in relation to the importance of the nodular venereal disease is purely clinical and circumstantial, while that of the abortion bacillus is chiefly from the laboratory. If the *Bacillus abortus* is inoculated into a pregnant heifer in order to test its virulence, it is injected into one affected with the granular venereal disease. If the granular venereal disease is capable of inducing abortion, and abortion follows the inoculation with the abortion bacillus, there is no conclusive proof which of the two infections, if they be distinct, caused the disaster. It has not been shown that the *Bacillus abortus* of Bang is or is not related to the granular venereal disease.

There are many defects in the evidence submitted in favor of each hypothesis. If we examine first the Bang theory, we note among other defective points in the evidence:

1. Experimental inoculations have been without adequate control. No adequate evidence has been submitted to show that, taken an equal number of pregnant cows or heifers of like age and other conditions, and, instead of inoculating them with the *Bacillus abortus*, they are given in the same manner (intravenously, hypodermically, etc.) an equal amount of an innocuous substance, such as salt solution, a similar precentage of the animals would not abort.

2. The alleged period of incubation required to induce abortion varies inconsistently, according to species. By referring to Table 3, it will be observed that in cows the average time required to induce experimental abortion in the 26 cases recorded was 131 days; in ewes it required 6 to 83 days to induce abortion or infection; in the guinea pig abortion followed inoculation after an average of 10 days. In other words, the evidence submitted suggests that no matter how brief the normal duration of pregnancy, an infection which usually requires an average of 131 days, or a trifle less than one-half the span of pregnancy in the cow, its natural host, so hastens its energies as to induce abortion in less than half the span of pregnancy in other species, no matter how brief that span may be. Indeed, the records of experimental infectious abortion in the guinea pig indicate that abortion follows in one-sixth the span of pregnancy after inoculation. We are accordingly offered the phenomenon of an infectious disease, the duration of the incubation of which varies widely according to animal species, though each species may be equally susceptible.

TABLE 3.—*Average periods of incubation of abortion.*

Species, source of data, etc.	Number of animals.	Average period of pregnancy when inoculated.	Average time of termination of pregnancy.	Average interval between inoculation and termination of pregnancy.
Cows.				
British Royal Commission:		*Days.*	*Days.*	*Days.*
Complete abortions	7	71	189	118
Premature births	1	103	254	151
Killed when abortion was apparently threatened	3	37	172	135
Average for 3 classes	11	65	190	126
Killed without symptoms of abortion	7	69	174	106
New York State Veterinary College:				
Complete abortion	5	141	199	58
Prof. B. Bang citing Poulsen:				
Cows infected by bull	7	1	199	199
Ewes.				
British Royal Commission:				
Complete abortion	1	45	128	83
Lambing (3) or dying at full term from torsion of uterus (1) and showing abortion bacilli	4	113	167	54
Killed without aborting before full term and showing abortion bacilli	1	101	107	6
Guinea pigs.				
British Royal Commission:				
Aborted and abortion bacilli recovered	1	Undet.	Undet.	19
Aborted, but abortion bacilli not recovered	4	Undet.	Undet.	10
Average for 2 classes	5	Undet.	Undet.	12
Bitches.				
British Royal Commission:				
Aborting, but no abortion bacilli recovered	2	34	53	20

3. The data upon the duration of incubation in the cow vary in such a manner as to invite grave doubts as to the reasonableness of the conclusion that the artificially introduced abortion bacillus caused the abortion. Referring again to Table 3, we find that the constancy of the average date of pregnancy at which the cows of various experimenters aborted is remarkable—5 by Dr. Moore at the New York State Veterinary College, averaging the one hundred and ninety-ninth day; 11 by the British Royal Commission, averaging the one hundred and ninetieth day; 7 by Poulsen, cited by Bang, the one hundred and ninety-ninth day; and 3 by Bang the two hundred and fourth day.

In the column recording the period of incubation the same lots show 126, 58, 199, and 114 days, respectively, which gives a very wide and inexplicable variation until a comparative study is made of the date of inoculation. It then appears that the period of pregnancy at which abortion occurred suggests that the duration of incubation is dependent upon the date of inoculation. In other words, inoculate pregnant cows at any date one likes, the average date of pregnancy at which abortion occurs remains the same. We might say that, according to recorded data, the inoculation at any time of a pregnant cow with abortion bacilli will tend to cause abortion about the two hundredth day of pregnancy, the organism tempering its rapidity of action according to the exigencies of the case.

If in Table 3 we let X equal the number of days elapsing after impregnation until inoculation is made and Y equal the number of days elapsing between inoculation and abortion, then $X+Y=$ about 200 days, although the values of X and Y may each vary inversely from 1 to 200.

4. The alleged cases of experimental abortion recorded by the different investigators present very grave questions in relation to the avenue or avenues of infection. These we discuss later in a separate chapter.

There is, it is true, much laboratory evidence tending to show that the introduction of the bacillus abortus intravenously, hypodermically, per vaginam or orem, may lead to the invasion of the utero-chorionic cavity and cause the death and expulsion of the fetus, but as yet no reliable means have been devised for determining that the same organisms did not exist already within the utero-chorionic space. Apparently a very high percentage of the experimental heifers and cows inoculated have aborted, but this is merely comparative, not positive.

In the experiments of the British Royal Commission, of 5 heifers inoculated subcutem, 1 aborted; of 9 heifers inoculated intrajugularly, 4 aborted; of 5 heifers inoculated per orem, 1 aborted; of 9 heifers inoculated per vaginam, 1 aborted; making a total of 28 heifers inoculated, of which 7, or 25 per cent, aborted.

This rate of abortion does not greatly exceed the prevailing rate of abortions in first pregnancies. However, the commission determined, by autopsy or otherwise, that 11 additional heifers were infected and might have aborted, which makes a total of 18, or 64 per cent, of their experimental heifers that were infected. It is not at all rare for more than 64 per cent of heifers to abort from natural infection.

In each case we have found recorded of abortion, in cattle in which an early autopsy has been performed, there has been found in the utero-chorionic space a peculiar exudate which has not been recorded as occurring in other organs or in the uterus of other animals than the cow, and in which the abortion bacilli are usually, if not always, found.

As with the abortion bacillus, so with the granular venereal disease; there are no adequate control observations. Under the conditions shown in Tables 1 and 2, no herds free from the granular venereal disease can be found, and hence we can not say that, without that malady, contagious abortion could or could not exist.

It is a notable clinical fact, however, that those herds abort most in which the granular venereal disease is most intense. When a large percentage of the cows and heifers have the disease of a severe type—when the nodules are very numerous, the vulvar mucosa deeply injected, red, inflamed and bleeding upon slight provocation, when there is an abundant muco-purulent vulvar discharge, when the vulvar lips are swollen and the malady takes on what some term the acute type—abortion is usually common and serious. When the disease is mild, or as some say chronic, or others cured, leaving behind, however, some clearly recognizable nodules, abortion occurs rarely.

A still more significant clinical evidence that the granular venereal disease has an important relation to abortion is that abortion occurs at that age of the animal when the granular venereal disease is most intense; that is, in cows not over 4 years old. Usually it is during the first or second pregnancy that cattle abort when the granular venereal disease is at its zenith.

The granular venereal disease is also claimed to be the essential cause of sterility in cows. A great variety of diseases may bring about sterility, as, for example, tuberculosis of the genital organs, but they constitute a very small minority of cases. The vast majority of cases of sterility are due, according to our observations, to one widespread infection, inseparable from contagious abortion. In the experience of the writer, fully 98 per cent of the sterility of cattle must be regarded as identical in etiology with abortion. In one case the infection prevents conception; in another it attacks the embryo or fetus to cause its death and expulsion, or its expulsion from the uterus in an immature though living state (premature birth), or its birth in a more or less normal state, at full term, the infection existing in the uterus causing metritis with or without retained placenta.

Sterility and contagious abortion are in effect comparative terms, without any clear line of demarcation between the two phenomena.

THE GRAVID UTERUS OF THE COW.

The uterus is a branched, hollow organ, divided into a cervix, a body, and two horns.

The cervix uteri is of great interest in the consideration of some of the phenomena of contagious abortion, as well as of sterility. In the nonpregnant animal it is 3 to 6 inches long and 1 to 3 inches or more in diameter. Its walls are thick, dense, and resistant. The cervical canal is a narrow, tortuous channel, affording an avenue of communication between the vaginal and uterine cavities. In the healthy nonpregnant cow, when not in estrum, the mucosa of the cervical canal is elaborately folded longitudinally. The folds are in immediate contact at every point, completely occupying the space of the channel, the contact of the mucous folds being rendered close and firm by means of the powerful contraction of the thick muscular walls of the cervix.

Invasion of the uterine cavity through the cervical canal from the vagina is further guarded by a series of transverse muco-muscular projections directed sharply toward the vagina. These barriers are one-half to one inch in length and act as encircling valves directed toward the vagina in a manner to prevent ingress from the vagina by deflecting any invader from the cervical canal into the cul-de-sac of the valves, while permitting a more free egress from the uterine cavity.

The anatomical arrangement of the walls of the cervical canal results in the channel being firmly closed in the normal nonpregnant cow which has not recently calved and is not in estrum. The closure is so firm, the canal so tortuous, and the valvular barriers are so effective that it is impracticable to insert a man's finger or even a sound from the vagina into the uterus. This leads to the popular delusion that sterility is caused by closure of the mouth of the womb—a wholly normal state. In our abattoir observations we incised the cervix uteri of over 1,500 nonpregnant cows and heifers and found in one only a closure of the cervical canal other than the normal approximation related above.

During estrum the cervical walls relax, the cervical canal dilates, and it is frequently possible to introduce a finger or sound into the uterine cavity. In severe cases of sterility accompanied by nymphomania the cervical canal is frequently dilated.

When pregnancy occurs preparations are promptly begun and early completed to hermetically seal the uterus. A tough transparent gelatinoid substance—the uterine seal—forms in the cervical canal. It extends from the external to the internal os; pushes between the longitudinal mucous folds, pushing them apart while filling completely the spaces between them, fixing each fold in a definite position and binding it on either side to the adjacent folds; pushes the summits of the mucous ridges apart in the center of the canal, which it completely fills; invades and fills the spaces behind the transverse valvular folds; and binds and closes in a most intimate manner the entire cervical canal. The uterine seal projects beyond the internal os into the uterine cavity as a hemispherical elevation and posteriorly projects in a similar manner into the vagina, where it may be recognized by digital palpation as an elastic, adhesive mass adhering to the finger tip as it is withdrawn, constituting almost always a valid proof of pregnancy. It begins very early after impregnation, and is more prompt in heifers than in cows. It is generally complete in the heifer when the embryo is one-fourth of an inch long and in the cow when the embryo has reached a length of one-half to one inch, though it is rarely delayed to a somewhat later period. After completion in its formation, that is, after its complete investment of the parts, it continues to grow in volume throughout pregnancy, the rounded projections at the internal os reaching in adult cows a diameter of 2 inches.

The uterine seal of the cow is a highly elaborate and interesting production apparently having as its office the simple function of a seal by which the uterine cavity with its contained young is hermetically sealed and invasion from the vagina excluded. In the more than 1,700 pregnant cows and heifers examined on the killing floor the apparent efficiency of the uterine seal was well designed to excite admiration. The vagina might show marked evidences of long-standing infection, but the vaginal end of the uterine seal was firm, translucent, unstained, and to all appearances undisturbed by the infection. At its uterine end it was frequently stained by the hemorrhages generally present at this point and at times its surface partly liquefied. When the exudate of abortion was present at the internal os there was a more marked tendency to liquefaction of the uterine end of the seal, but in each case where the fetus was still intact and the membranes sound the body of the uterine seal revealed no changes whatever. It appeared as resistant to bacterial invasion as a living tissue; indeed it seemed more resistant than the neighboring mucosa.

When the fetus was dead and decomposing the uterine seal was dissolved and had partially or wholly disappeared.

The uterine seal is of especial significance in considering the avenue of infection and date of invasion in contagious abortion.

During estrum the uterine cavity contains a considerable quantity of clear mucus. At or near the close of estrum, succeeding closely upon ovulation, in case impregnation fails to occur menstruation sets in. The mucosa then becomes injected, highly vascular, and swollen. The cotyledonal elevations of the mucosa enlarge, and from these a well-marked hemorrhage of bright-red blood occurs which later escapes per vulvam (menstruation). Should impregnation ensue, menstruation ordinarily fails, and the uterus continues large, soft, and smooth. The fertilized egg soon throws out its embryonic sac or afterbirth, so that when the embryo reaches the size of one-eighth of an inch the embryonic sac is already quite large, as thick and long as an ordinary lead pencil, almost colorless, very thin and delicate, lying wholly free within the uterine cavity without any visible trace of placental attachment.

Later, when the embryo has reached a length of 2 to 3 inches, the placental attachments appear, at first very feeble, as faintly red patches on the chorion, gradually enlarging and thickening, the chorionic tufts becoming longer and more complex, while the cotyledons of the uterus undergo corresponding development. The intimacy of contact between the chorionic and uterine placentæ grow apace throughout the duration of pregnancy. Upon this fact is based the common observation that when abortion occurs before the fetus has reached or materially exceeded 12 inches in length it is ordinarily expelled inclosed within its membranes. This is of importance. While retained placenta or afterbirth is notoriously common and serious after abortion, it is not likely to occur in early abortion, but only in those cases which have reached or exceeded the sixth or seventh month of pregnancy. The tendency to retained placenta increases with the advancement of pregnancy and reaches its highest degree in cases of premature birth, unless we except those cases which have reached the full period of pregnancy and given birth to living calves, in spite of extensive uterine infection.

It has been supposed and taught that the firmness of union between the chorion and uterus decreases toward the completion of pregnancy, and that the parts begin to prepare before parturition for the expulsion of the afterbirth. Observations on the killing floor directly contradict this assumption and show instead that the firmness of adhesion increases constantly up to birth.

Early in pregnancy the margins of the internal os uteri are thickly studded over with small placentæ without marked peduncles. At times they form a complete girdle about the internal os, and come in contact with each other over the os to constitute a broad, flat placental mass 2 to 3 inches across, totally masking the os. However, they are not enduring, and when the fetus has reached a length of 10 to 12 inches they begin to become detached and finally disappear. In the process of detachment more or less placental hemorrhage ensues, so that in a large proportion of cases where the fetus is 10 to 15 inches long a careful observation of the utero-chorionic space at the internal os reveals a small blood clot, resting usually upon the uterine end of the uterine seal, where it undergoes retrogressive changes. At first bright red, it later becomes black, then fades slowly to a pale yellowish red, to constitute a sticky remnant staining the anterior end of the uterine seal. The amount varies; while usually but a drop or two, it may reach one-half ounce or more. As pregnancy advances adjacent cotyledons begin to detach about their peripheries and small hemorrhages occur. Whether physiological or pathological, the hemorrhage is suggestive of importance in relation to contagious abortion because at the very point where the abortion exudate commences to form there exists generally an amount of inert blood coagulum to furnish a breeding ground for bacteria, like a blood clot in a wound.

Another phenomenon of a somewhat similar character is common among the larger, more typical cotyledons. As pregnancy advances there appears at the periphery of many placentæ a pale yellowish-gray zone, very narrow, but showing a marked variation in color from the other parts. The pale zone upon examination consists of chorionic tufts which have been withdrawn from the cotyledonal crypts, and the tufts, losing their placental contact and function, become nonvascular and present a necrotic appearance. Their appearance suggests mechanical separation during the to-and-fro movements of the fetal sac within the uterine cavity.

THE NECROTIC TIPS OF THE FETAL SAC.

The cornual prolongations of the fetal sac grow out very quickly against the apices of the cornua and are longer than the cavities they occupy, so that they become crowded and sinuous. At an early period the tip of the fetal sac in each cornu becomes necrotic and either extends forward toward the oviduct as a naked, flattened, yellow, hard cord, incrusted in a calcareous-like substance, or it becomes invaginated into the cavity of the amnion or allantois. In the gravid horn the necrotic tip is generally invaginated into the fetal sac, while in the nongravid horn it largely lies naked, 1 to 6 or more inches long, lying free in the apex of the horn.

When the necrotic tip is naked and exposed, when it comes in contact with the cornual mucosa, it is generally surrounded by a finely granular, yellowish or dirty lemon-colored fluid, suggesting a suspension of pale yellow brick dust in a fluid. There may be but a few drops, or the amount may reach 1, 2, or even 5 to 10 ounces. It appears like an exudate resulting from the mechanical irritation of the exposed necrotic tip and tends to be large or small in volume, according to the size of the necrotic tip.

While these necrotic tips are universal at the cornual apices, there appears rarely a very similar phenomenon at the internal os. Apparently in the few instances observed the fetal sac had pushed out for a distance through the internal os, and, like the projections into the apices of the horns, became necrotic, and was later surrounded by the pale, brick-dust sediment.

PREVALENCE OF ABORTION.

The history of contagious abortion of cows is extensive, though it loses much of its interest and definiteness because of the inadequacy of the means for its diagnosis.

Abortion statistics in any herd are necessarily inaccurate, and include only those cases in which the fetus has perished and been expelled at a period when its death and expulsion is recognized. In many outbreaks of abortion there is associated a large amount of sterility. Many of these instances of assumed sterility are in reality abortion. A cow will be served by the bull and fail to come in heat for two to five periods, convincing the owner that she is pregnant, when unexpectedly she again shows estrum. While such phenomena may depend upon a variety of causes, abortion unquestionably accounts for many of these cases. Occasionally the breeder chances upon the freshly expelled embryo, which may be only 3 to 4 inches long. Since these embryos come away inclosed within the fetal membranes, leaving no afterbirths, the discovery of the abortion is a remote possibility.

In rare cases the fetus dies from the infection of contagious abortion but is not expelled, and the cow or heifer appears sterile. Two things may occur: The fetus may undergo maceration, the tissues break down, some pus escape from the uterus, but largely remain in the organ as pyometra. In other cases the fetus does not break down, but desiccates to form an inert foreign body known as a mummy (lithopædion).

When pregnancy nears its close abortion again may escape unnoticed. A fetus may be expelled alive at the eighth month, or even earlier, because of the presence of the infection of contagious abortion in the uterus, and is commonly designated premature birth, though in fact its early expulsion is due to precisely the same cause as that which causes other fetuses to be expelled dead. Or, the infection being present, the fetus may live and develop up to the normal date for parturition, die immediately preceding labor, and be expelled fully developed, fresh, but dead, and it is classed as a stillbirth, though just as evidently an abortion as is the five months' fetus, killed by the same infection. Abortion statistics in any herd can accordingly be merely approximate.

ABORTION DATA IN HERD A.

As a basis upon which to build an outline of the behavior of abortion in a herd, we submit statistics from herd A in Table 4 below. This herd at first consisted largely of grades, but was later changed into a pedigreed herd. The period covered is 22 years, which serves to afford a fair opportunity for arriving at the average rate of abortion. An average annual rate of 12 per cent of abortions is shown. The vacillations from year to year are exhibited in the diagram, figure 1, and the prevalence of abortion according to age in another diagram, figure 2. During the earlier part of the time covered the herd consisted largely of adult cows, which were bought when mature, milked for a time, and sold. Later it has been the policy to grow all heifer calves and breed them. Thus there has been latterly a comparatively large number of heifers in first or second pregnancy.

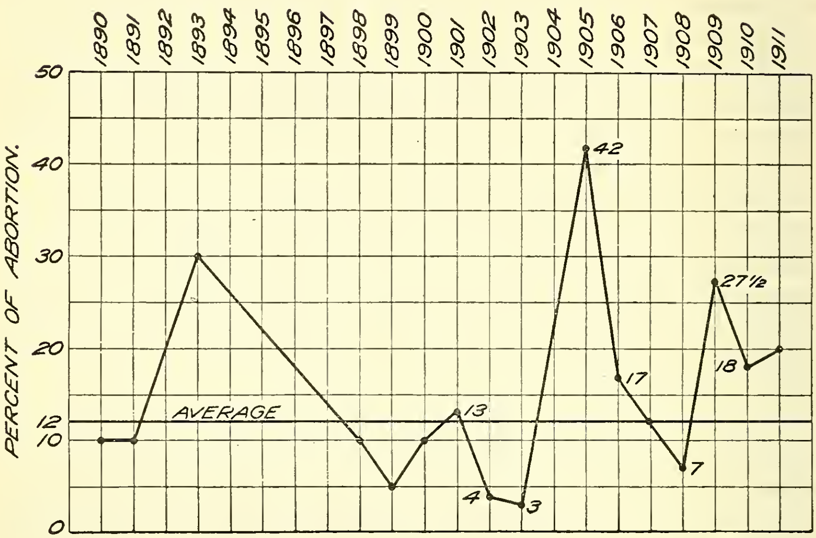


FIG. 1.—Percentage of abortion in herd A, by years.

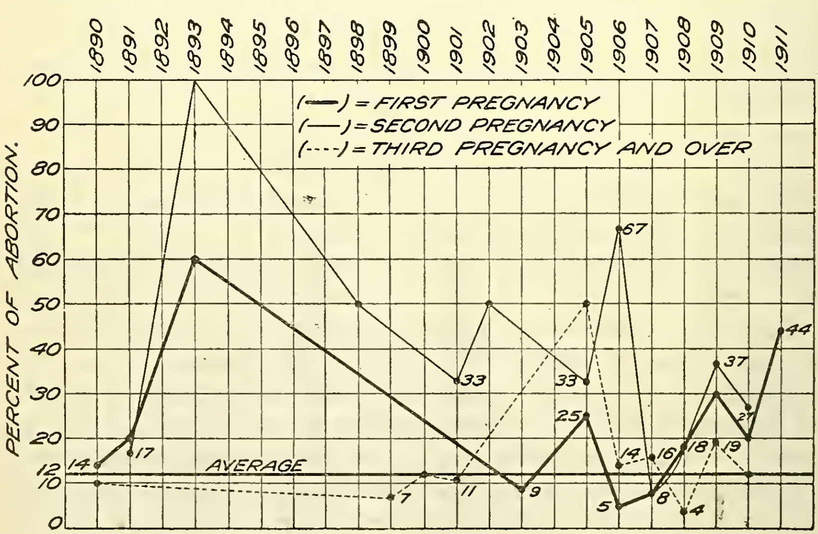


FIG. 2.—Influence of the number of the pregnancy on the percentage of abortion in herd A.

TABLE 4.—*Record and result of births and disposition of cows in herd A, 1890 to 1911.*

Name of animal.	Year born.	1890			1891			1892			1893			1894			1895		
		Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.
			Days.			Days.			Days.			Days.			Days.			Days.	
May	1881	4		Normal				5		Normal[1]									
Minnie	1882	4		do.[1]															
Aggie	1883	3		do.[1]															
Cora	1884	3		do.	4		Normal	5		Normal									
Do	1884							6		do	7		Normal[2]						
Daisy	1884	3		Normal[1]															
Sadie	1884			do.[1]															
Puss	1884	3	253	Abortion	4		Normal				5		Normal[1]						
Jane	1885			Normal.[1]															
Pet	1885	3		do				4		Normal	5		Normal	6		Normal	7		Normal.[1]
Freddie	1885	2		do	3		Normal	4		do	5		do	6		do	7		Do.[1]
Belva	1886	2		do	3		do	4		do	5		do	6		do.[1]			
F. J. E	1886			do			do.[1]												
Boise II	1887	2		do.[3]															
Beauty	1887	1		do	2		Normal	3		Normal									
Do	1887							4		do	5		Normal	6		Normal	7		Do.[3]
Gem of S. B	1887	2		Normal	3		Normal[3]												
G. Valentine	1887				1	268	Premature birth.	2		Normal	3		Normal						
Do											4		do	5		Normal	6		Normal.
Glista	1887	2		Normal	3		Normal	4		Normal[1]									
Shadow	1887						do.[1]												
Bertha	1888	1		Normal	2	268	Premature birth.	3		Normal	4		Normal	5		Normal	6		Do.[1]
Carrie	1888	1		do	2		Normal[1]												
Emma	1888										1		Normal	2		Normal	3		Normal.
Gazelle	1888	1		Normal				2+3		Normal	4		do	5		do	6		Do.[1]
Jennie	1888	1		do	2		Normal	3		do.[1]									
Pearl	1888	1		Abortion	2		do	3		Normal	4		Normal	5		Normal			
Ruby	1888	1	279	Normal	2	280	do	3	277	do				4	283	do	5	286	Normal.
Do	1888																6	283	Do.
Mollie	1889				1		Normal	2		Normal	3		Normal	4		Normal	5		Do.
Aggie II	1890							1		do.[1]									
Carrie II	1890				1		Normal[3]												
Daisy	1890				1		Normal	2		Normal	3		Normal	4		Normal	5		Do.[1]
Mabel	1890							1		do	2	198	Abortion				3		Do.[1]
Glista II	1890				1		Normal	2		do.[1]									
Roxy	1890							1		Normal	2	240	Abortion				3		Do.[2]

[1] Sold for beef. [2] Sold. [3] Died.

TABLE 4.—*Record and result of births and disposition of cows in herd A, 1890 to 1911*—Continued.

Name of animal.	Year born.	1890			1891			1892			1893			1894			1895		
		Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.
			Days.			*Days.*			*Days.*			*Days.*			*Days.*			*Days.*	
Dora	1891										1	268	Premature birth.	2		Normal	3		Mormal.
Ga. Valentine	1891										1	235	Abortion	2		do	3		Normal.
Glista III	1891										1		Normal	2		do	3		Do.[1]
Julia	1891										1		do	2		do	3		Normal.
Ruth	1891										1	283	Abortion[1]						
Clara	1892										1	169	do	2		Normal	3		Do.
Glista IV	1892													1		Normal	2		Do.
Gl. Netherland	1892																1		Do.
May II	1892													1		Normal	2		Do.
Nora	1892													1		do	2		Do.[1]
Sadie	1892													1		do	2		Normal.
Belva II	1893																1		Do.
Cherry	1893																1		Do.
Jennie II	1893																1		Do.

Name of animal.	Year born.	1896			1897			1898			1899			1900			1901		
		Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.
			Days.			*Days.*			*Days.*			*Days.*			*Days.*			*Days.*	
G. Valentine—continued	1887	7		Normal	8		Normal	9		Normal[1]									
Emma—continued	1888	4		do	5		do	6		do	7		Normal[1]						
Pearl—continued	1888	6		do	7		do.[2]												
Ruby—continued	1888	7	281	do				8	282	Normal	9	163	Abortion	10	138	Abortion[1]			
Floss—continued	1889									do			Normal[3]						
Mollie—continued	1889	6		Normal	7		Normal	8		do.[3]									
Dora—continued	1891	4		do	5		do	6		Normal	7		Normal[1]						
Ga. Valentine—continued	1891	4		do	5		do.[2]												
Julia—continued	1891	4		do	5		Normal	6		Normal	7		Normal	8		Normal	9		Normal.
Clara—continued	1892	4		do.[3]															
Clover—continued	1892															Normal[1]			
Glista IV—continued	1892	3		Normal	4		Normal	5		Normal	6		Normal	7		Normal	8		Do.[1]

Gl. Netherland—continued.	1892				2		do	3		do				4		Normal [3]			
May II—continued	1892	3		Normal	4		do	5		do	6		Normal	7		Normal	8	264	Abortion.
Sadie—continued	1892	3		do	4		do.[1]												
Belva II—continued	1893	2		do	3		Normal	4		Normal	5		Normal	6		Normal [3]			
Cherry—continued	1893	2		do	3		do	4		do				5					
Jennie II—continued	1893	2		do	3		do				4		Normal [3]			Normal [1]			
Do											5		Normal						
Chloe	1883																		Normal.
Bertha II	1894				1		Normal	2		Normal	3		Normal	4		Normal	5		Do.
Daisy	1894	1		Normal	2		do.[3]												
Pet II	1894	1		do	2		Normal	3		Normal [1]									
Rena	1894																		Do.
Ruth	1894	1		Normal	2		Normal	3		Normal	4		Normal [1]						
Stella	1894																		Do.
Tilda	1894															Normal			Do.
Belle	1895				1		Normal	2		Normal	3		Normal	4		do	5		Do.
Gr. St. Lambert	1895				1	277	do	2	157	Abortion	3	277	do	4	280	do.[5] [1]	5	178	Abortion.
Mable II	1895	1		Normal	2		do	3		Normal	4		do.[3]						
Rita	1895																		Normal.
V. St. Lambert	1895				1	283	Normal	2	190	Abortion	3	277	Normal	4	284	Normal			
Ada	1896							1		Normal	2		do	3		do.[1]			
Dena	1896																		Do.
Ga. Exile	1896										1	287	Normal						
Do	1896										2	277	do	3	259	Premature birth.	4	276	Do.
Kate	1896							1		Normal	2		do	3		Normal [3]			
Patty	1896																		Do.
Polly	1896																		Do.
Gl. De Kol	1897										1	275	Normal	2	273	Normal	3	279	Do.
Va. Exile	1897										1		do	2		do			
Vina	1897										1		do	2		do	3		Do.
Dina	1898																		Do.[1]
Dixie	1898																1		Normal.
Gl. Alpha	1898													1	273	Normal	2	168	Abortion.
Gl. Beta	1898													1	279	do	2	286	Normal.
Rose	1898													1		do	2	279	Do.
Ella	1899																1		Do.

[1] Sold for beef. [2] Died of milk fever. [3] Sold. [4] Died. [5] Sterile.

TABLE 4.—*Record and result of births and disposition of cows in herd A, 1890 to 1911*—Continued.

Name of animal.	Year born.	1902			1903			1904			1905			1906			1907		
		Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.	Pregnancy No.	Duration.	Result.
			Days.			*Days.*			*Days.*			*Days.*			*Days.*			*Days.*	
Julia—continued	1891	10		Normal	11		Normal [1]												
May II—continued	1892	9		Normal [1]															
Bertha II—continued	1894	6		Normal [2]															
Rena—continued	1894			Normal			Normal [3]												
Stella—continued	1894			do			Normal [3]												
Tilda—continued	1894			do.[3]															
Belle—continued	1895	6		Normal	7		Normal	8		Normal	9		Normal [3]						
Gr. St. Lambert—continued.	1895	5	282	do.[4] [1]															
Rita—continued	1895			Normal			Normal [3]												
Dena—continued	1896			do.[3]															
Ga. Exile—continued	1896	5		do.[5]															
M. Tabby	1896						Normal			Normal						Normal			Normal.[3]
Patty	1896			Normal			do.[3]												
Polly	1896			do			do.[3]												
Gl. DeKal	1897				4	282	Normal	5	282	Normal									
Do	1897							6	276	do	7	108	Abortion [3]						
M. of Wm. Towe	1897						do.[6]												
Va. Exile	1897	3		Normal	4		do.[1]												
Valley Girl	1897						do.[6]												
Vina	1897	4		Normal	5		Normal	6		Normal	7		Normal [3]						
Dixie	1898	2		do	3		do	4		do	5		do						
Foxey	1898						do [1]												
Gl. Alpha	1898	3	277	Normal				4	275	Normal	5	287	Normal						
Do	1898										6	279	do				7	286	Normal.
Gl. Beta	1898	3	279	Normal	4	291	Normal	5	282	do	6	218	Abortion	7	270	Normal			
Nina	1898						do			do						do			Normal.[1]
Rose	1898	3	286	Normal	4	284	do	5	286	do	6	193	Abortion	7	290	do	8	266	Do.[3]
Ella	1899	2	214	Abortion.	3	288	do	4	269	do	5	212	do.[4]						
Gl. Delta	1899	1		Normal	2	288	do	3	282	do	4	181	Abortion	5	272	Normal	6	281	Normal.
Gl. Gamma	1899	1		do	2	275	do	3	283	do	4	261	Premature birth.	5	282	do			
Meda	1899						do.[1]												
Va. Pilot	1899	1		Normal [1]															
A. Cowossie	1900																	158	Abortion.
Fidget	1900				1		Normal	2		Normal [3]									
Ga. Pilot	1900	1		Normal	2		do	3		do.[3]									
Gl. Epsilon	1900				1		Abortion.	2	273	Normal	3	280	Normal	4	274	Normal	5	276	Normal.
Ida. Peri	1900														295	do		286	Do.

Lily of R. M.	1900				1		Normal	2		Normal[5]									
Lina	1900				1		do	2	285	Normal	3	246	Premature birth.	4	282	Normal	5	286	Normal.
Sara	1900				1		do												
Do	1900				2		do				3		Normal[1]						
Su. of U	1900																		Normal.
Taffy of R.	1900				1	283	Normal	2	275	Normal	3	270	Normal	4	232	Premature birth.[1]			
Va. Dove	1900	1		Normal	2		do												
Edna	1901				1		do	2	280	Normal	3	147	Abortion	4	223	Abortion			
Gl. Eta	1901				1		do	2		do	3	199	do	4	278	Normal	5	275	Do.
Gl. Iota	1901							1		do	2	153	do	3	281	do	4	280	Do.
Jess	1901				1		Normal	2		do	3		Normal	4		do			
La Benton	1901															do		203	Abortion.
Do	1901																	230	Do.
Mary of M	1901				1		Normal[6]												
Queen	1901				1	284	Normal	2	287	Normal	3	260	Premature birth.[4]						
Dy. Maid	1902																4		Normal.
Ga. Alpha	1902							1		Normal[1]									
Ga. Beta	1902							1		Normal	2		Normal[1]						
Gl. Lambert	1902										1	275	Normal				2	286	Do.
Wh. Queen	1902							1		Normal	2		do	3		Normal	4		Do.[6]
Agnes	1903										1		Abortion[1]						
C. Wampa	1903										1	278	Normal	2	184	Abortion[4]			
Dolly	1903										1		do.[4][1]						
Ebony	1903												do.[3]						
Ga. Gamma	1903													1		Normal[5]			
Glista Ma	1903													1	280	do			
Do	1903													2	174	Abortion	3	275	Normal.
Glista Na	1903													1		Normal	2		Do.
Glista XI	1903													1		do	2		Do.[3]
Hazel	1903										1		Normal	2		do	3		Do.
N. Berta	1903													1		do	2	280	Abortion.[1]
Li. Clyde	1903													1	288	do	2	224	
Topsy	1903										1		Normal	2		do.[1]			Normal.[3]
Vt. Quintus	1903										1	245	Abortion	2	192	Abortion[1]			
Zelma	1903													1		Normal	2		Normal.
Amerilla III	1904																1		Do.
Anora	1904																1	275	Do.
Baby	1904													1		Normal[3]			
C. Belle	1904																1	261	Abortion.[6]
C. Marvelle	1904													1	274	Normal			
Curly	1904													1		do	2		Normal.[3]
Down	1904													1	278	do			
Della	1904													1		do	2		Do.[3]
Fawn	1904													1		do			
Ga. Delta	1904													1	272	do	2		Normal.
Gl. Omicron	1904													1		do	2		Do.

[1] Sold for beef. [2] Died of milk fever. [3] Sold. [4] Sterile. [5] Died. [6] Killed tuberculosis.

TABLE 4.—*Record and result of births and disposition of cows in herd A, 1890 to 1911*—Continued.

Name of animal.	Year born.	1902 Pregnancy No.	1902 Duration.	1902 Result.	1903 Pregnancy No.	1903 Duration.	1903 Result.	1904 Pregnancy No.	1904 Duration.	1904 Result.	1905 Pregnancy No.	1905 Duration.	1905 Result.	1906 Pregnancy No.	1906 Duration.	1906 Result.	1907 Pregnancy No.	1907 Duration.	1907 Result.
			Days.			*Days.*			*Days.*			*Days.*			*Days.*			*Days.*	
Gl. Pi	1904										1	271	Normal	2	198	Abortion.[1 2]			
Gl. Rhe	1904													1	279	Normal	2	277	Normal.
Gl. Sigma	1904													1		do	2		Do.
Gl. Tau	1904																1	271	Do.
Do	1904																2	273	Do.
Gl. Upsilon	1904													1	280	Normal			
Gwyme of O. H.	1904																1	278	Do.
Brier	1905																1		Do.
Dame	1905													1	232	Abortion[1]			
Gl. Chi	1905																1		Do.
Gl. Phi	1905																1	281	Do.
Gl. Psi	1905																1	278	Do.
G. Daisy W	1905																1		Do.
Lassie O. H	1905																1		Do.
T's Anne	1905																1	266	Do.

Name of animal.	Year born.	1908 Pregnancy No.	1908 Duration.	1908 Result.	1909 Pregnancy No.	1909 Duration.	1909 Result.	1910 Pregnancy No.	1910 Duration.	1910 Result.	1911 Pregnancy No.	1911 Duration.	1911 Result.
			Days.			*Days.*			*Days.*			*Days.*	
Gl. Alpha—continued	1898	8	277	Normal				9		Normal[3]			
Gl. Beta—continued	1898	8	282	do	9	286	Normal						
Do	1898				10	282	do						
Gl. Delta—continued	1899	7	272	Normal	8	274	Normal				9		Normal.
Gl. Gamma—continued	1899				6	284	do.[1]						
Gl. Epsilon—continued	1900	6	279	Normal	7	267	Normal	8	280	Normal	9		Normal.[4 1]
Ida. Peri—continued	1900		287	do.[2]									
Lina—continued	1900	6	302	Normal	7	279	Normal	8		Normal[4 3]			
Su. of U.—continued	1900			do			do			Normal			Normal.
Gl. Eta—continued	1901	6	274	do	7	281	do	8		do[4]	9		Do.
Gl. Iota—continued	1901	5	275	do				6	281	Normal	7		Do.[4 3]

LaBenton—continued	1901		289	Normal[2]									
Dy. Maid—continued	1902	5		Normal				6		Normal[4,2]			
Do	1902							7	236	Abortion			
Gl. Lambert—continued	1902	3	282	Normal	4	275	Normal[4,3]						
Glista Ma	1903	4	280	do	5		Normal	6		Normal	7		Normal.
Glista Ma	1903	3		do				4		do	5		Do.
Hazel	1903	4		do.[2]									
N. Berta	1903	3	283	Normal	4	284	Normal	5		Normal			
Gl. Fantine	1903										1	180	Abortion.[9,4,3]
Zelma	1903	3		Normal	4		Normal	5		Normal			
Amerille III	1904	2	143	Abortion[1,2]									
Anore	1904				2		Premature birth.[1]						
C. Belle	1904	2	280	Normal[1,2]									
C. Marvella	1904	2	279	Normal									
Do	1904	3	276	do	4	217	Abortion	5		Normal[1]			
Down	1904	2	274	Normal[1,2]									
Fern	1904	2		Normal									
Do	1904	3		do.[2]									
Ga. Delta	1904	3	272	Normal	4	251	Abortion	5	252	Abortion[4,1]			
Gl. Omicron	1904	3		do	4		Normal	5		Normal	6		Normal.[4]
Gl. Rhe	1904	3	276	do	4	189	Abortion[1,2]						
Gl. Sigma	1904	3		do	4		Normal	5		Normal[4,1]			
Gl. Tau	1904	3	161	Abortion	4	277	do	5		do.[1,4,2]			
Gl. Upsilon	1904	2	275	Normal[1,2]									
Gwyme of O. H	1904	2	285	do	3	284	Normal[1]						
Gl. Chi	1905	2		Normal	3	264	Premature birth.	4		Normal			
Gl. Omega	1905	1		do	2		Normal	3		do	4		Do.
Gl. Phi	1905	2	266	do.[1,2]									
Gl. Psi	1905				2	274	Normal	3		Normal	4		Do.
Gipsy	1905	1	283	Normal	2	286	do	3		do.[4,1]			
G. Daisy	1905	2		do.[2]									
T's. Anna	1905	2	240	Abortion	3	277	Normal	4	237	Abortion[4,3]			
Blanche	1906							1		Normal	2		Normal.
Charity	1906				1		Normal	2		do	3		Do.[4]
Effie	1906				1		do	2		do	3		Normal.
Flora	1906	1		Normal	2		do						
Ga. Zeta	1906	1	275	do				2	283	Normal[4,1]			
G. Queen	1906	1		do	2	247	Premature birth.	3		Normal	4		Do.[4]
Gl. Carlotta	1906				1	273	Normal	2		do.[4,1]			
Gl. Corinne	1906	1		Normal	2		do	3		do.[5,4,1]			
I. Buttercup	1906				1	283	do						
Do	1906				2	170	Abortion	3		Normal[4,1,2]			
Ly. Clay	1906	1		Normal				2		do.[3]			
Triple Crown	1906				1	200	Abortion	2		do.[4,3]			
Aurora	1907							1		do.[4]			
C. Inez	1907							1		Normal	2		Normal.
Eliza T	1907							1		do			

[1] Sterile. [2] Sold for beef. [3] Died. [4] Metritis. [5] Retained placenta.

TABLE 4.—*Record and result of births and disposition of cows in herd A, 1890 to 1911*—Continued.

Name of animal.	Year born.	1908 Pregnancy No.	1908 Duration.	1908 Result.	1909 Pregnancy No.	1909 Duration.	1909 Result.	1910 Pregnancy No.	1910 Duration.	1910 Result.	1911 Pregnancy No.	1911 Duration.	1911 Result.
			Days.			*Days.*			*Days.*			*Days.*	
Ga. Eta	1907				1	269	Premature birth.	2	270	Premature birth.	3		Normal.
Gl. Candida	1907				1	261	do.						
Gl. Dominican	1907							1	278	Normal [1]			
Gl. Elanor	1907							1	273	do. [1]			
Gl. Eloise	1907				1		Normal.	2	204	Abortion.	3		Do.
Gl. Eva	1907							1		Normal [2]			
Gl. Francesca	1907							1		do. [3]			
L. Marvel	1907				1		Normal.	2		Normal.	3		Do.
Purity	1907				1		do.	2	280	Abortion [4,3,5]			
Watoma	1907				1	193	Abortion.	2		Normal [3,5]			
Cordelia	1908										1		Do.
C. Clay	1908										1	255	Premature birth. [7]
C's Lizette	1908							1		Normal.	2		Normal.
Fay	1908										1		Do.
Ga. Iota	1908										1	210	Abortion.
Ga. Theta	1908							1		Abortion [4,3,5]			
Gl. Alpha II	1908							1	216	do. [3,2]			
Gl. Cassandra	1908							1		Normal [3,2]			
G. D. Bella	1908							1	256	Premature birth. [3,5]			
Gl. Ebony } Twins	1908							1		Normal [3,2]			
Gl. Echo } Twins	1908							1		do. [3,2]			
Gl. Eglatine	1908							1		do. [3]			
Gl. Elvira	1908							1		do. [3,5]			
Gl. Ernestin	1908							1		Normal.			
G. D. Fox	1908							1	249	Abortion [3,2]			
Ly. Clay II	1908										1		Normal.
Ly. Clay III	1908										1		Do.
Mota	1908							1		Normal.	2		Do.
Purina	1908							1		do. [3,2,1]			
Puritan	1908							1		Normal.	2		Do.
Ro. August	1908							1		Abortion [3,2]			
Berta O	1909										1		Do.
Gl. Cora	1909										1	250	Premature birth. [3]
Gl. Coreva	1909										1	210	Abortion. [4,3]

Gl. Dora	1909							1		Normal[3][2]			
Gl. Draba	1909										1	180	Do.
Gl. Dutchess	1909										1		Normal.
Gl. Elora	1909										1	245	Abortion.[4][3]
Gl. Flora	1909										1		Do.
K. Paleface	1909										1		Normal.
Ly. Clay IV	1909										1		Do.
S. Ly. Laurie	1909										1		Do.
Su. Oonan	1909										1		Do.

[1] Sold for beef. [2] Sterile. [3] Metritis. [4] Retained placenta. [5] Died.

Figure 1 shows graphically the rise and fall of abortion above and below the average rate of 12 per cent in herd A from year to year. The chart shows three abortion storms in which the percentage of known abortions exceeded 25, the most severe outbreak being in 1905, with recorded abortions in 42 per cent of pregnancies.

In figure 2 it is aimed to show the influence of age as expressed by the consecutive number of the pregnancy. The general aim in the herd has been to breed heifers at 16 to 18 months of age, so that the first calving ordinarily means about 2 years old, the second 3 years old, etc.

The intensity of abortion in first pregnancy seems to grow with the growth of the herd, while abortion in adult cows seems to decrease comparatively. As shown in figure 2, in 1911 the abortions in herd A amounted to 44 per cent of first pregnancies, to which abortion was confined exclusively for the year. The first pregnancies were proportionally the highest in the history of the herd.

Summary of abortion data in herd A.

Total number of cows	217
Total number of pregnancies	645
Average number of pregnancies per cow	3
Total number of abortions	78
Average abortions per annum	3.5
Average per cent of abortions per annum	12
Number of individual cows aborted	71
Percentage of cows which have aborted	33
Number of cows aborting twice	7
Number of cows aborting twice in succession	4
Number of cows died or killed after first abortion	10
Number of years covered	22
Number of cows in which no abortion occurred	6
Longest duration in years without abortion	4
Highest number of consecutive pregnancies without abortion	89

Among the 217 cows of herd A occur the records of the first three or more pregnancies of 80 individuals. Of these 80 animals, 18 were in the herd in 1905, 2 of which had aborted previously, and in one of these (50 per cent) abortion recurred.

Of the 80 cows in Table 4 of which we have records of the first three pregnancies, there were aborting in the first or second pregnancy 20, or 25 per cent; in the third or later pregnancy 18 or 22.5 per cent; while the number not aborting was 42, or 52.5 per cent.

The chronological order of abortions in these 80 individuals in their third or later pregnancies is shown in Table 5. The figures in parenthesis indicate that one animal in a group aborted a second time in the number of her pregnancy indicated by the figure.

TABLE 5.—*Chronological order of abortions in cows of herd A from third pregnancy onward.*

Number of pregnancy.	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	Total.
Third	......	1	......	......	......	......	4 (4)	......	......	1	1	......	......	7
Fourth	......	......	......	......	......	......	2	2 (3)	......	......	3 (5)	1 (2)	......	8
Fifth	......	......	1 (2)	......	......	......	1 (2)	......	......	......	......	1 (4)	......	3
Sixth	......	......	......	......	......	......	2	......	......	......	......	......	......	2
Seventh	......	......	......	......	......	......	1	......	......	......	......	......	......	1
Eighth	......	......	1	......	......	......	......	......	......	......	......	......	......	1
Ninth	1 (10)	......	......	......	......	......	......	......	......	......	......	......	......	1
Tenth	......	1 (9)	......	......	......	......	......	......	......	......	......	......	......	1
Total	1	2	2	......	......	......	10	2	......	1	4	2	......	24

Table 5 shows that when cows abort in their third or later pregnancy it usually occurs in a storm like that of 1905. Thus, in the 80 animals tabulated, 10 abortions, or 41 per cent of all the abortions in third or later pregnancies, covering a period of 22 years, occurred in one year. Fifteen of the 24 abortions occurred during the third and fourth pregnancies, thus indicating strikingly the influence of the age of the animal upon abortion.

ABORTION RECORD IN HERD B.

In the following data of herd B the annual rate of abortion increases from the 12 per cent of herd A to 17 per cent. The increase occurs not in adults, but in heifers, and especially in those pregnant for the first time.

Summary of abortions in herd B, May, 1909, to December, 1911.

Total pregnancies	1, 206
Total abortions	213
Percentage of abortions	17
Number aborting but once	167
Number aborting twice	20
Number aborting thrice	2
Total number of cows aborting	189

Abortions in first pregnancy, 99, or 46.5 per cent of all abortions and 50 per cent of first pregnancies.

Abortions in second pregnancy, 70, or 33 per cent of all abortions and 34 per cent of second pregnancies.

Abortions in third pregnancy, 26, or 12 per cent of all abortions.

Abortions in fourth or later pregnancy, 18, or 8.5 per cent of all abortions.

Repeated abortions.

First and second pregnancy	15
First, second, and third pregnancy	2
Second and third pregnancy	2
Third and fourth pregnancy	1
Fourth and fifth pregnancy	1
Fifth and sixth pregnancy	1
Total	22

Other abortion statistics available to us would not modify essentially the general picture of the disease. Generally we believe that the average rate of abortion in pedigreed herds falls between 10 and 15 per cent per annum, rising and falling from year to year, unseen possibly in the smaller herds for one, two, or three consecutive years, then showing itself again, gathering force for a while, and culminating in a great explosion of the disease which forces the percentage of loss up to 30, 50, or 75 per cent, or even higher. It is not at all rare in a group of 10 to 20 heifers pregnant for the first time for the abortion loss to reach 90 or even 100 per cent. In small herds of 5 to 15 or 20 animals, mostly adults, the percentage of abortion is usually far below the above ratio.

SYMPTOMS OF ABORTION.

The symptoms of cattle abortion are as yet extremely vague. They popularly fall into three groups—the signs of impending abortion, the phenomenon of aborting, and the evidences that abortion has occurred.

The symptoms of impending abortion comprise chiefly tumefaction of the udder and of the vulva, vaginal discharge, and sinking of the broad ligaments of the pelvis, any or all of which may fail or may be deceptive. Tumefaction of the udder is not common unless the pregnancy has passed the fifth month; even then it is not reliable. In milking cows it is usually unobservable. The erroneous assumption that tumefaction of the udder indicates that a heifer will certainly abort leads to the error that the use of certain nostrums have blocked an impending abortion. Heifers pregnant for the first time not rarely suffer from a severe mammitis or garget as early as the sixth month, which has no known relation to abortion. Heifers which have never been in calf show at times swelling of the udder, and may even milk freely. The sinking of the pelvic ligaments is more indicative of impending abortion, and may be regarded as an unfavorable sign when present, but this is only in a minority of cases.

The evidences of the act of the expulsion of the fetus are largely dependent upon the duration of pregnancy, because the force required for its expulsion naturally depends upon its dimensions. In the earlier stages of pregnancy no expulsive efforts are seen, and it is only by the chance observation of the embryonic sac passing through the vulva that the act is observed at all. As pregnancy becomes more advanced the expulsive act assumes more and more the general aspect of normal parturition.

If the act of the expulsion of the fetus passes unobserved and the afterbirth has come away, there is little to indicate that abortion has occurred until the cow again comes in heat. If she is well advanced in pregnancy the abortion is very liable to be followed by retained placenta, which is usually clearly recognizable.

The definite clinical diagnosis of impending abortion is essentially impossible until the condition has so far advanced that the preliminary acts of abortion, as dilation of the cervical canal, protrusion of fetal membranes, etc., have become established. The determination of the fact that abortion has occurred must be based upon the recognition of the expelled fetus or afterbirth as belonging to the animal, or, if it is known that she has been pregnant, it must be established by rectal or other examination that pregnancy has terminated.

The differential diagnosis between accidental and contagious abortion is largely impracticable in the living animal. It has been proposed to differentiate them in a variety of ways; for example, to separate the two classes of abortion by recognizing the presence of the *Bacillus abortus* in the placenta or uterine exudate of the one group while it is absent in the other. While some have laid claim to the possession of such skill, the accuracy of the conclusion that merely negative findings indicate the absence of contagious abortion does not seem wholly warranted.

McFadyean and Stockman, Sven Wall, Holth, and others claim much for the diagnosis of the disease by means of the complement-fixation and agglutination tests. Thus far, however, it has only been shown according to data submitted that certain animals which had recently aborted reacted. They have not shown that all reacting animals are bearers of the infection of abortion, nor that all bearers of the infection react. The character of the conclusion from the data assembled is well expressed by Wall: "A reaction indicates that the animal is or has been infected with contagious abortion." Animals which had aborted quite commonly reacted more than two years after abortion. Apparently an impending abortion may not ordinarily be foretold by these tests.

The post-mortem diagnosis of contagious abortion appears to be more certain and the phenomena fairly well established, especially in relation to the presence of the abortion exudate. This exudate, in the present state of our knowledge, is characteristic and conclusive. However, post-mortem examinations upon cows which have recently aborted have been all too few in number, but the phenomena presented are very uniform. We have had opportunity of making post-mortem examinations upon seven recently aborted cows and heifers, with the following results, which were in each case essentially identical:

Case 1.—A 2-year-old Hereford heifer shipped from Garden City, Kans., on May 17 to Kansas City and unloaded the following morning. It was found that during the night of May 19 she gave birth to a small, weak, live calf, at apparently about the seventh month. She was slaughtered about 11 a. m. The heifer was in good general condition and apparently healthy.

The calf, a heifer, was very weak, unable to get up or stand. Its hair was long, shaggy, and lusterless. It had the general appearance of emaciation. It measured 31 inches from occiput to base of tail and weighed 25 pounds. The buttocks were soiled from thin yellow diarrheic feces. The calf was destroyed at 10.30 a. m. by bleeding from the carotids, and the body cavity was laid open along the median ventral line. The spleen was markedly hemorrhagic. The liver was swollen, tense, glistening, and showed hemorrhagic areas. It was distinctly icteric in appearance. The heart showed hemorrhages beneath the pericardium along the groove between the ventricles.

The examination of the genital organs of the aborting heifer revealed the following changes:

The vagina was congested at the anterior portion and contained some dirty reddish-gray mucus, streaked with blood and apparently containing some pus.

The uterus measured 22 by 38 inches. Its exterior offered nothing notably abnormal. The walls were a trifle thick, dense, and opaque. The organ seemed plump, and involution apparently progressing favorably. There were no evidences of mechanical injury.

The cervical canal was dilated and its mucosa was ecchymotic (parturient contusion).

The fetal membranes were all retained. Those of the nongravid horn were edematous. Aside from the rent at the internal os through which the fetus was expelled, the membranes were intact and exhibited no trace of mechanical injury. About the internal os a few cotyledons were detached from the chorion, and all the cotyledons were readily detachable. After detachment the chorionic tufts were pale, dirty yellow, and adhesive to the fingers, like the abortion exudate. There were small interplacental hemorrhages, but nothing beyond what is usually observed in healthy gravid uteri. The inner surfaces of the amnion and allantois appeared normal and their cavaties were empty. The uterine contents were odorless.

The uterine mucosa was pale yellowish, dense, thickened, and somewhat granular in appearance.

In the utero-chorionic space of nongravid horn there was an abundant, dirty gray, flocculent, viscid, puriform exudate, quite tenacious in places, and especially abundant at the base of the horn and for 10 or 12 inches toward the apex, after which the cavity was empty.

In the gravid horn the exudate was very abundant and identical with that in the nongravid horn. It was most abundant near the internal os uteri and for a distance of 20 to 25 inches along the greater curvature, diminishing toward the apex of the horn until in that region the mucosa was approximately normal and clean.

Case 2.—A heifer apparently 2 years old and estimated at 625 pounds weight aborted in the car during transit to Kansas City. Nearly all the animals in the car were affected with ulcerative ano-vulvitis. The abortion was discovered about 9 a. m. The vagina was extensively ulcerated, cankerous-appearing, red, and bleeding at touch. The broken end of the umbilic cord lay within the vulva, appearing comparatively fresh.

The animal was killed by bleeding at 3 p. m., and the autopsy followed immediately. The uterus, vagina, and vulva were removed intact.

The uterus measured 16½ by 28 inches, was plump, firm, more opaque than a pregnant uterus, but except by careful examination would be passed as a gravid uterus with a fetus 4 to 8 inches long.

The uterine peritoneum was apparently normal and showed no visible traces of traumatism. Upon incising the uterus it was found that the fetal membranes were completely retained. A few cotyledons, in fact approximately all those in the cavity of the body of the uterus, were detached from the chorion. The chorion of the nongravid horn, except at its base, was also detached from the cotyledons. In the gravid horn the chorion was firmly adherent to the cotyledons and attempts to detach it resulted in its giving way and the chorionic tufts being more or less completely retained in the cotyledonal crypts.

The cotyledons were 2 to 3 inches in their greatest diameter and deeply injected, brownish-red in color. The intense injection extended one-half inch or more into the cortical substance of the cotyledons, after which they appeared a dirty, necrotic-like, yellowish-gray color. The cotyledons were hard, swollen, and infiltrated.

The afterbirth was retained due to cotyledonitis, which had evidently antedated the expulsion of the fetus and would probably have resulted eventually, had the heifer lived, in total necrosis and sloughing of the cotyledons. The placenta was not markedly putrid. There was but little if any fetor present. The odor was rather of an unpleasant sweetish character.

The chorionic tufts were soft, adhesive, and necrotic-looking. The tufts, where detached from the cotyledons, would stick to the fingers. The amniotic and allantoic cavities were empty except for scattering fragments of tissue débris or coagula.

The utero-chorionic cavity was filled with a puslike substance throughout its entire area. The exudate was dirty gray, flocculent, floating in thinner liquid. It wanted that adhesiveness usually observed in the abortion exudate in closed uteri. The admixture of fetal fluids had served to change the physical character of the exudate.

The uterine mucosa was inflamed, thickened, uneven, and granular in appearance. In some areas there was a dirty-gray firmly adherent exudate; in other areas the mucosa was naked, injected, inflamed, and showed petechial hemorrhages. The fetus was 28 inches from occiput to sacrum.

Case 3.—A 2-year-old heifer which had been driven a distance of 25 miles and yarded overnight in the Denver stockyards on June 2. At 7.45 a. m. June 3 she expelled an 11-inch fetus with the fetal sac complete. The heifer was slaughtered 4 hours after she aborted.

The carcass was thin and emaciated. The mammary gland was enlarged as though parturition were impending. After slaughter there escaped from the vulva one-half ounce or more of a dirty-grayish, flocculent exudate, faintly tinged with red. After the removal of the skin no traumatism of the body walls could be detected. Granular vaginitis was well marked, but not intense. The uterine walls were one-fourth of an inch thick, vascular, and petechial.

The uterine cavity, including both horns, contained 3 or 4 ounces of a dirty-looking, flocculent exudate, floating in a thin watery liquid. The clumps of exudate were somewhat viscid, and the masses were largely adherent about the pedicels of the cotyledons.

The exudate had the general appearance of that described as the typical exudate of contagious abortion, but its glutinous character had been modified by the presence in the cavity of portions of the amniotic and allantoic fluids.

The cotyledons were 1½ inches in diameter, hemorrhagic in the cortical area, and the surface was scarlet in color, like oxygenated blood. The cotyledonal crypts contained some chorionic tufts.

The chorion was edematous, one-half inch thick, and comparatively free from odor. The chorionic placental areas were pale, soft, and sticky.

Case 4.—Inoculated May 2, 1911 (10 c. c. of abortion-bacillus culture in the jugular vein), aborted May 9 and killed May 10, 1911. A few cotyledons near the internal os were scarlet. The cotyledons were covered more or less irregularly with a yellowish-gray substance resembling pus in consistency, but more yellow. This was found over the majority of the cotyledons. There was very marked edema beneath the mucosa near the internal os, and in this region were also several areas of redness.

Case 5.—Inoculated May 2, 1911 (15 c. c. of abortion-bacillus culture in the jugular vein), aborted May 28 and killed May 29, 1911. The placenta showed considerable edema. In the utero-chorionic space there was an abundance of a sticky yellowish substance in small masses 1 to 5 mm. in diameter. Some of the cotyledons were scarlet. The organism of abortion was recovered from the uterus.

Case 6.—Inoculated May 2, 1911 (15 c. c. of abortion bacillus culture in the jugular vein), aborted July 25, and killed July 26, 1911. In the utero-chorionic space there were found numerous irregular masses of a yellowish substance that tended to adhere to the chorion. This substance was in small flakelike masses varying in size from 1 to 10 mm. in diameter and from 1 to 3 mm. in thickness. It was also found around the separated cotyledons and was very much in evidence in the fundus of the uterus, where it had been washed by the fluids. A few cotyledons near the internal os were scarlet. The chorion showed slight edema throughout. The organism of abortion was recovered from the uterus.

Case 7.—Inoculated May 2, 1911 (10 c. c. of abortion bacillus culture in the jugular vein), aborted July 26, and killed July 26, 1911. The gravid horn of the placenta showed marked edema. A substance similar to that found in the utero-chorionic space of Case 6 was found, but was present here in a much smaller amount. The organism of abortion was not recovered.

The lesions recorded in the foregoing appear identical with those described as typical of contagious abortion. The uniformity with which the abortion exudate has been demonstrated in all recorded autopsies immediately following abortion in cows witnesses strongly that the abortion exudate has an essential relation in the causation of contagious abortion, and, so far as the small number of recorded autopsies can support, indicates that abortion in cows is an essentially contagious disease and that mechanical abortion is rare and negligible.

PHENOMENA WITHIN THE UTERINE CAVITY.

During our investigations we observed numerous instances where some suggestive phenomena appeared within the uterine cavity. Twenty-two of these cases presented evidences warranting the conclusion that the infection of contagious abortion was present, or (in cases where the fetus had perished and undergone more or less disintegration) that they had been infected with contagious abortion. While the cases vary somewhat in their character, they agree in a general way with each other and are in substantial accord with the lesions observed in the uteri of cows killed immediately after abortion.

Case 1.—Age four years, length of fetus 31 inches, right ovary normal, left ovary corpus luteum. Uterine seal intact. Exterior of uterus normal. The utero-chorionic space was filled throughout with an exudate of a dirty grayish color, puslike in appearance, odorless. The exudate was thickest at the cervix. The total amount of exudate was estimated at 1 gallon. The uterine walls were not materially thickened, the uterine mucosa was injected with some small, necrotic-appearing patches. The cotyledons were freely detachable, but not materially altered. The chorion appeared normal in thickness in the gravid horn, edematous in the nongravid. The uterine surface of the chorion was injected.

The allantois, amnion, and fetus were apparently normal.

Case 2.—Aged cow, fetus full term. Uterine seal intact. Upon opening the uterine cavity a yellowish-brown, tough exudate was found about the os uteri internum.

Case 3.—Aged, length of fetus 36 inches, about full term. Uterine seal softened. Utero-chorionic space contained a tough, pale yellowish-red puslike mass of exudate about the internal os. Further from the os internum, the utero-chorionic space contained much uterine sand, bright orange-colored. While the exudate extended over the entire utero-chorionic space, only that radiating from the internal os was typical of contagious abortion.

Case 4.—Aged, embryo $2\frac{1}{2}$ inches. Uterine seal absent, either unformed or broken down. Utero-chorionic space contains 10 to 12 ounces of thin, grayish-yellow purulent-like exudate. Fetus apparently normal.

Case 5.—Two-year-old, fetus 18 inches. Uterine seal softened and partly broken down at internal os, but intact and normal elsewhere. Radiating from os uteri internum in the utero-chorionic cavity for a distance of 4 inches is a tough, dirty grayish-yellow exudate.

Case 6.—Aged cow. Length of fetus 16 inches. Uterine seal intact. Abortion exudate in utero-chorionic space radiating from internal os uteri 2 to 3 inches in the nongravid and 12 to 15 inches in the gravid horn, mostly in flat, reddish-brown, tough, gluey masses 1 inch long by one-eighth inch thick. In other places the exudate is a dirty grayish yellow color, either semifluid or in tough, flat masses. The exudate is deposited chiefly about the cotyledonal stalks, especially the more primitive ones about the internal os.

Case 7.—Aged. Length of fetus, estimated 6 to 9 inches. Uterine seal destroyed. Horns 3 inches in diameter by 10 inches long, hard, tense, with sclerotic walls one-half inch. Uterine cavity contained 4 ounces of thin, brown, flocculent pus in which were masses of bones apparently from a fetus 6 to 9 inches long. Apex of right horn adherent to broad ligament. Abscess in uterine end of left oviduct containing one-eighth ounce thick yellow pus.

Case 8.—Aged. Twin pregnancy. Fetuses 9 inches, apparently long dead, macerated, dirty gray, soft, odorless.

Amniotic and allantoic fluids dirty gray, flocculent, opaque, odorless, chorion completely detached. Fetal membranes edematous, one-half inch thick. Utero-chorionic cavity filled with fluid like that in amnion and allantois.

Case 9.—Aged. Length of fetus, 30 inches. Uterine seal orange-colored and broken down. Orange-yellow, gluey masses of exudate about the internal os 1 by one-eighth inch in size.

Case 10.—Four-year old. Length of fetus, 2 inches.

The chorion of the left (nongravid) horn was detached from the right portion, necrotic, dirty grayish in color, and surrounded by a dirty-grayish fluid exudate. A tough yellowish exudate in the utero-chorionic space at internal os.

Case 11.—Aged. Fetus full term, apparently alive at time of slaughter. Exterior of uterus normal. Uterine seal apparently somewhat softened; otherwise normal.

Utero-chorionic space filled with exudate throughout, except at one point in greater curvature of the gravid horn, which appeared normal. The exudate varied in appearance, dirty reddish-gray in color, in some places collected in irregular, flat, firm, gluey masses 2 to 4 inches by one-eighth inch and at other points a semifluid, viscid mass.

The exudate was thickest about the internal os uteri, and from that point radiated out 18 inches to the apex of the nongravid horn, and 48 inches or more to the apex of the gravid horn. The gluey masses were largely adherent about the cotyledonal stalks. The chorion was markedly edematous, 1 to 2 inches thick.

Case 12.—Aged. Full-term fetus. Uterine seal intact. Utero-chorionic space filled with an abundant, tough, orange-brown, very gluey, sticky exudate, radiating out from the internal os 4 inches in the nongravid horn and 12 inches into the gravid horn, largely massed about cotyledonal stalks, but in places extending from cotyledon to cotyledon. Exudate one-fiftieth to one-twentieth of an inch thick, and in masses as much as 4 inches across.

Case 13.—Aged. Length of fetus, 20 inches. Uterine seal at internal os lemon-colored, elongated, ragged, and apparently mixed with muco-pus. Pressure on cervix caused oozing of yellowish exudate into uterine cavity. Uterine seal at os externum apparently somewhat softened, but otherwise normal.

Utero-chorionic space radiating from internal os contains a considerable amount of a thin, yellowish, puriform exudate.

Case 14.—Aged. Fetus full term. The uterine seal was normal, or slightly softened. Externally the uterus appeared normal. The entire utero-chorionic cavity of the gravid horn was covered with a layer of chocolate-colored, gluey exudate, so abundant and firm that the uterine mucosa and exterior of the chorion seemed firmly glued together between the cotyledons.

For a few square inches at the internal os the exudate is mixed with tenacious masses resembling thick, viscid pus. Similar masses to the extent of 2 to 3 ounces were in the nongravid horn, and it is quite possible that the puslike masses about the internal os emanated from the nongravid horn.

As usual, the exudate appeared largely clustered about the cotyledonal stalks, not because formed there, perhaps, but rather owing to the tendency of the cotyledons to push the uterus and chorion apart at these points and thus form room in which the exudate would tend to accumulate.

The chorion was edematous, 1 inch thick, especially in the nongravid horn.

The placentæ were readily detachable. The peripheral chorionic tufts were pale, anemic, apparently necrotic, while the deeper tufts were vascular and normal. This variation in color of chorionic tufts is essentially universal, if not normal.

Case 15.—Aged. Fetus full term. Uterine seal normal. The utero-chorionic space was filled throughout its entire area with a dark chocolate-colored gluey exudate, which was so adhesive that the separation of the chorion from the uterine mucosa required some force. Detaching the chorion from the uterus, the opposing surfaces, when macroscopically cleared of the exudate, remained sticky to the touch. The exudate was more uniformly distributed than observed in most cases, and disposed in a practically continuous sheet throughout the utero-chorionic cavity, thicker, as usual, about the cotyledonal stalks.

The uterine mucosa and uterine surface of the chorion were pinkish in color, and showed no marked discoloration, thickening, or other pathological changes.

The fetus, fetal fluids, amnion, and allantois appeared wholly normal.

The placental attachments were as usual, the placentæ readily detachable. At the periphery, as is usual, some of the chorionic tufts were withdrawn from the uterine crypts and were consequently blanched, dirty-gray in color, and soft.

Case 16.—Two-year-old. Length of fetus, 9½ inches. Uterine seal normal.

The fetal sac of the nongravid horn and of the uterine body about the internal os was necrotic.

The sac of the nongravid horn was 13 inches long, devoid of cotyledons, desiccated, yellow, flattened to one-eighth of an inch thick, twisted spirally. It lay wholly free in the horn cavity, surrounded by a dirty, viscid, yellowish-brown tough exudate, estimated at 1 ounce.

The utero-chorionic space of the gravid horn contained exudate for a distance of 6 inches from the internal os. The uterine mucosa over the involved area was pale yellowish, thickened, and roughened.

Case 17.—Aged. Fetus 38 inches long. Uterine seal intact.

Radiating from the internal os for a distance of 12 inches, the utero-chorionic cavity was filled with a brownish-yellow, very viscid pus-like exudate one-eighth to one-fourth of an inch in diameter. The fetus, amnion, and allantois were normal.

Case 18.—Aged. Length of fetus, 28 inches. Uterine seal intact.

Typical abortion exudate over entire utero-chorionic cavity. Exudate reddish-brown or light chocolate in color, in masses 1 by one-sixteenth inch, tough, sticky.

Case 19.—Aged. Length of fetus, 9 inches. Uterine seal destroyed and cervical canal dilated.

Exterior of uterus pale yellow, the walls three-eighths of an inch thick, edematous, from which the chorion was completely detached, macerated, and very fragile. Faintly sweetish odor. Utero-chorionic space filled with a thin liquid in which floated dirty-gray flocculent masses and some viscid mucus.

The fetal membranes were edematous and brownish-green.

Cotyledons 1 to 2 inches, scarlet, necrotic, and readily detachable from their stalks.

Case 20.—Aged. Length of fetus, 11 inches. Uterine seal intact.

Radiating from the internal os for 12 inches in the utero-chorionic cavity is a dirty yellowish-gray sticky exudate. Uterine mucosa injected, submucous petechiæ. The uterine walls at the apex of the gravid horn are one-half inch thick and very edematous.

Case 21.—Aged. Fetus 38 inches long. Uterine seal unbroken.

Exudate commences about 6 inches from the os uteri internum and extends to within 12 inches of apex of cornua, completely encircling it. The internal os is surrounded by thickly diffuse placentæ showing abundant inter-placental hemorrhages. Apparently the diffuse placenta and close apposition of uterus and chorion explain the absence of the exudate at this point.

The exudate is chestnut-colored, very tough, and sticky. It is collected most prominently about the cotyledonal stalks, in masses often one-half inch wide by one thirty-second to one-sixteenth inch thick. Portions of exudate lie free in cavity.

Case 22.—Aged. Fetus 36 inches long. Uterine seal intact.

Radiating from the internal os for a distance of 8 to 10 inches is a small amount of very sticky, tough, chocolate-colored exudate. Lesser quantities are observed near the apex of the gravid cornu.

The findings of Bang, McFadyean, and Stockman, along with those recorded above, seem to justify the conclusion that the abortion exudate is an essential and universal phenomenon in contagious abortion. It does not show that the presence of the abortion exudate in any stated amount must be followed by abortion, but rather that its presence imperils the life of the fetus.

AVENUE OF INFECTION.

The two natural avenues of infection suggested for cattle abortion are the genital tube and the alimentary canal. McFadyean and Stockman, and to a lesser degree Bang, consider the alimentary tract the chief avenue of infection and submit experimental evidence in which animals so exposed have aborted, or, having been killed while yet pregnant, have revealed the exudate and bacilli in the utero-chorionic cavity. They have not shown conclusively that other means of infection were eliminated. Ordinarily the experimenter could not know that the *Bacillus abortus* was not already in the utero-chorionic cavity or could not invade it through other avenues.

The infection by ingestion, as well as the experimental methods of intravenous and hypodermic inoculations, assume that the infection enters the blood and finally reaches the utero-chorionic space. But the supposed pathway by which the infection thus gains the utero-chorionic cavity is not stated. Presumably under this hypothesis the infection must pass from the blood either through the placental filter or through the inter-cotyledonal uterine mucosa.

To the hypothesis that the infection enters through the placental filter is opposed the size of the Bang organism, which is about that of the bacillus of tuberculosis, an organism which is not known to pass the placental filter. The failure of the *Bacillus abortus* to pass the placental filter is further evidenced by the investigations of McFadyean and Stockman, which show that the infection appears first in the utero-chorionic space, secondly in the the fetal fluids and the fetal alimentary canal, and lastly in the fetal blood, in reverse order to what we should expect under this hypothesis.

If the infection be introduced into the blood to escape into the utero-chorionic space through the intercotyledonal mucosa, we would expect the invasion to occur indifferently at any, and perhaps multiple points. A study of the location of the recorded lesions on pages 44–47 denies this.

Originally Bang held that the genital canal was the avenue of infection, in which case any phenomena resulting from the invasion should normally begin at the internal os and radiate therefrom forward. This is precisely what occurs with great uniformity. No recorded case presents evidence to the contrary.

It has been noted on page 23 that the uterine cavity normally becomes hermetically sealed when the embryo is one-half inch in length. The state of the uterine seal was closely observed, especially for any indications of changes from bacterial invasion. At no time when the uterine cavity was healthy were we able to note any sign of injury, mechanical or bacterial, to its outer or vaginal end nor in its central portion, regardless of the presence of muco-pus in the vagina, or of well-marked chronic vaginitis or other lesions, but in those cases where the fetus had died prior to the slaughter of the mother the uterine seal showed more or less complete disintegration. When the abortion exudate was present, the uterine end of the seal was stained, softened, and undergoing solution. Ità ppears to us, therefore, that the infection of contagious abortion not only enters the uterine cavity through the cervical canal, but precedes the formation of the uterine seal. We believe that as a rule the infection is present in the genital tract in cows and in virgin heifers prior to breeding.

Six 3-year-old heifers were subjected by us to an experiment. Three had calved once each; the other three were virgin heifers. For a few weeks prior to breeding, the genitalia of the six heifers and the bull were washed occasionally. After breeding, each received in the jugular vein vigorous cultures of the Bang abortion bacillus, with the following results:

1. First pregnancy. Bred May 5, 1911. Inoculated July 6, 1911 (10 c. c. in the jugular vein). Killed January 3, 1912. Uterine seal intact. Maternal and fetal membranes clean and normal. Abortion organism not found.

2. First pregnancy. Bred April 20, 1911. Inoculated July 6, 1911 (10 c. c. in the jugular vein). Killed November 14, 1911. Over the placenta from the internal os anteriorly for a distance of 10 inches there was a yellowish-white, nonodorous, pasty substance that adhered closely to the placental membrane. This substance was also found in thick rings immediately surrounding the cotyledons. The cotyledons were scarlet. Abortion organism found.

3. First pregnancy. Bred April 14, 1911. Inoculated July 6, 1911 (10 c. c. in the jugular vein). Killed October 25, 1911. All fetal and maternal structures appeared clean and normal. Abortion organism not found.

4. Second pregnancy. Inoculated January 30, 1911 (20 c. c. in the jugular vein). Killed August 10, 192 days after inoculation. Uterine seal intact; chorion, uterus, fetal membranes, and fetus normal; chorionic cavity empty. No abortion bacilli recognized microscopically or culturally.

5. Second pregnancy. Inoculated July 6, 1911 (7 c. c. in the jugular vein). Died August 2, 1911, of generalized tuberculosis. Fetus 5 inches in length. All fetal and genital structures appeared clean and normal.

6. Second pregnancy. Bred April 1, 1911. Inoculated July 6, 1911 (10 c. c. in the jugular vein). Killed November 6, 1911. All fetal and genital structures clean and healthy. Abortion organism not found.

It seemed that in these experiments strong evidence was brought forth to indicate that a very cursory, intermittent washing of the vagina of the heifer, guarding the cervical canal against invasion, and of the sheath of the bull prior to breeding exerted a very marked influence upon the question of abortion. The heifers occupied the same field where five adult cows aborted, and had every opportunity to take the infection into the alimentary tract.

These and other observations compel us to believe also that if, prior to breeding, the granular venereal disease be reduced to a minimum by repeated disinfection, and the cow is then bred to a clean bull, abortion is not probable, even with intravenous inoculation with abortion bacilli and with ample opportunity for natural infection by the alimentary tract or otherwise.

The amount of the abortion exudate in the uterus varies widely, from the mass 1 inch across at the internal os as recorded in one case by McFadyean and Stockman, to the complete invasion of the utero-chorionic cavity, but apparently abortion follows only in very extensive or complete invasion.

THE CONTROL OF CONTAGIOUS ABORTION.

If we accept the belief championed especially by McFadyean and Stockman, that the organisms may invade the uterus at any epoch of pregnancy or before conception, that the chief avenue of infection is the alimentary canal; that as shown by the agglutination and complement-fixation tests, the infection is in well nigh every herd;

that the organism is present in the milk of many herds; and that vaginal discharges, feces, and milk must contaminate the food of almost all cattle, the outlook for the control of abortion becomes discouraging, if not hopeless.

On the other hand, if we accept the original view of Bang that the cervical canal is the usual avenue of invasion of the uterus, or adopt our own view that it is essentially the sole avenue and that the invasion must always occur prior to the sealing of the uterus, the outlook becomes somewhat more favorable, though still a formidable task.

The history of attempts to control contagious abortion is everywhere strewn with disappointment, and has opened a rich field for much of the boldest quackery every practiced upon breeders. If our views are correct, the presence of an aborting cow amongst pregnant cows can have no danger because, if the utero-chorionic space in the uteri of the pregnant animals is clean and the uterine seal is normal, any infection eliminated by the aborting animal can not reach the uterine cavity of a neighboring healthy cow. Common decency, however, in the production of milk dictates that aborted fetuses should be promptly removed in a sanitary manner and aborters having retained placenta or vaginal discharges should be excluded from the dairy till healed, and that soiled stalls or gutters should be cleaned.

Repressive laws against contagious abortion in cattle have been proposed by various veterinarians, involving compulsory reporting of outbreaks, quarantine of infected herds, exclusion of affected animals from cattle shows, etc. So far as we know, no such laws have ever been put in force. The wide dissemination of the disease, its insidiousness, the uncertainty of its diagnosis, and other difficulties make the application of such laws impracticable.

The sale of aborting animals has been largely practiced by some breeders and dairymen. It is a wasteful and hopeless process. Our data indicate that 25 to 50 per cent of all cows ultimately abort once, so that the dispersal process is an economic waste and it fails to check abortion.

It has generally been claimed that one abortion affords a large degree of immunity. This is, according to our data, wholly erroneous. The idea that one or two abortions should confer immunity against future abortions is contrary to reason. It is the live mother and not the dead fetus which needs to be immunized. There is no more reason why a cow which has aborted shall thereby acquire an immunity than that one which gives birth prematurely to a calf because of the infection of contagious abortion in her uterus should become immune, or that a cow suffering from retained placenta from abortion infection, although the calf be carried full time and born healthy, should be immune.

In one herd during a period of 10 years 61 heifers were bred on the premises for the first time, of which 3, or 5 per cent, failed to conceive and 58 became pregnant. Among the 58 heifers in first pregnancy 21 animals, or 36 per cent, aborted or calved prematurely. Nine of the 21 aborting in first pregnancy did not conceive a second time. Ten, or 48 per cent, of the heifers aborting during first pregnancy had reached, at the date of compilation, the termination of second pregnancy with two abortions (20 per cent). Thirty-seven heifers calved from their first pregnancy, of which 25 (67 per cent) had terminated their second pregnancy at the date of compilation. Of these 25, 4 (16 per cent) aborted.

One of the four heifers which calved from the first pregnancy and aborted from the second had retained placenta, which should be accepted as indicating that the abortion infection had then seriously invaded the pregnant uterus. Adding her to the first group of 10 heifers which aborted during first pregnancy and conceived again, we have a total of 11, with 3 abortions, making 27 per cent of heifers aborting during first pregnancy and reaborting during second pregnancy. If we deduct this heifer from the group calving normally from the first pregnancy and aborting during the second, the total is reduced to 24 animals, of which 3 (12 per cent) aborted. In other words, the vital statistics of this herd indicate that a heifer which has aborted or given birth to a premature calf or in which calving has been complicated by retained placenta is more than twice as liable to abort during her second pregnancy as is a heifer which has calved normally from her first pregnancy.

The statement is frequently heard that after two abortions a marked immunity is acquired. Our data emphatically contradicts this. Few cows ever conceive after a second abortion. A large proportion of them succumb to metritis (placentitis with retained placenta), many fail to breed again, and many others are sold to the butcher or are otherwise excluded from the herd.

Regarding premature birth and retained placenta as equivalents of abortion, 4 animals in the herd aborted twice or oftener. Of these 4 reaborters, one was sold after the second abortion, another was sterile for a year and then bred regularly, the third bred regularly for seven years. The fourth cow aborted her first pregnancy and had retained placenta, her second pregnancy resulted the same; she was sterile her third breeding year; gave a premature birth with retained placenta her fourth breeding year; and a calf and retained placenta and fetal metritis in her fifth breeding year. The common belief that abortion induces immunity to future abortions is one of the most unfortunate errors which has been allowed to creep into the question of abortion in cattle. One abortion predisposes to reabortion.

Our data show that the immunity following abortion is not the immunity ordinarily following recovery from an acute contagious malady, but on the contrary is what we may designate age immunity. The animal has with age acquired a higher degree of resistance to abortion than she enjoyed as a heifer.

In view of the facts thus far elicited, it is doubly inexpedient to fight abortion by selling aborters. If there is truth in the belief that an animal from a herd where abortion is virulent may introduce a more highly virulent strain of infection into another herd, it is evidently wrong to sell such animals. The greatest objection to the selling plan for the control of abortion is that it causes a serious and needless drain upon the herd. As already stated, the resistance to abortion increases with age. If an aborter will again breed, she has in the meantime aged one year, has acquired increased resistance, and is on the whole a safer breeder than the previous year. Moreover, if properly handled at the time of aborting, as Bang early pointed out, the danger from reaborting may be very largely eliminated.

McFadyean and Stockman and others suggest the possibility or probability of establishing an efficient immunity through the use of biological products (abortins, bacterins), but the investigations in this direction have not yet afforded definite results. Nor can we see hope that the plan will succeed. Apparently their hopes are predicated upon an alleged natural immunity following one or two abortions. If our data are correct, the power to control abortion by this means is predicated upon our ability to induce an artificial immunity in a chronic disease incapable itself of producing natural immunity.

Sven Wall, Holth, and others have enthusiastically embraced the hypothesis that the disease may be controlled by isolating the infected animals with the aid of the agglutination, complement-fixation, or other laboratory tests, but a glance at their investigations intimates that a very large percentage of animals would need to be isolated, a large proportion of herds would have to install the method, and it is not yet determined that success would follow. The outlook at present is that the isolation would prove well-nigh as great an economic burden as the malady.

Brauer suggested many years ago the hypodermic administration of carbolic acid as a preventive for abortion, and many have had apparently good results, but there seems to be no great reason for accepting the alleged results as more than apparent.

Much has been claimed for vaginal disinfection of pregnant animals, but this plan has not been supported by conclusive evidence.

Our conclusion that the infection enters the uterine cavity through the cervical canal prior to or very soon after conception leads us to advise the thorough douching of the vagina for a time before and immediately following breeding. It is recommended to use for this purpose warm, feebly disinfecting solutions, such as 0.5 per cent bacterol, lysol, cresol compound, or other soapy coal-tar disinfectant. The soapy character tends better to dissolve the mucus in the vagina and cleanse the membrane more efficiently. More recently we have been using 0.25 or 0.5 per cent Lugol's solution, with apparently most excellent results. The solution should be introduced into the vagina at about the normal body temperature, 100° to 105° F. The vagina should be filled, in order that it may be fully dilated, the folds of mucosa obliterated, and the solution brought into contact with every part. It is best introduced by means of a gravity apparatus in the form of a 5-gallon vessel for medium or large herds, armed with a stopcock at the bottom, to which is attached a pure gum horse stomach tube. The vessel should then be suspended upon a manure or food track, or upon a special wire track by means of a pulley, so that it may be easily moved along behind the row of cows.

The horse stomach tube is introduced through the vulva into the vagina, and the fluid is allowed to enter the vagina by gravity.

The bull is to be handled in the same manner. The solution should be applied before and after each service by a similar, though smaller, gravity apparatus with a pure gum horse catheter for introduction into the sheath. While the fluid is passing into the sheath, the operator should prevent its escape by pressure upon the outlet until every part is well dilated and all mucous folds obliterated, so that the solution comes into contact with every portion of the mucous membrane.

The cleansing and disinfection of the genital organs of dairy cows should have a more important place in dairying than the prevention of abortion and sterility alone. Clean milk is well-nigh impossible from cows having vulvo-vaginal discharges which soil the tail, buttocks, and thighs. With the wide distribution of the granular venereal disease, as we have pointed out, a vulvar discharge from young cows is the rule, and so uniform a rule that it is commonly regarded as normal, although such discharges are not usually observed in other domestic animals. We accordingly hold that the disinfection of the vaginæ of dairy cows at intervals of three or four days should be made a rule of practice by dairymen who desire to be known as producing clean milk, while our experience has amply convinced us that the plan is economically sound in keeping the cows in better health.

Immediately after cows have calved or aborted, if there be retained placenta or uterine discharge, the uterine cavity should be at once carefully disinfected and the disinfection repeated once or twice daily so long as the cervical canal is freely open, in order to overcome the infection present and thereby do all possible to prevent sterility and to avoid abortion during the next pregnancy.

The proposed method of handling abortion and sterility is merely repressive, however important. We do not hope thereby to eliminate either abortion or the granular venereal disease from the herd, but only that we shall be able, at a justifiable cost, to reduce the losses from abortion and sterility. Accepting the infections of the genital tract as permanent, any measures against them should have a similar continuity and be accepted as one of the elements in the operation of dairying.

THE PRODUCTION OF SOUND HERDS.

Abortion and sterility are not alone in reducing the efficiency in dairying and breeding herds. In many herds similar losses occur from calf scours and pneumonia and from tuberculosis. These three great dairy scourges cause their chief devastation in the young. Scours and pneumonia destroy most of their victims during the first few weeks after birth. Abortion and sterility play their greatest havoc among cows and heifers 2 to 4 years old. Tuberculosis largely has its origin through the food of the calf, or the heifer becomes affected during her first years in the dairy. If cattle breeding and dairying are to be placed upon a more secure basis, it is first of all essential to maintain in health the new-born calves.

Calf scours and pneumonia have been sufficiently investigated that their nature is well enough known to undertake prevention with a reasonable measure of confidence. A method has been pointed out and its feasibility demonstrated whereby calves may be raised free from tuberculosis in spite of tuberculous parents. The measures advisable for the repression and prevention of these can be made to answer in large measure for the control of abortion and sterility, and any needed additions to the sanitary measures for the control of abortion would add to the efficiency of the measures relating to the other maladies.

The maternity and calf stables of our larger dairies and more important breeding herds constitute the fundamental source of the chief losses amongst dairy cattle. It is a notable fact that in many of our highest class, or highest classed, dairies the dairy stables are extravagantly well built, while the maternity and calf barns are disgraceful old ramshackles, more worthy of being called pest houses. The control of dairy plagues must begin and be most exact with the newborn calf when it is most vulnerable to disease, and in large dairy and breeding establishments the proper handling of the cow at the time of parturition and the care of the newborn calf should have first place in the entire scheme.

The infections causing calf scours and pneumonia, abortion and sterility, and tuberculosis are so thoroughly disseminated that for practical purposes, with some exceptions in relation to tuberculosis, all cows should be regarded as suspicious and all newborn calves treated as being in danger of exposure to the infection of any or all of these dairy plagues.

While the prospect for preventing abortion (and sterility) appears quite feasible, in the present state of our knowledge we can lay down no reliable means for wholly avoiding the infection of the granular venereal disease. If we accept the hypothesis of any recorded investigator or group of investigators, we have as yet no more promising method of getting a herd free from abortion than by taking the newborn calf and guarding it perpetually. The plan can at most be criticized only as beginning too early, because the fight against abortion might be delayed for economic reasons until the animal has reached the age of 6 to 12 months, when, according to Bang, McFadyean and Stockman, and others, they may take the bacilli in their food, and the infection lie in wait until pregnancy affords fuel for a conflagration. In the meantime the isolation is needed because of scours and pneumonia and tuberculosis, and while these two are being evaded the third may be simultaneously parried. The growing of sound calves in relation to the three scourges named appeals to us as the most interesting and urgent problem before the cattle breeder. In order to accomplish results radical changes in the handling of newborn calves must be established. Maternity and calf buildings must meet fully all demands for light, air, and temperature, and to these must be added practicability of thorough cleansing.

A PLAN FOR BREEDING SOUND ANIMALS.

We would outline the following plan for the breeders of pedigreed and valuable dairy cattle with a view to the production of cleaner and more efficient herds.

1. The construction or arrangement of independent maternity and calf nursery stables embodying all modern requirements for ventilation, light, heat, convenience for disinfection, and ample facilities for the exclusion of flies. The stables should provide sufficient individual stalls for all calving cows and individual stalls for calves until at least three months old.

2. A cow which is about to calve should be well cleaned and her posterior parts disinfected, after which she should be placed in a clean stall some days prior to expected parturition. Pending parturition the stall should be kept scrupulously clean and well disinfected. The tail, vulva, buttocks, and udder should be disinfected twice daily. In order to avoid the danger of infection to the calf while passing through the vagina of the cow during birth either by the infection of white scours, the granular venereal disease, or other malady, the vagina should be irrigated daily with a mild disinfectant such as 0.5 per cent Lugol's solution. Such attention to the vagina also tends

to carry away any infections within the vagina which immediately after the opening of the cervical canal of the uterus at the time of calving may otherwise drop into the uterine cavity and there establish disease.

3. When the calf is born it should be received upon a clean antiseptic sheet and at once carried to a clean calf stall and rubbed dry. If it is desired to allow the calf to remain temporarily with the cow, great care should be taken to see that the bedding is kept clean.

After the calf has been dried, if not earlier, the stump of the navel cord should be disinfected. It should not be ligated. Prepare a warm 1 to 1,000 solution of corrosive sublimate, fill a goblet or cup with it, and, having the calf held in a standing position, press the vessel against the floor of the belly so that the stump of the navel cord is submerged in the disinfecting fluid. Retain it in this position for at least 10 minutes. Immediately afterwards dust the stump of the cord over liberally with a disinfecting desiccating powder, as alum and camphor, and repeat every 30 minutes until the stump is dry.

The body openings (mouth, nostrils, vulva of heifer, and sheath of bull calf) should be disinfected with a 0.5 per cent Lugol's solution.

4. Prior to drawing milk from the dam or other cow for feeding the calf, or permitting the calf to suck, the udder and adjacent parts of the cow should be thoroughly disinfected. The milk should be drawn in a sterile vessel under the strictest cleanliness. If the milk is from a cow not known to be free from tuberculosis, it should be sterilized before feeding. Individual feeding vessels should be used and regularly sterilized.

When calves have reached 3 months of age, it may usually be fairly determined if they are free from disease, in which case they may be handled in groups. These, however, should be kept as small as economically practicable until the heifers have calved and are ready for the dairy. Even then the larger the number of animals in one stable the greater the risk of infection and the more destructive will it be if it gains entrance.

5. When breeding time for the heifer grown under the foregoing conditions is approaching, we would advise that her vagina be douched once daily for at least three weeks before breeding, at first with a 0.5 per cent Lugol's solution, and thereafter each second day with a 0.25 per cent solution. The douching should extend over at least one estrual period, or 21 days prior to breeding, and followed for an equal time after breeding, or until it is determined she is pregnant. The bull should preferably have been grown in the same manner as the heifers he is to serve and his genitals douched in a similar way.

CONCLUSIONS.

1. Abortion in cattle is essentially always the result of a chronic infection within the utero-chorionic space, revealing itself postmortem by the presence of the so-called abortion exudate, which contains generally, if not always, the abortion bacilli.

2. The granular venereal disease of cattle is, so far as known, universally distributed. From clinical observation it has a vital relation to contagious abortion. It is incurable in the present state of our knowledge, but may be greatly decreased in virulence.

3. Contagious abortion of cattle has attained an essentially universal distribution, frequently present merely as an unrecognized infection of the genital organs, not inducing actual abortion but causing premature birth, retained afterbirth, and sterility.

4. The ordinary if not sole avenue of the entrance of the infection of contagious abortion is the genital canal, and the invasion antedates the sealing of the uterus, which ordinarily occurs within 30 days after conception.

5. When conception has occurred and the cervical canal has been sealed, the fate of the fetus is settled. If a sufficiently virulent and voluminous infection exists in the utero-chorionic space, abortion may result; if such infection does not exist within the sealed utero-chorionic space when the formation of the seal is completed, it will not enter thereafter during pregnancy.

6. In the present state of our knowledge little or nothing can be done to prevent abortion once the pregnant uterus is sealed and the infection of contagious abortion exists within the hermetically sealed cavity.

7. By systematic disinfection of the genitalia immediately following abortion or premature birth, and also in retained afterbirth and kindred infections of the uterus, the affected animals may be largely guarded against future sterility and abortion. It is even more important that the vaginæ of heifers, whether virgin or previously bred, and cows shall be systematically disinfected for a period before and after breeding, until conception is assured.

8. It is equally important that the genital organs of breeding bulls be kept clean by regular disinfection, including washing immediately prior to and after service.

9. Most important of all, breeders of valuable cattle should institute definite, energetic, and permanent efforts to guard new-born calves simultaneously against the three great dairy scourges—calf scours and pneumonia, abortion and sterility, and tuberculosis.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 107

Contribution from the Bureau of Biological Survey, Henry W. Henshaw, Chief.
July 27, 1914.

(PROFESSIONAL PAPER.)

BIRDS IN RELATION TO THE ALFALFA WEEVIL.

By E. R. Kalmbach, *Assistant Biologist.*

INTRODUCTION.

The alfalfa weevil (*Phytonomus posticus* Gyll.), a pest introduced into the United States, has for several years been doing enormous damage to alfalfa crops in Utah. On invitation of and in cooperation with the Bureau of Entomology, the Biological Survey therefore undertook to ascertain the part played by birds and mammals in checking the increase of the weevil. Accordingly the writer spent from May 8 to July 25, 1911, and from April 1 to August 15, 1912, at various points in the infested region, investigating the food habits of local birds and of a few batrachians and other vertebrates. This bulletin chiefly considers the food habits of birds, but facts concerning the economic status of other vertebrates also are included.

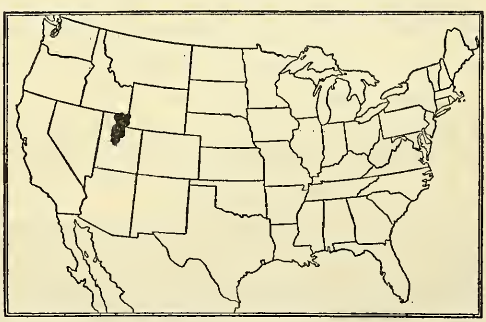


Fig. 1.—Known distribution of the alfalfa weevil (*Phytonomus posticus*), May 1, 1914. (Map by Bureau of Entomology.)

IMPORTATION AND SPREAD OF THE ALFALFA WEEVIL IN UTAH.

The time and method of initial introduction of the alfalfa weevil into Utah is unknown, but the first serious damage was noted in the spring of 1904, when a small infestation a few miles southeast of Salt Lake City was discovered. From this foothold the weevil spread and by September, 1911, had extended as far north as Tremonton,

Note.—This bulletin discusses the food habits and economic status of birds, and of the toad, frog, and a few other vertebrate enemies of the alfalfa weevil in Utah.

Utah, east to Evanston, Almy, and Lyman, Wyo., and northeast to Cokeville, Wyo., Randolph and Laketown, Utah, and Fish Haven, Idaho.[1]

An insect must become fairly common before it can form an appreciable portion of the food of birds; in most of the area covered by the writer's investigations the weevil probably had not become abundant until 1907 or 1908, and doubtless had not attracted the attention of birds much before that time. Thus any preference shown by birds for this character of food was necessarily acquired in the short period of four or five years.

LIFE HISTORY OF THE WEEVIL.[2]

The alfalfa weevil is a small snout beetle a little less than one-fourth inch in length, and when it appears in spring its color is very dark brown or black. It passes the winter in the adult stage, protected under piles of rubbish, in vegetation along ditch banks, the base of haystacks, etc. The beetles soon become active, and on fair, warm days may be found flying, sometimes in considerable numbers, when some fall prey to the earlier arrivals among the flycatchers and swallows. At this time of year the numbers are at the lowest ebb, since comparatively few survive the rigors of winter and live to perpetuate the race.

The seasonal activities of the insect are influenced strongly by temperature. In normal years many eggs are laid by the first of April and the bulk before the middle of June, but the process may continue as late as July.

From 10 to 12 days elapse before hatching. The pale, newly hatched larvæ soon work their way to the tender leaves and growing buds at the top of stalks, where for some time they may easily escape the notice even of birds, being of such minute size and confining their early feeding to the inner folds of the leaves. At first the larvæ restrict their depredations to the more succulent portions of the foliage, but by the time they have become full sized they feed anywhere upon the plant where green leaves remain.

The larvæ become full-grown in from 20 to 60 days, and during this time they pass through three stages. When fully developed they are about one-fourth of an inch long, of a bright green color, and have a conspicuous white stripe down the back. A paler stripe on each side and the black head aid in distinguishing it from other larvæ.

---

[1] Webster, F. M., Bull. 112, Bu. of Entomology, U. S. Dept. of Agr., May, 1912.

[2] The entomological data here given are from Bull. 112 of the Bu. of Entomology, U. S. Dept. of Agr., by F. M. Webster, and Bull. 110, Utah Agr. Coll. Exp. Sta., by E. G. Titus.

In the Salt Lake Valley the bulk of the larvæ appear in May and June, but at higher altitudes somewhat later. The period of greatest abundance is at the time of the first alfalfa harvest. The insects usually make heavy inroads on the first crop and after the harvest do serious harm by retarding the growth of the second crop. All new shoots are devoured as soon as they appear, and a field frequently remains barren for three to five weeks after the first cutting.

When full-grown the larvæ cease feeding, drop to the ground, and spin rather loosely woven cocoons, which are often attached to dry vegetation at the base of the plant. The insect now passes through the pupal stage and in from one to two weeks emerges as the adult. In this stage it is covered with many fine scales or hairs which give it a light brown color. The adults begin to appear in large numbers about the first of July and may often be found clustering by hundreds upon vegetation about the borders of recently cut fields or near the bases of newly constructed haystacks. Frequently they feed upon the foliage and scar the stems of plants other than the Leguminosæ; the writer has seen healthy amaranth plants laid prostrate in a comparatively few hours.

After a short period of flight, when again some may fall prey to birds that feed on the wing, the insects seek hidden places for the winter's hibernation. Beginning soon after early August the weevils appear less in evidence.

DISTRIBUTION OF WEEVIL-EATING BIRDS IN THE TERRITORY COVERED BY FIELD WORK.

The following somewhat general synopsis of the distribution and relative abundance in Utah of native birds will give a fair idea of the species most available as aids in the fight against the alfalfa weevil. This, combined with details regarding each species, as later presented, will show which birds are doing the most good in any locality.

One of the regions most severely infested by the weevil was that immediately south and southwest of Salt Lake City, extending east and west to the edge of the irrigated land. This has an average width of 4 miles and through it flows the Jordan River. In this area the English sparrow is the most abundant bird. Next comes Brewer's blackbird and in smaller numbers are the red-winged blackbirds, which confine the bulk of their feeding to the vicinity of marshes along the river or places where lack of drainage has produced ponds. Following these are Brewer's, vesper, and lark sparrows, and meadowlarks. Robins, though very numerous in migration, are not so frequently met at a later date. The remaining common birds, named approximately in the order of their abundance, are the rough-winged swallow, house finch, killdeer, horned lark, Arkansas kingbird, mourning dove, California quail, Bullock's oriole, black-headed grosbeak, cowbird, and yellow-headed blackbird.

A bird population differing in relative numbers from that of the region just described is found in Davis County, lying to the north of Salt Lake City and extending from the Wasatch Mountains to the Lake. As the area is narrow (at Farmington only about 4 or 5 miles wide), and is bordered on one side by the foothills and on the other by the barren flats of Great Salt Lake, a great variety of bird life may be found on a single farm. The English sparrow is not so plentiful, Brewer's blackbird being the most abundant species, but nearer the Lake the red-wings and yellow-heads vie with it for supremacy in numbers. California gulls sometimes occur in flocks of several hundred, especially where land is being cultivated. Magpies also are conspicuous and breed extensively in trees growing along creeks. The other species previously mentioned maintain about the same relative abundance, except that robins, Arkansas kingbirds, and other flycatchers are somewhat more numerous.

In the valley of the Weber the number of species is more limited, but there is no dearth of individuals. Here, as well as along Chalk Creek, which flows into the Weber, irrigated fields border the river in a long narrow strip, 1 to 2 miles wide. Bird life has segregated itself in these fields, while large numbers of birds which build in the sagebrush of the surrounding hills secure the bulk of food for themselves and their young in the lower, more fertile, tracts.

A "bench" lying to the east of this section and at some distance from the river afforded similar conditions and proved a most excellent feeding area for a number of more or less desert species dwelling on the sides of adjacent hills. Brewer's blackbirds were the most abundant, while along the upper borders of these fields and on the "bench" Brewer's, vesper, chipping, lark, and savannah sparrows appeared in great numbers. The green-tailed towhee, sage thrasher, and mountain bluebird also were present. On the lower fields robins were very numerous and bobolinks not uncommon, but no English sparrows were found.

The section about Alpine and American Fork, in Utah County, presented an avifauna very similar to that immediately south of Salt Lake City.

BIRDS FEEDING ON THE WEEVIL.

The following list includes all of the important bird enemies of the alfalfa weevil. Probably some spring migrants pick up a few while passing and some resident species, whose ordinary habits and food preferences would seem to preclude them from being enemies of the weevil, may occasionally feed on them. In the two seasons' work 45 species of birds were found to have eaten the insect, as follows:

California gull (*Larus californicus*).
Wilson's phalarope (*Steganopus tricolor*).
Killdeer (*Oxyechus vociferus*).
Valley quail (*Lophortyx californica vallicola*).
Western mourning dove (*Zenaidura macroura marginella*).
Red-shafted flicker (*Colaptes cafer collari*
Arkansas kingbird (*Tyrannus verticalis*).
Say's phœbe (*Sayornis sayus*).
Traill's flycatcher (*Empidonax trailli trailli*).
Desert horned lark (*Otocoris alpestris leucolæma*).
Magpie (*Pica pica hudsonia*).
Long-crested jay (*Cyanocitta stelleri diademata*).
Woodhouse's jay (*Aphelocoma woodhousei*).
Bobolink (*Dolichonyx oryzivorus*).
Cowbird (*Molothrus ater ater*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Thick-billed redwing (*Agelaius phœniceus fortis*).
Western meadowlark (*Sturnella neglecta*).
Bullock's oriole (*Icterus bullocki*).
Brewer's blackbird (*Euphagus cyanocephalus*).
House finch (*Carpodacus mexicanus frontalis*).
Pine siskin (*Spinus pinus*).
Western vesper sparrow (*Poœcetes grammineus confinis*).
Western savannah sparrow (*Passerculus sandwichensis alaudinus*).
Western lark sparrow (*Chondestes grammacus strigatus*).
White-crowned sparrow (*Zonotrichia leucophrys leucophrys*).
Western chipping sparrow (*Spizella passerina arizonæ*).
Brewer's sparrow (*Spizella breweri*).
Desert song sparrow (*Melospiza melodia fallax*).
Lincoln's sparrow (*Melospiza lincolni lincolni*).
Spurred towhee (*Pipilo maculatus montanus*).
Green-tailed towhee (*Oreospiza chlorura*).
Black-headed grosbeak (*Zamelodia melanocephala*).
Lazuli bunting (*Passerina amœna*).
Cliff swallow (*Petrochelidon lunifrons lunifrons*).
Bank swallow (*Riparia riparia*).
Rough-winged swallow (*Stelgidopteryx serripennis*).
Yellow warbler (*Dendroica æstiva æstiva*).
Macgillivray's warbler (*Oporornis tolmiei*).
Long-tailed chat (*Icteria virens longicauda*).
Sage thrasher (*Oreoscoptes montanus*).
Long-tailed chickadee (*Penthestes atricapillus septentrionalis*).
Western robin (*Planesticus migratorius propinquus*).
Mountain bluebird (*Sialia currucoides*).
English sparrow (*Passer domesticus*).

CALIFORNIA GULL.

(*Larus californicus.*)

No bird in the Salt Lake Valley is held in so great esteem by the people of Utah as the California gull. On numerous occasions in spring the writer witnessed the work of this bird on alfalfa fields, where it was common to see 200 to 300 following a harrow or plow in search of grubs, cutworms, and other insects turned up. Only five gulls were examined, and all but one were from badly infested alfalfa fields. In the stomach of only one was the weevil found.

Other prey, such as earthworms, ground beetles, and fly larvæ, seemed more attractive than the weevil to these birds. Apparently some had recently been feeding on the barren alkali flats surrounding Great Salt Lake. In one stomach were about 450 of the small carabid beetle (*Pogonus planatus*), so common about the decayed bodies of waterfowl which have died of disease in the vicinity of the Jordan River marsh, and in another were large numbers of pupæ of the alkali fly (*Ephydra gracilis*).

Though the California gull is one of the most valuable of Utah birds, as a weevil destroyer it is unimportant. However, so important are its services in other directions that it deserves the careful protection it receives.

WILSON'S PHALAROPE.

(*Steganopus tricolor.*)

A single stomach of Wilson's phalarope was examined, and the remains of one adult weevil were detected. Wilson's phalarope, however, can not be expected to render much service as a weevil destroyer, as its feeding habits restrict it largely to the immediate vicinity of lake shores and river banks.

KILLDEER.

(*Oxyechus vociferus.*)

The killdeer is found everywhere in the Salt Lake Valley, even to the upper edges of watered lands, where the highest irrigating ditches supply it with all the aquatic environment it needs. However, it appears to be more widely scattered in the spring than later in the season, when more are found about Great Salt Lake and along the Jordan River. Irrigation on an alfalfa field is always a great attraction, and in such situations as many as six or eight of these birds may be found in a field of three to four acres. Cutworms here fall easy prey.

Nineteen killdeers were examined, six of which were obtained in April. The weevil, aggregating 3.5 per cent of the food, was found in five of the six taken in that month. In each case the adult form was eaten and was found on an average of $4\frac{3}{5}$ per stomach.

Caterpillars (cutworms in some cases) constituted nearly 37 per cent of the food, and ground beetles came next with a percentage of 19.3. A large quantity of aquatic beetles in one stomach brought the monthly average of this food up to nearly 9 per cent, while carrion beetles (Silphidæ and Staphylinidæ), click beetles, dung beetles (*Aphodius*), and weevils other than *Phytonomus* were frequent constituents of the remaining animal food. The vegetable portion was either weed seeds or rubbish.

Three of five killdeers obtained in May had fed on the weevil to the extent of over 36 per cent of the food. In one, these insects composed the entire contents, save a trace of darkling and ground beetles. It required no less than 40 adults and 1 larva of the weevil to satisfy this bird's appetite. Another had eaten 18 adults.

Of the other food taken during May, spiders, ground beetles, aquatic beetles, flies, bees, and wasps occurred in quantities decreasing in the order named. The high proportion of spiders recorded was the result of one of the birds having fed on them almost exclusively. A few grain hulls in one stomach probably came from waste material.

The food for June, as learned from examination of eight stomachs, gives a good idea of what may be expected of the killdeer under favorable conditions. The weevil formed nearly a third of the monthly food, and was present in all of the stomachs but one. Of two birds which had destroyed surprisingly large numbers of the insect, one, from a newly cut field, had eaten 9 adults and 307 larvæ, and the other, feeding under similar conditions, had made away with 7 adults and 376 larvæ. A third had taken 42 larvæ and 1 adult.

Of other animal food items for this month ground beetles occurred in the greatest quantity. They were present in 6 of the 8 stomachs and comprised over 15 per cent of the monthly food. Snails were eaten extensively by two of the birds. Darkling beetles of the genus *Blapstinus* were frequently taken and formed nearly 11 per cent of the stomach contents. Dung beetles (*Aphodius*), bill bugs (*Sphenophorus* sp.), caterpillars, and wasps were other common ingredients. The vegetable portion was again unimportant, consisting entirely of weed seeds and rubbish.

The killdeer in no part of its extensive range is known to injure farm produce. The worst that can be said of it is that in its indiscriminate destruction of insects it may pick up a few that are beneficial. These, however, form an extremely small proportion of the bird's fare, while serious pests, as mosquitoes, craneflies, grasshoppers, and weevils of various kinds, are frequent components of its food. In addition to this already exceptional record, the killdeer must be considered as one of the most effective destroyers of alfalfa weevils. In early spring the birds are frequent visitors of infested fields, where many breeding weevils fall victims to the birds' voracity. The killdeer has been rightly removed from the class of game birds, where formerly it could be shot throughout much of its range. It may now continue its good work unmolested.

VALLEY QUAIL.

(*Lophortyx californica vallicola.*)

The valley quail, common in the irrigated portion of Salt Lake Valley, is frequently seen about alfalfa fields. Though a little shy in such environment, it appears to be perfectly at home and succeeds in raising broods wherever it finds sufficient cover. An open season is maintained for taking this bird during the month of October in the counties of San Pete, Uinta, Salt Lake, Davis, Weber, Utah, Sevier, and Carbon, while in some of the less densely populated sections a longer season is provided.

The valley quail has a good record as a weevil destroyer, based on a limited amount of material, but examination of it gives a fair idea of what can be expected of this bird. One was obtained in May and four in June. In the stomach of each the weevil was present in very large numbers, and in only one did the insects number less than 100 individuals in various stages of development. The five birds had eaten, respectively, 165 larvæ and 7 adults, 126 larvæ and 1 adult, 317 larvæ and 2 adults, 128 larvæ and 1 adult, and 75 larvæ and 2 adults, a total of 811 larvæ and 13 adults. In bulk this averaged 32.4 per cent of the stomach contents and at the same time formed 95.3 per cent of the animal portion of the bird's diet. In three cases the contents of the crop, which was full, were also included. Other animal food taken was divided in small lots under several heads.

The vegetable element, which formed 66 per cent of the stomach contents, was composed largely of weed seeds. Among these were found filaree (*Erodium cicutarium*), smartweed (*Polygonum* sp.), shepherd's purse (*Capsella bursa-pastoris*), Russian thistle (*Salsola tragus*), a vetch (*Astragalus* sp.), and dandelion (*Taxaracum taxaracum*). One bird had picked up about 400 seeds of alfalfa and another a quantity of wheat, estimated to be 55 per cent of the food. Thus the valley quail may become troublesome by feeding on grain or seeds of other cultivated crops. At present, however, it is not sufficiently abundant in Utah to be a source of anxiety, and the short open season now allowed is more than ample to keep it in check. This bird is one of the most valuable about the farm, and in Utah it appears to eat even more than its customary amount of animal food. Any change in legislation, therefore, should be in the direction of increased protection.

WESTERN MOURNING DOVE.

(*Zenaidura macroura marginella.*)

The reason for including the western mourning dove, an almost exclusively granivorous bird, among the weevil's enemies is based on the fragments of adults found in two stomachs. While this mourning dove can not be considered an effective enemy of the weevil, it renders service to man in the consumption of weed seeds, and as long as it does not become unduly abundant in grain fields its presence is desirable.

The vegetable food of the birds examined was largely weed seeds. Among these were those of amaranth (*Amaranthus blitoides*, *A. retroflexus* and *A. albus*), filaree (*Erodium cicutarium*), cockle (*Vaccaria vaccaria*), pigweed (*Chenopodium* sp.), ragweed (*Ambrosia artemisiifolia*), thistle (*Carduus* sp.), smartweed (*Polygonum* sp.), and sunflower (*Helianthus* sp.).

RED-SHAFTED FLICKER.

(*Colaptes cafer collaris.*)

The red-shafted flicker is sparingly distributed through the Salt Lake Valley, though the constantly increasing supply of suitable nesting sites caused by the growth of trees in the irrigated portion bids fair to increase its abundance.

Of the three birds examined, two had fed on the alfalfa weevil, a trace of an adult being present in each case. Ants, its favorite food, composed practically the entire contents of each of the stomachs. In one were no less than 390 adults and 190 pupæ of the small dark brown ant, *Myrmica scabrinodis.*

Although the flicker is the most terrestrial of woodpeckers it does little toward the reduction of the weevil, as it lives chiefly on ants. In this it doubtless is working for the best interests of man, as many large harvest ants of the West (*Pogonomyrmex*) do considerable damage to grain and forage, not only by cutting down the crop for a space of several feet about their domicile, but by building nests which menace the operation of the mower or reaper.

ARKANSAS KINGBIRD.

(*Tyrannus verticalis.*)

The Arkansas kingbird probably is the most abundant and evenly distributed flycatcher in the Salt Lake Valley. Though it is more at home in arid districts, the writer met it in great abundance about ponds where flying insects furnished ample food.

Of ten birds secured four had eaten weevils, but not more than three were found in any one stomach. The small number is probably due to the fact that flycatchers are necessarily limited in this work to the short period when the weevil is on the wing, as also are swallows. The small cicada (*Platypedia putnami*) was a favorite food of these birds.

SAY'S PHŒBE.

(*Sayornis sayus.*)

Only three stomachs of Say's phœbe were available for examination. In one a single adult weevil was found, a dark-colored and much-worn specimen which had hibernated. The remainder of the stomach contents consisted of a varied assortment of flying insects, among which were tabanid flies, a cricket, carrion beetles (*Silpha*), a blister beetle (*Cantharis*), and several Hymenoptera.

TRAILL'S FLYCATCHER.

(*Empidonax trailli trailli.*)

Traill's flycatcher is found in considerable numbers in willow thickets along streams and ditches in the Salt Lake Valley. Seven birds were obtained when conditions were most favorable for feeding on the weevil, but only two had fed on the insect, a single adult being eaten in each case. The aerial feeding habits of flycatchers as a family naturally limit their consumption of the weevil to the warmest of spring days or to the later season when the brood of the year takes wing.

The food taken most frequently was Hymenoptera, ants, wild bees, and a few parasitic forms. These were found in each stomach and comprised about 43 per cent of the contents. Flies of various kinds (17.5 per cent) formed the next most important item, and beetles, bugs, and Lepidoptera were eaten in lesser quantities.

DESERT HORNED LARK.

(*Otocoris alpestris leucolæma.*)

The desert horned lark, a hardy little bird of the open country, is an abundant resident throughout the Salt Lake Valley, especially in winter, when it is familiarly known by the name of snowbird. It is one of the earliest species to breed and frequently its eggs may be found when the ground is still white. In early spring horned larks often feed in the wind-swept stubble of alfalfa fields, when they come in contact with hibernating weevils. Though essentially a seed-eating bird, from May to July a considerable proportion of animal food, including the larvæ of the weevil, is taken.

Three of the four birds collected in April had fed on the insect, the adult form in each case, and it formed about 3½ per cent of their food, but only one stomach contained more than one individual. The remaining animal food was characterized by a large proportion of lepidopterous remains, most of which, however, was in a single stomach. The vegetable portion, forming over half of the food, was composed almost entirely of weed seeds.

Six birds taken in May had fed on the weevil, but the number of insects eaten could not be accurately determined, as much of the food was in an advanced stage of digestion. The adults and larvæ occurred in about equal proportions. One bird had fed upon this insect to the extent of 80 per cent of its food, another 70, and a third, which had devoured 13 adults, 48 per cent. An average of over 41 per cent of the food of the six birds consisted of alfalfa weevils.

Another noteworthy animal food was a considerable quantity of caterpillars, forming over 17 per cent of the whole. Ground beetles amounted to over 6 per cent, and grasshoppers 5 per cent. The animal portion of the horned larks' food for May was nearly three-fourths of the stomach contents. The vegetable part (26.5 per cent) was divided between weed seeds and wheat. This latter element formed about two-thirds of the vegetable portion and may have been secured from recently sown fields.

Each of five larks collected in June also had fed on the weevil, which formed 29 per cent of the food. One had taken 16 adults and 1 larva, and another 10 adults and 25 larvæ. In no case did the weevil form less than 10 per cent of the stomach contents, and in one it went as high as 60 per cent.

Hemiptera, Lepidoptera (caterpillars), and spiders figured prominently in the other animal food. Of the vegetable portion, weed seeds composed the bulk.

More extensive investigations have shown that with the exceptional cases where injury is done to newly-sown grain the farmer has little to fear from this bird. Its best service is in the reduction of the annual crop of weed seeds. The lark also consumes much insect food during summer months, and in Utah the alfalfa weevil has quite naturally entered into its diet. On fair days in early spring these insects are abundant in the stubble of alfalfa fields where horned larks are common, and the destruction of the weevil at this time is a very important factor in the reduction of the numbers of the annual brood. While the consumption of adults (3½ per cent in April) is rather low, it is believed that at this time of year the horned larks do the most good in their fight upon the weevil.

MAGPIE.

(*Pica pica hudsonia.*)

Though only locally abundant in the Salt Lake Valley, the magpie is one of the best known of the birds of Utah. As it is somewhat gregarious in habit, from 15 to 20 nests may be found comparatively close together. Upward of 40 nests were found in one stretch extending half a mile along a creek near Kaysville. As alfalfa fields flanked both sides of the stream, whatever was learned here concerning the magpie as a weevil enemy must be regarded as having been obtained under most favorable conditions.

Nestlings.—A series of 134 stomachs of nestlings was secured in May, and in 79 the weevil was found. It usually occurred in small numbers, the average for the lot being 4.8 weevils per bird, which amounted to 2.42 per cent of the food. Some, however, had eaten considerable numbers of the breeding adults. A half-fledged young had been fed 74 of the insects, and 5 others had eaten, respectively, 62, 55, 33, 26, and 24.

Examination of these stomachs shows how omnivorous are these birds, no less than 85 different items being recognized, besides large quantities of carrion and rubbish. In the material identified were six orders of insects, spiders, a shrimp, mollusks, a reptile, batrachians, earthworms, three species of birds, four of mammals, and seeds of eight species of plants. As each of these items has a different economic significance, the problem of the value of the magpie is complicated.

The largest animal food item was caterpillars (22.1 per cent), which occurred in 104 stomachs. Many of these were cutworms, gleaned from alfalfa fields along with the weevil. The remains of small mammals and carrion of many forms amounted to 14.75 and 11.86 per cent, respectively. Among the mammal remains were recognized meadow mice (*Microtus*), ground squirrels (*Citellus mollis*), a gopher (*Thomomys*), and a shrew (*Sorex leucogenys*). Associated with the carrion were large numbers of muscid pupæ and larvæ, which comprised 16.34 per cent of the stomach contents. It appeared from some of the material that parent birds visited a carcass of a beef or horse and removed only dipterous larvæ and pupæ, leaving the putrid animal matter as a breeding ground for more of the same. The stomachs of many young birds were nearly filled with the dipterous remains, only a few black or brown hairs indicating the source of the food. Ground beetles formed 5.15 per cent of the food, and miscellaneous Coleoptera, members of the genera *Necrophorus* and *Silpha* predominating, 4.05 per cent. Other insect food was divided in small quantities under several heads.

Other components of the animal food economically highly important were the remains of chickens and wild birds and their eggs. The feathers of what appeared to be a young chicken were found in the stomachs of two young birds of the same brood while fragments of eggshell occurred in 22 of the 134 collected. The entire stomach contents of one young magpie consisted of eggshell and what appeared to be its partially incubated contents. Another stomach was about four-fifths full of similar material.

FIG. 1.—YOUNG MAGPIES.

[Late broods of these birds were fed on alfalfa weevil larvæ.]

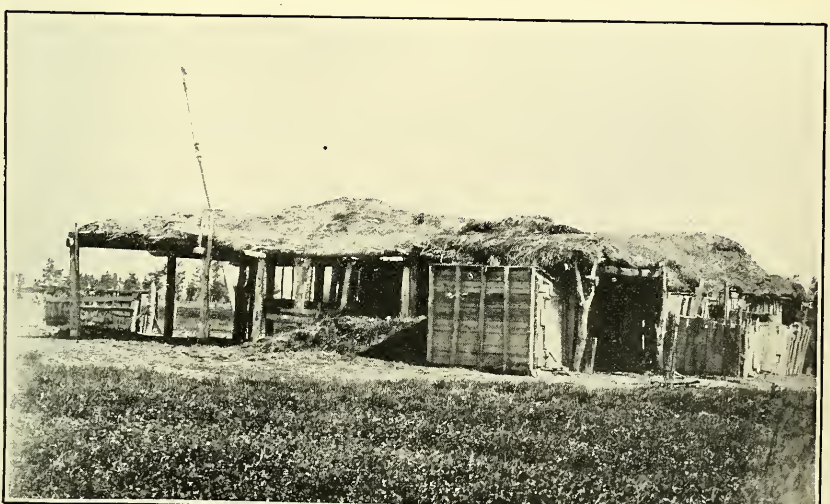


FIG. 2.—STRAW-THATCHED CATTLE SHED, A FAVORITE NESTING SITE FOR LARGE NUMBERS OF ENGLISH SPARROWS.

[These sheds were doubtless an important factor in maintaining the abundance of these birds in rural sections of Utah. See p. 46.]

Three of a brood of five fully fledged young had divided the remains of a small passerine bird. Another had been fed on what appeared to be the remains of a young robin, while a third had eaten eggs of the same species. The vegetable food was mainly rubbish.

In June late broods of magpies (see Pl. I, fig. 1) were frequently fed on the larvæ of the weevil. Eighteen of twenty-five birds examined had eaten the insect at an average of 5.6 adults, 0.08 pupa, and 29.24 larvæ per bird, amounting to 6.6 per cent of the stomach contents. The largest quantities of these insects occurred in this series of stomachs. A brood of six nestlings, about four to five days old, was observed in a cottonwood near the border of an alfalfa field. This field had been cut one morning, and during the afternoon the parent magpies were noticed making numerous visits, and judging from the well-filled stomachs of the young birds, the old birds had made good use of their time. This brood had consumed 36 adults, 2 pupæ, and 677 larvæ, an average of over 102 individuals per bird. As the young had also eaten a varied assortment of other food, comprising at least 25 different items, the weevil formed only 18.7 per cent of the contents.

The remaining animal food for June was essentially the same as for May, save that grasshoppers, taken in considerable numbers, amounted to over 13 per cent. Three of a brood of five had divided the remains of a sparrow, while one of another hatch had eaten the eggs of a robin.

Adults.—Being a resident the year round, the magpie was frequently seen on cold, windy April days visiting alfalfa fields. It was at first thought that bits of carrion or field mice might be the attraction, but analysis of stomachs showed that the birds were making diligent search in the stubble and under clods of earth for the adult weevils. Each of five birds examined had eaten weevils. One had taken no less than 160 adults, while others had eaten 60, 55, 45, and 19 adults, respectively. These composed 26.2 per cent of the magpie's food.

The omnivorous nature of these birds is not revealed this early, when comparatively few articles of food are available. Carrion occurred in four stomachs, amounting to over 40 per cent. Bones of a batrachian were found in another. Of the vegetable food, the larger part (19 per cent) was waste grain.

Eight magpies were collected in May, but the stomachs of three were too nearly empty to be of use. However, two of these revealed traces of adult weevils. Each of the other five had eaten this insect in quantities varying from 2 to 50 per cent of the stomach contents, while one especially remarkable stomach contained 181 adult weevils. No grain had been eaten by these birds, but there was an increased percentage of various insect items. Numerous pupæ of a muscid fly, as well as carrion beetles (*Silpha ramosa*), were found. Carrion occurred in four of the five stomachs and amounted to over a third of the food, while the remains of a freshly killed small rodent were found in the other. The stomachs of two birds contained fragments of hen's egg.

Each of the six adult birds collected in June had fed on the weevil to the extent of 9.67 per cent of their food. One had eaten 24 adults and 180 larvæ. In one stomach were feathers of a small bird. Ground beetles, caterpillars, grasshoppers, carrion, and a small rodent composed the bulk of the remaining animal food. The vegetable element (20.5 per cent) was divided about equally between wild fruit and rubbish.

Summary.—During early spring the adult magpie is valuable as a destroyer of weevils as they come out of hibernation. Complaints that it steals hen's eggs may be practically eliminated by the proper housing and screening of nesting fowls, but as long as hens are allowed to lay eggs promiscuously about the farm magpies will continue to reap their toll. The destruction of wild birds and their eggs is doubtless the strongest argument against the species. In view of its obnoxious traits, legal protection for the bird is not recommended.

LONG-CRESTED JAY.

(*Cyanocitta stelleri diademata.*)

Deductions as to the relation of the long-crested jay to the weevil were based on the examination of a single stomach. This bird was from a densely wooded creek bottom which afforded direct egress from the shrubby vegetation of its favorite habitat to the midst of an agricultural community.

Among the stomach contents were a single adult weevil, a dung beetle (*Aphodius*), a bee, a caterpillar, carrion, grain hulls, and a mass of dandelion seeds.

The favorite habitat of wooded hillsides and canyon slopes and the natural food preferences of the long-crested jay apparently preclude it from becoming very destructive to the alfalfa weevil.

WOODHOUSE'S JAY.

(*Aphelocoma woodhousei.*)

Woodhouse's jay is fairly common wherever dense scrubby vegetation along a stream provides its favorite environment. Three stomachs were examined and adult weevils were found in each, averaging 1 per cent of the food. Ground beetles, mast, and wheat were other important components of the food, and in the stomach of one bird were fragments of eggshell.

In view of the numerous objectionable habits of the closely related California jay it does not appear wise to recommend protection for this bird as a weevil destroyer. At the same time it is not numerous enough in agricultural districts of Utah to make any injurious habits which it may possess noticeable.

BOBOLINK.

(*Dolichonyx oryzivorus.*)

The bobolink, songster of hayfields and low meadows, is fairly common in Utah. It was found in moderate abundance in the vicinity of West and South Jordan, and Farmington, and along the Weber River and Chalk Creek in Summit County.

As a destroyer of the weevil it has an interesting record. In the stomach of each of the nine birds examined the insect was present in considerable numbers. A single bird collected in May had fed on 10 adult weevils, which formed 14 per cent of the food.

Seven bobolinks collected in June had taken the weevil at an average of about 8 adults and 42 larvæ per bird, to the extent of 68 per cent of the stomach contents. In the stomach of one, 6 adults and 90 larvæ formed the entire food. Another had eaten no less than 28 adults and 77 larvæ, amounting to 86 per cent of the stomach contents, while a third had eaten 3 adults and 61 larvæ. The only other food items in the last stomach were small fragments of a bug and a click beetle, estimated at 1 per cent. These birds also had fed to the extent of over 16 per cent of their food on caterpillars, which occurred in all but one of the stomachs. Bugs (Hemiptera) formed about half that amount.

A single bobolink collected in August had eaten 7 adults, which totaled 15 per cent of its food, while several caterpillars and lepidopterous pupæ formed an additional 71 per cent.

The bobolink does exceptionally good work as a weevil destroyer, for whenever it lives near infested alfalfa fields the insect forms its most important animal food. There appears to be no reason why it should not be fully protected. Its status in Utah is essentially the same as in the New England and other Northern States, where its economic merits have never been questioned.

COWBIRD.

(*Molothrus ater ater.*)

Previous investigations[1] of the economic status of the cowbird have shown that, judged from its food habits alone, the farmer has

[1] Beal, F. E. L., Food of the Bobolink, Blackbirds, and Grackles. Bull. 13, Biol. Survey, U. S. Dept. of Agr., 1900.

little to fear from this bird, but the fact that in its egg-laying habits it is parasitic, and frequently so on highly valuable species, has so complicated matters that its exact relation to agriculture is not yet thoroughly understood. In spring and summer the cowbird may be found usually in numbers of from two to six associated with one or more of its relatives in the vicinity of pastures or alfalfa fields. The cowbird's exceptional record as a weevil destroyer does much toward redeeming it for misdemeanors arising from its parasitism. Of the 15 birds collected only 1 had failed to feed on the insect.

Three cowbirds taken in May had eaten the weevil to the extent of over 60 per cent of their food. In one case it amounted to 95 per cent and was present at an average of about 7 adults and 30 larvæ per bird. Dung beetles (*Aphodius*) formed the bulk of the remaining animal food. Wheat, which was present in two stomachs, was estimated to be a fourth of the monthly sustenance.

Ten birds collected in June showed a continuation of the good work started in the preceding month. The only bird failing to eat the weevil was one which had taken three or four nymphs and one adult of the small cicada (*Platypedia putnami*), which formed nearly the entire stomach contents. The weevil, constituting 42.3 per cent of the food, was taken at an average of 6 adults, 1.4 pupæ, and 30.3 larvæ per bird. The largest number recorded for the species was 80 larvæ, 3 pupæ, and 3 adults, forming 80 per cent of the food. Of the remaining animal food Hemiptera was the most prominent item (18.7 per cent), and was composed of about equal parts of cicadas (*Platypedia*) and tree hoppers (Membracidæ). The vegetable food (27 per cent) was composed largely (18.3 per cent) of the seeds of weeds, among which were filaree, wild mustard, brome grass, and barnyard grass.

Two cowbirds taken in July had fed on the weevil, adults of the same year's brood in each case, to the amount of nearly 30 per cent of the stomach contents. The remains of a much-digested lepidopteran comprised about half of the food of one, and a mass of seeds of filaree, amaranth, smartweed, and sunflower formed about 80 per cent of the contents of the other stomach.

Summary.—The food habits of the cowbird in Utah during spring and summer appear to be above reproach. Grain forms but a small portion of its diet, while the alfalfa weevil is by far the largest ingredient of the animal portion. From the first of May to the middle of July the weevil forms over half the animal food, and much of the vegetable portion is composed of weed seeds. In recognition of the cowbird's work as a weevil enemy, it would appear that when every suppressive agency must be carefully conserved, the bird should be allowed to continue its good work unmolested by sportsman or small boy.

YELLOW-HEADED BLACKBIRD.

(*Xanthocephalus xanthocephalus.*)

The yellow-headed blackbird, or soldier bird, as he is more frequently called in the West, is the last of the three blackbirds to arrive in large numbers, although a few individuals are said to remain throughout the winter in favorable localities.

Nestling and juvenile birds.—As weevil enemies young yellow-heads do not rank as high as the nestlings of the other blackbirds. The insect amounted to 4.27 per cent of the stomach contents and occurred in 40 of 68 birds collected in June. Larvæ were preferred to adults, being taken on an average of 4.13 per bird, as compared with 0.74 for the latter. One nestling 4 or 5 days old had destroyed 48 larvæ, and a brood of three had eaten, respectively, 42, 25, and 40.

The work of a colony of about 15 or 20 yellow-heads upon an alfalfa field of three or four acres came under the writer's observation. The breeding marsh was fully half a mile from the source of food supply, and the flight of the parent birds to and from their nests was observed for about a half hour, during which the adults made visits to the fields at the rate of about one every minute.

Other animal food of the young, strongly indicative of the aquatic environment in which the bird lives, was dragonflies and their nymphs, which formed 43.86 per cent of the stomach contents, and occurred in all but 10 of the 68 stomachs. Some stomachs contained fragments of adult Odonata, which testifies to the ability of these birds to capture insects generally supposed to be effectively protected by their powers of flight. Caterpillars formed about a fourth (24.08 per cent) of the food. Ground beetles (5.7 per cent), spiders (5.54), grasshoppers (4.09), snails (3.76), and Hymenoptera (2.1) were the principal other ingredients of the animal food. The vegetable portion (2.13) was mainly rubbish.

Two juvenile birds collected in July had eaten the weevil, one of which had taken 2 adults and 30 larvæ.

Adults.—During April and May only two adult yellow-heads were collected each month, a too limited number to allow definite conclusions, but it shows that the birds were already preying upon the insect. One collected on the 23d of April had eaten a single adult, while the bulk of the stomach contents consisted of caterpillars. This latter element also composed 97 per cent of the food of the other April bird. The two birds taken in May had fed upon the insect, having eaten three and seven adults, respectively, which averaged 10 per cent of their food.

Of 21 stomachs collected in June only 4 failed to contain the weevil. The insect formed 43.48 per cent of the yellow-head's food and was taken at an average of more than 6 adults and 47 larvæ per bird. The largest number taken by any of this species was 190 larvæ and 2 adults. Another record was 160 larvæ and 2 adults. Three adults and 117 larvæ were eaten by one bird, while five others had taken more than 170 individuals apiece.

Of the other animal food Lepidoptera, in the form of caterpillars, is most important, amounting to nearly 31 per cent. These insects occurred in 15 of the 21 stomachs and in one constituted the entire food. Ground beetles (8.56 per cent), Hemiptera (4.95), weevils other than *Phytonomus* (4.24), and dragonflies (2.48) made up the bulk of the remainder. The vegetable food (1.2 per cent) was of no economic importance.

Seven birds collected in July show a decrease in the amount of weevils eaten and a corresponding increase in other food items, as grasshoppers, flies, and grain. Only two had eaten the insect, one having taken but a single adult, while the other had made away with 48. Grain amounted to nearly half (44.57 per cent) of the food, verifying the complaint against these birds at this time of the year.

Summary.—With the exception of the work of adult birds during the month of June, the yellow-headed blackbird can not be considered as among the more effective bird enemies of the weevil, but its uniformly good work on caterpillars during the entire season argues in its favor. Its strong liking for dragonflies is against it, and also there is little doubt that it lays heavy toll on ripening and shocked grain.

THICK-BILLED REDWING.

(*Agelaius phœniceus fortis.*)

The thick-billed redwing is a common breeder throughout the Salt Lake Valley wherever is found a clump of cat-tails, a favorite nesting site. As small marshes flank the Jordan River and the shores of Salt Lake, and are about other places where imperfect drainage has left a pool, the bird is fairly well scattered throughout the valley, and of the blackbirds ranks next in abundance to Brewer's.

Those birds which do not winter in the Salt Lake Valley arrive early enough to render valuable service in the destruction of weevils emerging from hibernation. In the spring of 1912 the writer found them fairly common, and the examination of one stomach secured on the 1st of April indicated that they were already at work on the insects.

Nestlings.—Thirty of fifty young redwings examined for June had eaten the insect, which amounted to 10.64 per cent of their food, and was taken on an average of 0.3 adult and 12.58 larvæ per bird. In several instances, where nesting marshes were situated near infested fields, large numbers of larvæ were eaten. A brood of three had consumed 60 larvæ, 84 larvæ and 1 adult, and 100 larvæ and 1 adult, respectively. Another hatch of three had averaged $32\frac{1}{3}$ larvæ apiece. Several other food items characteristic of these birds appeared with such regularity that the actual bulk of weevils in no case amounted to over 50 per cent.

Caterpillars formed the next most important item, totaling 27.38 per cent. Dragon flies (Odonata) and their nymphs, and snails, forming 9.84 and 6.46 per cent, respectively, were secured from the immediate vicinity of the nests. Spiders composed over 15 per cent, and ground beetles, with the genus *Amara* predominating, a little less than a tenth of the food. The major portion of the remaining animal food was divided about equally between aquatic beetles, bugs, flies, and grasshoppers. The vegetable food (6.84 per cent) was unimportant, as over half was rubbish taken accidentally with the food.

An observation for a period of an hour was made of a female redwing feeding a brood of four nestlings about three days old. The nest was situated in a clump of cat-tails with alfalfa fields not far distant. The parent bird divided her time between visits to the adjacent marsh and the near-by alfalfa, and made trips to the nest on an average of one every $3\frac{3}{4}$ minutes. Though the alfalfa was visited oftener than the marsh, the food of the nestlings was gleaned largely from the latter place, as over one-quarter of it was dragon flies and over half spiders, while the weevil amounted to but 7.25 per cent. The parent bird, however, had made good use of her time in the field, as her stomach contained 3 adults and 56 larvæ, comprising 45 per cent of the contents.

Adults.—The early warfare on the weevils by adult redwings is verified by examination of stomach contents, and although the insect formed but a small proportion of the bulk (4.94 per cent), it was present in 27 of the 36 birds used in this computation. Five of seven other stomachs, which were too nearly empty to be of use, also contained the insect. Weevils taken in April were breeding adults, and were eaten on an average of $2\frac{1}{6}$ per bird. The highest number eaten by any was 13.

Of other animal food, caterpillars and fly larvæ, mostly aquatic, composed slightly more than 13 per cent each. Aquatic beetles formed nearly 3 per cent and ground beetles nearly 2, while several other items occurred in small quantities, none over 1 per cent. Vegetable matter formed 57.08 per cent of the food, over half of which was grain, while the rest was divided between weed seeds (18.78) and a little rubbish.

During the month of May adult redwings increased their work on the alfalfa weevil until it comprised about one-sixth of their food, occurring in 23 of the 32 stomachs examined and averaging 4.84

adults and 2.41 larvæ per bird. The largest number of weevils in any one stomach was 12 adults and 75 larvæ. Of the remaining animal food caterpillars formed the most important element (16.63 per cent), while aquatic fly larvæ, some of which were Tipulidæ, amounted to about a tenth of the food. Ground beetles (4.44 per cent) and weevils other than *Phytonomus* (2.25 per cent) were the only other items worthy of mention. Among the latter the clover-root curculio (*Sitones*) and several species of *Sphenophorus*, living on sedges, occurred repeatedly. The vegetable element amounted to 44.9 per cent, about two-thirds of which was grain. The rest consisted of weed seeds and rubbish.

In June, the period of greatest abundance of nestlings, these birds eat the largest proportion of weevils. While parent birds are obtaining food for their young, they are inclined to partake of much the same varieties. Of 42 birds examined only 2 had failed to eat at least a trace of the weevil, and it was taken on an average of 5.24 adults and 27.16 larvæ per bird. In bulk it amounted to 40.76 per cent of the stomach contents. One male had eaten 5 adults and 108 larvæ. A female had made away with 24 adults and 68 larvæ. A pair collected in a breeding marsh had taken, respectively, 12 adults and about 90 larvæ, and 2 adults and 100 larvæ. The records of a few others are 12 adults and 73 larvæ, 5 adults and 77 larvæ, 13 adults and 58 larvæ, 6 adults and 61 larvæ, and in each of two cases 6 adults and 60 larvæ.

Next in importance to the weevil came caterpillars, which composed 17.38 per cent of the food for June. Aquatic and ground beetles formed a little over 5 per cent each; flies (largely the larvæ of aquatic species) 4.29 per cent; and spiders 3 per cent. The vegetable portion (12.67 per cent) was largely grain.

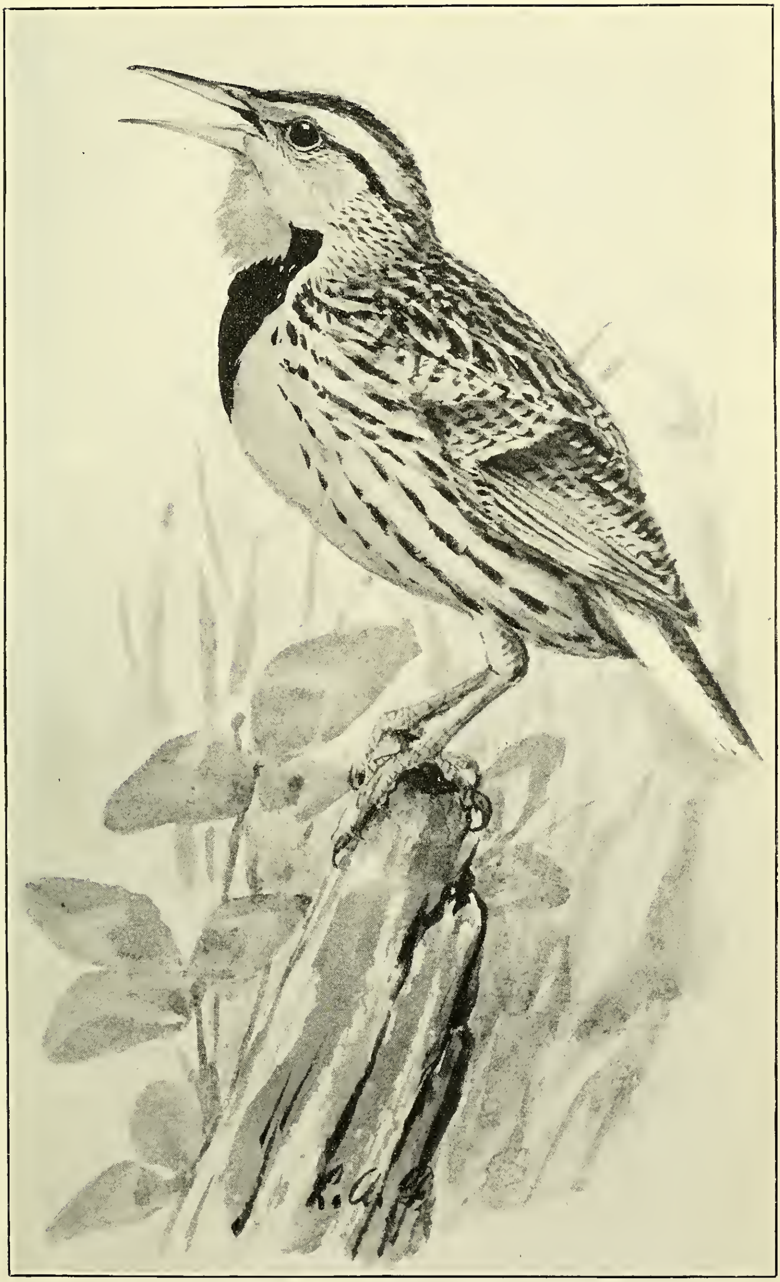
In July one male devoured 2 adults and 10 larvæ of the weevil.

Summary.—While the adult redwing eats its largest amount of weevils (over 40 per cent) in June, its greatest worth as a weevil destroyer lies in the fact that it is among the earliest of the weevil-eating migrants, often preying on these insects when snow is still on the ground. The food habits of the young are also in the bird's favor.

WESTERN MEADOWLARK.

(*Sturnella neglecta.*)

The western meadowlark (Pl. II) is a familiar bird of the Great Basin, and judging from early records is becoming more numerous in Utah as time goes on. Being a resident the year round, it is a common visitor to alfalfa fields as soon as snow leaves, and is more frequently met during April and early May than later in the year.



WESTERN MEADOWLARK.

In April, 27 of these birds were collected, and the weevil, which was found to comprise one-sixth of their food, was present in all but seven. The insects taken were adults, and the average was 14.4 weevils per bird. One bird had taken 75 of these insects, another 60, and three others 51, 48, and 33, respectively.

Other animal food is important, as the largest single item was caterpillars, amounting to nearly 22 per cent. These insects were present in all but 6 of the 27 stomachs, and in several instances formed a considerable proportion of the food. In one 15 caterpillars formed three-fourths and in another an equal number composed about two-thirds of the stomach contents. Ground beetles, many of which were of the genus *Amara*, amounted to about one-eighth of the food. Hymenoptera, largely parasitic ichneumons, were eaten to the extent of 6.5 per cent, while weevils other than *Phytonomus*, scarabæid beetles, Hemiptera, and Diptera formed about 2 per cent each. Of the vegetable food (27.26 per cent) a considerable portion (15.89 per cent) was grain, while the remainder was weed seeds and a little rubbish.

During May an increased consumption of caterpillars appears to explain a decrease in the percentage of weevils. The larvæ, eaten on an average of 3.83 per bird, and adults at the rate of 7.58, totaled nearly 11 per cent of the bird's food. A male taken in May had destroyed the largest number of adults, 81 of the insects comprising 92 per cent of the stomach contents. Another had made away with over 70 larvæ and 32 adults, while a third ate 40 larvæ and 10 adults.

Caterpillars amounted to nearly a third of the month's food (31.66 per cent), occurring in all but seven of the stomachs collected, and frequently composing the major portion of the food. In one case a bird had destroyed at least 20 of these insects and in two others 16 and 15, respectively, were eaten. Ground beetles were found in all but 2 of the 29 stomachs and amounted to over a quarter of the food. In two cases over 20 of these beetles were found in the stomach. Among them were several of the genus *Calosoma*, doubtless beneficial, but on the other hand there were large numbers of several species of the genus *Amara*, which are injurious to vegetation. Orthoptera (grasshoppers and crickets) composed 6.83 per cent, Hemiptera and scarabæid beetles about 3 per cent each, and several other insects were present in small quantities. The vegetable element was materially less than in May, being only a little over 9 per cent, and about two-thirds of it was grain.

In June the meadowlark maintains about the same relation to the weevil as during the preceding month. There is, however, an increase in the proportion of larvæ eaten. Examination of 14 stomachs revealed an average of 4.78 adults and 11.93 larvæ per bird, which amounted to nearly an eighth of the food. One bird worthy of mention had taken no less than 100 larvæ and 4 adults and another had eaten 44 larvæ and 27 adults. Other food items vary but little in their relative proportions from those of May. Caterpillars formed a little less than a third of the contents and ground beetles about a fourth. Hymenoptera, many of which were parasitic ichneumons, composed 6.5 per cent, spiders 4.7, and weevils of the genus *Sphenophorus* about 4 per cent. The vegetable element was of no importance.

By July the abundance of other insect food caused the meadowlark to greatly reduce the proportion of weevils taken. The insect was eaten by only one of five birds examined. This bird, a fully fledged young, had consumed 16 adults of the year's brood, which formed 22 per cent of its food, giving an average of 4.4 per cent for the material collected in this month. Ground beetles and grasshoppers were the most important of the other food items.

Summary.—As a weevil destroyer the western meadowlark renders its most valuable service during the early days of spring, when many breeding adults fall prey to its diligent search. Its fondness for ground beetles and caterpillars, especially cutworms, has a tendency to reduce the percentage of weevils eaten during the following months. The good it does in the destruction of caterpillars more than offsets the harm arising from the eating of ground beetles. As the latter are very abundant throughout alfalfa fields, and as many are of species of doubtful economic value, the bird should not be too severely judged on this score. Examinations show that the meadowlark, at least from April to July, is not a menace to grain in Utah. On the other hand, its being a resident the year round makes it a valuable asset as a destroyer of hibernating insects, especially the alfalfa weevil.

BULLOCK'S ORIOLE.

(*Icterus bullocki.*)

Bullock's oriole secures much of its food from trees, caterpillars being the largest single item. Although the alfalfa weevil in all its stages is found most frequently on or near the ground, it was present in each of seven stomachs collected. Two birds taken in June had fed on it to the extent of 8⅓ per cent of their food, while in the following month it formed nearly twice that amount. One bird collected in July had eaten no less than 21 adults, equaling 30 per cent of its food. No larvæ were taken by these birds even though this form of the insect was in great abundance, so that the adults may have been captured either on the wing or upon the branches of trees which had intercepted their flight.

Of other animal food caterpillars are most important, and they occurred in four of the seven stomachs. One bird had fed almost exclusively on these insects, there being only a trace of an alfalfa weevil. In bulk caterpillars formed over a third of the food during May and June. Hymenoptera, in the form of wild bees and ants, composed about a fourth of the contents of five stomachs. Vegetable food entirely of grain, which was probably waste, occurred in three of the stomachs collected in July, and formed about a fifth of the food for the month.

In spite of the accusation that Bullock's oriole injures peas and small fruit, its good qualities outweigh its harmful traits. It already has a favorable record as an insect destroyer, but we may now add the alfalfa weevil to the list of noxious forms eaten by this bird.

BREWER'S BLACKBIRD.

(*Euphagus cyanocephalus.*)

Brewer's, or the white-eyed blackbird (Pl. III), as it is commonly known in Utah, is the most abundant blackbird of the State. It is very evenly distributed throughout the Salt Lake and the Weber valleys. At a point east of Hoytsville a large tract of irrigated land, much of which is given up to alfalfa, lies rather isolated from the river valley proper and at an altitude of several hundred feet above it. Brewer's blackbirds nested abundantly at the lower level, and as soon as nestlings were hatched the parents began making regular trips to the badly infested fields above, adult birds being observed several times traveling considerably over half a mile between the alfalfa and the nest. Another colony made trips of about a third of a mile from their nests in the sagebrush to a portion of a field which was particularly badly infested. Later, parent birds brought their families to the infested fields, where, in flocks of 15 to 20, they spent the entire day.

Nestling and juvenile birds.—Under this head are included young birds of any age, from the nestling of a day or two to the fully fledged bird. Of 125 stomachs examined, 78 were for the month of June, 45 for July, and 2 for August.

In June the weevil formed 20.14 per cent of the stomach contents and was eaten by 60 of the 78 birds. Together these birds had caused the destruction of 231 adults and 904 larvæ, an average of 2.96 adults and 11.59 larvæ per bird. Though the weevil does not occur in such large quantities in this series as in those collected later, the following records are noteworthy: A fully fledged young bird had eaten from 45 to 50 adults and no less than 60 larvæ, comprising 87 per cent of the stomach contents. Another had taken from 15 to 20 adults and 60 larvæ. Sixty-four larvæ were found in the stomach of a nestling three or four days old, while four other nestlings had eaten, respectively, about 40 adults, 40 larvæ, 37 larvæ, and 31 larvæ and 1 adult.

The animal portion of the food of the young Brewer's blackbird at this time of the year is of economic importance and amounts to nearly 94 per cent. Conspicuous are caterpillars (mostly cutworms), which totaled 34.57 per cent, or over a third of the stomach contents. These insects, abundant in many fields and doubtless doing considerable injury, together with adult Lepidoptera, occurred in 59 of the 78 stomachs, in several cases amounting to over 90 per cent of the food. Ground beetles (Carabidæ) amounted to 11.45 per cent. While these beetles, as a family, are considered beneficial, being mainly predaceous, there are some which injure vegetation. This is especially true of the genus *Amara*, which made up the greater portion of this part of the food. Spiders were eaten freely by the nestlings and constituted 9.37 per cent of the food. Flies amounted to 7.34 per cent, while the remaining animal food was divided in small quantities among insects of several orders.

The vegetable food is of little importance at this time of the year, both from its character and relatively small proportion (6.08 per cent). Over three-fourths was of rubbish, which testifies to the voracious temperament of the young, while weeds and a little grain formed the rest.

The young Brewer's blackbirds obtained in July were fully fledged and were out of the nest picking up much of their own food. Of 45 birds only 2 had failed to eat the weevil, and in the remaining stomachs it amounted to 25.47 per cent of the food. An average of 11.47 adults, 0.24 pupa, and 25.53 larvæ, or over 37 weevils in one stage or another for every bird, was the record made by these juvenals. A few cases will illustrate the importance of these birds as weevil destroyers. One had eaten 229 larvæ, 7 pupæ, and 20 adults; another made away with 140 larvæ and 6 adults, and the record of a third was 4 adults and 150 larvæ. The abundance of adult weevils of the year's brood in the middle of July is indicated by the stomach of a young blackbird, which contained 95 insects in this stage. Another had captured 10 adults, 1 pupa, and 126 larvæ. Other interesting records are as follows: 94 adults; 1 adult and 60 larvæ; 26 adults and 45 larvæ; 21 adults and 35 larvæ; 3 pupæ and 63 larvæ; 3 adults and 50 larvæ; and 5 adults and 52 larvæ.

The weevil composed about one-third of the animal food during this period, which in turn amounted to 77.8 per cent of the total contents. Of other animal food Lepidoptera, mostly caterpillars, formed 13.18 per cent, a little less than two-fifths of the amount taken in June. Hymenoptera, many of which were parasitic, made up 11.29 per cent. Hemiptera, the bulk of which was composed of the small cicada, *Platypedia putnami*, formed 10.11 per cent. Ground beetles totaled 8.67, while the remaining portion was divided in small quantities under several heads.

BREWER'S BLACKBIRD.

The vegetable food, amounting to 22.2 per cent, becomes important in this month, as nearly two-thirds was of grain, mostly wheat, the rest consisting of weeds and rubbish.

By August most of these blackbirds had forsaken the alfalfa fields and were paying attention to grain. Such animal food as they needed was amply supplied in the season's crop of grasshoppers. Two stomachs secured are too few for accurate deductions, but both contained adult weevils, 25 and 12 respectively averaging 13 per cent of the contents. Grasshoppers made up 38.5 per cent, while the vegetable element, all of which was grain, amounted to 43.5 per cent.

Field observation and analysis of material collected indicate that the young of Brewer's blackbird hold a very high place among the enemies of the weevil. While the stomach contents may not show so high a percentage as in some other species, the size and voracious nature of the bird means that a large quantity of food is consumed. The other elements of its animal food also are highly in its favor.

Adults.—In the season of 1912 Brewer's blackbirds did not become abundant before the first of May. Only two adults were secured in April, one of which had eaten a single weevil. The other, taken in a cattle corral during a snow storm, had eaten nothing but grain.

In May 45 stomachs were collected, some of which contained surprisingly large numbers of these insects. Only four of the birds examined had failed to partake of this food, and its bulk amounted to 16.85 per cent of the stomach contents. The advancement in the life cycle of the weevil in the season of 1911 over that of 1912 is readily shown by this material. The 11 birds taken in the former year averaged 6.64 adults and 50.09 larvæ apiece, while those of 1912 had taken no larvæ whatever but had eaten 10.76 breeding adults apiece. A female collected in May, 1911, had eaten 25 adults and 246 larvæ, comprising 89 per cent of the food. This same bird also had eaten a grasshopper, a cricket, a caterpillar, and a clover-root curculio (*Sitones hispidulus*). A male taken in the same month had consumed no less than 10 adults and 200 larvæ, equaling 97 per cent of the food, while another had eaten 6 adults and 105 larvæ. While the material of 1912 did not reveal such large numbers, the work was confined entirely to the destruction of breeding adults. The highest number taken in May of the latter year was 50 adults. One bird had eaten 33, while five others had taken over 20 individuals apiece.

Caterpillars, with a percentage of 15.67, were the most important of other animal foods. Hemiptera, the greater part of which was the small cicada, *Platypedia putnami*, and carabid beetles, with the genus *Amara* predominating, composed about 6½ per cent each. Orthoptera, Hymenoptera, and Diptera about equally divided the balance of the animal food. The vegetable contents, amounting to 34.11 per cent, was largely grain, much of which doubtless was waste.

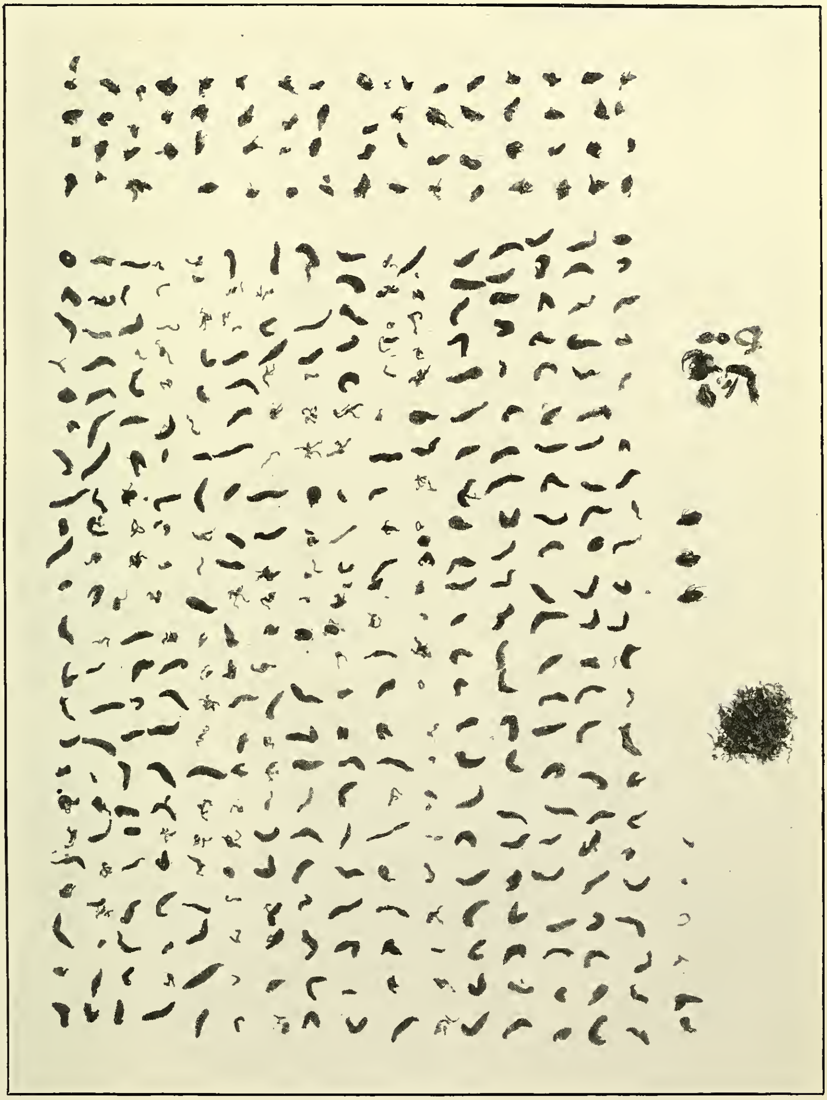
Adult blackbirds consume the largest proportion of alfalfa weevils in June, when the insect comprises nearly a third (32.70 per cent) of the food. Among the 99 stomachs examined are to be found records of the most remarkable work done by this bird. Only four had failed to eat the insect. The 99 birds together had made away with 580 adults, 68 pupæ, and 4,406 larvæ, averaging 6.4 adults, 0.7 pupa, and 48.9 larvæ, or 56 individuals per bird. Though this bird has a strong liking for insects of larger size, as cutworms and beetles of various kinds, the weevil formed the greater portion of the contents of many stomachs. In 11 cases it amounted to 90 per cent or more of the food.

A female secured from a post-breeding flock had devoured the largest number of weevils recorded for any individual bird—374 larvæ, 65 pupæ, and 3 adult weevils, a total of 442 individuals, comprising 96 per cent of the stomach contents. (See Pl. IV.) It also had eaten the larvæ of an aquatic beetle, a caterpillar, a dipterous larva, a nymph of a tree hopper (Membracidæ), two spiders, and a little rubbish, including a seed of filaree. Three birds had eaten, respectively, 281 larvæ, 268 larvæ and 6 adults, and 240 larvæ and 17 adults. In each case the weevil comprised 90 per cent of the food. Another had eaten 212 larvæ and 4 adults. In each of 14 other birds the combined number of larvæ, pupæ, and adults amounted to over 100, noteworthy among which was one containing 1 adult and 190 larvæ; another with 3 adults and 170 larvæ: and a third with 14 adults and over 140 larvæ.

Besides the weevils eaten during this month (32.7 per cent) the adult birds had taken nearly an equal quantity (27.83 per cent) of caterpillars. In seven stomachs this item made up over 90 per cent, while in one it formed the entire contents, the bird having eaten about 23 of these insects. Carabid beetles, Hemiptera, Orthoptera, and spiders formed the bulk of the remainder. The vegetable food, amounting to but little more than 5 per cent, was unimportant, as much was rubbish.

In July the depredations of these birds on the weevil are confined almost wholly to feeding on the adults of the year, which by this time are out in great numbers, especially in the vicinity of haystacks and along ditch banks, where they early seek places of hibernation. In one favorite resort of these birds about the base of a recently constructed stack, so many adult insects had fallen from the hay while the stack was being built that a brush of the hand in the debris at the base would disclose a squirming mass of hundreds which produced a distinctly audible "whir" in their scramble through the dry hay for new places of shelter.

During this month the weevil formed 20.26 per cent of the food, taken on an average of 12.45 adults and 1.79 larvæ per bird, and it was



STOMACH CONTENTS OF A BREWER'S BLACKBIRD.

[This individual had consumed the largest number of alfalfa weevils recorded for any bird—a total of 374 larvæ, 65 pupæ, and 3 adults, which comprised 96 per cent of the food.]

found in all but one of the stomachs. The highest number taken by any bird was 40 adults and 51 larvæ. This single stomach contained almost all the larvæ recorded for the adult Brewer's blackbird in July, which may be explained by the lateness of the season in the Weber Valley where it was collected. The contents of stomachs taken at this time in the upper valley corresponded to those taken three or four weeks previously in the vicinity of Salt Lake. Another bird had eaten 60 adults, while a third had taken 40. Eight birds collected in 1911 well show the character of the food when the weevil begins to disappear. Of the entire food 5.75 per cent was weevil while 91.5 was grasshoppers. Though much grain was being harvested in this region none was eaten by these birds.

Of animal food other than the weevil, grasshoppers are conspicuous, amounting to 27.2 per cent of the month's food. Caterpillars, ground beetles, and Hymenoptera, many of which were wild bees, comprised a little less than 10 per cent each. The rest of the animal food was divided in small quantities among several items of little economic importance. Of the vegetable portion (11.52 per cent), much was grain, the bulk of which was taken from the ripened crop.

Summary.—Brewer's blackbird, both old and young, is working for the best interests of the Utah farmer and in spring and summer is among the most effective bird enemies of the weevil. The adults appear to take slightly greater quantities of these insects than do the young, whose preference is for cutworms. Late in the season a marked liking for grasshoppers on the part of the old birds is also to their credit. About one-fifth of the food of both old and young during May, June, and July consists of weevils.

This bird is seldom shot or otherwise molested in Utah, where its economic worth is now fully appreciated, it having recently been afforded legal protection.

HOUSE FINCH.

(*Carpodacus mexicanus frontalis.*)

In Utah the house finch is probably the least insectivorous of all the finches, and in California has been much criticised because of its vegetarian habits. Primarily a seed-eating bird, it is true to its normal habits in Utah.

Nine of these birds were examined, but only two had eaten the weevil, the larval form in each case. One had taken two and the other three. Caterpillars, the only other animal food eaten, occurred in one stomach and composed about 15 per cent of the contents. The vegetable portion of the food consisted of weed seeds, of which three species were identified: Dandelion (*Taxaracum taxaracum*), shepherd's purse (*Capsella bursa-pastoris*), and smartweed (*Polygonum hydropiper*). Parts of other seeds were present, but, as this bird is especially adept at hulling even the hardest and smallest of seeds, the partly digested embryos gave no clue as to their identity.

The house finch may render some service in checking the increase of the weevil by destroying adults early in the season, but owing to its almost exclusively vegetarian diet this must be small. Whatever worth this species has lies in its consumption of weed seeds.

PINE SISKIN.

(*Spinus pinus.*)

The stomach of the only pine siskin examined contained traces of an adult alfalfa weevil, but from what is known of its food habits in other parts of its range, this bird can not be regarded as important as a weevil destroyer. It is primarily a seed eater, and its animal food is confined mainly to such forms as plant lice and scale insects.

WESTERN VESPER SPARROW.

(*Poœcetes gramineus confinis.*)

The western vesper sparrow arrives in the Salt Lake Valley in March, when, during cold, blustery days, it may be found often in parties of three to six flitting about weed patches, usually not far from the protecting cover of a creek bottom. Later in the season it is a common breeder in the sagebrush areas adjacent to cultivated fields, and from here it makes regular trips to alfalfa fields in search of the weevil.

In April, 16 of these birds were collected in alfalfa fields. All but three had fed on adult weevils, which amounted to about a twelfth of the food. The small size of the stomachs means that in numbers the weevil will be limited. An average of a little less than two adult weevils per bird was maintained for this month, while eight weevils is the highest record of a single bird.

Other investigators have shown that the food of this bird varies from wholly vegetarian in midwinter to upward of 90 per cent animal during summer. In Utah insect life began to form an appreciable portion of the food in April, and amounted to a little less than a quarter of the stomach contents. A third of this was the alfalfa weevil. Of the other items the clover-root curculio (*Sitones* sp.) occurred frequently and totaled about 4 per cent of the contents. Fourteen of these were found in one stomach. Dung beetles (*Aphodius*) formed about an equal amount, while the remaining animal food was divided in small quantities under several heads. Of the vegetable food (76 per cent) about 19 per cent was grain and 57 per cent weed seeds. The latter element was present in all but one of the stomachs and in four instances formed practically the entire contents. Among the weed seeds were those of filaree (*Erodium cicutarium*), sunflower (*Helianthus* sp.), pigweed (*Amaranthus retroflexus* and *A. blitoides*), cockle (*Vaccaria vaccaria*), smartweed (*Polygonum* spp.), panic grass (*Panicum* sp.), and brome grass (*Bromus* sp.).

Four vesper sparrows were collected in May, three of which had eaten the weevil, the fourth having been secured in a wooded ravine some distance from the nearest field. The weevil formed nearly 40 per cent of the stomach contents of the four, with an average of about three adults and six larvæ per bird. In the remaining food, caterpillars (8.25 per cent), grain (11 per cent), and weed seeds (42 per cent) predominate.

Examination of a series of 19 stomachs in June shows that these fringilline birds are decidedly insectivorous during the breeding season. Every one had fed on the weevil, and in 4 it amounted to over 95 per cent of the food, while the average for the month was nearly 60 per cent. As many birds were collected at a time when the larvæ were most abundant, this form of the insect appeared in large numbers in some stomachs. An average of 3.8 adults and over 24 larvæ per bird was recorded. One bird had eaten 2 adults and 60 larvæ, another 6 adults and 55 larvæ, and a third 1 adult and 50 larvæ. The weevil contents of several others are as follows: 5 or 6 adults and about 45 larvæ; 2 adults and 45 larvæ; 1 adult and 40 larvæ; 7 adults and 28 larvæ; and 10 adults and 21 larvæ.

Of the other animal food items Hemiptera, composed chiefly of the small cicada, *Platypedia putnami*, so abundant in the oak chaparral of the foothills at this time of the year, formed the next largest portion (7.79 per cent). Clover root curculios (*Sitones*), "bill bugs" (*Sphenophorus*), caterpillars, parasitic Hymenoptera, and grasshoppers follow in the order named. The vegetable portion (10.63 per cent) is divided between grain and the weed seeds previously mentioned.

For the month of July a larger series of stomachs (44) affords added evidence of the remarkable work of these sparrows as destroyers of the weevil. Only one had failed to feed on the insect. There was an increase in the average number of adults taken (5.36) and a decrease in the number of larvæ (18.43) as compared with the preceding month, because of the presence of more adults of the year's brood during July. Animal food comprised 73.02 per cent of the contents, 52.09 per cent being weevils. One bird had eaten 65 larvæ and 2 adults and was carrying 17 larvæ of the weevil in her bill for her young. Another had taken 46 larvæ and 22 adults. The stomach of a full-fledged sparrow collected in July, and still being fed by its parents, contained 45 larvæ and 8 adults. Eighteen other birds had eaten 25 or more weevils in one stage or another, and 3 had also eaten a few pupæ.

Of the remaining items of animal food, caterpillars (5.59 per cent), ground beetles (4.2), and Hemiptera (mainly the small cicada, *Platypedia putnami*) (4.09) were most conspicuous. Weed seeds again were prominent, amounting to 22.3 per cent, while grain formed about $4\frac{1}{2}$ per cent.

Summary.—Though the individual vesper sparrow is unable to consume as many of the insects in question as some of his larger and more voracious neighbors, as Brewer's blackbird or the robin, its economic relation to the weevil is nevertheless important. During June and July it subsists on the pest to the extent of over half of its food, while from a fifth to a third more is composed of other equally injurious insects, together with weed seeds. The grain eaten is doubtless mainly waste. These birds, whose natural home is in the dry sagebrush areas, probably are just beginning to discover the food supply obtainable in alfalfa fields. As they become more accustomed to visiting the alfalfa, we may expect them to render still greater service in the suppression of the pest.

WESTERN SAVANNAH SPARROW.

(*Passerculus sandwichensis alaudinus.*)

The western savannah sparrow is to the average person an inconspicuous individual in the bird life of Utah, even though fairly abundant in many sections. It is frequently met in the Salt Lake Valley, but is much more common in the valley of the Weber, where in some fields it is the most abundant of the sparrows.

In May, 1911, seven savannah sparrows were obtained. All but one had fed on the weevil, and this pest composed 72.42 per cent of the stomach contents. The larvæ apparently were preferred, for, although adult weevils were common, they occurred at an average of only a little over one per bird, while the larval form was found at the rate of 21 in every stomach. One had eaten no less than 61 of the green worms, the highest number recorded for the species.

The remaining food, which, save a mere trace of rubbish, was entirely animal in character, verifies the claim that this bird is one of the most highly insectivorous of sparrows, and that "they take equal rank in this regard with such notable insect destroyers as the catbird, robin, and bluebird".[1] The food other than weevil was decidedly in the bird's favor as a large part was caterpillars, fly larvæ, plant lice, and some unidentified coleopterous larvæ.

[1] Judd, S. D., The Relations of Sparrows to Agriculture, Bull. 15, Biol. Survey, U. S. Dept. of Agr., 1901.

Five stomachs of this species were available for June, and in every one the weevil was found. A large quantity of caterpillars in two stomachs reduced the percentage of weevils taken, but the results show that in this month the savannah sparrow is continuing the good work started earlier in the season. The weevil composed 37.4 per cent of the stomach contents and an average of a little over 1 adult and 11 larvæ were taken by each bird. The other food, again almost wholly animal, contained, besides nearly 30 per cent of caterpillars, a quantity of spiders, estimated at a little over a fifth of the food. This latter item was present in four of the five birds and was practically the only food which could not be considered in the bird's favor.

Nine stomachs collected in July reveal in a most striking manner the worth of this insectivorous sparrow as an enemy of the weevil. All of these birds had eaten the insect, and in six instances it amounted to 90 per cent or upward of the food, the average consumption for the month being 80 per cent. These birds were collected in the Weber Valley, where larvæ were very abundant, and they fed on the insect at the rate of 16½ larvæ and a little less than 2 adults per bird. The highest number eaten by a single bird was 26 larvæ and 1 adult.

Of the remaining food Hemiptera formed the largest portion (7.67 per cent). Included here are many small bugs of the genus *Corizus*. Caterpillars composed about 5½ per cent. The vegetable portion, 2.22 per cent, was entirely weed seeds.

Summary.—Of the native sparrows of Utah probably none can equal the western savannah as a destroyer of the alfalfa weevil, unless, under favorable conditions, it may be the western chipping or Brewer's sparrow. It not only appears to be the most highly insectivorous of the fringilline birds in this area, but also includes in this diet more than an ordinary share of weevils. During May, June, and July this insect forms from a half to two-thirds of its food, sufficient evidence in itself to induce every farmer to become familiar with the savannah sparrow and encourage its presence about infested fields.

WESTERN LARK SPARROW.

(*Chondestes grammacus strigatus.*)

The lark sparrow, one of the most robust and conspicuously marked of western sparrows, is found in abundance throughout the Salt Lake and Weber Valleys, and occurs in approximately the same numbers wherever found. It is frequently seen about alfalfa fields, and is one of the effective bird enemies of the weevil.

It is common by the first of May, and the 14 birds collected in this month show that they already were capturing breeding adults.

Weevils composed nearly 24 per cent of the lark sparrow's food and were present in all but one of the stomachs examined. With the exception of one bird collected in the season of 1911 all had been feeding on the adult form of the insect, it being eaten at an average of over five apiece. Fifteen was the highest number taken by a single bird.

About half of the remaining animal food (7.3 per cent) was caterpillars, with click beetles (Elateridæ) and clover-root curculios (*Sitones* sp.) next in order. The vegetable portion, 62.5 per cent, was divided between grain and weed seeds. The former, composing about two-thirds of it, may, to a certain extent, have been picked up from newly sown fields, but no serious complaints have been made against this bird.

Six lark sparrows collected in June show a considerable increase in the amount of weevils eaten (31.2 per cent). The insect was present in each of the stomachs at an average of about 7 adults and 7 larvæ per bird. In one the 4 adults and 30 larvæ present formed 77 per cent of the food. Caterpillars and grasshoppers, totaling about 14 per cent each, are the most important of other animal food items. The clover-root curculio (*Sitones* sp.), which is abundant in many sections, was present in small numbers in four of the six stomachs. The vegetable portion was again characterized by waste grain, which composed nearly a third of the contents.

In July the insect formed nearly 30 per cent of the food and was eaten by each of the 11 sparrows secured at the average rate of about 7 adults and 7 larvæ, the same as for the preceding month. The best record for the month and for the species was 13 adults and 49 larvæ, while the bill of the bird eating them contained 6 additional larvæ. Caterpillars, occurring in seven stomachs, were next in importance and composed 16 per cent of the remaining animal food. The vegetable element, which formed nearly half of the food, was, as in the two preceding months, noteworthy for its high proportion of grain (45.5 per cent).

A single bird collected in August had eaten several adults of the year's brood, amounting to 8 per cent of its food. The remaining portion of the stomach contents was entirely wheat.

Summary.—The claim that the lark sparrow is a greater lover of grain than most other native sparrows[1] is apparently substantiated by the writer's work in Utah. It is quite possible that some grain is secured from newly sown fields or from the ripening or shocked crop, but no noticeable losses have been attributed to this bird. As an effective enemy of the weevil the lark sparrow must not be over-

[1] Judd, S. D. Relation of Sparrows to Agriculture. Bull. 15, Biol. Survey, U. S. Dept. of Agr., 1901.

looked. Though its animal food is somewhat less than that of most of its relatives during the summer, in May, June, and July this bird showed a marked preference for the weevil. It was taken more frequently than any other food item, and formed about 57 per cent of the animal food.

WHITE-CROWNED SPARROW.

(*Zonotrichia leucophrys leucophrys.*)

The white-crowned sparrow is a common migrant throughout the Salt Lake Valley and breeds in the higher parks of the Wasatch. The single bird available for this investigation was secured in May, and its stomach contained the remains of one adult alfalfa weevil. Though not an extensive insect eater the white-crowned may assist in reducing the weevil during spring months.

WESTERN CHIPPING SPARROW.

(*Spizella passerina arizonæ.*)

Only eight stomachs of western chipping sparrows are available for examination. One each was taken in May and June, and six in July. Of these only one, a bird collected near Salt Lake City, in May, 1911, had failed to eat alfalfa weevils. This bird had fed almost exclusively on plant lice. The bird taken in June had eaten 38 of the weevil larvæ, composing 98 per cent of the food, while five lepidopterous eggs made up the balance. Each of the six birds collected in July had fed on the insect at an average rate of about 1 adult and 17 larvæ apiece. These composed 76.5 per cent of the monthly food, and in one instance comprised the entire contents of the stomach, 32 larvæ being needed to fill it. The stomach containing the smallest quantity (12 per cent) had three-fourths of its contents composed of weed seeds. Of two birds which were evidently feeding young, one had in its bill 6 larvæ of the weevil, and the other had 8 larvæ and a caterpillar. Of animal food other than weevils, bugs and spiders were most prominent and the vegetable element of 12.6 per cent was entirely weed seeds.

Too few chipping sparrows were examined to allow a general conclusion, but its habits apparently justify placing this bird on a par with its close relative, Brewer's sparrow, in its relation to the alfalfa weevil. The larvæ of the weevil are suitable both in size and availability as food for a bird of this character. Examination of a larger series of stomachs probably would show that the chipping sparrow feeds on the weevil to the extent of upward of four-fifths of its food during the months of the greatest abundance of the insect.

BREWER'S SPARROW.

(*Spizella breweri.*)

Brewer's sparrow, or the little sagebrush chippy, as it is sometimes called, has, like several of its close relatives, learned within the past four or five years that alfalfa fields afford an excellent supply of animal food. In some localities during May and June there is little to choose between the merits of this bird and the savannah sparrow as weevil destroyers.

Brewer's sparrow does not become abundant until May, and in this month 14 were obtained. Half of these were taken in the season of 1911 when the weevil larvæ were well advanced. These insects composed 43.43 per cent of the food, and occurred in all but one of the stomachs, averaging 2.2 adults and 6.9 larvæ per bird. Twenty-four larvæ was the largest number present in any one stomach.

The stomach of the bird which had not fed on the weevil was nine-tenths full of plant lice, a food item which occurred in 7 of the 14 stomachs, and amounted to over 38 per cent of the food. In one case these insects composed practically the entire contents (97 per cent). Caterpillars were present in five stomachs, forming 7.7 per cent. Spiders and miscellaneous beetles were estimated at about 3 per cent each, and the remaining animal food was of small quantities under several heads. The vegetable portion (1.1 per cent) was entirely weed seeds.

Each of the 15 Brewer's sparrows collected in June had fed on the weevil. Three were nestlings, but their food differed but little from that of adults. In only one instance did the weevil amount to less than a fourth of the food, while in one it composed the entire stomach contents, 25 larvæ being present. Three others were examined in which the weevil formed over 95 per cent of the food, these birds having eaten 17 larvæ, 19 larvæ and 1 adult, and 28 larvæ, respectively. The average of 0.4 adult and 15.3 larvæ eaten by these birds totaled nearly two-thirds (64.6 per cent) of the food.

Caterpillars superseded plant lice as the next most important food during this month, forming 14.5 per cent of the stomach contents, while the latter amounted to only about half that quantity. Spiders, the only other important component of the animal food, were eaten freely by four birds, giving a percentage of 6.13 for the month. Merely a trace of weed seeds was present.

In July 13 of the 17 Brewer's sparrows collected had fed on the weevil, but a decrease in the bulk was noted, it composing 44.8 per cent of the stomach contents as compared with 64.6 per cent for June. There was a slight increase in the number of adults eaten (0.6) and a corresponding decrease in the larvæ (11.8). The highest number of larvæ recorded for an individual of this species is 45. These composed approximately 77 per cent of the food of this sparrow while the remains of a caterpillar and two pupæ of a moth added 20 per cent. One bird ate 3 adults and 18 larvæ, which comprised 94 per cent of the stomach contents, and it also carried 9 larvæ in its bill.

The other July food indicates a tendency toward a more vegetarian diet. About a fifth of the food was vegetable, while most important among the animal food items other than alfalfa weevils were caterpillars (11.9 per cent), Hemiptera, many of which were leaf hoppers (Jassidæ) (9.71), and spiders (2.12). The vegetable element was made up almost exclusively of weed seeds, dandelion and seeds of an unidentified grass occurring most frequently.

Summary.—Brewer's sparrow must be ranked among the most effective enemies of the weevil. During the height of the weevil season it subsists to the extent of over half its food on this pest. Other insects equally injurious, as plant lice and caterpillars, also fall prey to this bird. In the summer months upward of 90 per cent of its food consists of injurious insects and the seeds of weeds. The remaining tenth is composed of insects that are either neutral in their economic relations or indirectly beneficial to man. The amount of grain taken is insignificant.

DESERT SONG SPARROW.

(*Melospiza melodia fallax.*)

The desert song sparrow is one of the commonest of the native sparrows of Utah during the early spring months, when it may be found in the thickets along streams or irrigating ditches. Considerable numbers also pass the winter in favorable spots, which enables them to come in contact with hibernating adult weevils.

All but 2 of 11 birds collected in April had fed on the insect. Another bird whose stomach was too nearly empty to be of use in this investigation also had eaten weevils. In no case did more than 4 individuals appear in one stomach. In bulk they formed 7.35 per cent of the food.

Of other animal food the aquatic larvæ of stratiomyid flies composed the major portion, nearly 12 per cent. Caterpillars were present in two stomachs (7.27 per cent) and among other items which occurred in smaller quantities were spiders (5.45), dung beetles (*Aphodius*) (3.9), ground beetles (3.18), click beetles (2.72), and aquatic beetles (2.63). The vegetable portion was largely the seeds of weeds (31.18 per cent), among which were those of amaranth, pigweed, sunflower, ragweed, brome grass, and a sedge. Two birds had fed extensively on wheat, which brought the average for the month up to 16.45 per cent.

Two song sparrows collected in May had been doing good work on the weevil. In one, 5 larvæ and 1 adult formed 24 per cent of the food, while in the other 22 larvæ and 2 adults comprised about three-fourths of the stomach contents. Besides this the former had eaten a cricket and a large cutworm, and the latter two click beetles and a spider.

A single bird taken in June had destroyed 29 larvæ, which made up nearly two-thirds of the food; the rest of the contents included three click beetles, a caterpillar, three plant lice, two ants, a snail, seeds of three weeds, and a little grain.

As the song sparrow spends much of its time in early spring in localities selected by the weevil as places of hibernation, it must be looked upon as a valuable agent in the control of the pest. It also aids in the reduction of the number of larvæ later in the season. This bird, along with several other native sparrows, is frequently confused with the English sparrow, especially by the small boy engaged in killing the latter for bounty. This not only is one of the most potent arguments against a bounty system, but also reveals the need on the part of people generally of a more intimate knowledge of the appearance and economic value of insectivorous birds.

LINCOLN'S SPARROW.

(*Melospiza lincolni lincolni.*)

Lincoln's sparrow is a fairly common migrant in Utah, and was found in considerable numbers during April, often in company with its relative the song sparrow. Being almost entirely terrestrial in its feeding, it is seldom seen by the casual observer.

This bird renders its best service as an enemy of the weevil in destroying hibernating adults hidden in the localities it frequents in early spring. Each of three birds examined had fed on the insect, and it composed 8⅔ per cent of the food. Adult insects were taken in every case and were eaten at an average of about two per bird. Among the remaining food were found the clover-root curculio (*Sitones* sp.), crane flies, aquatic beetles, and weed seeds.

SPURRED TOWHEE.

(*Pipilo maculatus montanus.*)

The spurred towhee is most common over the oak-covered foothills of the Wasatch, and wherever this growth extends to the close proximity of alfalfa fields it may be considered an enemy of the weevil. As it is a resident species and terrestrial in habits it comes in touch with hibernating adults. Only two of these birds were collected, both in April, and each had fed on the insect. One had eaten but a single adult, amounting to 1 per cent of its food, and the other had taken at least 8, which comprised about an eighth of the stomach contents. Other food items highly in the bird's favor were seeds of brome grass, ragweed, and filaree; also the remains of click beetles, the parents of wireworms, were present in both stomachs.

As other investigations[1] have shown that the various subspecific forms of this towhee are, in other localities, of benefit to man, and since in Utah it was found to feed on the weevil, there is every reason for its conservation. Its greatest service as a weevil destroyer is rendered in the colder months.

GREEN-TAILED TOWHEE.

(*Oreospiza chlorura.*)

The older name of canyon finch is one that fittingly describes the habitat of the green-tailed towhee. Among the oak chaparral of the lower altitudes of the Wasatch this bird is often met, and as it frequently follows down the course of a mountain stream it may be found about the borders of alfalfa fields. This was observed many times in the valley of the Weber, but at no point in the irrigated areas of the Salt Lake Valley can the bird be called abundant. Six of the eight examined had fed on the weevil. One taken in May had eaten four or five adults (35 per cent) as well as a ground beetle, three darkling beetles, a hymenopteran, and a stinkbug. Another taken in June had the contents of its stomach too finely digested for accurately estimating percentages, but fragments of alfalfa weevils were recognized. Each of the other four towhees collected in June had fed on the insect, which formed an average of 57.5 per cent of the monthly food. One had destroyed 27 larvæ and 3 adults. Ground beetles, darkling beetles, Hymenoptera, and bugs were the more important of the other animal food items, while of the vegetable food weed seeds predominated.

This towhee's warfare on the weevil is conducted only in comparatively few fields located at favorable points in higher altitudes. Little though this may be, this bird should be carefully protected, especially since in other directions it is working for the best interests of the farmer.

BLACK-HEADED GROSBEAK.

(*Zamelodia melanocephala.*)

The black-headed grosbeak is a fairly common and rather evenly distributed species in the Salt Lake Valley, and is most frequently seen about the upper branches of shady cottonwoods.

---

[1] Beal, F. E. L., Birds of California. Bull. 34, Part II. Biol. Survey, U. S. Dept. of Agr., 1910.

Investigation of the food habits of eight of these birds, four of which were young, revealed that every one had fed on the weevil, though in some instances it amounted to only 1 per cent of the food. An adult taken in May had, besides one weevil and another beetle, the pulp and skin of an unidentified fruit. Three adult grosbeaks collected in June had subsisted on the weevil to the extent of 16, 1, and 95 per cent of their food, respectively. The first of these had eaten no less than 35 larvæ and 7 adult weevils; the second, 3 adults; and the third, 83 larvæ and 8 adults. Along with these were found remains of ground beetles, weevils other than *Phytonomus*, stinkbugs (Pentatomidæ), the small cicada (*Platypedia*), the seeds of weeds, and fruit of a hawthorn (*Cratægus*).

The four young grosbeaks were of the same brood, nestlings about two-thirds fledged. Their nest was located in a creek bottom flanked on one side by a badly infested alfalfa field. The consumption of weevils by these birds was at an average of 3 per cent for the brood, while 7 adults was the largest number taken by a single bird. The presence in the immediate neighborhood of large numbers of the small cicada, *Platypedia putnami*, may account for the relatively small proportion of weevils taken. The former insect occurred in each of the stomachs and averaged 88.5 per cent of the food. These young birds had also eaten small quantities of ground beetles, clover-root weevils, carrion beetles (*Silpha*), and a click beetle.

The number of stomachs available for this investigation is too limited to say how great is the work of the black-headed grosbeak as an enemy of the weevil, but the fact that each of the eight birds examined had fed on the insect indicates that it is picked up whenever found. Other investigations [1] have shown that with the exception of occasional depredations upon small fruit there is nothing objectionable in the food habits of this bird. When to its already favorable record we add the destruction of even a limited number of the alfalfa weevil, no doubt remains as to the economic, to say nothing of the esthetic, worth of this bird to the people of Utah.

LAZULI BUNTING.

(*Passerina amœna.*)

The lazuli bunting is frequently found about shrubbery along streams and on a few occasions was seen visiting the alfalfa in search of food. Only three stomachs were examined. One bird, taken in a wooded ravine some distance from the nearest irrigated fields, had failed to feed on the insect. The contents of its stomach were entirely vegetable, consisting of at least 60 seeds of *Montia.*

[1] McAtee, W. L., Food Habits of the Grosbeaks. Bull. 32, Biol. Survey, U. S. Dept. of Agr., 1908.

Two others had eaten the weevil, and in one of these 12 adults formed one-half of the contents while 5 adults and 29 larvæ in the stomach of the other composed 99 per cent of the food, a single seed of dandelion being the only other ingredient. The former of these had fed also on a cicada, a grasshopper, an ant, and a little grain. The lazuli bunting, aside from its esthetic value, is a bird of considerable economic importance. The products of the farm seldom enter into its diet, while among its customary food may be found the seeds of troublesome weeds and many noxious insects, including the alfalfa weevil.

CLIFF SWALLOW.

(*Petrochelidon lunifrons lunifrons.*)

With the exception of the rough-winged, the cliff swallow is the most abundant swallow in the territory covered by the present investigation. As enemies of the alfalfa weevil the most effective work of this and other swallows almost continuously on the wing is either at the time of the spring flight of the weevil or when the brood of the year takes wing later in the season.

Twenty stomachs of the cliff swallow were examined, three of which were of adults and the rest nestlings. The adults were collected early in June, when the birds were engaged in nest building and their stomachs contained 2, 6, and 8 adults, respectively, which formed about 12 per cent of the contents. Ground beetles composed over 40 per cent of the food. Besides these were found fairly large amounts of Hemiptera (bugs), Odonata (dragon flies), and aquatic, scarabæid, and other beetles.

In the stomachs of 17 nestlings collected later in the month the weevil formed but a part of 1 per cent of the contents, and was present in 7 of the 17 stomachs. In only one, however, did this insect occur in considerable numbers, that of a nestling about a week old which had been fed 21 adults. Another had eaten 5, and a third, 3.

As these birds were not far distant from extensive marshy areas, large quantities of the small aquatic beetle (*Helophorus lineatus*) were found in their stomachs. These had been eaten by each of the nestlings and formed about a sixth of their food. As many as 50 of these beetles were found in a single stomach. A small black ant occurred in each of the stomachs, in some cases in surprisingly large numbers, and in bulk it comprised a little over half of the young cliff swallows' food. The remains of flies of several species formed over a fourth of the stomach contents.

The work of all swallows upon the alfalfa weevil is confined to the two flight periods of the adult insect. During the earlier flight, when the life of the weevil is at its lowest ebb, any reduction of its numbers is of the utmost importance in suppressing the number of the season's brood. Though the cliff swallow does not arrive in Utah in abundant numbers much before the 10th of May many breeding alfalfa weevils may still fall as its prey. These birds feed on no product of the farm unless it is an occasional honey bee, but they include in their diet many of our most serious insect pests, noteworthy among which is the cotton-boll weevil in the Southern States.

BANK SWALLOW.

(*Riparia riparia.*)

The finding of two adult weevils in the stomach of a single bank swallow is the only evidence that this bird is among the enemies of the insect. Other elements in the food were numerous dung beetles (*Aphodius*) and several flies, including a syrphid.

ROUGH-WINGED SWALLOW.

(*Stelgidopteryx serripennis.*)

Over much of the alfalfa district of Utah the rough-winged is the most abundant of swallows. Nesting in banks of streams or railway cuts, they at times are in close proximity to infested fields.

Examination of twenty-one of these birds revealed the fact that the greatest consumption of weevils took place late in summer, when the year's brood had taken wing.

Of five birds collected in May, two had fed on the insect, which comprised 4 and 2 per cent, respectively, of their food. The remains of flies, some of which were of the genus *Bibio* (March flies), formed nearly two-thirds of the stomach contents, while small Hymenoptera and dung beetles (*Aphodius*) also figured prominently in the percentages.

During June only three of a series of eight had fed on the weevil, to an average extent of 1 per cent of the stomach contents for the month. Flies of various kinds were taken in considerable numbers and formed about three-fourths of the food. Small Hymenoptera were present in six of the stomachs.

In July the birds began to prey upon the flying adults of the year's brood. Six of the eight swallows examined had fed on the insect, which composed 23 per cent of their food. The weevils had been taken on the average of nearly 8 per bird, 18 being the highest number recorded from a single stomach. In this case it formed over a third of the contents, and in another 11 weevils made up nearly a half. Ants, found in each of the stomachs, amounted to over half of the swallow's food. Neuropterous insects were also detected in several cases.

No rough-wings were collected in August, but in all probability these birds continue to prey on the insect during late summer whenever a flight takes place.

The rough-wing probably is as effective an enemy of the weevil as the cliff swallow, but, like the latter, its work is limited to warm, fair days of spring and late summer. In addition to the good work of this bird upon this insect its economic status, based on other activities, is in its favor.

YELLOW WARBLER.

(*Dendroica æstiva æstiva.*)

The yellow warbler is the most common of breeding warblers throughout the Salt Lake Valley. Whenever its favorite nesting site of willows along the banks of streams and irrigating ditches occurs about the borders of alfalfa fields, this bird is brought in contact with the weevil.

Five birds were collected in June and two in July. Only those taken in the latter month were feeding on the weevil. One had eaten 11 larvæ and 1 adult, the other 6 larvæ. Besides, the latter had in its bill 3 weevil larvæ, a bug, and 9 flies. In bulk the weevil composed nearly a fourth of the food of the two.

The other yellow warblers had fed extensively on caterpillars, which were found in each of the stomachs and formed nearly 70 per cent of the food. One half-grown nestling had been fed exclusively on these insects. Small Hymenoptera, some of which were parasitic, were next in abundance, forming nearly a fifth of the contents.

Although abundant about the borders of alfalfa fields, yellow warblers were seldom observed dropping down to them in search of food. The upper branches of willows are their favorite resorts and apparently their food is largely secured from such places.

MACGILLIVRAY'S WARBLER.

(*Oporornis tolmiei.*)

Listing Macgillivray's warbler as an enemy of the weevil is based on the examination of only one stomach. Two breeding adult weevils eaten in May formed about 2 per cent of the contents. There were also present the remains of a click beetle, a dung beetle, a flea beetle (*Systena* sp.), and a large amount of unidentified insect fragments.

LONG-TAILED CHAT.

(*Icteria virens longicauda.*)

Our knowledge of the long-tailed chat as a weevil destroyer is based on the examination of three stomachs. In two the insect was present, one containing a mere trace of an adult, and in the other 2 adults composed about 3 per cent of the food.

The chat's food habits are strikingly like some of the flycatchers. Hymenoptera form a conspicuous element in its diet, as do also flies and other forms which the bird may secure from its favorite haunt in the tree tops. One bird had eaten six wild bees, aggregating 94 per cent of the food, and another had fed on the small cicada (*Platypedia putnami*), which formed about two-thirds of the stomach contents.

As a check upon the weevil little can be expected from the long-tailed chat, because of its arboreal habits. Its food is of little economic importance, much being of a neutral character, while a certain proportion of beneficial insects appears to offset the good it does in the destruction of noxious forms. The inestimable value of its wonderful song, however, is alone sufficient reason for the most careful preservation of the species.

SAGE THRASHER.

(*Oreoscoptes montanus.*)

The sage thrasher, a bird of the arid regions, arrives in the Salt Lake Valley about the middle of March, and its rather weak song may then frequently be heard about the edges of alfalfa fields bordering on sagebrush areas.

Examination of 10 stomachs showed that the sage thrasher feeds on the weevil to a considerable extent. In bulk it formed about an eighth of the food and was present in seven of the stomachs. The best work appeared to be done in June, when the insect was eaten at the rate of about 3 adults and 6 larvæ per bird. One bird had eaten 3 adults and at least 34 larvæ, which composed 44 per cent of the stomach contents.

Ground beetles were present in all but two of the stomachs examined and formed about 30 per cent of the food in June and a lesser amount in April and July. These beetles and a trace of an ant formed the entire contents of one stomach. Darkling beetles of the genera *Blapstinus* and *Eleodes* also were frequently eaten, composing a fifth of the food. Hymenoptera, spiders, and caterpillars were other important ingredients. The only vegetable food was a quantity of currants found in one stomach.

The sage thrasher can not be regarded as a very effective enemy of the alfalfa weevil, except when alfalfa fields extend toward its native haunts among the sagebrush. Under ordinary conditions its food habits are strongly in the bird's favor, but occasional complaints have been made that it injures small fruits.

LONG-TAILED CHICKADEE.

(*Penthestes atricapillus septentrionalis.*)

The long-tailed chickadee was frequently met along the borders of alfalfa fields and in the shrubbery of creek bottoms in irrigated sections. Being a resident all the year, in early spring it could be found searching diligently over the branches and trunks of cottonwoods or flitting through dense thickets of hawthorn or willows. In such environment it is quite possible for the chickadee to come in contact with hibernating weevils.

Six birds were collected in April, and the weevil was present in the stomachs of three. Two of these contained 2 adults apiece, while the third had 3, and this food amounted to about 3 per cent of the stomach contents.

Much of the food of these small birds was very finely divided and in some cases unidentifiable. In three of the six stomachs, however, large numbers of plant lice were detected. Small lepidopterous cocoons also were found.

Even though the amount of food consumed by one of these birds is small, there is reason to believe that the chickadees secure many of those adults which make their winter quarters in crevices in the bark of trees.

WESTERN ROBIN.

(*Planesticus migratorius propinquus.*)

The western robin is a resident of parts of the Salt Lake Valley the year round, but in the more exposed situations and in the higher valleys surrounding Salt Lake it is a migrant and summer breeder. In the lower valley it becomes very abundant in April and early May, while a month or two later, though still common, it is most frequently found in the shade of orchards or in truck-crop areas, where the more thoroughly watered ground assures it a constant supply of one of its favorite foods—earthworms. In the valley of the Weber the robin was an abundant breeder and a frequent visitor to the infested alfalfa fields.

Forty-five birds were collected in April, but four stomachs, being nearly empty, were not used in the computation. Three of the four stomachs discarded, however, showed traces of the weevil. Of the others, 28 contained the insects, adults in every case, which comprised a little over 14 per cent of the food. This material gave an average of 5.63 adult weevils per bird. The best individual work done by any robin in this month is credited to a male, which had captured no less than 56 of these insects. Another had eaten upward of 20.

Caterpillars, many of which were cutworms, were taken with almost as great avidity as the weevil, occurring in 27 stomachs, but the larger size of these insects resulted in a much higher percentage, 23.24. One stomach contained at least 90 young caterpillars. Click beetles (Elateridæ) and their larvæ, wireworms, were found in 18 stomachs and amounted to 11.10 per cent of the contents. One bird had eaten no less than 5 adults and 40 larvæ of *Limonius occidentalis*. The other more important elements of the animal food were earthworms (8.68 per cent), flies (5.97), dung beetles (Scarabæidæ) (5.70), and ground beetles (3.97). Carrion, unassociated with bone fragments to denote its origin, was found in several stomachs. The rather careless feeding habits of this bird are attested by a large amount of rubbish in the food. This occurred in 23 stomachs and amounted to nearly 12 per cent of the bulk. A little grain (2.10 per cent) also was eaten.

For the month of May only four stomachs are available. Each contained the weevil, totaling 7.25 per cent of the food. No very large numbers of the insect were recorded, but this is attributed to the limited amount of material. The other food items maintained approximately the same relative proportions as in April.

During June a series of 17 stomachs was collected largely about Coalville, in the Weber Valley, where these birds bred in considerable numbers. The weevil, present in 10 stomachs, composed 23.77 per cent of the food, and was taken at an average of about 2 adults and 42 larvæ per bird. Two birds had eaten exceptionally large numbers of the insect. One destroyed 2 adults and 253 larvæ, and the other 3 adults and about 241 larvæ; the latter composed 80 per cent of the food. Two other noteworthy records were 1 adult and 75 larvæ, and 5 adults and 40 larvæ, respectively. Caterpillars, again a prominent part of the food, were present in all but three of the stomachs and amounted to nearly a fifth of the contents. Ground beetles, darkling beetles (*Eleodes*), carrion beetles (*Silpha*), and carrion were the other prominent animal food items. Rubbish, comprising the bulk of the vegetable element, amounted to more than a fourth of the contents.

Examination of 18 robins collected in July showed a falling off in the amount of weevils eaten. Eleven birds had fed on the insect at the rate of 4 adults and 13.8 larvæ per bird and to the extent of 9.39 per cent of the monthly sustenance. One stomach contained 2 adults and about 220 larvæ. Caterpillars, still a conspicuous element (37.72 per cent), occurred in 12 stomachs. Earthworms made up nearly a fifth of the food, while ground, carrion, and darkling beetles maintained about the same proportions as in June. The only vegetable food other than rubbish worthy of notice occurred in a single stomach, which was filled with the skin and pulp of an unidentified fruit.

Summary.—As is the case with several other resident species the robin does its most effective work in early spring. Much of its time is then spent about the borders of alfalfa fields, where many weevils are emerging from winter quarters. Though the actual percentage for April (14.29) is less than two-thirds of that for June (23.77), there is no question that the good done is much greater in the earlier month, when the rigors of winter have reduced the insect to its lowest ebb; and any agency in the work of destruction that can be brought to bear at this time is of the utmost importance. The food of the robin in Utah speaks highly in its favor. Some complaint was heard that it injures cherries, but this trait does not seem sufficiently uniform to offset the good it does. Until the weevil is reduced in numbers the services of the robin as a destroyer of breeding adults alone ought to earn for it the utmost protection.

MOUNTAIN BLUEBIRD.

(*Sialia currucoides.*)

The mountain bluebird is an abundant breeder throughout the higher altitudes of Utah and in spring and fall is a migrant in the irrigated valleys. In the spring flocks of 5 to 15 often may be seen in the vicinity of infested fields. In their search for food, usually confined to the borders of fields and along roadsides where fences and telephone poles afford favorite perches, the bluebirds come in contact with hibernating or recently emerged adult alfalfa weevils. A considerable number of bluebirds were encountered in April in the Salt Lake Valley, and in July they were found in post-breeding flocks in alfalfa fields in the Weber Valley. At the latter place the fully fledged young were feeding extensively on the larvæ, which were then present in great numbers.

Of seven birds collected in April five had fed on breeding weevils. In bulk the weevils composed over 4 per cent of the food and were taken at an average of about two and one-half per bird. Twelve was the highest number recorded for any individual.

The major portion of other animal food at this time of year consisted of caterpillars (32.5 per cent) and ground beetles (31.3 per cent). In one stomach eight cutworms formed about four-fifths of the food and in another a similar number composed over 72 per cent. Among the ground beetles the genus *Amara* predominated. Crickets appeared prominently in two, and in one a large number of dung beetles (*Aphodius*) formed about two-thirds of the food.

Each of the nine birds collected during July had fed on the insect, which amounted to 11 per cent of the food. One, a juvenile bird, had eaten at least 70 of the larvæ, forming 40 per cent of its food; another, 17 larvæ and 5 adults; and a third about 12 larvæ and 3 adults.

The remaining animal food of the bluebirds at this time was characterized by a large proportion of hemipterous remains made up largely of the small cicada (*Platypedia putnami*), so abundant among the oak chaparral of the foothills.

The mountain bluebirds, like many other spring and fall migrants, render their most valuable services as weevil destroyers in early spring. More extensive investigations of their general food habits have established the fact that, as a family, they are among the most persistent of insect feeders and at the same time molest no product of the farm. Their presence should be fostered at every opportunity, and there is reason to believe that as our western country becomes more thickly settled these gentle birds may become as familiar about dooryards as are their eastern relatives.

ENGLISH SPARROW.

(*Passer domesticus.*)

From its enormous abundance throughout much of the weevil-infested region of Utah, as well as from the fact that, individually, it is a most effective enemy of the alfalfa weevil, the English or house sparrow must be placed very high in the scale of weevil enemies. There is no bird in which the people of Utah are more interested than this much-criticized foreigner and, as its efficiency as an insect destroyer has frequently been questioned, special pains have been taken to present as thorough a consideration as possible of the relation of the sparrow to the alfalfa weevil.

The English sparrow presents a problem in Utah somewhat different from that in many other parts of its range. Though by no means uncommon in the city streets, the never-ceasing chatter of hundreds of these birds heard along country roads and about farmyards readily makes an observer realize that in many rural sections of the Salt Lake Valley this species is by far the most abundant.

A factor partly responsible for this condition is the presence on almost every farm of one or more straw-thatched sheds for housing live stock and in these the birds nest. (See Pl. I, fig. 2.) These sheds are constructed usually with the ceiling about 8 or 9 feet from the ground. The framework is made of heavy logs overlaid with limbs and smaller boughs, and upon this the straw is placed to a depth of 2 to 5 feet. Into the straw the sparrows dig holes about the size of one's arm and sometimes extending inward for a foot or 18 inches. Masses of nest material also may be found placed upon the beams or limbs used in the framework. Frequently upward of 100 nest holes, both occupied and deserted, may be found in a roof about 20 or 30 feet in dimensions. Lombardy poplars, cottonwoods, and box elders, abundant in the valley, are also favorite nesting sites.

FOOD OF YOUNG BIRDS.

For investigating the food habits of young English sparrows 1,039 stomachs, mostly of nestlings, are available. These were secured as follows: First half of May, 16; second half, 530; first half of June, 382; second half, 36; first half of July, 40; and second half, 35. The bulk of this material was collected from the middle of May to the middle of June, which about coincides with the period of greatest abundance of these young birds as well as of the larval form of the weevil. The largest number was from the vicinity of Murray, Midvale, West and South Jordan, Sandy, and Riverton, an area in which this bird is by far the most abundant species.

May 1 to May 15.—Examination of birds collected during this interval showed that the parent birds were already visiting alfalfa fields for food for the hungry nestlings. The weevils fed to the young were adults which had hibernated, a very important economic service when is considered the potential harm of each pair of weevils during the course of a season, as embodied in their progeny.

About one-half of the total animal food, 14 per cent, consisted of the weevil. Thirteen of the 16 birds collected had fed on this insect, indicating that this food is probably picked up whenever found. These nestlings had eaten a total of 218 adult weevils, or an average of 13⅝ per bird. A brood of three, about 2 or 3 days old, had eaten 60, 50, and 32 per cent, representing 58, 41, and 28 weevils, respectively.

The contents of these stomachs consisted of 28.06 per cent animal and 71.94 per cent vegetable matter. Of the animal food other than weevils 4.19 per cent was caterpillars, while 4.37 per cent consisted of scarabæid beetles of the genus *Aphodius*. Ground beetles aggregated 2.56 per cent; Hymenoptera, 1.12 per cent; and Orthoptera (grasshoppers and crickets), slightly less than 1 per cent. The remaining portion of animal matter was composed of other insects in small quantities.

The largest portion of the vegetable food was wheat, found in 15 of the 16 stomachs, and amounting to 65.62 per cent.

May 16 to May 31.—The weevil was eaten by the 530 birds to the extent of 36.12 per cent of the stomach contents, which is the highest proportion of this food eaten in any of the semimonthly periods covered. As this figure was obtained from the examination of so large a series of stomachs, it doubtless is not far from a true representation of what these young birds do at this time of year. The remarkable persistency with which the parent birds seek this food for their young is well shown. Of 530 young birds, only 19, or 1 out of about every 28, had failed to eat the weevil.

Among the birds notable for their stomach contents were 7 in which the weevil composed the entire food, 11 in which it amounted to 90 per cent or over, and 16 in which it was 80 per cent or over. The number of insects that may be contained in the stomachs of these young birds is remarkable. A nearly fledged young of a brood of four had eaten no less than 20 adults and 110 larvæ, while the remaining three had consumed 27 adults and 29 larvæ together. Two young birds, about a week old, had eaten 62 adults and 92 larvæ between them. A brood of four, about 4 days old, had taken, respectively, 38 adults and 33 larvæ, 33 adults and 65 larvæ, 41 adults and 67 larvæ, and 25 adults and 60 larvæ, or an average of 34¼ adults and 56¼ larvæ apiece, equaling 51 per cent of the stomach contents. Another brood had eaten a total of 53 adults and 200 larvæ, averaging $10\frac{3}{5}$ adults and 40 larvæ for each bird. Four other young, about 2 days' old, had devoured 4 adults and 195 larvæ.

A brood of three, 3 or 4 days old, had taken a total of 210 adults and 12 larvæ from a badly infested field adjacent to the shed in which the nest was located. Another brood of the same number had eaten 190 and 15; a brood of two, 129 and 5; while three other young birds, 3 or 4 days old, had taken no larvæ, but had consumed 183 adult weevils. On May 27 the writer collected a brood of five young birds, 5 or 6 days old, whose stomachs contained a total of 308 adults and 151 larvæ, an average of 61.6 and 30.3 per bird, and amounting to 70.4 per cent of the contents.

Of the 530 stomachs collected for this period, there was one which contained over 100 larvæ, 7 which had from 75 to 99, 29 with from 50 to 74, and 90 with from 25 to 49. As to adult weevils, there were 5 stomachs containing from 75 to 99, 21 with from 50 to 74, and 74 with from 25 to 49. Many stomachs contained from 15 to 25 larvæ, as well as adults, the total frequently exceeding 40 individuals.

The food, other than weevils, next most important was Lepidoptera, comprising 18.36 per cent of the contents, and almost entirely made up of caterpillars. In 28 stomachs caterpillars composed three-fourths or more of the contents. Though at present these insects are not causing so much damage as the weevil, yet the good service of the birds in destroying them must be recognized. Ground beetles (Carabidæ) made up 4.65 per cent of the stomach contents, the principal portion being of the genus *Amara*. Diptera, made up largely of Tipulidæ (crane flies), comes next in order, with a percentage of 3.9. Spiders, eaten principally during the first 2 or 3 days of the nestlings' life, composed 3.78 per cent, and scarabæid beetles, mainly of the genus *Aphodius*, represent 2.75 per cent. Hymenopterous insects made up 2.08 per cent of the contents. The remainder of the animal food, a little less than 3 per cent, was scattered among several groups of insects, of which carrion beetles (Silphidæ), grasshoppers, and bugs (Hemiptera) were most important.

The vegetable food, as usual, was composed almost entirely of wheat and oats. Much of this must be considered waste, though some complaints that sparrows steal chicken feed are verified by this examination.

June 1 to June 15.—A percentage of 26.75 shows the extent to which the 382 young, examined in this period, were feeding on the weevil. A total of 4,907 adults and 5,336 larvæ were eaten, an average of 12.85 adults and 13.97 larvæ for each bird. In 1911 of 22 birds 3 had failed to feed on the insects, while in 1912 only 1 out of 360 did not eat them, this being a very young bird in which spiders and caterpillars formed much of the stomach contents.

Stomachs containing remarkably large numbers of these insects for so small a bird are to be found in this material. One brood of five half-grown young consumed, respectively, 55 larvæ and 1 adult; 110 larvæ and 2 adults; 95 larvæ and 3 adults; 85 larvæ and 4 adults; and 123 larvæ and 1 adult, an average of 93.6 larvæ and 2.2 adults for each bird. A brood of three averaged 5⅔ adults and 88 larvæ apiece, one of these having eaten 170 larvæ and 5 adults, the largest number recorded for a young of this species. Four young collected on June 1, 1912, were still busy with the breeding adults, which were abundant, 272 adults as well as 4 larvæ being consumed, an average of 68 adults and 1 larva apiece. Another hatch of 4, about two-thirds grown, had taken a total of 54 larvæ and 176 adults, one of these alone having eaten 42 larvæ and 50 adults. Another brood of 4 were making heavy inroads on the larvæ, a total of 218 larvæ and 26 adults being their record. A single bird of another hatch had destroyed 150 larvæ and 14 adults, while another made away with 95 larvæ and 8 adults. Numerous other cases occurred where individual nestlings had eaten upward of 50 weevils in one stage or another of development.

Of the 382 birds examined 5 had eaten more than 100 larvæ; 6 had taken from 75 to 99; 17, from 50 to 74; and 49, from 25 to 49. The adults were not taken in quite so large numbers, two birds having eaten from 75 to 99; 9, from 50 to 74; and 46, from 25 to 49.

The total animal food in this period was 60.81 per cent, of which 35.06 was other than weevil. About one-third of this, or 11.3 per cent, consisted of Lepidoptera, principally caterpillars; 7.15 per cent was ground beetles (Carabidæ); 5.31 per cent Diptera, mainly Tipulidæ; while the remainder, 11.3 per cent, was made up of various insects, of which dung beetles (*Aphodius*), bugs (Hemiptera), grasshoppers, spiders, and parasitic Hymenoptera were most important.

The vegetable food (comprising 39.19 per cent of the contents) is again characterized by the predominance of wheat, with a little other grain and some weed seeds.

June 16 to June 30.—Most of the first crop of alfalfa has been cut by this time, and in badly infested regions the fields are kept barren by the work of the larvæ, which prey on every green shoot of the new crop as it makes its appearance. English sparrows still frequent the fields after food for their young, though the increased percentages of some of the other food items, especially grasshoppers, indicate that the weevil is becoming less abundant. Many insects have pupated, and in that stage are little eaten by birds. Thirty-six stomachs collected in this half of the month show a percentage of 18.25 of weevil food. All but three of these contained the insect. Examination revealed a noticeable decrease in the number of these insects taken by young birds at this time—an average of but 4.97 adults and 5.36

larvæ apiece. A single pupa was eaten by one bird, while many of the adults were those of the new brood. Only a few stomachs are especially noteworthy. The highest number of weevils taken by any bird in this period was 52 larvæ and 9 adults, eaten by a nestling. Three other birds had taken 27 larvæ, 26 larvæ and 3 adults, and 20 larvæ, respectively.

Considerable interest is attached to the other animal food, which amounted to nearly 42 per cent of the contents. Grasshoppers and crickets occurred in more than half of the stomachs, amounting to 16.3 per cent, while injurious caterpillars totaled 19.64 per cent. Weevils, other than *Phytonomus*, and spiders comprised 1.50 and 1.88 per cent, respectively, while Hymenoptera, mainly parasitic, made up 1 per cent. The vegetable food, 39.78 per cent, showed a slight increase in the consumption of weed seeds, but by far the largest portion, 36.64 per cent, was grain, some of which was that taken from the newly headed crop.

July 1 to 15.—The 40 stomachs collected in this period show a remarkable falling off in the amount of weevils eaten, *Phytonomus* composing only 0.77 per cent of the contents. This may be largely accounted for by local conditions. Most of the birds were secured at a point where grasshoppers were appearing in large numbers and, though alfalfa fields which had been badly infested earlier in the season were near-by, but few weevils were found at this time. Most of those eaten were adults of the new brood, but they averaged less than one apiece for the birds collected, while the 40 birds together had eaten but 13 larvæ.

The abundance of grasshoppers is readily indicated in the results of the stomach analysis, which showed a percentage of 35.23, or nearly three-fourths of the animal food. These insects were present in 36 stomachs, and in several instances composed more than 90 per cent of the contents. Caterpillars were still frequently taken, amounting to 8.82 per cent. Of the vegetable food, 52.03 per cent of the contents, the greatest portion (51.63 per cent) was wheat. In this case it was almost entirely composed of grain taken from the growing crop.

July 15 to July 31.—By this time the second crop is well advanced in most fields and serious damage by the weevil has ceased for the season. Most of the weevils abroad are adults of the year's brood. The 35 stomachs collected gave a weevil percentage of 9.2. This increase over that of the first half of the month may be largely attributed to more favorable local conditions, though there probably were more adult weevils available. The birds had eaten an average of 4.82 adults and 1.63 larvæ each, and the insect occurred in 31 of the stomachs, usually in limited numbers. Were a larger amount of material available, a gradual decrease in this work as the month progressed probably would be manifest. The largest amount eaten by any was by a nestling 3 or 4 days old, which had 13 larvæ and 14 adults in its stomach. Orthoptera (grasshoppers and crickets) continued to increase and in this series of stomachs comprised nearly a quarter (24.71 per cent) of the total contents, being eaten by 20 of the 35 birds. Ground beetles, Hemiptera, Lepidoptera, and Hymenoptera, made up the bulk of the remainder. The vegetable food, practically all grain, amounted to 58.20 per cent.

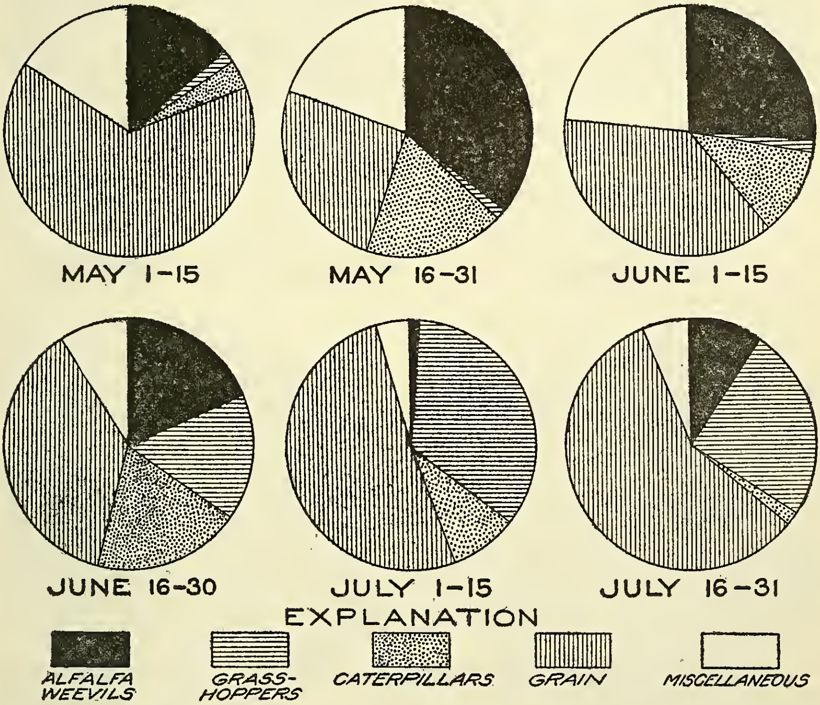


FIG. 2.—Diagram showing the food of young English sparrows during semimonthly periods in May, June, and July.

The diagram presented in figure 2 and the following tabulation represent each of the six semimonthly periods from the first of May to the end of July, and the proportions of the various food elements may easily be seen by comparing the various sectors of the different circles:

Semimonthly periods.	Alfalfa weevils.	Grass-hoppers.	Caterpil-lars.	Grain.	Miscella-neous.
May 1-15	14.00	0.94	4.19	65.62	15.25
May 16-31	36.12	.66	18.36	25.05	19.81
June 1-15	26.75	1.03	11.30	38.84	22.08
June 16-30	18.25	16.30	19.64	36.64	9.17
July 1-15	.77	35.23	8.82	51.83	3.35
July 16-31	9.20	24.71	1.86	58.20	6.03

Stomach analysis of these birds also revealed the fact that the value of the young English sparrow as a weevil destroyer varies considerably and rapidly as his nestling life progresses. From the blind, naked, and helpless bird of a day or two, which must necessarily be fed on the softest and most easily assimilated foods, as weevil larvæ, caterpillars, spiders, etc., to the lusty-lunged fledgling, whose food is characterized by grain and hard-shelled insects, differing but little from that of the adult, we find all intermediate stages. That some idea may be given of the proportion of the several principal food items found to occur at various stages of the nestling's life, the writer has arranged the material into four groups which represent as nearly as possible birds of the first, second, third, and fourth quarters, respectively, of the nestling life. Six of the principal food items, namely, alfalfa weevils, ground beetles, caterpillars, flies, spiders, and grain, are considered in showing the change of food habits as life progresses, and these are illustrated in figure 3. Orthoptera (grasshoppers) form an important article of food late in the season and would have been included had field work been continued until fall. These insects, especially the nymphs, were eaten extensively by nestlings of the first and second quarter during July. The following tabulation shows the changing percentages of foods during the four quarters of nestling life:

Quarterly periods.	Alfalfa weevils.	Ground beetles.	Caterpillars.	Flies.	Spiders.	Grain.	Miscellaneous.
First quarter	37.95	2.55	26.65	6.71	6.43	5.28	14.43
Second quarter	29.87	5.11	16.09	4.01	1.99	31.69	11.24
Third quarter	26.05	6.23	4.72	2.55	.69	49.25	10.51
Fourth quarter	18.75	7.43	3.12	.62	.35	63.18	6.55

As the bird becomes older there is a gradual decrease in the consumption of weevils, as well as of other soft and easily digested foods, as caterpillars, flies, and spiders, while the hard-shelled ground beetles are taken in greater quantity. Grain, mostly wheat, early becomes an important food item, and by the time the bird has left the nest it is well fitted to uphold the reputation of its parents.

FIELD OBSERVATIONS ON THE FEEDING OF NESTLINGS.

Observations also were made of the amount of food given the young English sparrows and the frequency of the feedings. Parent birds were timed for a period, usually an hour, and at the end of this time the incoming bird was captured and the contents of its bill and throat recorded. By taking the average of a number of such observations the writer was able to get a fair idea of the amount of food consumed daily by a nest of these young birds.

In the first observation a sparrow was noticed feeding four nearly fledged young. The parent bird appeared at the nest with food at an average of once every $7\frac{2}{3}$ minutes. When examined on the last trip the incoming bird had two grains of wheat in its bill.

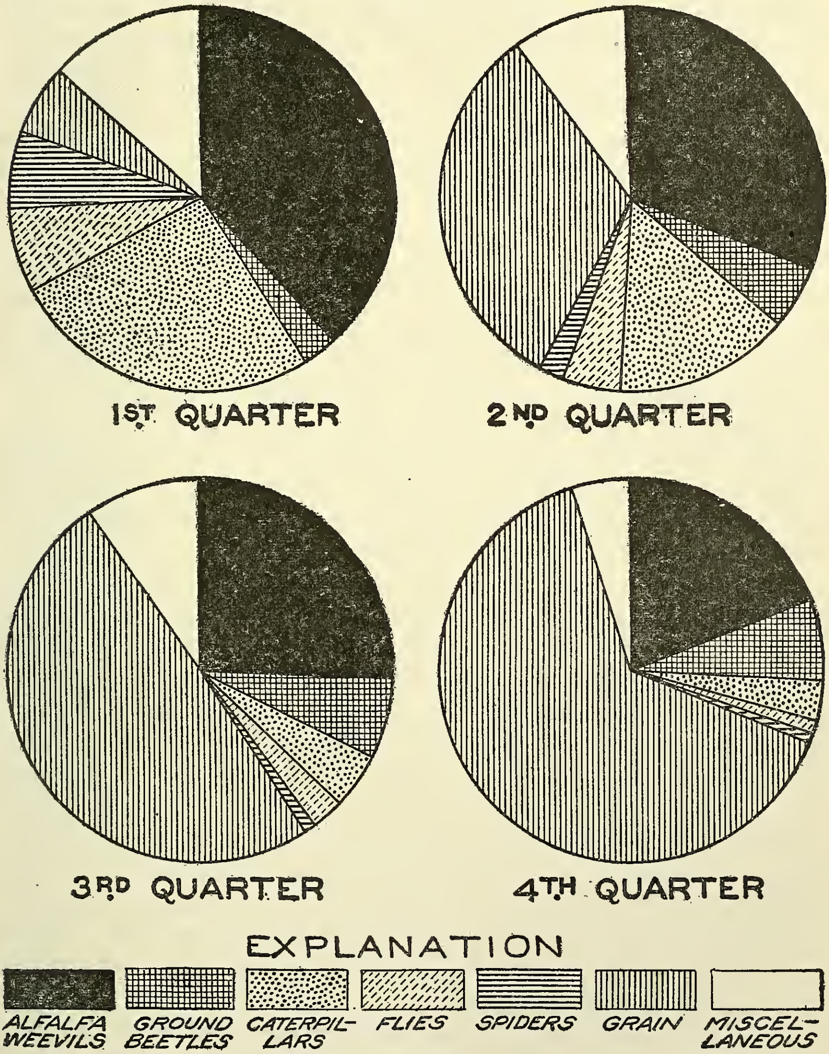


FIG. 3.—Diagram showing the food of young English sparrows during the four quarters of their nestling life.

Another observation gave an average of $5\frac{5}{11}$ minutes for every feeding. This nest contained two young, about 4 or 5 days old, but the writer failed to secure the adult at the end of the hour.

Observation of a brood of six young, 4 to 5 days old, showed that feedings took place at 5-minute intervals. The male, which was captured, carried 17 larvæ of the weevil in his bill.

Another series of observations gave an average of 5 minutes between the feedings. The female in this case carried a ground beetle (*Harpalus amputatus*), a caterpillar, and 9 larvæ of the alfalfa weevil in her bill and throat.

Observations of feeding of nestlings on an unoccupied farm showed that visits were made at the rate of 17 trips an hour, or about one trip every 3½ minutes. The female was carrying 28 larvæ of the weevil on her last trip.

From this series of five observations it appears that the parent English sparrows visited their nest on an average of about once every 5⅓ minutes, or a little more than 11 trips an hour. The four adults captured had as food for their young 2 kernels of wheat; 17 alfalfa weevil larvæ; 1 ground beetle, 9 weevil larvæ and a caterpillar; and 28 weevil larvæ, respectively. Three other adults taken in the fields had food for nestlings in their bills. This amounted to 18 weevil larvæ and an aphid in the first, 5 larvæ in the second, and 3 coccinellid larvæ, 13 weevil larvæ, and 2 pupæ in the third.

Though this is a rather heterogeneous assortment, it would appear that 15 larvæ of the weevil or their equivalent in bulk of other insects would be a fair estimate of an average amount of food brought in at each trip by adult birds. In fact, it is certain that the material brought in frequently greatly exceeded this amount.

Allowing, then, 15 larvæ at each trip and 11 trips per hour, these birds would bring in 165 larvæ per hour. Then, assuming that the young were being fed for 12 hours each day, a conservative estimate, we would have a total of 1,980 larvæ consumed by one brood in one day. As previously stated, straw-thatched sheds containing upward of 100 nest holes, both old and new, are frequent, and it is not uncommon to find farmyards where this number of nests are occupied. There are also ample nesting sites about the other buildings and in the ever-present Lombardy poplar, cottonwood, or box elder. Such a colony of birds would devour a daily total of 198,000 larvæ, or an equivalent bulk in other food. As the young birds remain in the nest for at least 10 days and are probably fed several days longer by the adults, they will have eaten food equivalent to the bulk of 1,980,000 larvæ during their nestling life.

As these birds are not feeding exclusively on this insect, the average amount of weevils eaten by young English sparrows during the height of the season being about 25 per cent of their food, under average conditions we would have the young of such a colony eating 495,000 weevils. While there may be some farms where only comparatively few larvæ are eaten, there must be others where favorable circumstances will bring the total destroyed by the nestlings of one brood nearer the larger figure.

To the number of weevils destroyed by the young we must add those eaten by the adult birds during this time. As four nestlings appear to be a fair average for a brood, there would be one-half as many adults as young; and although the food of old birds was only about 18 per cent weevils during May, June, and July, it amounts to a considerable quantity in the period that they have young in the nest to feed.

While the writer does not wish to have too great emphasis placed upon such somewhat theoretical deductions, at least they serve to show, with a fair degree of certainty, what might be expected of such a colony under favorable circumstances.

ADULT ENGLISH SPARROWS.

Careful observation shows that adult sparrows are frequent visitors to alfalfa fields. Their visits are most often when there are young to be fed, and at such times the parent birds consume much the same kind of food as their progeny, especially the adult weevil. Fields nearest barnyards, where these birds nest, are benefited most, but numerous cases were observed where the adult birds were traveling considerably over 100 yards to secure the desired food. Wherever these birds nested in large numbers a more or less regular stream of adult sparrows was observed flying to and from the badly infested portion of some near-by alfalfa field.

In the two seasons' work 104 stomachs of adult English sparrows were collected, 14 in April, 67 in May, 20 in July, and 3 in August.

April.—But few adult English sparrows were found in alfalfa fields this early in the season. Breeding and nest building were occupying their time, and they were seldom seen far from farm buildings, where they found ample food in horse droppings and chicken feed.

Weevils (adults in every case) occurred in 6 of the 14 stomachs and amounted to a little over 1 per cent of the contents. As the entire animal food amounted to but 2.57 per cent, the weevil formed almost half of it. In every case save one, only a single insect was taken, and in that instance two adult weevils composed 10 per cent of the contents.

The other animal food consisted entirely of dung beetles (*Aphodius*). Seeds of such plants as pigweed (*Chenopodium*), amaranth (*Amaranthus retroflexus*), and filaree (*Erodium cicutarium*) made up 3 per cent, while the remainder was grain, mostly wheat.

As these birds were collected in April, 1912, when very inclement weather prevailed, the food was confined almost entirely to that secured about the barnyard.

May.—The 63 birds taken in May indicate a beginning of the season's work on the alfalfa weevil. Forty-six had feed on the insect, which amounted to 8.75 per cent of the stomach contents, and an average of 2 adult weevils and 2.1 larvæ for each bird was recorded from this series. One bird had eaten 5 adults and 43 larvæ, and another 2 adults and 26 larvæ. A bird collected in 1912 had eaten 25 breeding adults.

The remainder of the animal food (1.05 per cent) was divided in small quantities among insects of several orders. The vegetable portion, as usual, was conspicuous by the high percentage of grain (87.19) while the remainder (3 per cent) was weed seeds.

June.—The highest percentages of weevils eaten by the parent birds were in June. The 20 birds examined had destroyed 26 adults and 229 larvæ, an average of 1.3 adults and 11.45 larvæ apiece, amounting to 29.55 per cent of the contents. Only 4 of the 20 had failed to eat at least one weevil. One had eaten 49 larvæ and 1 adult, comprising 90 per cent of the contents; another had taken 41 larvæ, while the 27 larvæ and 2 adults eaten by a third amounted to 99 per cent of its food. Most of these birds had nestings to feed, and the contents of their bills is recorded under the consideration of the food of nestlings.

The greater portion of the remaining animal food was composed of weevils other than *Phytonomus.* Of the vegetable portion, 68.4 per cent, a little over 3 per cent was weed seeds, while the remainder was grain, mostly wheat.

July.—In July only three adult sparrows were examined—far too small a number from which to make reliable deductions. However, these showed that weevils were still being eaten, as they were present in all three stomachs, averaging 18 per cent of the bulk, which, save a single clover-root weevil (*Sitones*), was the entire animal food. This latter insect, known to do damage to alfalfa as well as clover, was found quite frequently but in small quantities in the stomachs of both adult and young sparrows.

SUMMARY.

Considering the various phases of the economic relation of the English sparrow to the alfalfa weevil, it may safely be asserted that this bird is a most effective enemy of the pest. This is particularly true of nestling birds in May and June. In view, however, of the ability of this bird to do serious damage to standing grain, and to take heavy toll from the farmers' chicken feed, legal protection for the species can not be advocated. While there doubtless are altogether too many of these birds about some farms, a reduction in their numbers may be much more satisfactorily effected by the individual farmer[1] than by the aid of a bounty law, such as has been in force

[1] Full directions for trapping and poisoning English sparrows, as well as directions for their use as food, may be found in Farmers' Bulletin 493, U. S. Dept. of Agr., The English Sparrow as a Pest, by Ned Dearborn.

in some counties of Utah for the past few years. Such a law, besides being an incentive to misrepresentation and fraud and expensive in its operation, very frequently, as in this case, utterly fails in accomplishing its object.

BIRDS NOT FEEDING ON THE WEEVIL.

A number of Utah birds which had not fed on the alfalfa weevil were also examined. From the nature of their food habits or from the isolation from alfalfa fields of their favorite habitats some are prevented from becoming potent factors in the control of the weevil, but additional field work might show others to be enemies of the pest. The following species were examined, the number of each being indicated:

Black-crowned night heron (*Nycticorax nycticorax nævius*)	1
Avocet (*Recurvirostra americana*)	2
Black-necked stilt (*Himantopus mexicanus*)	1
Western willet (*Catoptrophorus semipalmatus inornatus*)	1
Long-billed curlew (*Numenius americanus*)	1
Snowy plover (*Ægialitis nivosa*)	2
Desert sparrow hawk (*Falco sparverius phalœna*)	2
Burrowing owl (*Speotyto cunicularia hypogæa*)	2
Lewis's woodpecker (*Asyndesmus lewisi*)	2
Black-chinned hummingbird (*Archilochus alexandri*)	1
Kingbird (*Tyrannus tyrannus*)	6
Olive-sided flycatcher (*Nuttalornis borealis*)	1
Pale goldfinch (*Astragalinus tristis pallidus*)	4
Northern violet-green swallow (*Tachycineta thalassina lepida*)	1
Cedar waxwing (*Bombycilla cedrorum*)	2
White-rumped shrike (*Lanius ludovicianus excubitorides*)	1
Rock wren (*Salpinctes obsoletus obsoletus*)	1
Ruby-crowned kinglet (*Regulus calendula calendula*)	2

DOMESTIC FOWLS AS WEEVIL ENEMIES.

The efficient work of domestic fowls in feeding on the alfalfa weevil had been noted by many farmers, and a few were making excellent use of broods of young chickens and turkeys by placing them in badly infested fields. Here these fowls satisfied their appetite for animal food, and when their feeding was confined to a limited area there was a noticeable improvement in the subsequent growth of alfalfa.

Mr. William Blood, of Kaysville, conducted experiments with chickens in the summers of 1911 and 1912. After cutting the first crop in a field of about 15 acres he set out three colony houses containing 100 eight-weeks-old chicks, 90 five weeks old, and 160 two weeks old, respectively. These broods were moved from place to place as the area about the houses was cleaned up. In this way the work of these diligent workers was distributed over most of the field.

On June 29 the writer made the photographs reproduced in Plate V. Figure 1 shows the growth at a point in the field where the chickens were allowed to do their first work after the cutting of the crop. The second crop responded immediately, and some of the stalks were 9 to 10 inches high. The stake shown in the foreground is about 3 inches high. Figure 2, taken on the same day, shows the bare and apparently dead stubble of the first crop at a place farthest from the colony houses where the chickens had not been feeding.

There may be danger when a limited area is overstocked with chickens that their feeding on the growing crop will impair its progress, but by a judicious scattering and moving of the broods these young birds may be used to excellent advantage. They not only materially benefit the subsequent crop of alfalfa, but also find an abundant supply of animal food.

OTHER VERTEBRATE ENEMIES OF THE WEEVIL.

As toads (*Bufo lentiginosus woodhousei*) were abundant in well-watered fields, and frogs (*Rana pipiens*) were often found in alfalfa adjacent to ditches, an investigation was made of their food habits, and it was found that both were feeding on the weevil. A salamander (*Ambystoma tigrinum*) collected in 1911 had eaten one adult. A blue racer (*Zamenis constrictor flaviventris*) collected north of Salt Lake City, and another taken near Bountiful, had failed to eat any. Mr. E. G. Titus records[1] horned "toads" (*Phrynosoma* spp.), swifts (Lacertilia), and a small garter snake (*Eutænia* sp.) as enemies. He also mentions having found a shrew (*Sorex* sp.) which had fed on a single weevil. The stomach of one of these, a *Sorex obscurus*, collected by the writer near Midvale contained none.

As a fairly good series of stomachs of both the Rocky Mountain toad and the leopard frog were secured, a detailed account of their relation to the weevil follows.

ROCKY MOUNTAIN TOAD.

(*Bufo lentiginosus woodhousei.*)

Toads are essentially nocturnal, especially during the hot, dry months of summer at the altitude of the Salt Lake Valley. Although on cool, cloudy days they may be abroad in alfalfa fields, ordinarily they seldom feed much before sundown or after the morning sun has dried the dew.

As an enemy of the alfalfa weevil the Rocky Mountain toad renders its best service in the destruction of breeding adults during spring and early summer. Later in the year the bulk of the larvæ

[1] Bull. 110, Utah Agr. Coll. Exp. Sta., p. 49, Sept., 1910.

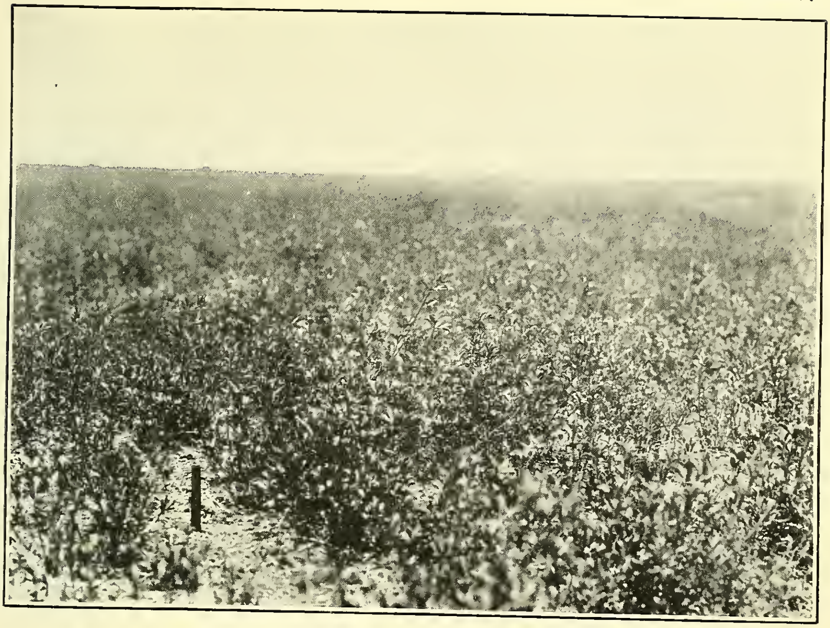


FIG. 1.—WORK OF CHICKENS ON AN INFESTED FIELD.

[This shows the second crop of alfalfa well started in a part where chickens had been allowed to feed. The stake in the left foreground is about 3 inches high.]

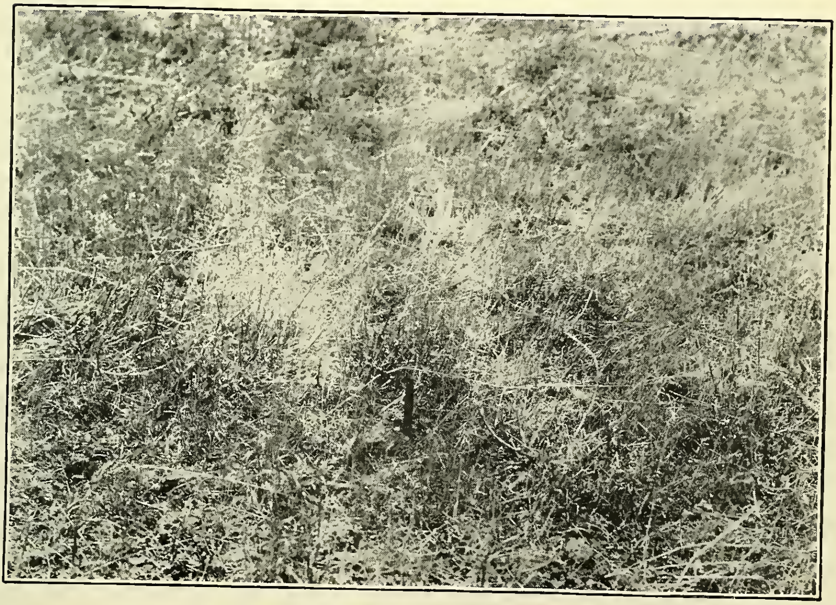


FIG. 2.—PART OF SAME FIELD WHERE CHICKENS HAD NOT FED.

[Note the dry leafless stubble of the first crop two weeks after cutting. Photographs taken the same day.]

are out of its reach, except when the crop has been cut. At such times larvæ which have been dislodged and are seeking new feeding places are quickly seized by the hungry toad. After raking, the same condition prevails until the larvæ have again established themselves and become practically stationary during their feeding operations. Mr. E. G. Titus records having examined the stomach of a toad found in a recently cut field.[1] Over 800 larvæ had been eaten by this batrachian, "and there was also present a mass of more or less digested animal matter which apparently contained a good many more larvæ. From this same toad there were also taken 75 (adult) weevils, and there were in the partly digested mass the wing covers of more weevils." Though the writer collected toads which had eaten a considerable number of larvæ, none had equaled this remarkable record.

Twenty-eight specimens of this toad were collected, 2 in April, 8 in May, and 18 in June.

Each of the two taken in April had fed on the adult weevil, one having eaten 9 and the other 20, which amounted to over a fifth of their food. Besides this they had fed on several ground beetles of the genera *Harpalus*, *Amara*, and *Pterostichus*. These formed over half of the stomach contents. In one stomach was also a large crane fly, and in the other a mass of ants.

Seven of the eight toads collected in May had eaten the weevil, adults in all cases but one. In bulk this element formed nearly 15 per cent of the food and was taken on an average of about 10 for each toad. Thirty-eight adults was the highest number recorded for an individual. Besides the weevil a large quantity (30 per cent) of ground beetles, mostly of the genera previously mentioned, was consumed. Ants occurred in seven stomachs, forming nearly 18 per cent of the food. Click beetles (*Drasterius elegans* and *Monocrepidius vespertinus*), which were abundant in some sections, and do serious injury to such crops as corn and wheat, were eaten freely. Even the large sluggish cutworm so common in alfalfa fields was also taken.

Sixteen of the 18 toads secured in June had fed on the weevil to the extent of about a twelfth of their food, and at an average of about 15 adults and 1⅓ larvæ apiece. One had devoured 83 of the adults and another had made away with 28 adults and 15 larvæ. Ground beetles were eaten by every one of the toads and formed nearly a fourth of the food. One toad had taken no less than 68 *Amara fallax*, which at times are injurious to vegetation. Ants were present in all but two of the stomachs and in bulk amounted to over 21 per cent. Among these were found many specimens of the western harvest ant (*Pogonomyrmex occidentalis*). Numerous other

[1] Bull. 110, Utah Agr. Coll. Exp. Sta., p. 50, Sept., 1910.

Coleoptera, including May beetles, click beetles, darkling beetles, and a few weevils, made up nearly an eighth of the food. Caterpillars (7.9 per cent), spiders (2.1 per cent), and miscellaneous insects (7.8 per cent) composed the bulk of the remaining contents. About half of these stomachs contained varying quantities of vegetable rubbish, doubtless swallowed accidentally along with the insects.

While the toad destroys a considerable number of beneficial ground beetles, some "ladybirds" (Coccinellidæ), carrion and dung beetles (Silphidæ, *Aphodius*, etc.), and spiders, it also destroys even greater quantities of insects highly injurious to man. Among these may be mentioned May beetles (the adults of the white grub); click beetles (parents of the wireworm); various snout beetles, including the alfalfa weevil; ants; and caterpillars, including cutworms and army worms. The function of the toad in nature appears to be a rather indiscriminate reduction of insect life coming within reach. These batrachians therefore are especially valuable in the suppression of a terrestrial insect which has become unduly abundant. As such a condition prevails in Utah, every effort should be made to conserve the numbers of this valuable insect destroyer, whose worth is generally underestimated.

LEOPARD FROG.

(*Rana pipiens.*)

This alert batrachian often may be found in alfalfa adjacent to water and in low, damp fields. Like the toad, it is highly insectivorous, but in its more aquatic environment its diet differs somewhat. Conditions are not so favorable for its becoming as effective an enemy of the alfalfa weevil as the toad, although adult weevils hibernating in the brush along ditches may form an appreciable portion of its food.

Two of the three frogs secured in May had fed on the weevil, in each case a single insect being taken. In bulk this averaged about 1 per cent of the food. Ground beetles, earthworms, flies, spiders, and neuropterous insects were the principal other components.

In June four of the six collected had eaten weevils, which formed a larger proportion of the diet ($2\frac{1}{2}$ per cent). One frog had eaten six adults, and larvæ had been taken in three of the four cases. Ground beetles, which again figured prominently in the diet, occurred in five of the six stomachs and formed about 40 per cent of the food. A stink bug (*Euschistus variolarius*), which has been injurious to vegetation, appeared to be a favorite food. It formed 17 per cent of the stomach contents. Click beetles, caterpillars, and spiders made up the greater portion of the remainder. Vegetable rubbish, as in the case of the toad, was freely taken while swallowing insect food.

The food habits of the leopard frog stamp it as one of the most beneficial of the lower vertebrates. Its only harm lies in the destruction of beneficial predaceous and parasitic insects, but this is outweighed by its persistent attack upon such insect pests as mosquitoes, crickets, grasshoppers, and the predaceous water beetles injurious to small fish fry. It is deplorable that so many of these batrachians are being slaughtered, either for fish bait or for the small morsel of food which their legs afford.

CONCLUSION.

The investigation of the food habits of the birds of Utah in relation to the alfalfa weevil verifies the statement frequently made that the abundance of an insect, and consequently the ease with which it may be secured, are important factors governing the food habits of birds. With the exception of a few restrictions placed upon certain species by their methods of feeding, insectivorous birds are to a certain degree indiscriminate in their choice of food. Flycatchers, swallows, nighthawks, etc., are limited in a large measure to flying insects; thrushes, meadowlarks, blackbirds, and gallinaceous species secure most of their insect food from the ground; while warblers, chickadees, woodpeckers, cuckoos, etc., feed largely among the tree tops. It is the ground-feeding birds which come into most intimate contact with the alfalfa weevil, but birds that feed on the wing may secure the insect at the time of its spring and summer flights; and such species as search for their food over trunks of trees may come into contact with a few hibernating adults. Over much of the territory covered by the writer in his two seasons' work these bird enemies of the weevil had learned to search for the insect as a food in the comparatively short period of four or five years, a fact which makes the large proportion of this food eaten by some species the more remarkable.

With the possible exception of a fungous disease, which in some localities destroyed large numbers of the pupæ, there probably was, at the close of 1912, no other natural agency which had done more in holding the alfalfa weevil in check than the native birds. Being alert to detect any unusual abundance of suitable food in the insect world, they were among the first to turn their attention to this new pest, and when once a convenient supply of this food was found in the alfalfa these fields became popular with many species. It is quite possible that in the case of some of the birds examined a knowledge of the location of this insect had been only recently acquired, and a few years more experience with it would place these species much higher in the scale of weevil enemies.

The laws enacted in the State of Utah for the protection of bird life are, on the whole, adequate and well enforced, and the love for bird life by the people of Utah has been a powerful agency in making this possible. Since the writer's investigations in 1911–12 a law was passed (effective March 11, 1913) giving protection to one of the effective enemies of the alfalfa weevil—Brewer's blackbird. However, during the present crisis of the insect outbreak, it appears wise to suggest that added protection be given to another enemy of the weevil, and that there be removed from the statute books a bounty law on a third.

The species deserving added protection, for a short period at least, that its good work in the suppression of the weevil may continue unimpaired, is the valley quail. Its numbers at present throughout most of the alfalfa area are too limited to threaten serious harm to grain crops. In fact, from what was learned regarding the food habits of this bird in relation to the weevil, it is far too scarce for the best interests of the Utah farmer. A shorter open season or even absolute protection for a few years would rapidly increase its numbers to a point where it could do effective work on the insect.

Removal of the bounty law on the English sparrow is recommended, not so much because the bird requires added protection, as for the reason that this law, as is the case with most laws of this nature, utterly fails to materially reduce the number of these birds, and at the same time it has been the reason for the destruction of many birds of other and beneficial species. A reduction in the numbers of the sparrow, if desired, can be much more effectively accomplished either by the efforts of individual farmers or by the employment of competent men to make a thorough and extensive campaign of trapping, poisoning, or nest destruction. Where chicken feed can be protected and where grain fields will not be jeopardized these birds may well be allowed to continue unmolested their good work on the alfalfa weevil.

INDEX.

○

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 108

Contribution from the Bureau of Soils, Milton Whitney, Chief.

August 5, 1914.

(PROFESSIONAL PAPER.)

HARMFUL EFFECTS OF ALDEHYDES IN SOILS.

By Oswald Schreiner and J. J. Skinner,
Scientists in Soil Fertility Investigations.

INTRODUCTION.

In the course of a study of the soils on the Mount Vernon estate, Virginia, large samples from the flower garden were subjected to a special examination in the laboratory. In this flower garden box hedges, roses, and other perennial garden plants have grown for years and manure has been liberally applied. The soil is a brown mellow loam containing enough sand and vegetable matter to effect an excellent structural condition. At a depth of about 15 inches the surface soil passes into a reddish brown to yellowish brown clay loam. This subsoil in turn grades into a compact red clay, faintly mottled in places with grayish colors, at a depth of approximately 24 inches. This layer of material resembles a hardpan formation. The compact condition undoubtedly affects the movement of moisture and air. The examination of the soil in the laboratory showed that the surface soil was acid and the subsoil decidedly so.

When subjected to the methods for isolating organic substances from soils as devised in this laboratory, saccharic acid, acrylic acid, mannite, and salicylic aldehyde were obtained. The details of the isolation of these compounds have already been reported [1] and only the salicylic aldehyde is of interest in the present paper. It was obtained as follows:

The soil was extracted with 2 per cent sodium hydroxide, and the solution thus obtained was acidified with sulphuric acid and filtered. The acid filtrate was shaken out with several portions of ether, the ether extracts being combined and shaken with a concentrated

[1] Shorey, E. C., Some Organic Soil Constituents, Bul. 88, Bureau of Soils, U. S. Department of Agriculture, p. 19 (1913).

NOTE.—This bulletin deals with the discovery and properties of aldehydes in soils. These are shown to affect crops unfavorably and decrease the yield greatly. The results are of interest to agricultural experimenters and those practical farmers whose training interests them in the advance of scientific agriculture.

43777°—Bull. 108—14——1

aqueous solution of sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid, and air blown through to remove sulphur dioxide. This solution was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation over a small volume of water. The solution remaining was filtered from a small quantity of resinous insoluble material and as thus obtained was a slightly colored solution having an aromatic odor and the properties of a solution of salicylic aldehyde. On slow evaporation of the water there was left a yellow oil, soluble in water with some difficulty, but very soluble in alcohol or ether. The water solution developed a pink color in fuchsine aldehyde reagent almost immediately and gave an intense violet color with ferric chloride. When treated with phenylhydrazine, a precipitate was formed which on recrystallization from alcohol was in the form of yellow leaflets that melted at 143°, the characteristic form and melting point of the phenylhydrazone of salicylic aldehyde. The separation of this compound from ether solution by an aqueous solution of sodium bisulphite and the color produced with fuchsine reagent fix it as an aldehyde. The general properties of the compound and the formation of the hydrazone melting at 143° are sufficient to identify it as salicylic aldehyde.

As the large sample of soil collected was used up in the above isolation and identification of some of its organic constituents, a second shipment of the soil was secured and sufficient salicylic aldehyde obtained to make some tests of its action on plants.

The effect of the soil aldehyde was tested on wheat by growing the plants in water cultures. An experiment was made with the aldehyde dissolved in pure distilled water. The wheat was grown in water in culture jars holding 250 c. c. One jar contained pure distilled water, and the second contained the water in which was dissolved the aldehyde separated from the soil. The plants grew for two weeks. The aldehyde was quite harmful, reducing growth about 37 per cent. Another experiment was made, using a good nutrient solution with and without the substance. The aldehyde from the soil was extremely harmful, even in the good nutrient solution; the green weight of the plants was reduced 40 per cent. These experiments with the salicylic aldehyde extracted from the soil on growth are shown in Plate I, figure 1. The plants show the harmful effect of the substance on growth. It will be seen that both tops and roots in nutrient solution and in distilled water are badly affected by the presence of the salicylic aldehyde.

Having thus demonstrated the harmful action of this substance when isolated from a soil, there remains a further study of the action of this compound on various plants and in various culture solutions, in soils in pots, and finally in the field. For these further studies, which required quantities impossible of procuring from the soil itself, the chemically prepared salicylic aldehyde was used.

EFFECT OF SALICYLIC ALDEHYDE ON PLANTS IN SOLUTION CULTURES.

EFFECT ON WHEAT.

The method of growing wheat seedlings in solution cultures is fully described in previous bulletins.[1]

Salicylic aldehyde was used in amounts of 10, 25, 50, 100, and 200 parts per million dissolved in pure distilled water. A culture of distilled water without salicylic aldehyde was included in the test and used as a control. The cultures grew from May 4 to May 16, 1912. It became at once apparent that the salicylic aldehyde was very harmful to the seedling wheat, even in the lowest concentration of 10 parts per million. The appearance of the series of plants on the sixth day is shown in Plate I, figure 2. In the culture solution containing 10 parts per million growth was reduced 31 per cent; in the 25 parts per million solution growth was reduced 69 per cent; with 50, 100, and 200 parts per million the plants were killed.

EFFECT ON CORN.

The effect of salicylic aldehyde on corn plants was tested by growing the corn in nutrient solutions of calcium acid phosphate, sodium nitrate, and potassium sulphate, with and without salicylic aldehyde.

The aldehyde was used in amounts of 10, 25, 100, and 200 parts per million. One corn plant was used in each culture jar containing 250 c. c. of the solution. The plants were germinated and put in the solution when they were about 1½ inches high. The corn grew in the solutions from May 26 to June 20, 1912. A photograph of the cultures, taken when the plants had been growing for 10 days, is shown in Plate II, figure 1. The harmfulness of this substance to corn is clearly shown. The effect was very noticeable, even in the culture containing 10 parts per million. In the culture containing 200 parts per million there was very little growth; the plants were almost dead.

In Table I are given the green weights of the plants, taken when the experiment was concluded. The last column indicates the relative growth.

TABLE I.—*Effect of salicylic aldehyde on corn in nutrient solutions of calcium acid phosphate, sodium nitrate, and potassium sulphate.*

No.	Treatment.	Green weight.	Relative growth.
		Gram.	
1	Nutrient solution	1.00	100
2	Same + 10 parts per million salicylic aldehyde	.60	60
3	Same + 25 parts per million salicylic aldehyde	.60	60
4	Same + 50 parts per million salicylic aldehyde	.21	21
5	Same + 100 parts per million salicylic aldehyde	.21	21
6	Same + 200 parts per million salicylic aldehyde	.10	10

[1] See especially Bul. 70, Bureau of Soils, U. S. Dept. of Agriculture.

The figures in the table show a decreased growth due to the salicylic aldehyde. Ten parts per million reduced growth from 100 to 60, or 40 per cent, 50 and 100 parts per million were also extremely harmful, and very little growth occurred in the 200 parts per million solution.

EFFECT ON COWPEAS.

An experiment with cowpeas, similar to that with corn seedlings, was made, using the same concentrations of salicylic aldehyde and the same nutrient solution. The plants grew in the solutions from June 15 to June 28. One plant was used in each culture.

The effect of the aldehyde on the cowpea plants was similar to that with wheat and corn. In Plate II, figure 2, are shown the plants as affected by the aldehyde. From this it is seen that amounts larger than 10 parts per million are extremely harmful to the cowpea.

In Table II is given the green weight of the cowpea plants taken at the end of the experiment, and their relative growth.

TABLE II.—*Effect of salicylic aldehyde on cowpeas in nutrient solutions.*

No.	Treatment.	Green weight.	Relative growth.
		Grams.	
1	Nutrient solution	1.35	100
2	Same + 10 parts per million salicylic aldehyde	1.35	100
3	Same + 25 parts per million salicylic aldehyde	.70	51
4	Same + 50 parts per million salicylic aldehyde	.35	26
5	Same + 100 parts per million salicylic aldehyde	.20	15
6	Same + 200 parts per million salicylic aldehyde	.15	11

The figures in the table show that salicylic aldehyde in amounts of 10 parts per million did not affect the green weight. The green weight was the same in that culture as in the nutrient solution which did not contain aldehyde. The culture containing 25 parts per million of the aldehyde, however, produced a much smaller plant than the control. The growth was reduced from 100 to 51. Solutions containing 50, 100, and 200 parts per million produced very poor plants. The plants made very little growth and were almost dead when the experiment was discontinued.

EFFECT ON CABBAGE.

An experiment in nutrient solution was made to determine the effect of the salicylic aldehyde on young cabbage plants. The nutrient solution was the same as that used with corn and cowpeas. The salicylic aldehyde was used in quantities varying from 10 to 200 parts per million. In each culture 10 young cabbage seedlings were grown. The plants were supported in the culture jar by means of a cork, similar to the manner in which the wheat seedlings were grown. The plants grew in the solution from May 25 to June 12, 1912. A photograph of the cultures was taken when they had grown seven days, and is shown in Plate III, figure 1. Growth was materially reduced by 10 and 25 parts per million, while 50, 100, and 200 parts per million killed the plants. Cultures stronger than 50 parts per million are not shown.

When weighed at the termination of the experiment, growth in the culture containing 10 parts per million salicylic aldehyde was found to be reduced 39 per cent. With 25 parts per million growth was reduced 61 per cent. This shows that the aldehyde in small amounts was quite harmful to the young cabbage plants.

EFFECT ON RICE.

When tested on rice seedlings in water and in nutrient solutions the salicylic aldehyde was found to be harmful to this crop also. The distilled water solutions of 10 parts per million of salicylic aldehyde gave a depression of 16 per cent in the green weight of the plants. In the nutrient solutions the 10 parts per million of salicylic aldehyde gave a depression of 15 per cent in the green weight.

EFFECT OF SALICYLIC ALDEHYDE IN SOIL IN POTS.

EFFECT ON WHEAT.

Experiments were made to study the effect of salicylic aldehyde in soil. Paraffined wire pots[1] holding approximately 1 pound of soil were used. The soil was a heavy clay loam. Before potting, portions of the soil were treated with varying amounts of salicylic aldehyde. Six wheat plants were grown in each pot. The experiment was begun May 27 and discontinued June 18. In Plate III, figure 2, are shown the plants as they appeared near the end of the experiment. This shows that the salicylic aldehyde was harmful. The final results are given in Table III.

TABLE III.—*Effect of salicylic aldehyde on wheat plants in soil.*

No.	Treatment.	Green weight.	Relative growth.
		Gram.	
1	Clay loam untreated	0.65	100
2	Same + 10 parts per million salicylic aldehyde	.65	100
3	Same + 25 parts per million salicylic aldehyde	.50	77
4	Same + 50 parts per million salicylic aldehyde	.40	61
5	Same + 100 parts per million salicylic aldehyde	Dead	
6	Same + 200 parts per million salicylic aldehyde	Dead	

As seen from the table the aldehyde in amounts of 10 parts per million in the soil had no effect. Larger amounts than 10 parts per million were quite harmful. With 25 parts per million growth was

[1] Method as described in Circ. 18, Bureau of Soils, U. S. Dept. of Agriculture.

reduced from 100 to 77, or 23 per cent. With 50 parts per million the growth was reduced from 100 to 61, or 39 per cent. In amounts of 100 and 200 parts per million the plants were killed.

EFFECT ON CORN.

The action of salicylic aldehyde in soil and also in sand was tested as to its effect on corn. The aldehyde was added to a clay soil and to pure quartz sand in amounts of 50 parts per million. One pot each of the soil and sand untreated was run as a check. The corn was planted May 23 and grew until June 20. One corn plant was grown in each pot containing soil and two plants in each pot containing sand.

A photograph of the plants is shown in Plate IV, figure 1. The first two pots contain soil and the last two sand. Number 2 in each case had been treated with salicylic aldehyde. Growth in the treated pots is seen to be much smaller than the growth in the check pots. The effect of the salicylic aldehyde in the sand is seen to be greater than in the clay soil.

The green weight of the plants was taken at the termination of the experiment. The salicylic aldehyde was found to have reduced growth in the clay soil from 100 to 76, or 24 per cent, and in the sand from 100 to 40, or 60 per cent. The harmful effect was more marked in the quartz sand than in the clay soil, which is probably due to the absorptive power of the clay being far greater than that of the sand, and perhaps also to the higher nutritive value of the soil in comparison with the pure sand.

EFFECT ON CLOVER.

The clover was grown in an ordinary flower pot holding 6 pounds of soil, using a good loam soil, the Hagerstown loam. One pot was untreated, the other had a total of 100 parts per million of the salicylic aldehyde added to it.

When the soil was potted 50 parts per million of the aldehyde was added, and clover then sown, 0.5 gram of seed per pot. Later, when the clover was up, 25 parts per million more of the aldehyde was added in solution through a funnel passing into the soil nearly to the bottom of the pot, thus avoiding direct contact with the tops or roots of the clover. Three weeks later another 25 parts per million was added in the same manner. The experiment lasted from April 12 to June 21, 1912. From the beginning the effect of the aldehyde on the clover was noticeable.

In Plate IV, figure 2, is shown the appearance of the pots when the clover was well up. The inhibiting effect of the salicylic aldehyde is clearly shown. The control was of a deep green color, while the treated pot showed not only a poor growth, but also a much faded color, and had a decidedly unhealthy appearance.

The green weights taken at the termination of the experiment were 8.5 grams from the control pot and only 4.2 grams from the salicylic aldehyde treated pot, a decrease of approximately 50 per cent.

In the foregoing salicylic aldehyde has been shown to be harmful to wheat and rice seedlings in distilled water, to wheat, corn, cowpeas, cabbage, and rice in nutrient solutions, and to wheat, corn, and clover in soil in pots.

EFFECT OF SALICYLIC ALDEHYDE IN SOLUTION CULTURES WITH VARIOUS FERTILIZER INGREDIENTS.

EFFECT ON WHEAT.

The effect of salicylic aldehyde on wheat plants was further studied by growing the seedlings in nutrient culture solutions containing the ordinary fertilizer salts, calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained calcium acid phosphate only, some sodium nitrate only, and some potassium sulphate only. Other solutions were composed of mixtures of two salts, calcium acid phosphate and sodium nitrate, calcium acid phosphate and potassium sulphate, and sodium nitrate and potassium sulphate. Still other solutions had all three constituents in various proportions. The compositions of the various solutions is given in the first three columns of the tables which are to follow.[1] Two sets of cultures were prepared; to one set were added merely the nutrient salts; to a similar set 10 parts per million of salicylic aldehyde were added in each culture in addition to the nutrient salts. The culture solutions were changed every three days, four changes being made in the course of the experiment. The solutions were analyzed for nitrates immediately after each change. The phosphate and potassium were determined on a composite solution of the four changes. The culture grew from May 15 to May 27, 1912.

When the plants had grown for several days, it was noticeable that the salicylic aldehyde cultures were developing more slowly. Each of the cultures seemed affected, regardless of the composition or the proportion of the nutrient salts.

When the plants had grown for 12 days with four changes of the solutions, the green weights were taken. The results obtained with the solution of different fertilizer ingredients are grouped in the tables which follow, so as to bring together those cultures which were composed principally of phosphate, those which were composed principally of nitrate, and those composed principally of potassium salt. In each group there were 21 cultures. A fourth group, comprising six cultures, is also given. It includes those cultures with a nearly equal proportion of the three salts.

[1] The solutions were prepared as described in Bul. 70, Bureau of Soils, U. S. Dept. of Agriculture.

Table IV gives the growth in cultures composed principally of phosphate, without and with 10 parts per million of salicylic aldehyde. The composition of the culture solution is given in the first three columns. As will be seen, the solutions contained principally phosphate, but also varying smaller amounts of nitrate and potash. In the fourth column is given the green weight of the plants grown in solutions which contain no salicylic aldehyde, and in the fifth column the weight of the plants in solutions containing 10 parts per million of salicylic aldehyde.

By comparing these two columns in the table it is seen that the green weight of the salicylic aldehyde culture is less in every case, with one exception only, than the green weight of the culture of the same fertilizer mixture without the salicylic aldehyde. The total green weight of the 21 normal, or control, cultures was 39.61 grams, against 31.74 grams for the 21 cultures with salicylic aldehyde.

TABLE IV.—*Effect of salicylic aldehyde on wheat in nutrient culture solutions composed principally of phosphate.*

Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.	Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.
P_2O_5	NH_3	K_2O	Green weight.	Green weight.	P_2O_5	NH_3	K_2O	Green weight.	Green weight.
Parts per million.	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*	*Parts per million.*	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*
80	0	0	1.02	0.76	48	8	24	2.50	1.54
72	0	8	1.32	1.04	48	16	16	2.60	1.92
72	8	0	1.30	1.14	48	24	8	2.50	1.88
64	0	16	1.32	1.22	48	32	0	1.64	1.34
64	8	8	1.70	1.44	40	0	40	1.75	1.10
64	16	0	1.54	1.14	40	8	32	1.90	1.52
56	0	24	1.24	1.38	40	16	24	2.98	2.16
56	8	16	2.34	1.52	40	24	16	2.88	2.14
56	16	8	2.04	1.66	40	32	8	2.28	1.74
56	24	0	1.34	1.28	40	40	0	1.80	1.60
48	0	32	1.62	1.22					

Table V gives the results of salicylic aldehyde in nutrient solution in which the principal ingredient is nitrate.

As seen in the fourth and fifth columns of the table, the growth in cultures with salicylic aldehyde are much smaller than the growth in solutions containing merely the nutrient salts. The total green weight of the 21 cultures in nutrient salts was 49.36 grams, and the green weight of the 21 nutrient cultures containing 10 parts per million salicylic aldehyde was only 36.11 grams. From these figures it is seen that salicylic aldehyde in these nutrient solutions, principally nitrogenous, as in the phosphate solutions, is quite harmful to wheat plants.

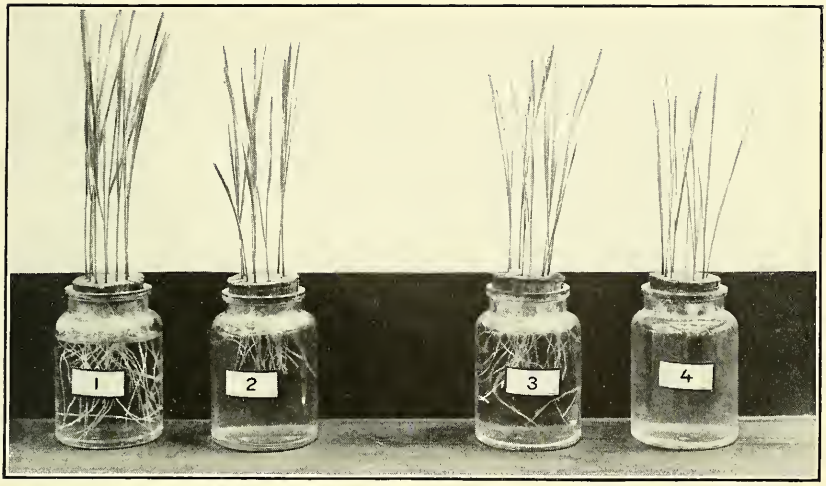


FIG. 1.—EFFECT OF SALICYLIC ALDEHYDE EXTRACTED FROM MOUNT VERNON GARDEN SOIL ON WHEAT SEEDLINGS.

(1) Nutrient solution; (2) nutrient solution plus salicylic aldehyde; (3) distilled water; (4) distilled water plus salicylic aldehyde.

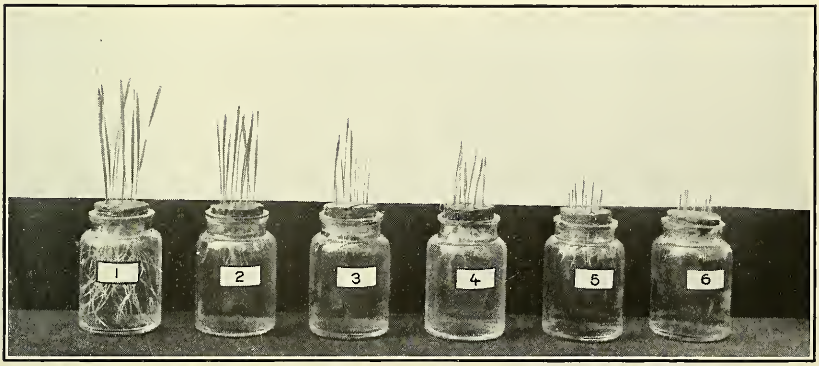


FIG. 2.—EFFECT OF SALICYLIC ALDEHYDE ON WHEAT SEEDLINGS IN WATER SOLUTIONS.

(1) Control in distilled water; (2) same plus salicylic aldehyde 10 parts per million; (3) 25 parts per million; (4) 50 parts per million; (5) 100 parts per million; (6) 200 parts per million.

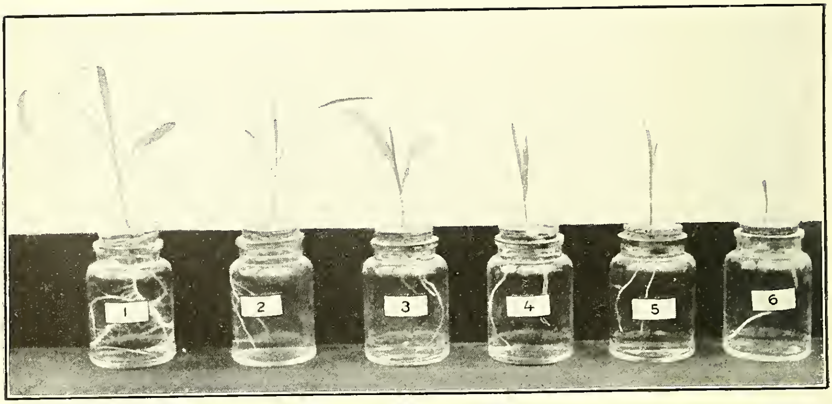


FIG. 1.—EFFECT OF SALICYLIC ALDEHYDE ON CORN IN NUTRIENT SOLUTIONS.

(1) Control in nutrient solution; (2) same plus salicylic aldehyde 10 parts per million; (3) 25 parts per million; (4) 50 parts per million; (5) 100 parts per million; (6) 200 parts per million.

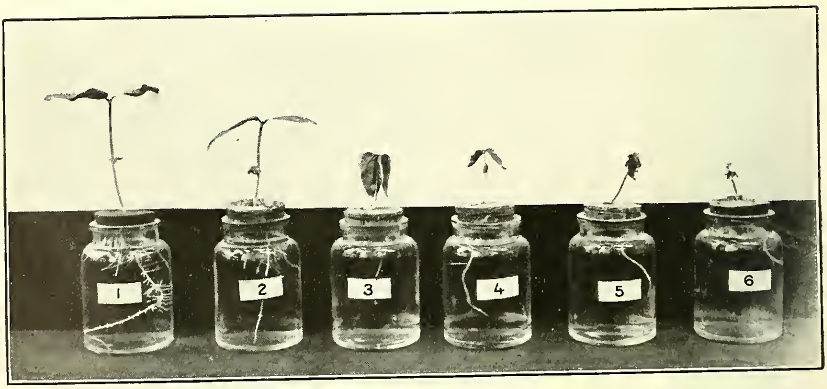


FIG. 2.—EFFECT OF SALICYLIC ALDEHYDE ON COWPEAS IN NUTRIENT SOLUTION.

(1) Nutrient solution; (2) same with 10 parts per million salicylic aldehyde; (3) 25 parts per million; (4) 50 parts per million; (5) 100 parts per million; (6) 200 parts per million.

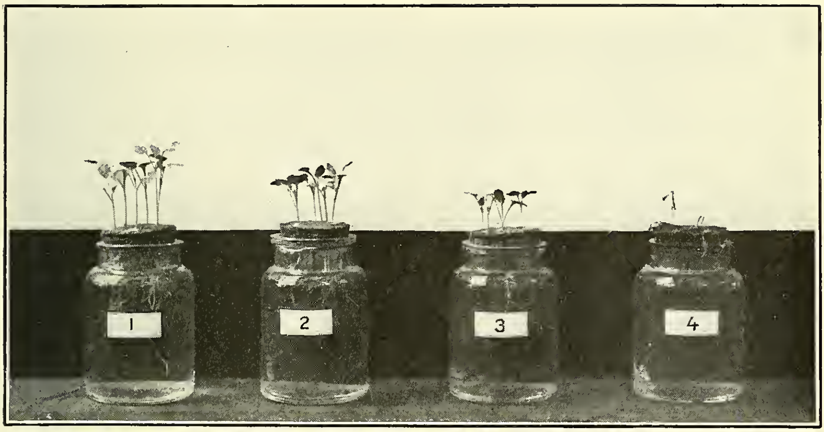


FIG. 1.—EFFECT OF SALICYLIC ALDEHYDE ON CABBAGE SEEDLINGS IN NUTRIENT SOLUTIONS.

(1) Nutrient solution; (2) same plus 10 parts per million salicylic aldehyde; (3) 25 parts per million; (4) 50 parts per million.

FIG. 2.—EFFECT OF SALICYLIC ALDEHYDE ON WHEAT IN SOIL.

(1) Clay soil; (2) same plus salicylic aldehyde 10 parts per million; (3) 25 parts per million; (4) 50 parts per million; (5) 100 parts per million.

FIG. 1.—EFFECT OF SALICYLIC ALDEHYDE ON CORN IN SOIL AND SAND.

(1) Clay soil; (2) same plus 50 parts per million salicylic aldehyde. (1) Sand; (2) same plus 50 parts per million salicylic aldehyde.

FIG. 2.—EFFECT OF SALICYLIC ALDEHYDE ON CLOVER IN SOIL.

(1) Soil untreated; (2) soil with a total of 100 parts per million of salicylic aldehyde.

TABLE V.—*Effect of salicylic aldehyde on wheat in nutrient culture solutions composed principally of nitrate.*

Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.	Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.
P_2O_5	NH_3	K_2O	Green weight.	Green weight.	P_2O_5	NH_3	K_2O	Green weight.	Green weight.
Parts per million.	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*	*Parts per million.*	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*
0	80	0	1.80	1.31	8	48	24	3.12	1.60
0	72	8	2.00	1.60	16	48	16	2.74	1.74
8	72	0	1.86	1.30	24	48	8	2.34	2.00
0	64	16	2.00	1.50	32	48	0	1.80	1.56
8	64	8	2.50	1.84	0	40	40	2.50	1.54
16	64	0	1.76	1.40	8	40	32	3.44	2.12
0	56	24	2.04	1.74	16	40	24	3.00	2.10
8	56	16	3.00	1.78	24	40	16	2.70	2.10
16	56	8	2.24	2.04	32	40	8	2.20	1.88
24	56	0	1.72	1.54	40	40	0	1.80	1.60
0	48	32	2.60	1.82					

Table VI gives the effect of salicylic aldehyde in cultures, principally potassic, similar to Table IV for the phosphate cultures and Table V for the nitrate cultures.

From this table it is seen that the aldehyde cultures are much smaller than the normal cultures. The total green weight of the 21 normal cultures was 47.67 grams against 33.74 grams for the cultures containing the salicylic aldehyde.

TABLE VI.—*Effect of salicylic aldehyde on wheat in nutrient culture solutions composed principally of potash.*

Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.	Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.
P_2O_5	NH_3	K_2O	Green weight.	Green weight.	P_2O_5	NH_3	K_2O	Green weight.	Green weight.
Parts per million.	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*	*Parts per million.*	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*
0	0	80	1.30	0.90	8	24	48	3.25	2.02
0	8	72	1.32	1.48	16	16	48	2.42	1.90
8	0	72	1.30	1.14	24	8	48	2.40	1.44
0	16	64	2.20	1.42	32	0	48	1.54	1.15
8	8	64	2.20	1.62	0	40	40	2.50	1.54
16	0	64	1.46	1.18	8	32	40	3.15	2.34
0	24	56	2.22	1.50	16	24	40	3.32	2.08
8	16	56	3.00	2.24	24	16	40	3.20	2.05
16	8	56	2.52	1.74	32	8	40	2.70	1.70
24	0	56	1.60	1.10	40	0	40	1.75	1.10
0	32	48	2.32	1.70					

The six cultures composed of approximately equal amounts of P_2O_5, NH_3, and K_2O is given in Table VII. The total green weight of the cultures in nutrient salts without salicylic aldehyde was 18.92 grams, and the total green weight for the cultures of similar composition with 10 parts per million salicylic aldehyde was 12.37 grams.

TABLE VII.—*Effect of salicylic aldehyde on wheat in nutrient culture solutions composed of phosphate, nitrate, and potash.*

Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde.	Composition of culture solution.			Without salicylic aldehyde.	With salicylic aldehyde.
P_2O_5	NH_3	K_2O	Green weight.	Green weight.	P_2O_5	NH_3	K_2O	Green weight.	Green weight.
Parts per million.	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*	*Parts per million.*	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*
32	16	32	2.94	1.86	24	24	32	3.68	2.04
32	24	24	3.12	2.30	24	32	24	3.00	2.00
32	32	16	2.84	1.97	16	32	32	3.34	2.20

From the foregoing results it is seen that salicylic aldehyde in amounts as small as 10 parts per million is harmful to the growth of wheat in nutrient solutions. In regard to the composition of the nutrient solutions affecting the harmfulness of the aldehyde it might be said that an analysis of the total green weights obtained in the case of the mainly phosphatic, the mainly nitrogenous, and the mainly potassic fertilizers given in Tables IV, V, and VI, respectively, shows that the least harmful effects are noted in the phosphatic group of cultures. This group as a whole shows a depression due to salicylic aldehyde of approximately 20 per cent in growth, while the other two groups showed approximately 27 and 29 per cent below the respective group of cultures without the aldehyde.

ABSORPTION OF NUTRIENT SALTS.

As salicylic aldehyde has been shown to be harmful to growth in culture solutions containing nutrient salts, it will be interesting to study its effect on the removal of nutrients from the solutions during the growth of the plant.

As stated above the concentration differences produced by the growth of the plants in the various cultures was determined by making an analysis for nitrates at the termination of every three-day change, and of phosphate and potassium on a composite of the solutions from the four changes.[1] It is possible, therefore, to compare the results obtained in the normal cultures without salicylic aldehyde and in the cultures where 10 parts per million of salicylic aldehyde were present in the solution.

The sum total of P_2O_5, NH_3, and K_2O removed from solution by the growing plants in all of the cultures under study was 1,646.6 milligrams in the normal cultures and 1,332.3 milligrams in the nutrient cultures containing salicylic aldehyde. The figures show the total of plant nutrients removed to be less in the cultures containing salicylic aldehyde than in the normal cultures, which indicates that the salicylic aldehyde cultures used less nutrients than the normal. The results of the examination of the three constituents separately are as follows:

[1] These determinations were made colorimetrically as described in Bul. 31 and Bul. 70, Bureau of Soils, U. S. Dept. of Agriculture.

Phosphate.—The amount of phosphate, stated as P_2O_5, removed from the total number of solutions during the experiment was 395.7 milligrams for the normal cultures and 344.2 milligrams for the cultures containing salicylic aldehyde. The salicylic aldehyde cultures absorbed 51.5 milligrams of P_2O_5 less than the normal cultures.

Nitrate.—The total amount of nitrate, stated as NH_3, removed from the total number of solutions during the course of the experiment was 578.3 milligrams for the normal cultures and 454.9 milligrams for the salicylic aldehyde cultures. The salicylic aldehyde cultures used 123.4 milligrams less nitrate.

Potassium.—The amount of potash, stated as K_2O, absorbed by the plants in the total number of cultures was 672.6 milligrams in the case of the normal cultures and 533.2 milligrams for the cultures with salicylic aldehyde. As with the phosphate and nitrate, the salicylic aldehyde cultures absorbed less potash, there being a difference of 139.4 milligrams in favor of the normal cultures.

An examination of the above figures shows a more nearly normal absorption of phosphate than of the nitrate or potash under the influence of the salicylic aldehyde. This would appear to be in harmony with the relatively lessened toxicity of the aldehyde in the mainly phosphatic nutrient solutions.

EFFECT OF CALCIUM CARBONATE ON THE ACTION OF SALICYLIC ALDEHYDE.

In order to study the effect of salicylic aldehyde under physiologically alkaline conditions, an experiment was made in nutrient culture solutions containing calcium carbonate. The cultures were prepared as in the experiments already recorded. The solutions were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate in different proportions. Salicylic aldehyde was used in quantities of 10 parts per million, and 100 milligrams of calcium carbonate were added to each culture in the control set and in the salicylic aldehyde set. The plants grew from March 23 to April 4, 12 days. The solutions were changed every three days. The green weights of the plants grown in solutions without and with salicylic aldehyde are given in the fourth and fifth columns of Table VIII.

TABLE VIII.—*Effect of salicylic aldehyde in nutrient cultures containing calcium carbonate.*

Composition of nutrient solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.	Composition of nutrient solution.			Without salicylic aldehyde.	With salicylic aldehyde, 10 parts per million.
P_2O_5	NH_3	K_2O	Green weight.	Green weight.	P_2O_5	NH_3	K_2O	Green weight.	Green weight.
Parts per million.	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*	*Parts per million.*	*Parts per million.*	*Parts per million.*	*Grams.*	*Grams.*
48	16	16	2.85	1.95	8	64	8	2.70	2.45
64	8	8	2.00	1.95	16	16	48	3.55	2.55
16	48	16	3.19	2.45	8	8	64	2.60	2.05

These data show that salicylic aldehyde was harmful even in nutrient solutions containing an excess of lime. The growth in each culture with salicylic aldehyde was less than the corresponding culture which contained no salicylic aldehyde. The total growth of the six control cultures was 17.89 grams against 13.40 grams for the six salicylic aldehyde cultures. Putting the normal at 100, the salicylic aldehyde cultures become 75, a reduction in growth of 25 per cent.

In another test, involving a much larger number of cultures of varying composition, essentially the same result was obtained. In this case the growth was depressed 21 per cent as an average.

In the previous experiment, involving a larger number of nutrient solutions without calcium carbonate, growth was reduced 27 per cent by salicylic aldehyde, used in the same concentration as in the experiment with lime carbonate.

The roots of the plants were not as much stunted by the salicylic aldehyde in the presence of lime carbonate as they were in the experiment when no lime carbonate was used. The tops, however, were equally affected in the carbonate cultures. From these experiments under alkaline conditions it is seen that the harmfulness of salicylic aldehyde can in no wise be attributed to any slight acidity it may possess.

OCCURRENCE OF ALDEHYDES IN GARDEN AND FIELD SOILS.

The discovery of salicylic aldehyde with the harmful properties toward plants shown in the preceding section led to a study of the extent to which material of this type is likely to be encountered in soil investigations. In extending this study to many soils it was not feasible to examine large quantities of each soil, so that it was not possible to demonstrate clearly the identity of the aldehyde obtained, but it was possible so to treat a sample of soil as to obtain the compounds of an aldehyde nature contained therein, separated from compounds having nonaldehyde properties. This aldehyde material was tested as far as the quantity permitted for such reactions as are given by salicylic aldehyde, namely, coloration with ferric chloride, and the general aldehyde reaction with fuchsine reagent. In all cases the aldehyde was subjected to the physiological test as to its effect on plant growth, using wheat seedlings in the well-known manner. The procedure employed in extracting the aldehyde material from the soil and the manner of testing it was as follows:

Twelve to sixteen pounds of soil were used in the examination for aldehyde. The soil was extracted with 8 liters of a 3 per cent solution of sodium hydroxide. The solution was stirred for 6 to 8 hours and, after settling, the liquid was poured off. The alkaline extract was acidified with sulphuric acid and filtered from the so-called humus precipitate. The acid filtrate was shaken out with several portions of ether, the ether extract combined and shaken with a concentrated aqueous solution of sodium bisulphite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combination with the sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid, and air was blown through to remove the sulphur dioxide liberated. This acidified solution, in which the aldehyde is now liberated from its combination with the bisulphite, was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation. There remained a small quantity of material, often resinous or oily in appearance.

This material was further purified by again taking up in water, extracting with ether, and the ether solution, after filtering, allowed to evaporate. Sometimes this operation was repeated. The purified residue contains the aldehyde material, if present.

This aldehyde material was treated with a small quantity of water. The aqueous solution is frequently colored, and on evaporation a yellow oil is often noticeable, as would be the case if salicylic aldehyde were present. The odor of the latter is also sometimes observed, although in other cases other odors are perceptible, suggesting other aldehydes.

The fuchsine reagent was added to a portion of the solution, and to another portion a small amount of ferric chloride was added. Salicylic aldehyde, as mentioned, gives a violet color with ferric chloride and a pink color with the fuchsine reagent. Where both these reactions were observed the soil was considered as containing aldehyde. While the nature of the material is not thereby definitely shown to be salicylic aldehyde, yet the manner of isolation with ether and extraction therefrom with sodium bisulphite, together with the reaction shown with the fuchsine reagent, show the material to be an aldehyde, and the physical character of fluidity and the reaction with ferric chloride make it quite probable that in most of these cases salicylic aldehyde was under consideration. The amount obtained did not permit of further identification than is here given, especially as the main object was to determine the physiological property of the extracted material.

The main portion of the material remaining after making the above tests was dissolved or mixed with 250 c. c. of pure distilled water and the resulting liquid used as a culture for wheat seedlings in order to test the physiological effect of the extracted material from the soil. This was done with every soil examined, whether the above tests were negative or positive.

In order to study the presence of aldehydes in soils a number of samples were tested. Included in this test were a number of soils sent to this bureau from time to time by gardeners and greenhouse men. The soils submitted were garden and greenhouse soils, on which the owners had experienced some difficulty in producing vegetables or flowers. Often the soils had grown good crops, were intensively cultivated and heavily manured, and later failed. In this respect the conditions were similar to those on the Mount Vernon soil. This soil had been used for growing flowers and garden plants for a long period of years, had been intensively cultivated and heavily manured for a long time, had failed to show further response to manure, had been declining in productivity, and had been shown to contain salicylic aldehyde in the investigations reported. It seemed profitable therefore to include soils in this examination which in some degree had a similar history.

In addition to this adventitious examination of soil samples a similar survey was made with soils collected in the open field by the field men of this bureau under instructions furnished them. Accordingly, samples of field soils were collected from various parts of the United States. A productive sample and an unproductive sample of the same soil type, either from the same field or at least in the same vicinity, were sent in for investigation. The history of the soils as to crops grown, fertilization, drainage, etc., were secured as far as available.

The results of this examination for the occurrence of aldehyde compounds in soils include good and poor samples from many parts of the United States, comprising acid, neutral, and alkaline soils, soils of different cropping, different texture, origin, drainage conditions, climatic conditions, etc. The results of the examination of these soils will now be given.

A total of 74 soils are described in the two following tables. Of these 14 are garden and greenhouse soils which had failed to grow good crops and 60 are field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. In this connection attention should again be called to the fact that the field samples were collected in pairs, one good and the other poor, of the same soil type and from the same field or locality, so that statements concerning productivity pertain to the relation existing between the samples of the same type.

These soils were all subjected to the method described for obtaining aldehyde compounds from soils and the material thus obtained tested with the reagents mentioned. Five of the garden soils and twelve of the field soils gave an appreciable amount of aldehyde compounds when thus extracted, and this material gave positive reactions with the fuchsine reagent and with the ferric chloride. These soils are briefly described in Table IX, together with the results obtained when the material was tested in the manner described with seedling wheat.

TABLE IX.—*Soils in which aldehydes were demonstrated to be present.*

No.	Soil.	Field record.	Location.	Crop on soil when sample was taken.	Reaction of soil.	Effect of extracted aldehyde material on growth of wheat.	Notes.
1	Garden soil, loam		Mount Vernon, Va	Flowers	Acid	Very harmful.	Rich loam, well manured for over a century.
2	Garden soil, silt loam		Mechanicsburg, Pa	Vegetables	Very acid	do	Poultry manure and commercial fertilizers used for 10 years.
3	Garden soil, red loam		Orange, N. J	do	Acid	Slightly harmful.	Rich loam; declining. Heavy manuring ineffective.
4	Truck soil, red loam		Chester County, Pa	Truck crops	Alkaline	Very harmful.	Commercial fertilizers and rotation. Trucked for 20 years. Crops now failing. Soil contains excess of salts (0.15 per cent). Subsoil also contains aldehyde material.
5	Greenhouse soil, loam		Arlington, Va	Flowers	Neutral	do	Heavily manured.
6	Memphis silt loam	Poor	Lafayette County, Miss	Grass	Acid	do	Pasture 20 years. No fertilizer.
7	Aurora silt loam	Good	Miller County, Mo	Corn	Slightly acid	Harmful	Manure occasionally. No fertilizers.
8	Norfolk very fine sandy loam	do	Pender County, N. C	Cotton	Acid	do	Well manured, occasionally fertilized.
9	do	Poor	do	do	do	Very harmful.	No manure; 200 pounds commercial fertilizer.
10	Portsmouth silt loam	do	Perquimans County, N. C	Corn	Slightly acid	Harmful	No manure; 200 pounds fertilizer.
11	Miami stony loam	do	Oneida County, N. Y	Meadow	Acid	do	Not fertilized.
12	Ontario loam	do	do	Corn	Neutral	do	Stable manure.
13	Muskogee silt loam	do	Muscogee County, Okla	Cotton	Acid	do	No manure; no fertilizer.
14	Norfolk fine sandy loam	do	Georgetown, S. C	Corn	do	do	
15	Salt Lake clay	do	Cache County, Utah	Wheat	Alkaline	do	Drainage poor.
16	Dekalb silty clay loam	Good	Preston County, W. Va	Grass	Slightly acid	do	Manured.
17	do	Poor	do	Fallow	do	do	No manure; low-grade fertilizer used.

TABLE X.—*Soils in which no aldehydes could be demonstrated.*

No.	Soil.	Field record.	Location.	Crop on soil when sample was taken.	Reaction of soil.	Effect of extracted material on growth of wheat.	Notes.
1	Garden soil, loam		Washington, D. C.	Flowers		No effect	Heavily manured.
2	do		Pittsburgh, Pa	do	Acid		Manured. Responds to lime.
3	Garden soil, gray sandy loam		Philadelphia, Pa	Garden crops	do	Harmful	
4	Garden soil, loam		Phoenixville, Pa	do	Alkaline	No effect	Well manured. Salt content high.
5	Garden soil, gray loam		Philadelphia, Pa	do	do	do	Drainage poor.
6	Garden soil, waxy, black		Green County, Ind	do	Acid	do	Responds to lime and potash fertilizers.
7	Greenhouse soil, loam		Arlington, Va	Flowers	Neutral	do	Soil had weathered for months since it had been used in flora culture.
8	Greenhouse soil, raw soil		do		Acid	do	Poor raw soil used as basis for making greenhouse soil No. 7, this table, and No. 5, Table IX.
9	Dark-gray loam		Sanford, Fla	Citrus trees	Alkaline	do	Calcareous soil.
10	Tifton sandy loam	Good	Covington County, Ala	Corn	Slightly acid	Harmful	
11	do	Poor	do	do	do	do	
12	Huntington fine sandy loam	Good	Pope County, Ark	do	do	Slightly beneficial.	
13	do	Poor	do	do	do	do	
14	Decatur clay loam	Good	Chattooga County, Ga	Cotton	Acid	Not tested	
15	do	Poor	do	do	do	do	
16	Neosho silt loam	Good	Cherokee County, Kans	Wheat	Slightly acid	Beneficial	
17	do	Poor	do	Corn	do	do	
18	Colby silt loam	Good	Jewell County, Kans	do	Neutral	do	
19	do	Poor	do	Wheat	do	do	
20	Osage loam	Good	Greenwood County, Kans	Grass	Alkaline	do	
21	do	Poor	do	Corn	do	do	
22	De Kalb silt loam	Good	Christian County, Ky	Clover	Neutral	No effect	
23	do	Poor	do	Tobacco	do	Slightly harmful.	
24	Miami loam	Good	Genesee County, Mich	Grass	Slightly acid	Harmful	
25	do	Poor	do	Wheat	do	do	
26	Carrington silt loam	Good	Goodhue County, Minn	Barley	do	Beneficial	
27	do	Poor	do	Grass	do	do	
28	Memphis silt loam	Good	Lafayette County, Miss	Corn	Neutral	No effect	
29	Summit silt loam	do	Cass County, Mo	Oats	Not tested	do	
30	do	Poor	do	Wheat	do	do	
31	Aurora silt loam	do	Miller County, Mo	Millet	Slightly acid	do	
32	Freehold loam	Good	Monmouth County, N. J	Grass	do	Beneficial	
33	do	Poor	do	Corn	do	Slightly harmful.	
34	Dutchess silt loam	Good	Orange County, N. Y	Millet	Neutral	do	
35	do	Poor	do	Grass	do	Harmful	

36	Chandler loam	Good	Ashe County, N. C	Corn	do	No test
37	do	Poor	do	do	do	do
38	Toxaway fine sand	Good	do	Grass	Slightly acid	Harmful
39	do	Poor	do	do	do	do
40	Portsmouth silt loam	Good	Perquimans County, N. C	Cotton	do	do
41	Miami stony loam	do	Oneida County, N. Y	Corn	Acid	Slightly harmful.
42	Ontario loam	do	do	Oats	Neutral	do
43	Muskogee silt loam	do	Muskogee County, Okla	Peanuts	Acid	Beneficial
44	Berks shale loam	do	Lehigh County, Pa	Grass	Slightly acid	No effect
45	do	Poor	do	do	do	do
46	Norfolk fine sandy loam	Good	Georgetown County, S. C		do	do
47	Clarksville silt loam	do	Robertson County, Tenn	Wheat	Acid	do
48	do	Poor	do	Clover	do	do
49	Jordan loam	Good	Cache County, Utah	Oats	Alkaline	Beneficial
50	do	Poor	do	do	do	do
51	Salt Lake Clay	Good	do	Wheat	do	Slightly harmful.
52	Carrington silt loam	do	Dane County, Wis	Tobacco	Neutral	Harmful
53	do	Poor	do	Oats	Acid	do
54	Sioux fine sandy loam	Good	Buffalo County, Wis	Corn	Slightly acid	No effect
55	do	Poor	do	Rye	do	do
56	Miami silt loam	Good	Jefferson County, Wis	Corn	Neutral	Harmful
57	do	Poor	do	Alfalfa	do	do

In Table X are given the remaining soils, which gave none or only an insignificant amount of extractive material when subjected to the method for obtaining aldehyde from soils, nor did this extract give the reactions with the above reagents. We must conclude therefore that the aldehyde material, salicylic aldehyde or other aldehydes, are either absent or present in much smaller quantities in the soils of Table X than in the soils given in Table IX.

From Table IX it will be seen that the soil aldehyde is in every case harmful to growth, and that all the soils behave in this respect like the Mount Vernon soil (No. 1), which has been already more fully described and in which salicylic aldehyde of poisonous properties was demonstrated.

In Plate V, figure 1, is shown the effect of this material from soil No. 2. This had been used for gardening and trucking for the last 10 years, and had been manured each year with poultry manure and commercial fertilizers. The soil in the last two years produced poor vegetables and truck crops, and corn failed entirely. The soil is grayish yellow in color, is quite acid and low in organic matter. The separated aldehyde extract was harmful to the growth of wheat seedlings, causing a decrease of 33 per cent.

In figure 2 of Plate V is shown the effect of the aldehyde extract from soil (No. 4), showing an alkaline reaction. This soil had been growing vegetables and truck crops for 20 years with frequent use of commercial fertilizers. Corn, cabbage, and cantaloupes had failed in certain sections of the field for the last two years, whereas formerly the soil grew excellent truck crops of all kinds. The soil and subsoil were quite alkaline to litmus paper, and both showed the presence of considerable aldehyde material. This aldehyde reduced growth of the test plants by 26 per cent, both tops and roots being severely injured.

The heavily manured greenhouse soil (No. 5, Table IX) is particularly interesting in that considerable aldehyde was found, whereas neither the raw soil (No. 8, Table X) nor similarly treated soil which had been used and then weathered for some time (No. 7, Table X) contained the harmful aldehyde material. This examination was made because the soil in question had been used on benches for floriculture and did not give good results. Soil No. 5, Table IX, was a composite taken from two benches in the greenhouse where carnations and roses did not thrive. This contained aldehyde, which, when tested with wheat seedlings, gave reductions in growth of 35 per cent. Soil No. 7, Table X, had been previously used for greenhouse purposes and had been made in the same way by manuring heavily the raw soil, but without experiencing any difficulty. Since then it had been in a pile outside for several months. At the time of testing no aldehyde could be found, nor was the residue obtained harmful to the seedling wheat. Soil No. 8, Table X, was the raw soil as it was hauled from the field prior to the incorporation of manure in preparation for greenhouse use. No aldehyde could be detected in this soil, nor did such residue as was obtained show any harmful effect.

Soil No. 11, Table IX, the poor sample of Miami stony loam, contained aldehyde, and the depressed growth obtained is shown in Plate VI, figure 1, together with the effect of the identically extracted good field sample. The latter showed no aldehyde reactions, but as seen from the photograph it was, nevertheless, somewhat harmful—a fact which is recorded in Table X under No. 41.

Soil No. 12, Table IX, the Ontario loam, poor, from Oneida County, N. Y., together with its good companion sample, recorded as soil No. 42 in Table X, presents an interesting story. In 1907 both fields were poor, unproductive soils. Both fields were manured heavily every year. One field responded to this treatment, the other did not.

The field now good, represented by soil No. 42, Table X, grew corn in 1907 and produced a poor crop. In 1908 the field was manured and planted to oats, giving a good yield. It was manured every year after this. In 1909 and 1910 hay was grown with good results, the largest crop being in 1910. In 1911 an excellent crop of corn was grown, and in 1912 oats were again grown with good yields.

The other field represented by soil No. 12, Table IX, was in meadow in 1907 and gave poor yields. In 1908 the field was manured and planted to corn, which failed entirely. It was manured every year after this without good results. In 1909 oats were planted, but made very little growth. In 1910 and 1911 grass was sown and gave poor results. In 1912 the soil was heavily manured and again planted to corn. The yield of stover was very poor, and no grain was formed.

The laboratory examination of the two soils showed them to be neutral in reaction. The good soil gave no reactions for aldehydes when extracted for this purpose, but the extractive material was slightly harmful. The poor soil, however, gave considerable amounts of aldehyde material, and this was distinctly harmful to the wheat seedlings, reducing growth 28 per cent.

Soil No. 15, Table IX, the Salt Lake clay, is from a poor spot in an otherwise good field. The remainder of the field is represented by soil No. 51, Table X, and was collected about 35 feet from the poor spot. The color of the soil in the poor spot is light gray, while the good soil is gray with a pink tint. This spot is generally bare and seldom produces a crop, while the remainder of the field is very productive, yielding from 20 to 30 bushels of wheat per acre. The drainage in the poor spot is poorer than in the remainder of the field. The subsoil of both good and poor soil is a light, calcareous clay. Both soils are alkaline in reaction, and both showed the same content of water soluble salts (0.03 per cent). The good sample contained no aldehydes, and such residue as was obtained proved only slightly harmful to wheat seedlings, whereas the poor sample contained considerable aldehydes, which proved very harmful to wheat seedlings in the cultural tests, reducing growth 30 per cent.

Returning now to a discussion of Table IX as a whole, it is shown that the aldehyde extract is uniformly harmful to the test plants. This is apparent from the next to the last column of the table.

In the third column is given the field record of the soils as to their productivity, the data being furnished by the collector. The garden soils already mentioned were all soils with which trouble of one kind or another had been experienced. In general, this column shows that the soils containing the aldehyde were also poor soils in garden and field, with some few exceptions. In this column is found one notable exception, in the Aurora silt loam, good (No. 7, Table IX), from Miller County, Mo. This soil contained aldehyde, whereas the corresponding poor sample (No. 31, in Table X), from another farm, gave no indication of the presence of aldehyde. This observation was confirmed by procuring a new sample from the farmer on the good soil six months later. The other exceptions are the Norfolk very fine sandy loam, good (No. 8, Table IX), and the Dekalb silty clay loam, good (No. 16, Table IX), in which aldehyde was found, but it will be noticed that in both these cases the poor soil contained the aldehyde also (Nos. 9 and 17, Table IX). It would appear therefore that both the good and poor soil samples contained some aldehyde. It might be further pointed out that in both cases the greater productivity of the sample designated as good is doubtless due to the direct fertilizing value of the applied manure, the less productive samples having no manure applied. That manure is not antagonistic to aldehyde is indicated by its presence in the exceedingly well-manured garden soils, in the same table (see notes in last column), as well as by some of the field results already given.

Some of the soils given in Table X, showing no aldehydes, have been discussed in connection with the preceding table. The remainder require no further discussion here, inasmuch as no aldehyde was found in either the good or poor samples.

From these two tables it is at once apparent that only a relatively small number of the poor soils showed the presence of aldehyde, which means that the poorness of many of the soils in Table X must be attributed to other causes, since soil infertility may be due to a great many factors other than the presence of toxic compounds, and especially any particular toxic compound.

The material extracted in the aldehyde method was in all these cases extremely small and gave no aldehyde reactions, but in some cases it proved harmful nevertheless. What the nature of the harmful substance in these cases was it is impossible to state, as further study was excluded. If aldehyde was present, it was at least so small in amount that it escaped chemical detection, nor does the method wholly exclude the occurrence at this place of traces of other compounds. In the majority of cases the material was not harmful, occasionally even showing a slightly good or stimulating effect.

Seventy-four soils are described in the foregoing tables. Of these 14 were garden and greenhouse soils which had failed to grow crops, and 60 were field soils, under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. These soils were all examined for aldehydes. Of the 14 garden soils, five contained aldehydes, and of the 60 field soils 12 contained aldehydes.

(1) *In soils from widely different sections.*—The soils examined were from various parts of the United States; soils from 20 States make up the list. They vary from very unproductive to extremely fertile soils. Aldehydes were found in soils from nine States as widely separated as New York and Mississippi or Oklahoma. Its presence is therefore not confined to any locality.

(2) *In soils of different texture.*—The soils in which aldehyde occurred are not soils of any specific type or texture. The above list of soils containing alhehyde comprises clays, clay loams, silt loams, silty clay loams, loams, stony loams, fine sandy loams, and very fine sandy loams. There is therefore no apparent relation with soil type, or texture.

(3) *In unproductive soils.*—The unproductive soils examined can be divided into two classes: (1) Garden soils, comprising soils which have been highly fertilized and manured, heavily cropped and intensively cultivated, and later failed to produce good crops. This class includes several greenhouse soils. (2) Field soils, growing general farm crops with ordinary farm methods of cultivation.

Fourteen poor garden soils were examined, five of which contained aldehydes. All of these soils were very unproductive and failed entirely or grew very poor garden crops. Nine of the 30 unproductive field soils examined contained aldehydes.

(4) *In productive soils.*—Of the 30 productive soils examined three contained aldehydes. These were the Aurora silt loam, from Miller County, Mo.; Norfolk very fine sandy loam, from Pender County, N. C.; and Dekalb silt loam, from Preston County, W. Va.

(5) *In acid, alkaline, and neutral soils.*—It is interesting to note that some of the soils which contained aldehydes were acid, some neutral, and others alkaline. Three of the garden soils were acid, one

was alkaline, and one was neutral. Of the field soils which contained the aldehyde, ten were acid, one alkaline, and one neutral.

(6) *In soils growing different crops.*—Four of the soils which were found to contain aldehydes were garden soils and had been used for growing garden crops continuously for several years. One was a greenhouse soil and had grown carnations and roses. Twelve of the soils in which aldehyde was found were used for the growth of general field crops. A rotation of several crops was practiced on most of these soils. At the time the samples were collected three were in grass, four were growing corn, three were growing cotton, one was in wheat and one was fallow. These observations, together with the fact that no aldehydes were found on other soils growing the same crop, would seem to indicate that no close relation exists between the crop being grown and the presence of aldehyde.

EFFECT OF SALICYLIC ALDEHYDE ON COWPEAS, STRING BEANS, AND GARDEN PEAS GROWN IN THE FIELD.

The effect of salicylic aldehyde under field conditions was tested on plots at the Arlington Experiment Farm, Va. Three crops, cowpeas, string beans, and garden peas, were grown on the treated soil during the summer of 1913. Adjoining each plot growing a different crop, two check plots of equal size were planted with the same crop. The area of each plot was one-fourth of a square rod.

The soil on which the experiment was made is a heavy silty clay loam, low in organic matter. The land was plowed early in May and prepared for seeding with the above leguminous crops. Three applications of salicylic aldehyde were made, the first on May 20, one day before the crops were planted. The second application was made after the plants were up, on June 5, the third on June 24. Each application was at the rate of 35 pounds per acre, or 105 pounds per acre in all.

The salicylic aldehyde was applied by dissolving in water and sprinkling the solution uniformly on the surface of the land before planting and the soil cultivated thoroughly. After planting, the second and third applications were made by sprinkling the solution between the rows of plants, and the soil then cultivated.

All of the three crops germinated uniformly. The untreated check plots made the better growth from the very start. The effect of the salicylic aldehyde was noticeable throughout the experiment. The crops were grown to maturity and harvested.

EFFECT ON COWPEAS GROWN IN THE FIELD.

Both treated and untreated plots were sown to cowpeas on May 21, 1913, and the crop harvested on September 7, 1913. The cowpeas on the salicylic aldehyde treated plot were much stunted in growth.

The appearance of the plants on June 27 is shown in Plate VII, figure 1. The four rows of plants on the left are growing on the treated plot and the four rows on the right on an untreated plot. It is evident that the salicylic aldehyde is interfering with the proper development of the young plants. The effect became even more marked as the plants approached maturity. When mature, the peas were picked from the vines and weighed. After drying, the peas were shelled and measured. The vines themselves were cut and their weight taken. After curing, the weight of the dry hay was recorded. In Plate VII, figure 2, are shown the vines and peas as gathered from the check plot and from the salicylic aldehyde treated plot. The effect of the salicylic aldehyde in depressing crop yields is apparent.

In Table XI are given the results obtained in this experiment with salicylic aldehyde on cowpeas. The results are given as obtained from the individual plots and also in terms per acre:

TABLE XI.— *Yield of cowpeas as affected by salicylic aldehyde in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.		Pods.	Vines.		Pods.
	Green.	Cured.		Green.	Cured.	
	Pounds.	*Pounds.*	*Pounds.*	*Tons.*	*Tons.*	*Tons.*
Check *a*	28.0	10.0	6.6	8.96	3.20	2.11
Check *b*	23.0	8.5	5.6	7.36	2.72	1.79
Average check	25.5	9.3	6.1	8.16	2.96	1.95
Salicylic aldehyde	16.0	4.3	3.5	5.12	1.38	1.12
Difference	9.5	5.0	2.6	3.04	1.58	.83

From the table it will be seen that the average yield of green vine and pods on the check plots was 10.11 tons, and on the salicylic aldehyde plot it was only 6.24 tons, making a total decrease of crop, 3.87 tons, or 38 per cent. The yield in pods alone was reduced 43 per cent, and in vines alone, 35 per cent. The cured hay, minus the pods, was reduced in yield as much as 1.6 tons per acre, a decrease of 50 per cent.

EFFECT ON STRING BEANS IN THE FIELD.

The string beans were less affected by the salicylic aldehyde than the cowpeas, and also less than the garden peas. The seeds were sown May 21; they germinated well, and a good stand was secured. As the crop grew it became apparent that there was a difference in the growth of the treated plots and the untreated, but it was not as marked as with the cowpeas. On July 22 the crop was harvested and the weight of green vine and beans obtained separately. The results are given in Table XII, and a photograph of the harvested crop is shown in Plate VIII, figure 1.

TABLE XII.—*Yield of string beans as affected by salicylic aldehyde in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.	Beans.		Vines.	Beans.	
	Pounds.	*Pounds.*	*Pints.*	*Pounds.*	*Pounds.*	*Pecks.*
Check *a*	3.55	1.90	4.75	2,272	1,236	190
Check *b*	2.94	1.66	4.15	1,882	1,062	166
Average check	3.24	1.78	4.45	2,070	1,149	178
Salicylic aldehyde	2.71	1.25	3.12	1,734	800	125
Difference	.53	.53	1.33	336	349	53

The average yield of vines and beans on the check plots was 3,219 pounds per acre, and on the salicylic aldehyde plot it was only 2,534 pounds, a decrease of 685 pounds of green matter per acre.

The yield of marketable bean crop was reduced 53 pecks per acre, or 30 per cent.

EFFECT ON GARDEN PEAS IN THE FIELD.

The garden peas were sown on May 21 and the matured vines and pods harvested separately on June 30 and weighed. A good stand was obtained. The plants showed from the start the effect of the salicylic aldehyde, and this became more pronounced with the other additions and as they neared maturity. Fruit formation was practically nothing on the salicylic aldehyde treated plot. The appearance of the treated and untreated plot on June 24 is shown in Plate VIII, figure 2. The harvested crops are shown in Plate VIII, figure 3. The weights and measurements obtained are given in Table XIII.

TABLE XIII.—*Yield of garden peas as affected by salicylic aldehyde in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.	Peas.		Vines.	Peas.	
	Pounds.	*Pounds.*	*Pints.*	*Pounds.*	*Pounds.*	*Pecks.*
Check *a*	1.72	1.66	4.50	1,101	1,062	180
Check *b*	1.50	1.48	4.00	950	947	160
Average check	1.61	1.57	4.25	1,030	1,004	170
Salicylic aldehyde	.52	.16	.43	333	102	17
Difference	1.09	1.41	3.82	697	902	153

The photograph and the table show conclusively the extremely harmful action of the salicylic aldehyde on garden peas. The yield of total plant material, vines and pods, was 2,034 pounds per acre as an average of the untreated checks, as compared with 435 pounds on the salicylic aldehyde plot, a decrease of 1,599 pounds. The marketable crop—that is, the peas in shell—was depressed from 1,004 pounds to only 102, or 90 per cent, practically a total failure.

FIG. 1.—EFFECT OF ALDEHYDE EXTRACTED FROM GARDEN SOIL (NO. 2, TABLE IX) FROM MECHANICSBURG, PA., ON GROWTH.

(1) Distilled water; (2) distilled water plus aldehyde.

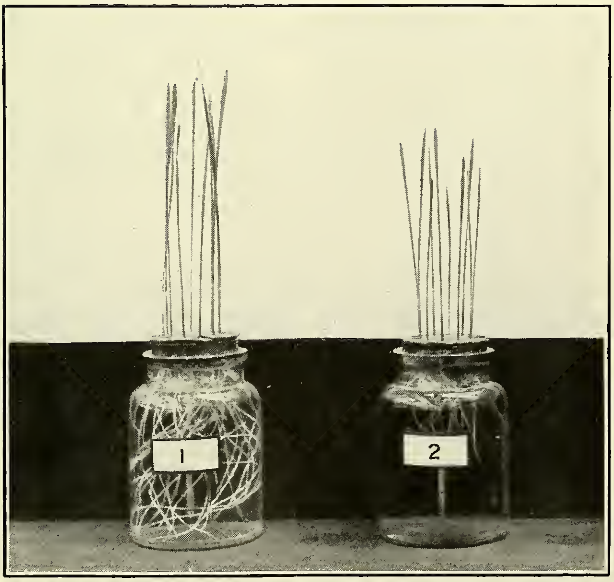


FIG. 2.—EFFECT OF ALDEHYDE EXTRACTED FROM A POOR GARDEN SOIL (NO. 4, TABLE IX) ON WHEAT SEEDLINGS.

(1) Distilled water; (2) distilled water plus aldehyde from garden soil.

EFFECT OF SUBSTANCE EXTRACTED FROM POOR AND GOOD MIAMI STONY LOAM (NO. 11, TABLE IX, AND NO. 41, TABLE X) ON WHEAT PLANTS.

(1) Distilled water; (2) distilled water plus material from poor soil containing aldehyde; (3) distilled water plus material from good soil showing no aldehyde reactions.

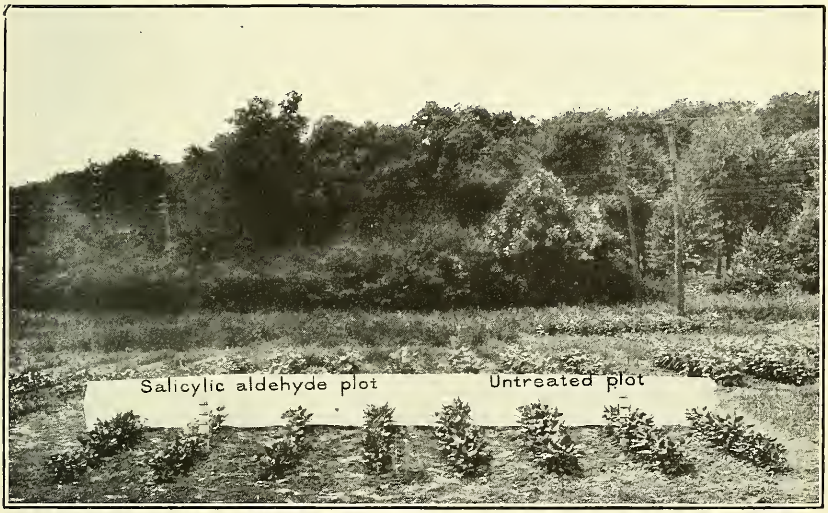


FIG. 1.—EFFECT OF SALICYLIC ALDEHYDE ON COWPEAS IN THE FIELD.

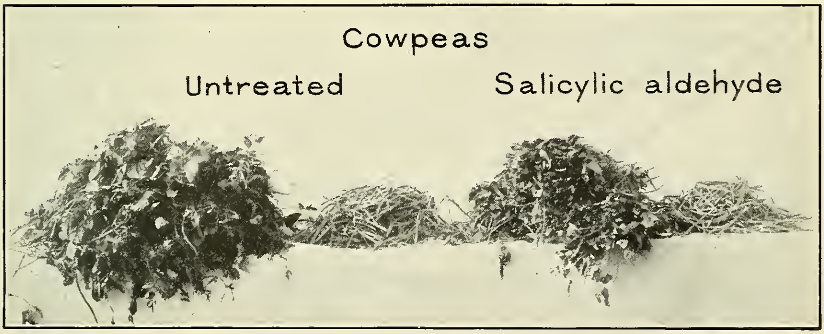


FIG. 2.—YIELD OF COWPEAS, VINE AND POD, ON CHECK PLOT *b* AND ON SALICYLIC ALDEHYDE TREATED PLOT.

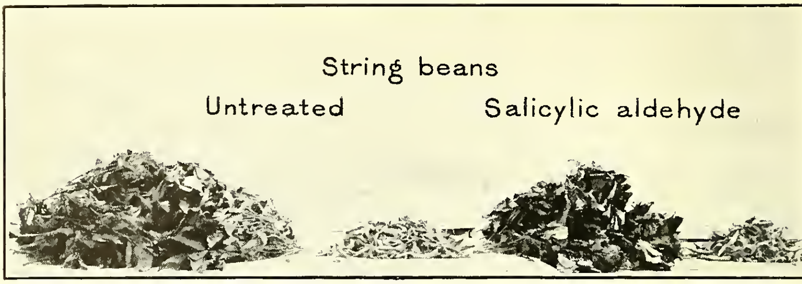


FIG. 1.—YIELD OF STRING BEANS, VINE AND POD, ON CHECK PLOT *b*, AND ON THE SALICYLIC ALDEHYDE TREATED PLOT.

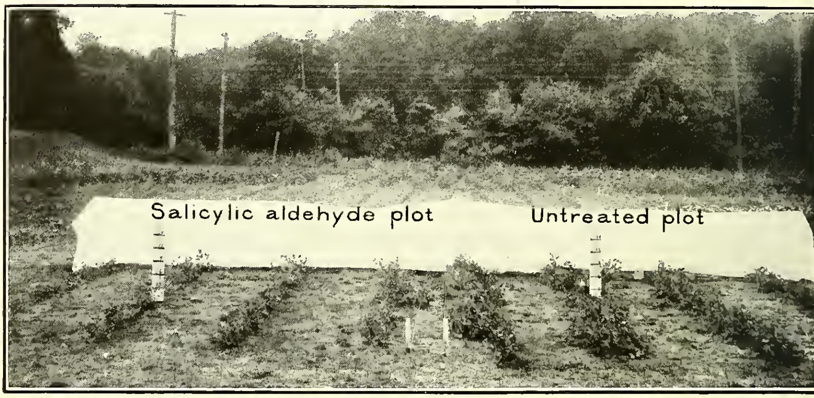


FIG. 2.—EFFECT OF SALICYLIC ALDEHYDE ON GARDEN PEAS IN THE FIELD.

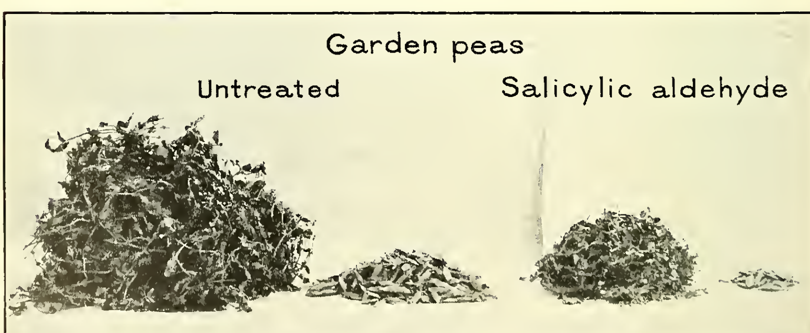


FIG. 3.—YIELD OF GARDEN PEAS, VINE AND POD, ON CHECK PLOT *b* AND ON THE SALICYLIC ALDEHYDE TREATED PLOT.

EXAMINATION OF THE FIELD PLOTS FOR ALDEHYDE SIX MONTHS AFTER APPLICATION.

That salicylic aldehyde can persist in some soils would seem to be indicated by the fact that the second shipment of Mount Vernon soil, collected six months later than the first, likewise contained salicylic aldehyde; also by the fact that the two samples of Aurora silt loam from Miller County, Mo., collected six months apart, both contained aldehydes.

In order further to verify this ability of the aldehyde to persist in some soils, the salicylic aldehyde treated field plots were subjected to an examination for aldehyde as had been done with the soil samples from garden and field described in preceding paragraphs. Soil samples were collected from the cowpea plots, the string bean plots, and the garden pea plots, i. e., one sample from each check plot and each salicylic aldehyde plot.

The six samples were examined for aldehyde. The three check samples contained none; the three treated plots showed the presence of aldehyde. The residues obtained in this procedure for separating aldehydes were tested with wheat seedlings, as described earlier in this paper. The extract from the check plots, which showed no aldehyde, grew plants as well as pure distilled water, whereas the extracted material from the aldehyde treated plots proved harmful to the wheat seedlings. The extract from the cowpea salicylic aldehyde plot decreased growth 32 per cent, that from the string bean plot decreased growth 27 per cent, and that from the garden pea plot decreased growth 26 per cent.

The existence of the harmful compound in the soil was also shown in another way by growing wheat in the greenhouse in paraffined wire pots, using the respective soils from the salicylic aldehyde treated plots and the check plots. Two pots, with six plants each, were used for each soil. The plants grew from December 11 to January 6. The results of this experiment are given in Table XIV. The table shows that the salicylic aldehyde in the soils of the treated plots six months after the salicylic aldehyde was applied was harmful to wheat.

TABLE XIV.—*Growth of wheat in soil taken from the field plots six months after treatment with salicylic aldehyde.*

Plot.	Wheat on soil from check plots.	Wheat on soil from salicylic aldehyde plots.	Relative growth, check=100.
	Grams.	*Grams.*	
Cowpea plot	1.48	1.18	80
String bean plot	1.54	1.11	72
Garden pea plot	1.47	1.22	83

A similar experiment was made with these soils, except that the crops grown in the pots were identical with those which had grown in the field the preceding season, that is, cowpeas were grown on the cowpea soil from the check plot and from the salicylic aldehyde plot, string beans on the string bean soil from both the check and treated plot, and garden peas on the garden pea soil from both check and treated plot. Two pots were used in each case and two plants were grown in each pot. The plants grew from December 11 to January 6. The vegetative growth made in this experiment is given in Table XV.

TABLE XV.—*Growth of cowpeas in soil from the cowpea field plots, string beans in soil from the string bean field plots, and garden peas in the soil from garden pea field plots. Collected six months after treatment with salicylic aldehyde.*

Crop grown in pots in greenhouse and previously in the field.	Soil from check plots.	Soil from salicylic aldehyde plots.	Relative growth, check=100.
	Grams.	*Grams.*	
Cowpeas	4.30	3.80	88
String beans	7.80	7.20	92
Garden peas	5.60	4.30	77

The table shows that the salicylic aldehyde treated soil was still harmful to the respective crops in samples collected six months after the application of the salicylic aldehyde, the test plants growing about five months after the harvesting of the same crop in the field. It is also interesting to note that the relative order of toxicity shown toward the different crops is the same in these smaller vegetative experiments in the paraffined wire pots as in the case where the crops were harvested in the field. This would also seem to indicate that the observed order of toxicity toward these plants, namely, garden peas, cowpeas, string beans, may be more than accidental.

SUMMARY.

Compounds of an aldehyde nature exist in many soils. Such soils are usually unproductive. When separated from the soils, the aldehyde material is toxic to plants in pure water and in nutrient solutions.

One of these soil aldehydes is identified as salicylic aldehyde. This compound in very small amounts is harmful to plants in distilled water and in nutrient solutions. It is harmful to plants grown in pots of soil. It greatly decreases the yield of crops grown in the field. It persists in the field soils for months.

There is some evidence which suggests that lime and phosphate ameliorate the effects of salicylic aldehyde. Its chemical nature suggests that increased oxidation in soils under field conditions probably prevents its formation or accumulation.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 109

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
June 11, 1914.

THE MOLDS OF CIGARS AND THEIR PREVENTION.

By R. H. True,
Physiologist in Charge of Plant Physiological and Fermentation Investigations.

INTRODUCTION.

In 1901 a number of complaints were received from eastern cigar manufacturers to the effect that considerable losses were being sustained through the appearance of moldy growths on the finished products. These growths in some cases appeared within about three days after the manufacture and the boxing of the cigars, thus frequently being noticed before they left the factory. In some instances, however, they did not appear until after considerable periods of time. If the mold was detected before the cigars left the factory, the only recourse was to wipe off the growth by hand, a rather expensive process. Perhaps equally objectionable results followed when the mold was not discovered until the cigars were in the hands of the buyers. In either case very considerable loss was likely to result. The writer was asked to study the problem and, if practicable, to work out feasible means by which the trouble could be remedied. Several factories in which this trouble appeared were visited, managers were consulted, and materials for further work were obtained.

FACTORY CONDITIONS.

In order to get light on the conditions to be dealt with, the processes involved in making the brands of cigars most liable to mold were observed in the factories. In the case of one factory more difficulty was experienced with Sumatra wrappers than with other sorts, and the trouble was believed to be worse in rainy seasons than at other times. The mold usually appeared most abundantly on the "head," or closed end of the cigar, less frequently on the veins or

---

Note.—This paper discusses the losses due to the development of molds on cigars, outlines the studies directed toward the prevention of them, and presents practical directions for the use of an effective remedy. The molds were found to be introduced principally through the gum-tragacanth paste used to fasten the small flap at the head of the cigar. The sterilization of the paste by using a nearly saturated solution of boric acid instead of water in mixing it has proved so successful that it has become a routine process in the factory in cooperation with which the investigations were conducted.

other elevated portions of the wrapper, but in some cases the entire surface was more or less involved.

The wrapper leaf is usually prepared for use the day before it is actually used in manufacture. It is first brought into the necessary moist condition, or gotten into "case," by dipping into water. The leaves are bound into small bundles in which the bases of the leaves are tied together. These bundles, or "hands," are grasped by their bases and carried down into and through the "casing" liquid with a scooping motion, so performed as to drag the bundle of leaves with the bases ahead, the blades of the leaves being pulled through the liquid. After this quick dip, the bundles are shaken and set upright on a draining board to permit the surplus liquid to drain away. The pile, loosely packed together, is then covered with a moist cloth and allowed to stand until the droplets of water clinging to the surface of the leaves have been absorbed. In a few hours the leaf becomes soft and pliable without giving the impression of being wet. The ribs are then pulled out and the broad leaf blades are worked up as their size, shape, and quality may determine. The freshly made cigars are then sorted according to colors and boxed immediately, or sometimes held in bundles, to be packed later.

In this condition each cigar is round, and the prescribed number of cigars when placed in the box overfill it, so that the cover must be brought into place by the use of pressure. Here the moist cigars yield to each other and take on such flattened sides and angles as may be required to get the box closed. Sometimes the lids of the boxes are considerably bent by the pressure of the fresh cigars, and the boxes are then placed for a day in large presses before they are nailed up. In warm weather the mold sometimes appears while the boxed cigars are in the presses; that is, within 48 hours after they are made, but more frequently within a week or two after making. When warm, humid weather conditions prevail it is not rare for molds to appear while the cigars are in transit or in storage. Since heat and moisture are necessary conditions for mold development, it follows that little trouble is experienced in the winter months but much during the hot summer months.

A number of attempts had been made by the factory managers to remove this source of loss. Small quantities of vinegar in the water (1 pint in 4 or 5 gallons) used for casing wrapper leaf were found to aggravate the trouble. When the leaf was cased in vinegar at full strength the molds were suppressed, but the luster of the leaf was thought to be impaired. Casing in alcoholic solutions was found to be helpful, but too expensive. Small quantities of glycerin were found to be useless in suppressing molds, but helpful in retaining moisture in the wrapper.

LABORATORY INVESTIGATIONS.

Cigars on which mold had developed were obtained from several sources and submitted to examination. Two forms of mold seemed to be present—one, of most common occurrence, a small organism of grayish or whitish appearance, usually thinly scattered over the cigars, but most abundant and frequent at the head of the cigar, and the other a larger organism, occurring usually near the head of the cigar in rather sharply defined patches of a dazzling white color. The latter organism was much less frequently seen.

It being evident that the factories offered favorable conditions for retaining spores of molds when once introduced, it was clear that general treatment looking toward the eradication of these organisms was out of the question, assuming that it was practicable to prevent the entrance of new infections on tobacco leaf and other materials brought in. The most serious localized sources of trouble were therefore sought.

PASTE USED.

Gum tragacanth is used in small quantity to fasten the wrapper of the cigar in place. The wrapper is rolled tightly on the cigar, the rolling proceeding from the open end toward the head, the last portion of the wrapper remaining free being a small flap of leaf which serves to finish off the head. This small flap receives a little paste on the under surface and is then carefully brought into place. The cigar is then usually rolled with some pressure between the hand and the board or table at which the cigar maker works, thus giving it the desired regularity of form. Thus, a little paste is always found at the head of the cigar, and if an excess has been applied, especially if the paste is rather thin, a portion is liable to be squeezed out on to the board or table at which the maker works, and the cigars may receive a more or less extensive smear of paste over the surface of the wrapper.

The paste as usually made up contains about 10 parts by weight of gum tragacanth to 90 parts of water. A large stock is generally made in one container, sometimes only enough to last for the day and sometimes enough to last for a longer period. An inspection of the paste pots in several factories showed that while some were in fairly clean condition the sides of others were thoroughly covered with molds, indicating that in some cases little attention was paid to cleanliness regarding this feature.

An inspection of the wrapper leaf in no case showed visible mold, although it is a matter of common observation that when tobacco leaves are kept sufficiently moist in a closed space they can be made to mold.

MOLDS IN TRAGACANTH GUM.

Tragacanth gum is usually bought in considerable quantities for use in the larger factories, and, if the samples obtained in this investigation from several such sources were representative, the highest grades of the gum are not used. It was thought possible that these gums themselves might be carriers of molds, and several samples were set away in sterile Petri dishes to which a small quantity of sterile distilled water was added. These cultures, like others to be described, when not under observation were kept in a dark chamber in which the temperature varied between 21.5° and 25° C. In three days all the samples showed an abundant growth of molds, which began to develop fruiting stages on the fourth day. For further study, cultures were transferred to a medium containing one-half of 1 per cent sodium chlorid, 1 per cent peptone, 1 per cent beef broth, and +10 points acidity. Other cultures were also prepared on sterilized tragacanth gum, partly prepared on a thick paste and partly on a thinner paste.

Cultures on beef agar and peptone flourished and yielded a variety of organisms, which were turned over for identification to Mrs. Flora W. Patterson, Mycologist of the Bureau of Plant Industry. Four forms appeared with great regularity. Most conspicuous and quickest in growth were (1) *Rhizoporus nigricans* Ehren., a large organism forming large, loose, conspicuous hyphal masses; (2) *Mucor racemosus* Fres. var. *brunneus* Morini, a smaller organism rapidly forming a loose, white mass of hyphæ; and (3) *Penicillium* sp., a somewhat slower organism in point of development, marked by its white round-headed conidiophores. This organism in the early stages was striking by reason of its brilliant whiteness, but as the cultures grew older the more usual bluish color appeared. The last common form was (4) *Aspergillus candidus* Link, a very small mold, characterized by its slower growth, its dingy white color, and its appearance in mixed cultures as a minute undergrowth among the above-mentioned larger organisms. No attempt was made to carry out a further study of these organisms. It seemed clear, however, that the Aspergillus was more at home on the tragacanth medium than on the beef agar and peptone as here offered.

MOLDS ON WRAPPER LEAF.

As it seemed very probable that the wrapper leaves, like most other free surfaces, might give lodgment to spores of molds and thus become agents of infection, it was thought desirable to see what molds could be cultivated from them. Accordingly, cultures in the media previously described were prepared from the washings obtained by rinsing the surfaces of wrapper leaves with sterile water. Several organisms were obtained in small quantities, and Mrs. Patterson identified the following: (1) *Aspergillus subgriseus* Pk., (2) *Macrosporium commune* Rabh., (3) *Sterigmatocystis castanea* Patters., (4) *Cladosporium herbarum* (P.) Link, (5) *Penicillium* sp. In general, the leaf surfaces were rather sterile of molds.

MOLDS ON CIGARS.

Samples of moldy cigars obtained from various sources were also investigated by the method described, and the following organisms were identified by Mrs. Patterson: (1) *Aspergillus candidus* Link, a very small dingy white mold, occurring as a rather sparse growth on cigars, especially near the head, but frequently in diffuse growth over a considerable part of the surface, which seems to be the most often present on cigars and is probably responsible for most of the trouble; (2) *Penicillium* sp., a widely distributed mold, likely to appear on a great variety of substances; (3) *Sterigmatocystis castanea* Patters., an unusual form, not likely to be a cause of harm here; (4) *Cladosporium herbarum* (P.) Link, one of the molds commonly turning up on decaying vegetable matter, probably not a source of serious trouble here.

It will be seen that the organisms responsible for the most serious trouble (*Aspergillus candidus*, easily first in importance, and *Penicillium glaucum*) are not represented in the list of organisms introduced on the wrapper leaf, but seem to be always present in the tragacanth gum. The conclusion seems, therefore, to follow that in the case in hand the paste used in fastening the wrapper at the head of the cigar brought with it the troublesome organisms.

INFECTION EXPERIMENTS ON WRAPPER LEAF.

It having been rendered probable that the tragacanth paste was inoculated with the molds from the start, the next question to be answered was that of the seat of the growth of molds on the wrappers. As it has already been shown that the paste itself is a favorable culture medium for these organisms, it follows that the tobacco leaf in itself is not necessarily a favorable support for the molds. However, it is well known that moist tobacco leaves do become moldy under conditions favoring this process, and experiments were made having for their object the infection of wrapper leaves with the two species of mold last mentioned. These attempts failed to produce mold on the leaves used in the absence of any substance foreign to the leaves that might act as a source of food for the fungi.

INFECTION EXPERIMENTS ON CIGARS.

In view of the nature of the problem under study, the fact that cigars could be infected with molds was not open to doubt. Since it had been shown that these molds do not readily grow on wrapper leaf, it appeared probable, in view of the fact that the infection was introduced with the tragacanth paste, that the growth on the cigar was confined to the paste present on the wrapper. It was thought desirable to try to check up this conclusion by attempting to grow these molds on cigars. Accordingly, repeated attempts were made to grow the organisms in question on pieces of cigars moistened and placed in sterile Petri dishes or test tubes. In some cases these pieces molded and in others they did not. Usually the piece at the head of the cigar molded without difficulty, while those portions from other parts of the cigar molded less readily.

This seemed to confirm the view that the molds were introduced with and in general grew on the paste, and the appearance of the mold over a large part of the surface of a cigar indicated the smearing of excess paste over a corresponding portion of the surface.

REMEDIAL MEASURES.

Having located the cause of the trouble in the organisms above discussed and having found the point of their entrance, as well as the seat of their activities, to be in the tragacanth paste, practical remedial measures seemed to lie along the line of sterilizing the paste.

In view of the conditions governing the subsequent handling and final utilization of cigars, an acceptable sterilizing agency must combine several characteristics. It must be permanent, since cigars sterilized for but a short time are liable to mold at a later period when conditions of heat and moisture concur with or follow the exposure of the cigars to the infecting organisms. The substance must be odorless and tasteless; otherwise it will alter the taste and aroma of the cigar, points on which smokers, and therefore dealers, are very sensitive. It must not alter the color or the luster of the wrapper, since on these the selling quality of the cigars in considerable part depends.

STERILIZATION OF THE PASTE.

A variety of substances having antiseptic properties were chosen for test. In general they were dissolved in water, and the resulting solutions were either added to the paste already made or were used instead of water in making up the paste. These pastes were then inoculated with the molds obtained from the moldy cigars or from tragacanth gum.

A thin paste containing 10 grams of gum in 1 liter of water was first used. Hydroquinone, thymol, and sodium salicylate were introduced in concentrations as strong as could be used without influencing in an objectionable degree the taste, color, or odor. These pastes were then inoculated with *Aspergillus candidus* and *Penicillium glaucum.* In all cultures except that containing 5 c. c. of a molecular solution of hydroquinone in 100 c. c. of paste, both molds appeared and throve.

A thicker paste, containing 10 grams of gum in 250 c. c. of distilled water, was made and a series of cultures prepared to which hydroquinone, thymol, and boric acid were added. Inoculation with the same molds followed. Hydroquinone in permissible concentration failed to suppress the organisms. Thymol in saturated solution, 1 c. c. and 3 c. c. per 100 c. c. of paste, suppressed them, but gave so marked an odor of thymol that the use of this substance was regarded as not advisable. Boric acid, 1 c. c. to 10 c. c. of saturated solution in 100 c. c. of paste, failed to suppress the organisms. Indeed, both grew more luxuriantly in these cultures than in the cultures containing simple paste. Cultures containing about 0.12 gram of dry boric acid in 100 c. c. of paste remained sterile.

In a third series of tests, solutions of the disinfectants were used instead of water in making the pastes. Solutions of hydroquinone and of boric acid were used in several proportions, as follows: For 1 gram of dry gum 25 c. c. of solution were used, consisting, respectively, of hydroquinone in molecular, one-half molecular, and one-fourth molecular concentration and boric acid in saturated solution at room temperature and in one-half saturated concentration. Since at 60° F. 1 part of boric acid dissolves in 26 parts by weight of water, it will be seen that the stronger boric-acid solution used instead of water in making the paste contained roughly 3.8 per cent of the acid. The paste cultures when made up were decidedly stiff and kept the form of small cakes in the Petri dishes. These cakes were inoculated with the two molds, and the cultures containing hydroquinone and the more concentrated boric-acid solution remained sterile. The culture containing the one-half normal boric-acid solution proved a more favorable medium for these molds than the plain paste.

It was rendered clear by these experiments that hydroquinone is effective when a solution containing 2.7 grams in 100 c. c. of solution is used instead of water in making the paste. Likewise, when a solution containing roughly 3.8 grams of boric acid in 100 c. c. of solution is similarly used molds are suppressed.

Tests of the adhesive quality of the pastes so prepared were made and it was conclusively shown that the presence of these chemical substances does not decrease the value of the paste in this particular.

After considering which of these substances should be recommended for general use, boric acid was chosen because it is cheaper, does not undergo change in the paste, is more readily obtained, and is not liable to injure anybody if used in excess. The disadvantages of hydroquinone lie in its contrasted properties on the points enumerated.

PRACTICAL DIRECTIONS FOR THE USE OF THE REMEDY.

A practical course of treatment based on the use of boric acid was accordingly outlined for tests on the factory basis. Since the paste evaporates water between the time of making and of using, a concentration somewhat less than saturation was recommended in making the paste. This would also tend to decrease the liability of the acid to crystallize out in a conspicuous way on the surface of the cigars should paste happen to be smeared on them. The following concise directions were prepared: Place boric acid in warm water at the rate of 1 ounce of dry acid to $1\frac{3}{4}$ pints of water. Stir till the acid is all dissolved. Use this solution instead of water in making up the paste. Great care should be taken not to use more paste on the cigar than is necessary, since it is liable to be smeared on the surface of the cigar, where the boric acid in the paste tends to crystallize, giving an appearance suggesting mold.

These directions have been followed for some years in the factory in which the complaints originated, and when the writer was last in communication with those in charge the boric-acid treatment was in use as a routine practice and only in rare instances were molds found troublesome.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 110

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
August 8, 1914.

FATTENING CATTLE IN ALABAMA.

By Dan T. Gray, *Formerly Professor of Animal Industry, Alabama Polytechnic Institute*, and W. F. Ward, *Animal Husbandry Division, Bureau of Animal Industry.*

I. Wintering Steers Preparatory to Summer Fattening on Pasture.
II. Fattening Steers on Pasture in Alabama.
III. The Influence of Winter Feeding upon Gains Made the Following Summer.

INTRODUCTION.

The investigations reported in the following pages are a continuation of the cooperative work started in 1904 between the Bureau of Animal Industry and the Alabama Experiment Station. Previous results will be found recorded in Bureau of Animal Industry Bulletins 103, 131, 147, and 159, and Department of Agriculture Bulletin 73.

The map (fig. 1) shows the general location of the farms in Alabama where the experiments were conducted, also the principal markets which are accessible to cattlemen from various sections of the South. The shaded lines indicate the area where the climatic conditions and the pasture grasses are relatively similar to those of western Alabama. This shaded portion represents the area to which the results of the experiments outlined in Parts I and III of this bulletin are applicable.

The cattle from Texas, northern Louisiana, Arkansas, western Mississippi, and Tennessee usually go to the Fort Worth, St. Louis, or Kansas City market. Those of eastern Mississippi and Alabama may be sent to either the St. Louis or the New Orleans market; the cattle of southern portions of Mississippi, Alabama, Georgia, and Florida are usually sent to the New Orleans market, or to Tampa, Fla., for export to Cuba; while the cattle of the Carolinas, northern Georgia,

Note.—This bulletin is a report of progress on experiments begun in 1904 in cooperation with the Alabama Agricultural Experiment Station and reported in B. A. I. Bulletins Nos. 103, 131, 147, and 159, and department Bulletin No. 73, and gives the results of work done during the last and two preceding years. It is applicable to those portions of the South where the climatic conditions and pasture grasses are similar to those in that section of the State where the tests were made.

43865°—14——1

eastern Tennessee, and Virginia are usually shipped to Richmond, Washington, Baltimore, or Jersey City to be slaughtered. While there are no large markets, except Fort Worth, located in the South, it is possible for many of the cattlemen to ship their cattle to one of the better markets. It is also probable that with the development of the live stock industry of the South the southern markets will grow, and transportation facilities, which are poor at the present time, may increase in efficiency. If it were possible to get as good train service for cattle in the South as it is in the West, there is no portion of the

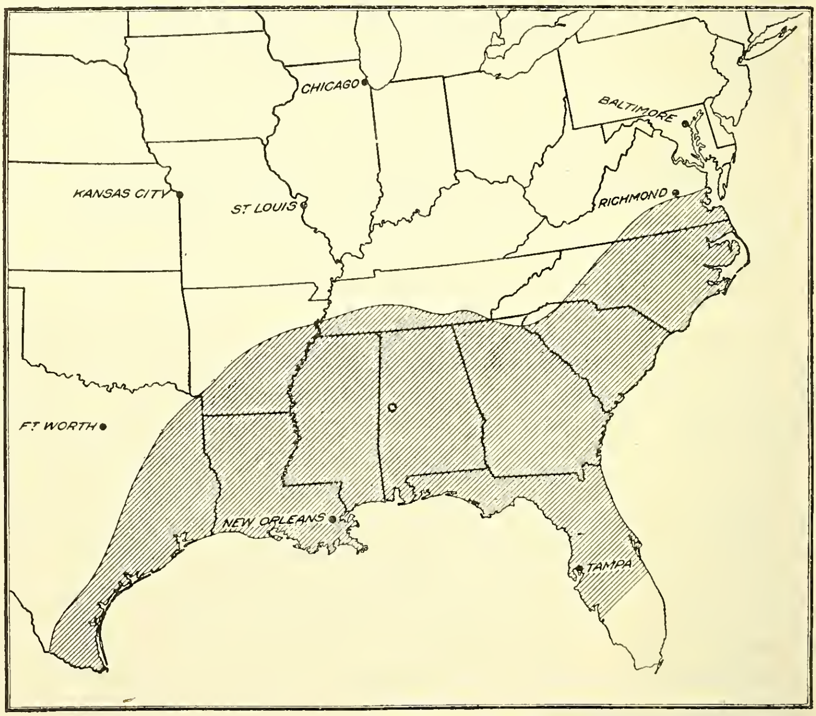


FIG. 1.—The shaded area represents the portion of the United States to which the results secured in the Alabama feeding experiments are applicable. The dark circle in Alabama shows the approximate location of the test farm. The location of the various cattle markets to which southern cattle are shipped are shown.

South from which cattle could not be shipped with relative ease to a good market.

Of the various problems which arise concerning the care of cattle on the farm, one of the most frequent deals with the methods of carrying the stock cattle through the winter. As a rule the growing of cattle through the grazing season gives little trouble, but the farmer is often puzzled as to the method to follow in wintering the stock. This is especially true during years when not enough roughage has been harvested to feed all the cattle. At times good steers have been sold at sacrifice prices in the fall under such conditions, when, if they could have been wintered there would have been an abundance of grass to fatten them the following summer.

The buying of commercial feeds to use for wintering stock cattle has been practiced to a certain extent, though it is far more common in the South to turn the cattle loose on the range and let them take care of themselves the best they can during the winter. Cattle treated in this manner always become very thin before spring, and some losses occur. A few of the better stockmen, who handle their mature cattle in this manner, sometimes drive up the thinnest of the cattle during the latter part of the winter and give them some feed until grass comes in the spring.

I. WINTERING STEERS PREPARATORY TO SUMMER FATTENING ON PASTURE.

This is the third in the series of experiments to determine the most profitable methods of wintering mature steers in the South, which were to be fattened on pasture the following summer, and to study the effects of the various methods of wintering on the rapidity of the gains made by the steers during the subsequent summer fattening. The results secured in the two previous years have been reported in former bulletins.[1] The results of the work during the third winter (1909–1910) are given herewith.

PLAN OF THE WORK.

The same general plan that had been followed during the two previous years was adhered to. The cattle were bought in the fall and held in the pasture until the grass was exhausted. They were then turned into the cornfields and allowed to remain until the work was started on December 8, 1909. The tests were made on the farm of Mr. O. E. Cobb, of Sumter County, Ala., and were under the direct supervision of Mr. H. J. Chatterton, who was stationed upon the farm and devoted his entire time to the work.

At the close of the winter work the steers were redivided into groups and used in the summer fattening work.

CATTLE USED.

The steers used in these tests were 2 and 3 year old grades of the Hereford, Shorthorn, Aberdeen-Angus, and Red Polled breeds. They were poorer in quality and smaller in size than the steers which had been used in the two previous tests. Many of them were only half bred, while some even carried a predominance of scrub blood. They would have classed as common to fair stockers on the market. They were bought principally of neighboring farmers in western Alabama. All were cattle which had been infested with the cattle tick ever since they were calves.

CHARACTER OF THE WINTER RANGE AND PRICES OF THE FEEDS USED.

The cattle were kept in inclosed fields which had been used for growing cotton and corn. The range consisted of the above-mentioned fields and some waste land upon which had grown the native

[1] See Bureau of Animal Industry Bulletins 131 and 159.

grasses. Crab grass and some Johnson grass had grown up between the rows and furnished some grazing. The corn had been snapped from the stalk and the entire stalks were left in the field. No canebrakes were available, and the cattle which were not fed had to depend entirely upon the stalks in the cultivated fields and the native grasses.

The cottonseed meal fed to lot 2 was of the same grade as that in previous years and contained about 38 per cent protein. The hay used for lot 4 consisted of very coarse Johnson grass mixed with weeds and was damaged to such an extent that it could not have been sold at all. It could not be cut at the proper stage because of a prolonged rainy spell. The grass had to be cut, however, to permit the next cutting to grow off, and instead of using the coarse grass for filling ditches, as is often done in similar cases, the hay was raked and stacked in a long rick just outside the hayfield, next to a field in which the steers were to be wintered.

The prices placed upon the feeds at the time of the test were as follows, these being the current prices of hulls and meal at the time the experiment was made:

Cottonseed meal	per ton..	$26
Cottonseed hulls	per ton..	6
Damaged hay	per ton..	5

The duplication of the test of the previous year with cotton seed to supplement the range could not be carried out as the price of this feed had increased from $14 per ton to over $20 per ton, and at such prices the seed could not be profitably used when cottonseed meal sold for but a few dollars more per ton.

No price was placed upon the stalk fields and the open range. No revenue would have been secured from them if they had not been grazed by the cattle.

METHOD OF FEEDING AND HANDLING THE CATTLE.

The cattle ran in the inclosed fields at all times and were not penned at any time of the day or night. No shelter was provided for them, but during bad weather they sought natural shelters, consisting of plum thickets, rows of hedge trees, and hillside nooks, which gave protection from the winds. The feed was placed in feed troughs and racks, which had skids in order that they might be pulled from place to place. By this method the manure was dropped in different places and the animals did not have to stand in the mud while eating. The troughs were placed as near the feed barn as practicable, in order to obviate hauling the feed long distances. The cattle were fed once each day, just before sundown. Salt was given the animals at feeding time to induce them to come the more readily to their feed. No salt was given for several days previous to each weigh day.

All the animals were dehorned, tagged, divided into groups which were uniform in quality and size, and each one was weighed on two consecutive days at the beginning of the test. Thereafter each group was weighed as a whole every 28 days until the close of the test, at which time each steer was again weighed.

The steers of lot 4, which received the damaged hay in addition to the range, were not fed upon the same farm as the other steers. The hay was 1½ miles from the scales, and it was found after the test had been in progress for some time that the hay could not be weighed out and the refuse weighed back each day, so accurate feed records were not kept for this lot. The weight records of these steers are correct, however, and are shown herein; not that any value is placed upon them as far as the winter work is concerned, but in order that the gains made by these steers the following summer may be studied and compared with the gains made during the summer by the steers of the other winter lots. This phase of the work will be discussed in full in another portion of this bulletin.

As soon as all the cotton had been picked the steers were divided into groups, tagged, weighed, and started on feed. The test began December 8, 1909, and continued until March 9, 1910, at which time melilotus and grass had begun to grow enough to furnish grazing. Melilotus grows luxuriantly throughout that portion of the State and furnishes good early grazing.

RESULTS OF THE WINTER FEEDING.

The winter of 1909–10 was a severe one, it being much colder than the average winter in Sumter County, with a great deal of rain and one hard sleet during December, which covered everything with ice for two days. Cold rains and winds made it hard upon the steers. During January the weather was cold, but there was not much rain. Light freezes occurred throughout the month. The month of February was about the average of several years. There were a number of cold nights, with freezes and some rains, but the weather was not as severe as during the first part of the winter. The feed on the range however, was almost exhausted, while during December it was plentiful.

The following table shows the rations fed, the number of steers in each lot, the average weight per steer at the beginning and the end of the test, the total gain, and the average daily gain per steer for the 91-day period.

TABLE 1.—*Results of wintering steers in 1909–10, December 8 to March 9, 91 days.*

Lot.	Number of animals.	Ration.	Average initial weight.	Average final weight.	Average gain (+) or loss (−).	Average daily gain (+) or loss (−).
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	23	Range alone	637	531	−106	−1.16
2	15	Range plus half ration of cottonseed meal and hulls	633	676	+ 43	+0.47
4	23	Range plus half ration of coarse hay	651	579	− 72	−0.79

It may be seen that the average weight of all steers was about 640 pounds. In the work previously reported the average weight of the animals in 1908–9 was about 705 pounds, and in 1907–8 about 725 pounds. The above table shows that every steer of lot 1, which had no feed in addition to their range, lost 106 pounds in weight during the winter, while the steers fed meal and hulls in addition to the range (lot 2) gained 43 pounds per head. These steers (lot 2) received the same amount of feed per head as those in similar lots for each of the previous years, but as they were smaller animals they gained in weight instead of practically holding their own, as had been done previously. The steers of lot 4 lost 72 pounds each during the winter, showing that while the hay given them helped them to a certain extent they did not receive enough of it. It was estimated that about 11 pounds of hay was given each steer per day, but a large amount of this was refuse, which was not consumed.

The average daily gain or loss per steer was minus 1.16 pounds for lot 1, plus 0.47 pound for lot 2, and minus 0.79 pound for lot 4 during the winter of 1909–10.

AMOUNT OF FEED CONSUMED.

In Table 2 is shown the amount of concentrates and roughage fed to the steers of lot 2 during the winter. The steers of lot 1 did not receive any feed in addition to the range. The amount of hay consumed by the steers of lot 4 could not be determined accurately for reasons previously mentioned, so no weights are given.

There is no doubt that the steers of lot 1 needed a greater acreage of range than the steers which received feed in addition to the range. This is shown by the fact that they exhausted their range of 10 acres per head about four weeks before the winter was over and had to be turned out to secure something to eat from the outside. The steers of lots 2 and 4 did not eat all of the feed in their fields before the test was over, although feed became scarce and very poor in quality during the latter part of the test. If a valuation could be placed upon the range, therefore, it is seen that lot 1 should be charged more than the other lots.

The steers of lot 2 each consumed 221 pounds of cottonseed meal and 808 pounds of hulls during the winter. This was an average daily ration of 2.4 pounds of cottonseed meal and 8.9 pounds of hulls per steer. A ration of 2.4 pounds of cottonseed meal and 8.9 pounds of hulls in addition to the range is therefore seen to produce an average daily gain of 0.47 pound on steers weighing 633 pounds each.

TABLE 2.—*Quantity of feed consumed per steer during winter 1909–10, 91 days.*

Lot.[1]	Number of steers in lot.	Ration.	Total amount consumed per steer.		Daily amount consumed per steer.	
			Cottonseed meal.	Hulls.	Cottonseed meal.	Hulls.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
2	15	Range plus cottonseed meal and hulls	221	808	2.4	8.9

[1] Lot 1 was on range alone; lot 4 was on range plus coarse hay, but the quantity of the latter was not accurately determined.

As there is no way of estimating the amount or price of feed per acre on range, no charge has been made for it. Range in this portion of the State is still free during the winter, and unless cattle are turned upon it the farmer gets no returns from it. When cottonseed meal is worth $26 per ton and hulls are worth $6 per ton, as they were at the time this experiment was made, the feed consumed by each steer cost 5.8 cents per day, or $5.30 per head for the whole winter.

MONTHLY GAINS OR LOSSES DURING THE WINTER.

The gains or losses made by the steers during the different months of the winter will vary greatly each year, depending chiefly upon weather conditions. Cold, dry weather does not cause severe losses in weight of beef cattle, but cold rains followed by cold winds or sleet storms injure them very materially, as they get chilled through and the feed is rendered unpalatable and at times unavailable, due to a covering of ice.

The following table shows the gains or losses made by the groups for each month during the winter of 1909–10:

TABLE 3.—*Results of feeding by 4-week periods.*

Lot.	Number of steers.	Ration.	Gain or loss per steer first period (Dec. 8 to Jan. 4).	Gain or loss per steer second period (Jan. 5 to Feb. 1).	Gain or loss per steer third period (Feb. 2 to Mar. 1).	Gain or loss per steer fourth period (Mar. 2 to Mar. 8).[1]
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	23	Range alone	−10	−41	− 9	−46
2	15	Range plus cottonseed meal and hulls	+27	+ 1	+28	−13
4	23	Range plus coarse hay	− 8	− 5	−35	−24

[1] The last period has but 7 days.

From the table it is seen that during the month of December the steers of lot 1 each lost 10 pounds, those of lot 2 gained 27 pounds, and those of lot 4 lost 8 pounds in weight. December was the most severe month during the winter of 1909–10, and that larger losses in weight were not experienced can only be accounted for by the fact that the steers were in good flesh to withstand the weather and that the feed on the range was better during this month than at any subsequent time.

In January the losses were greater, the steers of lot 1 losing heavily, decreasing in weight 41 pounds each, while the cattle of lot 2 gained 1 pound and the steers of lot 4 lost 5 pounds each.

The losses in February were heaviest with the hay-fed cattle, as their range was becoming exhausted. The steers of lot 1 had been turned outside during this period and lost about 9 pounds each. A gain of 28 pounds per head is shown by the steers of lot 2.

The steers of all of the lots showed a heavy loss during the last week of the winter work. There is little doubt, however, that a considerable part of the loss shown during this period was made during February and was not reflected in the weights taken on March 2. This was due to the weather conditions when the cattle were weighed on March 1 and March 8, respectively. On the former day the weather was warm and the cattle had taken on a large fill; on the latter day these conditions were reversed, so that the weights taken on March 1 showed the steers in a more favorable condition than was actually the case.

FINANCIAL STATEMENTS.

The cattle had been bought during the summer and early fall of 1909, and as they were of very common breeding they had cost but 2½ cents per pound at that time. Cattle at the present time are worth from 50 to 100 per cent more in that section than they were four years ago. The following financial statement shows the cost of the cattle the following spring. No statement is given for lot 4 because the value of the hay could not be ascertained.

Financial statement of winter feeding.

Lot 1. Range alone:		
To 637-pound steer, at $2.50 per hundredweight	$15.92	
By value of same steer in spring, 531 pounds, at $3 per hundredweight		$15.93
	15.92	15.93
Lot 2. Range plus cottonseed meal and hulls:		
To 633-pound steer, at $2.50 per hundredweight	15.83	
To 223 pounds cottonseed meal, at $26 per ton	2.87	
To 808 pounds cottonseed hulls, at $6 per ton	2.42	
By value of steer in spring, 676 pounds, at $3 per hundredweight		20.28
By required increase in value over range steer to break even (12½ cents per hundredweight)		.84
	21.12	21.12

From the above statement it is seen that steers which cost $2\frac{1}{2}$ cents a pound in the fall and weighed 637 pounds each at that time had cost 3 cents per pound in the spring when they received range alone and no charge was made for the range. In other words, the loss in weight during the winter had increased their cost in the spring one-half a cent per pound.

The steers of lot 2 were in fine condition in the spring, being heavier than when started in the experiment in the fall, but owing to the cost of the feed consumed their value had increased to \$3.12½ per hundred pounds, or 62½ cents per hundred pounds over the fall price.

The winter work terminated March 9 and the steers were redivided into lots for the summer feeding work, and charged at their spring cost. It remains to be seen by the summer work whether it was more profitable to feed the cattle through the winter, thus bringing them through to pasture in good condition, or to permit them to run on range without feed and thereby lose about 100 pounds of flesh during the winter, bringing them to the grazing season in very poor but thrifty condition. This feature is fully discussed later.

No losses from death are recorded here among the range cattle, but it is quite common to lose a steer occasionally during severe winters, when such a loss would probably not occur if the cattle were getting some feed. That phase of the subject is not considered here and is so variable that cattlemen will have to make such deductions as will suit their conditions.

SUMMARY OF THE WINTER WORK.

1. The steers which received range alone lost 106 pounds each in weight during the winter, and this loss in weight caused an increase in cost of one-half a cent per pound in the spring. No charge was made for the grazing during the winter.

2. The steers of lot 2 made a gain of 43 pounds in weight during the 91-day period. There was an average of 2.4 pounds of cottonseed meal and 8.9 pounds of hulls consumed per day by each steer in this lot at a cost of 5.8 cents, or \$5.30 for the winter.

3. The spring cost of the steers in lot 2 was \$3.12½ per hundredweight, or an increase of 62½ cents per hundredweight over the fall price. They were in good condition at the close of the test.

4. The steers of lot 4, which were fed coarse damaged hay, lost 72 pounds each in weight during the winter.

SUMMARY OF THREE YEARS' WINTER WORK.

For the sake of comparison a general summary of the three years' winter work is given below. There are some variations in the figures from year to year, due chiefly to the character of the winter and the prevailing climatic conditions. The averages of the three years' work are also included in the table:

TABLE 4.—*Summary of three years' winter feeding.*

	Lot 1. Range alone.	Lot 2. Range plus cottonseed meal and cottonseed hulls.	Lot 3. Range plus cowpea hay.	Lot 4. Range plus damaged hay.	Lot 5. Range plus cotton seed.
Average weight per steer in the fall:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1907–8	722	725	724	....	....
1908–9	705	705	....	689	706
1909–10	637	633	....	651	....
Grand average	688	698	724	680	706
Gain in weight per steer during the winter:					
1907–8	−97	−6	−9	....	....
1908–9	−106	+3	....	−40	−40
1909–10	−106	+43	....	−72	....
Grand average	−101	+8	−9	−64	−40
Feed consumed per steer per day:					
1907–8	None.	2.35 meal. 8.50 hulls.	8.50 cowpea hay.	....	....
1908–9	None.	2.41 meal. 8.71 hulls.	....	11.8 damaged hay.	4.71 cotton seed.
1909–10	None.	2.39 meal. 8.90 hulls.	....		
Grand average	None.	2.38 meal. 8.70 hulls.	8.50 cowpea hay.	11.8 damaged hay.	4.71 cotton seed.
Average increase in cost per hundredweight due to cost of wintering:	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1907–8	39	67	53	....	....
1908–9	45	78	....	53	64
1909–10	50	62½	....	....	....
Grand average	45	69	53	53	64
The required increase in value per hundredweight over range cattle to break even:					
1907–8	....	28	14	....	....
1908–9	....	33	....	8	19
1909–10	....	12½	....	....	....
Grand average	....	25	8	8	19

The weights of the steers in the various lots were very uniform each year. The steers used the last year of the test were about 85 pounds smaller than the steers used the first year.

The loss in live weight of the steers of lot 1 was very uniform for the three winters, being 97, 106, and 106 pounds, respectively, for the three years. The steers which received hulls and meal lost 6 pounds each the first year, gained 3 pounds the second year, and gained 43 pounds the final year of the experiments. The grand average for the three years shows the loss to be 101 pounds for each of the steers on range alone; a gain of 8 pounds for those fed on meal, hulls, and range; a loss of 9 pounds on those which received cowpea hay; a loss of 64 pounds on those which were fed the coarse damaged hay; and a loss of 40 pounds for those which had the range supplemented with cotton seed.

Each steer of lot 2 consumed almost the same amounts of meal and hulls per day for the three winters. The average amount consumed for the three years was 2.38 pounds of cotton seed meal and 8.7 pounds of hulls per day. This amount, in addition to the range, proved to be enough to make 700-pound steers hold their fall weight throughout the winter.

Cowpea hay was fed but one winter, and steers which received $8\frac{1}{2}$ pounds each per day weighed practically the same in the spring as in the fall. It is seen that $8\frac{1}{2}$ pounds of bright cowpea hay proved equal to $8\frac{1}{2}$ pounds of hulls and 2.35 pounds of cottonseed meal for wintering steers.

The cost per 100 pounds of cattle in the spring is secured by adding the cost of feeds consumed in the winter to the fall cost of the steers and dividing this total cost by the spring weight.

When no charge is made for the use of the winter range it was found that the average cost of wintering the steers, or in other words, the difference between the cost price in the fall and the cost price in the spring, for the range steers was 45 cents per hundredweight, while it was 69 cents for cattle given meal and hulls, 53 cents for those receiving cowpea hay, 53 cents for the steers fed damaged hay, and 64 cents for the steers that were given cotton seed to supplement the range.

The cost of the feeds were such that, to break even on the winter feeding, the cattle fed meal and hulls would have to be worth 25 cents per hundredweight more than the range cattle, while the cattle fed cowpea hay and those given damaged hay would have to sell for 8 cents per hundredweight more than the range stock.

II. FATTENING STEERS ON PASTURE IN ALABAMA.

Some results of fattening steers upon pasture during the summer months have already been published.[1] The results of two additional years' work are presented herewith. It should be understood, however, that this comprises only a report of the progress of the work, as the experiments are being continued and new phases of the subject are being investigated.

PLAN AND OBJECTS OF THE WORK.

The cattle were bought in the fall, as they could be bought much cheaper at that time than in the spring. In fact, steers could hardly be bought at all in the spring. When grass appears the owners of steers usually will not sell them unless at a premium. The details of carrying the cattle through the winter months are discussed in another part of this bulletin. Just as soon as the grass appeared in the spring the tests were inaugurated, and only two objects were in mind—

1. To determine the profit, if any, in fattening native Alabama steers on pasture for the fall market.

2. To determine whether it would be profitable to supplement the pasture with a small ration of cottonseed cake.

Owing to the fact that suitable pasture was not available upon the farm of the experiment station at Auburn, Ala., the work was carried on upon the land of and in cooperation with Mr. O. E. Cobb, of Sumterville, Ala., where similar work has been in progress for six years. Mr. Cobb furnished the cattle, the pastures, and the feeds, while the Bureau of Animal Industry and the experiment station authorities provided trained men to have personal supervision of the work. Messrs. H. J. Chatterton and S. S. Jerdan, both of whom are graduates of an agricultural college, were stationed upon the farm and looked after the details of the feeding.

THE CATTLE.

No attempt was made to get steers for this work which would grade far above the average of the State. Only such steers were used as could be bought in Sumter, Wilcox, Marengo, and neighboring counties. An attempt was made, however, to select the best steers from among those raised in the western part of Alabama, but as the experiments required the use of a large number of animals it was not always possible to select steers which carried a predominance of beef

[1] See Bureau of Animal Industry Bulletins 131 and 159.

blood. Nevertheless, the great majority of the animals contained some Aberdeen-Angus, Shorthorn, Hereford, Red Polled, or Devon blood. Some had a predominance of Jersey blood, and some few carried no admixture of any kind of improved blood. They varied from 2 to 4 years in age, the majority being 2 years old when they were purchased in the fall. As will be seen later, they were small. At the inauguration of the tests in April they ranged from 545 to 576 pounds in weight. They were, however, in their lightest form, as they had no doubt lost on the average not less than 75 pounds each during the previous winter months.

WINTERING THE STEERS.

Previous work has shown that it does not pay to feed such steers so as to produce marked gains in live weight, unless the object is to finish them for the market very early in the summer season. Fortunately the Cobb farm is unusually well supplied with rough and cheap feeds, and these are the kind that should be largely depended upon for getting mature steers through the winter months. Large areas of old corn and cotton fields were available. Between the rows there is always reasonably good growth of crab grass, which is really an exceedingly valuable cheap feed and affords no little grazing. Along the fences and ditches also was a considerable growth of native grasses, which had fallen down and dried after the first two or three frosts, but nevertheless afforded some grazing. During an average winter there are one or two native plants, such as wild vetch or Augusta vetch and melilotus, which come up in February and furnish some grazing until the appearance of the usual summer grasses. Of course, steers handled in this way during the cold months lose very materially in weight; in fact, during severe winters the losses by death may be quite heavy.

SUMMER PASTURE AND PASTURE LANDS.

The summer pastures used in these experiments consisted of a mixture of sweet clover (melilotus), Japan clover (lespedeza), Johnson grass, crab grass, and some Bermuda grass. The melilotus seed had been planted, but the other plants were purely voluntary. As a rule melilotus becomes available for light grazing by March 15, while the Japan clover and Bermuda grass seldom afford good grazing before May 15.

The pasture was divided into fields for the purpose of the experimental work, the size of each one depending upon the number of cattle grazed upon it, and also upon whether the steers were to be fed a light or a heavy ration, or no supplementary feed at all. The object was to have an abundance of pasture for each lot of cattle so the results obtained would be comparable.

In 1910 the pastures were ready for grazing by April 7, but the following year no material benefit could be derived from them until April 21. These two dates, therefore, mark the inauguration of the tests for the summers of 1910 and 1911.

The pasture land was rolling, some of it being rather rough and gullied, while the remainder was slightly rolling or almost level with just enough slope to drain well. The soil of the pasture lands is of three distinct classes—Houston clay, Orangeburg clay, and Waverly loam. The hill or rough portions of the pastures are made up of the Houston clay, which varies from almost white to brown in color, and is usually termed "lime-hill prairie land." The soil is 4 to 8 inches deep, underlain by 18 to 36 inches of grayish clay, which usually rests upon lime rock that outcrops frequently. The Orangeburg clay consists of 4 to 8 inches of reddish sandy loam, underlain by either red clay or sandy clay subsoil. This soil is found on the slightly rolling land between the hills and the creek. The Waverly loam is found in level stretches near the creek and branches. It is the deposition of the silt and clay from the flood waters of the streams, and is fertile, though sometimes rather wet. There is considerable lime in all of these soils, so melilotus and the other pasture plants mentioned above grow readily.

As this land is similar to that found throughout the prairie sections, or "black belt," of Alabama and Mississippi, and the pasture plants are the same throughout that region, the results secured from the grazing experiments outlined in this part of the bulletin are strictly applicable to all parts of that prairie region.

METHOD OF FEEDING AND HANDLING DURING THE SUMMER.

The steers which received no feed in addition to the pasture required very little care and attention. They were salted at regular intervals and weighed every 28 days. This was about all the attention they required.

The steers which received cottonseed cake in addition to the pasture were fed once a day, and this was done about sundown, or the cool part of the afternoon, so that all would come out to the feed troughs. The feed was not thrown upon the ground, but placed in feed troughs situated at convenient places in the pastures, and the hay when fed at all was fed from hay racks. As the steers had been dehorned the previous winter, each animal occupied not more than 3 feet at the trough. When cattle are thus fed in properly constructed hay racks and troughs practically no feed is wasted. A good supply of water was afforded by creeks and artificial pools.

During the summer of 1910 some difficulty was experienced in getting the cattle dipped properly. The dip used for destroying the cattle ticks was an emulsion of crude petroleum, but for some unexplainable reason the oil did not emulsify and when the steers were dipped the first time several were badly blistered, and the hair and hide peeled off the legs and the lower part of the body of almost all the animals. During the remainder of the test the steers were greased by hand after being confined, one by one, in a chute. The steers made fairly satisfactory gains in spite of all of these unfavorable circumstances. In 1911 the dipping vat was filled with the official arsenical solution, and no difficulties or unfavorable results were encountered.

PRICES AND FEEDS USED.

Cottonseed cake and alfalfa hay were used in addition to the pasture. The pasture was used in all of the tests, the cottonseed cake was used for about one-half the lots, and the alfalfa hay was fed in one case only. The cottonseed cake was charged against the steers at the market price, and an estimated price, corresponding as nearly as possible to the market price, was placed upon the alfalfa hay. The following values were placed upon the feeds:

Cottonseed cake	per ton	$26.00
Alfalfa hay	do	16.00
Pasture (per head)	per month	.50

The hay was practically all freshly cut alfalfa and was of excellent quality. The cottonseed cake was not of the best quality. That used in 1910, or a part of it at least, got wet while it was being hauled from the mill to the farm; and a part of this cake had been carried over and was fed in 1911. The steers ate it up clean, however. The cake had been broken into nut size and sacked at the mill.

In regard to feeding cake rather than meal, the statement in a former publication is here quoted:

> This cake can be purchased in the large cake size, just as it comes from the press, for about $2 a ton cheaper than in the nut size. Some feeders find that it pays to break the cake on their own farms. The cake is the same as cottonseed meal, except that it is not ground into meal. There are several advantages in feeding cake in place of meal, especially in summer feeding. A rain does not render the cake unpalatable, but it will often put the meal in such a condition that the cattle will not eat it. Again, no loss is incurred with the cake during windy days, whereas the meal, when fed in the open pasture, is sometimes wasted on account of the winds. Furthermore, the cake requires chewing before being swallowed, and therefore must be eaten very much slower than the meal, so when a number of steers are being fed together the greedy one has little chance to get enough cake to produce scours. When cottonseed meal is fed the greedy steer often scours because he can bolt the meal and get more than his share; this not only injures the steer but makes the bunch "feed out" unevenly.

DAILY RATIONS.

When steers are fattened on pastures in the Western States it is the custom to feed large amounts of grain, principally corn. As a result of feeding these heavy rations—sometimes as much as 20 pounds of grain per steer daily—the western feeders cause their steers to make larger gains, as a rule, than those reported in this bulletin. It should be noted, however, that in these cases the corn is cheap compared with the price of this grain in the South.

The table below shows that the only supplementary concentrate used in these tests was cottonseed cake, and that it was used sparingly. As previously stated, the cake was only fed once a day, about sundown.

TABLE 5.—*Average daily rations.*

APRIL 7 TO AUGUST 3, 1910 (118 DAYS).

Lot.	Number of steers.	Ration.	Total feed eaten by each steer.	Average daily feed eaten by each steer.
			Pounds.	*Pounds.*
A	25	Pasture alone		
B	34	Pasture and cottonseed cake	411 cake	3.48 cake.
G	25	Pasture, cottonseed cake, and alfalfa hay	411 cake 269 hay	3.48 cake. 2.28 hay.

APRIL 21 TO SEPTEMBER 8, 1911 (141 DAYS).

Lot.	Number of steers.	Ration.	Total feed eaten by each steer.	Average daily feed eaten by each steer.
A	25	Pasture alone		
B	25	Pasture and cottonseed cake	505 cake	3.58 cake.

In 1910 each steer in lots B and G were started off (April 7) on an average daily ration of 1.5 pounds of cake. On April 18 this amount was raised to 2.5 pounds, and by May 19 the amount being consumed daily was 5 pounds per steer.

Throughout the whole test each steer averaged but 3.48 pounds of cake daily. It was thought that it might be profitable to feed a small amount of alfalfa hay along with the pasture and the cake, so the steers in lot G were given an average daily feed of 2.28 pounds of hay along with the cake and the pasture. It will be seen later, however, that no favorable results were secured from the use of the hay.

It is seen that the cottonseed cake was fed sparingly in 1911 also, as each steer in lot B consumed on the average only 3.58 pounds daily. On April 21 each steer was started off on 2 pounds of cottonseed cake daily. The amount was raised gradually until May 17, when the 25 steers were being fed 94 pounds of cake each day. The amount was not increased after that date.

TOTAL AND DAILY GAINS.

When the small size of the steers is taken into consideration the gains were entirely satisfactory. The steers, however, were in exactly the proper condition for making good gains on the pastures, as the majority had simply been "roughed" through the previous winter and were, consequently, thin in flesh. Part III of this bulletin shows that a thin steer makes much more rapid gains during the pasture season than one in good flesh. The gains also show that the pastures used were good.

TABLE 6.—*Total and daily gains.*

APRIL 7 TO AUGUST 3, 1910 (118 DAYS).

Lot.	Ration.	Average initial weight of each steer.	Average final weight of each steer.	Average total gain of each steer.	Average daily gain.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
A	Pasture alone	544	737	193	1.64
B	Pasture and cottonseed cake	576	809	233	1.98
G	Pasture, cottonseed cake, and alfalfa hay	563	783	220	1.86
	APRIL 21 TO SEPTEMBER 8, 1911 (141 DAYS).				
A	Pasture alone	563	810	247	1.75
B	Pasture and cottonseed cake	565	805	240	1.70

In 1910 the steers of lot A which ran on pasture and had no feed in addition made the smallest gains, each steer increasing 193 pounds in weight from April 7 to August 3. In lot B, where cottonseed cake supplemented the pasture, each steer made a total gain of 233 pounds. The animals in lot G, where both cake and alfalfa hay were used to supplement the pasture, made greater gains than those which were on pasture alone, but did not gain as rapidly as the steers in lot B, where cake was the only supplement. In this case it did not pay to introduce the hay into the ration, as the gains were not increased and the final selling value of the steers was not enhanced. Alfalfa hay has a laxative tendency, and when it is fed in conjunction with pasture and cake this tendency is magnified. The steers gained at the average daily rate of 1.64, 1.98, and 1.86 pounds in lots A, B, and G, respectively.

In 1911 the results do not agree with the results of 1910 in respect to the daily gains. It is noticeable, also, that the steers in lot A, where nothing was fed except pasture, made more rapid gains than those where cake was used as a supplement. The daily gains in lots A and B were 1.75 and 1.70 pounds, respectively. But, as will be seen in the financial statement, the feeding of the cake did have a favorable influence, as the cake-fed steers sold for 1 cent a pound more than the pasture-fed ones. The cake-fed steers also dressed out a slightly higher percentage of marketable meat. The cake-fed steers appeared to be in very much better condition and their hair was very much sleeker and glossier than that of the others.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS OF GAIN.

Table 7 shows the number of pounds of feed required to make 100 pounds of gain in each lot, the cost of the cottonseed cake to make the gains, and also the cost when both the cake and the pasture are charged against the gains. With the exception of the case where alfalfa hay was used (lot G, 1910), the increase in live weight during the fattening period was put on at a profit. That is, each pound added to the weight of the steers during the fattening period did not cost as much as it sold for on the market. This is an unusual state of affairs in fattening cattle, as under average winter conditions, and summer conditions also, where heavy supplementary grain feed is given, each pound of increase during the fattening period is made at a loss, the profit in feeding coming from the increase in value of the original weight.

The economical gains in these tests were mainly due to two factors: First, the daily gains were satisfactory, notwithstanding the fact that a small amount of high-priced feeds was consumed by each steer, and second, the animals were grazing a pasture, which is the cheapest feed that can possibly be obtained in Alabama. When a large amount of concentrated feed is used to supplement the pasture, the cost of the increase in weight will be much more expensive than was the case in these experiments.

Table 7.—*Quantity and cost of feed required to make 100 pounds of gain.*

April 7 to August 3, 1910 (118 Days).

Lot.	Ration.	Quantity of feed to make 100 pounds of of gain.	Cost to make 100 pounds of gain.	
			Not including cost of pasture.	Including cost of pasture.
		Pounds.		
A	Pasture alone			$1.10
B	Pasture and cottonseed cake	176 cake	$2.29	3.19
G	Pasture, cottonseed cake, and alfalfa hay	187 cake 122 hay	3.41	4.37

April 21–September 8, 1911 (141 Days).

Lot.	Ration.	Quantity of feed to make 100 pounds of of gain.	Not including cost of pasture.	Including cost of pasture.
A	Pasture alone			$1.02
B	Pasture and cottonseed cake	229 cake	$2.98	4.03

The cheapest gains, of course, were made in the two lots where nothing was fed but pasture. But the conclusion should not be immediately drawn that the greatest profits were realized on these two lots. While exceedingly economical gains were made, the steers were cheap at the end on account of not being fat, and were sold for low prices. The financial statement sets this forth.

In 1910 it cost from $1.10 in lot A to $4.37 in lot G to make 100 pounds of increase in live weight; in lot B, where cake and pasture were fed, each 100 pounds of increase in weight cost $3.19. It is shown again, therefore, that cake with alfalfa hay was not as efficient and economical as cake alone. When cake alone was fed along with the pasture only 176 pounds were required to produce an increase in weight of 100 pounds, but when alfalfa hay and cake were both fed it required 187 pounds of cake and 122 pounds of hay to produce the same increase in weight.

During the summer of 1911, 229 pounds of cottonseed cake were required to make 100 pounds of gain. When the cost of both the pasture and the cake was charged against the gains it cost $1.02 and $4.03 to make 100 pounds of increase in weight in lots A and B, respectively.

PRICES REALIZED FOR PASTURE AND COTTONSEED CAKE WHEN FED TO THE CATTLE.

The statement below illustrates the fact that southern pastures may be put to profitable use by means of beef cattle, and adds further evidence to the assertion that the farmer can usually well afford to buy certain outside feeds—those not grown upon the farm—and feed them to his cattle. It will be observed that lot G is not included in the statement. This lot received some hay in addition to the cake, but as the hay was only a partial ration the results in this case would be inconclusive. With the price of pasture fixed at 50 cents a month per steer and cottonseed cake at $26 a ton, the following prices were realized as a result of feeding to the cattle:

Cottonseed cake, lot B:		
1910	per ton	$69.37
1911	do	50.94
Pasture:		
Lot A, 1910	for season	8.95
Lot B, 1910	do	11.02
Lot A, 1911	do	7.80
Lot B, 1911	do	8.81

It is seen that the cottonseed cake, which cost $26 a ton, was fed to the steers and sold by means of them for $50.94 and $69.37 a ton. Regarding the pasture, there are thousands of acres in the South, and good ones, too, that lie idle all the year. If these idle areas were set to pasture and grazed by live stock excellent profits could be realized. In 1910 the grazing proved to be worth from $8.95 to $11.02 for each steer. In 1911 the pasture was worth for each steer, $7.80 in lot A and $8.81 in lot B. It would not have been possible to have made these profits had the pastures not been established.

SLAUGHTER DATA.

The experimental farm was located 9 miles from the railroad, so the steers had to be driven that distance before being loaded on the cars. They were all shipped to Meridian, Miss., a distance of 40 miles, but were on the cars about 14 hours owing to a long delay through being sidetracked. The steers were weighed on the farm before being started on the road to the shipping point, as they were sold by farm weights after a 3 per cent shrink. As soon as they reached Meridian they were fed and watered, and after eating, drinking, and resting each one was weighed again.

TABLE 8.—*Slaughter data.*

Lot.	Ration.	Average farm weight of each steer after 3 per cent shrink.	Average market weight of each steer.	Average net shrinkage.	Per cent of dressed to market weight.
	1910.				
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*
A	Pasture alone	736	706	30	51.3
B	Pasture and cottonseed cake	809	785	24	54.2
G	Pasture, cottonseed cake, and alfalfa hay	783	714	69	57.6
	1911.				
A	Pasture alone	810	765	45	51.1
B	Pasture and cottonseed cake	805	773	32	51.4

In 1910 each steer in lots A, B, and G lost on the average 30, 24, and 69 pounds, respectively, in weight as a result of being shipped. It is seen that the hay-fed steers lost heavily in weight. On account of suffering a heavy loss in transit these steers dressed out, by market weights, a high percentage, or 57.6 per cent, while the steers in lots A and B dressed only 51.3 and 54.2 per cent, respectively. In 1911 the two lots of steers finally dressed out practically the same.

FINANCIAL STATEMENT.

The cattle from both tests were sold to a buyer of Meridian, Miss. Cattle were then, of course, much cheaper than they are now (1913), and the prices seem low compared with present prices. In 1910 the steers in lot A sold for $3\frac{1}{2}$ cents a pound, those in lot B for $4\frac{1}{2}$ cents a pound, and those in lot G for 4 cents a pound. In 1911 the steers in lot A sold for $3\frac{1}{2}$ cents a pound and those in lot B for $4\frac{1}{2}$ cents a pound. These cattle were all sold on the farm after a 3 per cent shrink. The grass-fed steers made economical gains, but they sold finally at a very low price; not so low, however, but that profits were realized.

Financial statement.

1910.

Lot A, pasture alone:		
To 25 steers, 13,608 pounds, at $2.95 per hundredweight	$401.44	
To pasture, at 50 cents per steer per month	52.75	
Total expenditure	454.19	
By sale of 25 steers, 18,414 pounds, at $3.50 per hundredweight		$625.24
Total profit on lot	171.05	
Average profit on each steer	6.84	
Lot B, pasture and cottonseed cake:		
To 34 steers, 19,586 pounds, at $2.95 per hundredweight	577.79	
To pasture, at 50 cents per steer per month	71.74	
To 13,976 pounds of cottonseed cake, at $26 per ton	181.69	
Total expenditure	831.22	
By sale of 34 steers, 27,514 pounds, at $4.25 per hundredweight		1,134.27
Total profit on lot	302.95	
Average profit on each steer	8.91	
Lot G, pasture, cottonseed cake, and alfalfa hay:		
To 25 steers, 14,069 pounds, at $2.95 per hundredweight	415.04	
To pasture, at 50 cents per steer per month	51.75	
To 10,264 pounds of cottonseed cake, at $26 per ton	133.43	
To 6,715 pounds of alfalfa hay, at $16 per ton	53.72	
Total expenditure	653.94	
By sale of 25 steers, 19,571 pounds, at $4 per hundredweight		759.36
Total profit on lot	104.42	
Average profit on each steer	4.18	

1911.

Lot A, pasture alone:		
To 25 steers, 14,078 pounds, at $2.50 per hundredweight	$492.73	
To pasture, at 50 cents per steer per month	63.00	
Total expenditure	555.73	
By sale of 25 steers, 20,255 pounds, at $3.50 per hundredweight		687.66
Total profit on lot	131.93	
Average profit on each steer	5.28	
Lot B, pasture and cottonseed cake:		
To 25 steers, 14,123 pounds, at $3.50 per hundredweight	494.31	
To 12,614 pounds of cottonseed cake, at $26 per ton	163.98	
To pasture, at 50 cents per steer per month	63.00	
Total expenditure	721.29	
By sale of 25 steers, 20,128 pounds, at $4.50 per hundredweight		878.59
Total profit on lot	157.30	
Average profit on each steer	6.29	

Satisfactory profits were made in every experiment and on every lot, but greater profits were made on some lots than on others. The financial results, as a whole, are in keeping with the results obtained in former work. It paid both years to supplement the pastures with cottonseed cake, but it did not pay to feed alfalfa hay.

In 1910 each steer that was fed pasture alone (lot A) returned a clear profit of $6.84, each steer that was fed on cottonseed cake along with the pasture (lot B) returned a clear profit of $8.91, while each hay-fed animal (lot G) yielded a profit of only $4.18.

In 1911 the results were very similar to those secured in 1910. An average profit of $5.28 was made on each one of the pasture-fed steers, while $6.29 was the average profit realized on each cake-fed animal.

SUMMARY OF SUMMER WORK OF 1910 AND 1911.

1. The objects of these tests were, first, to determine the profits in fattening native Alabama steers on pasture for the fall market, and, second, to determine whether it would be profitable to supplement the pasture with a small ration of cottonseed cake.

2. The majority of the animals used carried some improved beef blood, but some had a predominance of Jersey and scrub blood. They varied from 2 to 4 years old and were small for their age.

3. The steers were divided into lots and given the following feeds: In 1910 (Apr. 7 to Aug. 3)—Lot A, pasture alone; lot B, pasture and cottonseed cake; lot G, pasture with cottonseed cake and alfalfa hay. In 1911 (Apr. 21 to Sept. 8)—Lot A, pasture alone; lot B, pasture and cottonseed cake.

4. In 1910 the average daily gains were 1.64, 1.98, and 1.86 pounds in lots A, B, and G, respectively. In 1911 the average daily gains were 1.75 and 1.70 pounds in lots A and B, respectively.

5. In 1910 the total cost to make 100 pounds of increase in live weight was $1.10, $3.19, and $4.37 in lots A, B, and G, respectively. In 1911 the total cost to make 100 pounds of gain was $1.02 and $4.03 in lots A and B, respectively.

6. In 1910 the net profits per steer were $6.84, $8.91, and $4.18 in lots A, B, and G, respectively. In 1911 the net profits per steer were $5.28 and $6.29, respectively.

7. It did not pay to use alfalfa hay along with pasture and cottonseed cake, but it did pay to feed cottonseed cake along with the pasture.

III. THE INFLUENCE OF WINTER FEEDING UPON GAINS MADE THE FOLLOWING SUMMER.

INTRODUCTION.

Mature steers in Alabama when turned upon the range to pass through the winter upon what feed they could secure from the cotton and corn fields and the native grasses on the waste lands lose very materially in live weight. In our experiments covering three winters' work the losses in weight averaged slightly over 100 pounds per head, and the steers, while still thrifty in the spring, were very poor. Other steers, which received in addition to the range a half ration of cottonseed meal and hulls, did not lose weight, but were slightly heavier in the spring than when they were started in the test the previous fall. Another lot of steers which had received a half ration of good cowpea hay in addition to the range, practically held their fall weight throughout the winter. The steers of the last two lots were in excellent condition in the spring, or in that condition which is desired by many farmers in buying steers for grazing purposes. Two other lots which were wintered, respectively, on range plus damaged hay and range plus cottonseed lost in weight during the winter, but to a much less extent than the cattle which received range alone.

The question has often arisen as to whether it is more profitable to allow steers which are to be finished for market in the summer to become as thin as is the case with those which have to depend upon the old fields to furnish winter subsistence, or to give them some feed during the winter so they would be in good condition when put on pasture in the spring. To answer this question, it is necessary to know how large gains cattle will make during the summer which had become very poor during the previous winter, as compared with the summer gains made by steers which were given some feed during the winter months. It is also desirable to know if steers thin in flesh will ever get as fat on pasture as those which are in good condition in the spring and, if so, how long it will take them to attain this degree of fatness.

It is the purpose, therefore, to here bring together information on this subject which is based on the three seasons' work reported in detail in Bureau of Animal Industry Bulletin 131 and in Parts I and II of the present bulletin. Much of the detail of the work need not now be repeated; it will suffice to mention briefly the general outline of the experiments, as follows:

GENERAL PLAN OF THE THREE YEARS' WORK.

The steers were purchased each fall, divided into lots, and wintered in five different ways, as shown in Table 9. At the end of the winter work the steers were redivided into groups, which were to be fattened on grass and supplementary feeds during the summer months. The steers that had been used in the winter work were so divided that some of the animals of each winter lot were placed in each group of cattle for the summer fattening. In this way the effects of the treatment given during the winter upon the gains made by the steers during the summer could be studied.

The feeding during the summer consisted of finishing the cattle on pasture alone, as compared with finishing them on pasture in combination with some supplementary feed, as cottonseed cake, cotton seed, cold-pressed cottonseed cake, cottonseed cake and corn, etc.

The steers used in the experiments contained a large percentage of Jersey and scrub blood, although most of them had the blood of some one of the various beef or dual-purpose breeds in their veins. All had been raised in Sumter County or neighboring counties in Alabama on tick-infested premises, and were from 2 to 4 years old. Their weights ranged from 600 to 900 pounds in the fall, with an average of about 700 pounds.

DISCUSSION OF THE RESULTS.

In order to present this subject as clearly as possible, the results will be considered from two main standpoints; the first giving a comprehensive view of the three years' work arranged under the five different methods of winter treatment, showing the results of the summer feeding obtained from each one separately (see Table 9); the second presenting a similar view under each of the six methods of summer fattening, showing in a direct manner the results of the several methods of winter treatment upon the gains made with each kind of summer feed (see Table 10). These tables are also supplemented by three charts (figs. 2, 3, and 4), giving the results in graphic form.

COMPARISON OF RESULTS UNDER WINTER METHODS OF FEEDING.

The results secured under each method of winter feeding are seen in Table 9, which is divided into five sections, each one representing a fixed winter ration followed by various kinds of summer feeding, both winter and summer work extending over three years. The winter lots of cattle are designated by the numbers 1, 2, 3, 4, and 5, while those fed during the summers are listed as groups A, B, C, E, F, and G, each number and each letter standing for a separate method of feeding. The columns of the table show, in order, the number of steers in each summer group, the average weights in the fall, and the average total and daily gains for the winter and summer, and for both combined.

TABLE 9.—*Results of winter feeding of steers on subsequent gains in summer fattening.*

Group and summer ration (average for 3 years 1908, 1909, and 1910).	Number of steers in group.	Average weight of steers in fall.	Winter gains.[1]		Summer gains.		Combined winter and summer gains.	
			Average total gain per steer.	Average daily gain per steer.	Average total gain per steer.	Average daily gain per steer.	Average total gain per steer.	Average daily gain per steer.
1. STEERS WINTERED ON RANGE ALONE.								
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Group A. Pasture alone	17	662	− 92	−1.02	225	1.79	133	0.62
Group B. Pasture and cottonseed cake (medium ration)	25	692	−104	−1.14	282	2.21	178	.82
Group C. Pasture and cold-pressed cake	8	723	− 99	−1.18	196	1.74	97	.49
Group E. Pasture and cotton seed	6	709	−117	−1.19	351	2.28	234	.93
Group F. Pasture and cottonseed cake (heavy ration)	12	715	−102	−1.08	267	2.31	165	.79
Group G. Pasture, cottonseed cake, and alfalfa hay	4	592	− 93	− .94	267	2.26	174	.81
Average for all groups		688	−101	−1.10	261	2.09	160	.74
2. STEERS WINTERED ON RANGE AND COTTONSEED MEAL AND HULLS.								
Group A. Pasture alone	18	723	− 14	−0.16	194	1.53	180	0.83
Group B. Pasture and cottonseed cake (medium ration)	21	681	− 8	− .09	244	1.89	236	1.07
Group C. Pasture and cold-pressed cake	10	689	− 1	− .01	215	1.92	214	1.09
Group E. Pasture and cotton seed	3	675	30	.23	263	1.71	293	1.17
Group F. Pasture and cottonseed cake (heavy ration)	13	729	60	.63	208	1.71	268	1.24
Group G. Pasture, cottonseed cake, and alfalfa hay	3	571	39	.43	224	1.90	263	1.26
Average for all groups		698	8	.088	220	1.76	228	1.06
3. STEERS WINTERED ON RANGE AND COWPEA HAY.								
Group A. Pasture alone	9	767	− 21	−0.25	170	1.52	149	0.76
Group B. Pasture and cottonseed cake	8	678	− 10	− .12	248	2.22	238	1.22
Group C. Pasture and cold-pressed cake	7	722	6	.07	212	1.89	218	1.11
Average for all groups		724	−9.6	− .11	208	1.86	199	1.01
4. STEERS WINTERED ON RANGE AND DAMAGED HAY.[2]								
Group A. Pasture alone	11	648	− 66	−0.70	218	1.59	152	0.65
Group B. Pasture and cottonseed cake	12	643	− 51	− .54	244	1.76	193	.82
Group E. Pasture and cotton seed	3	731	− 52	− .53	341	2.22	289	1.15
Group F. Pasture and cottonseed cake (heavy ration)	17	729	− 63	− .67	228	2.00	165	.79
Average for all groups		680	− 64	− .67	236	1.83	172	.77
5. STEERS WINTERED ON RANGE AND COTTON SEED.								
Group A. Pasture alone	5	657	− 44	−0.45	284	1.84	240	0.95
Group B. Pasture and cottonseed cake	9	671	− 47	− .48	301	1.95	253	1.01
Group E. Pasture and cotton seed	3	717	− 46	− .47	270	1.76	224	.89
Group F. Pasture and cottonseed cake (heavy ration)	8	772	− 25	− .26	280	2.00	255	1.07
Average for all groups		706	− 40	− .40	287	1.93	248	1.00

[1] A minus sign (−) indicates loss.

[2] The figures used for group 4 are for the whole period of 98 days of the year 1909 instead of the 70-day period reported in Bureau of Animal Industry Bulletin 131.

STEERS WINTERED ON RANGE ALONE.

In the first section of the table are shown the results secured on the steers of lot 1, which were later divided among the groups A, B, C, E, F, and G for the summer work. There were in lot 1 a total of 72 steers which received no feed during the winter except what they secured from the open range. It is seen that the various groups in this lot did not lose the same in weight during the winter, as these losses ranged from 92 pounds on the steers that were later fed as group A to 117 pounds for the six steers that were fed during the summer in group E. The losses do not seem so variable, however, when they are compared with the average loss, which was 101 pounds for all the steers of the lot. The six steers of group E, which lost 117 pounds each during the winter, experienced this loss in a 98-day period.

The 72 steers of lot 1 averaged 688 pounds each in weight in the fall and lost an average of 101 pounds each during the winter, or 1.10 pounds per day per steer during that period.

As the length of the winter feeding periods varied from 84 to 98 days and the same number of steers were not used in each lot for each of the three winters, it can readily be understood that the efficiency of the feeds should not be judged by a comparison of the total gain or loss in weight per steer, but should rest upon a comparison of the average daily losses per head. The average daily losses for all steers of lot 1 was 1.10 pounds per steer, and there is no great variation from this average except in the case of group G, in which there were but four steers.

During the summer there is seen to be great variations in the total gains and the daily gains per steer, as each group was given a different feed, although they were all wintered alike.

The steers of group A, which were grazed on pasture without feed during the summer, made an average daily gain of 1.79 pounds per day during the summer, or an average of 0.62 of a pound per day for the winter and summer periods combined.

The steers of group B, however, which had been wintered exactly the same as those of group A but received cake in addition to pasture in the summer, made a daily gain of 2.21 pounds per steer during the summer, or 0.82 of a pound per day for the winter and summer periods.

In group C, which was fed pasture with cold-pressed cottonseed cake in addition, the daily gain during the summer was 1.74 pounds each, or 0.49 of a pound per day for the two periods.

The steers fed cotton seed in addition to pasture (lot E) did better, gaining 2.28 pounds per steer per day in the summer and 0.93 of a pound for both winter and summer, while each steer of group G, which received cottonseed cake and alfalfa hay with the pasture, made 2.26 pounds gain per day during the summer and 0.81 of a pound for the combined periods.

Group F was composed each year of some steers from each of the winter lots that were heavier and in better flesh in the spring than the average of the lot. They were finished for early summer market by feeding a heavier ration of cottonseed cake on grass for a short time, hence this group is not directly comparable with any of the other summer groups of cattle. However, the steers of group F in lot 1 can be compared with group F in lot 2, etc.

Each steer in group F, lot 1, made a daily gain of 2.31 pounds per steer during the summer. As they had made a daily loss of 1.08 pounds each during the winter the average daily gain for the whole period was reduced to 0.79 of a pound per steer per day.

The average daily gain during the summer for all steers in the various groups of lot 1 was 2.09 pounds per head, and the average daily gain per steer for the winter and summer periods combined was 0.74 of a pound.

The average for all the groups of lot 1 shows the loss to be 101 pounds per steer during the winter and the summer gain to be 261 pounds per steer, or a net gain of 160 pounds per steer for a period of about seven months. While these steers made a daily gain of 2.09 pounds each during every day of the summer period, they had a winter loss of 101 pounds to overcome, so the total gain for the whole period was low.

STEERS WINTERED ON RANGE AND COTTONSEED MEAL AND HULLS.

Under lot 2 are shown the results secured by feeding steers a half ration of cottonseed meal and hulls during the winter in addition to the grasses of the open range. It is immediately seen that the steers in this lot did not experience the loss in weight as was the case with the steers of lot 1. The total gain per steer during the winter for all of the groups in lot 2 except group F varied from a loss of 14 pounds per head to a gain in weight of 39 pounds per head, and the average daily gains varied from a loss of 0.16 of a pound per steer to a gain of 0.43 of a pound per steer. The steers in group F are left out of the comparison for the reason previously stated. The average gain for each steer of lot 2 for the whole winter was 8 pounds, while the steers of lot 1 experienced an average loss of 101 pounds per head.

During the summer the steers of lot 2, which received pasture alone, made the smallest daily gains. They also made the smallest daily gains for the whole test, or from fall until the end of the test in the summer. The largest daily gains during the summer were made by the steers which received cold-pressed cottonseed cake on pasture. This gain amounted to 1.92 pounds per day.

The steers fed cottonseed cake in addition to pasture and those fed cottonseed cake and alfalfa hay on pasture gave practically the same results, gaining an average of 1.89 and 1.90 pounds per day per head. Cottonseed failed to produce as good gains on these steers as cottonseed cake during the summer months, but the gain produced during the winter and summer periods when combined was practically the same for each lot.

The average of all steers in lot 2 shows that by giving a half ration of cottonseed meal and hulls to the steers on winter range there was no loss in weight, but a gain of 8 pounds each. The gain made during the summer, 220 pounds, was not as large as that made by the thin steers, but the total gain in weight for the whole period was 228 pounds, as compared with 160 pounds for lot 1. Lots 1 and 2 are strictly comparable, as the total number of steers was 72 and 68, respectively, and each lot was composed of similar groups of cattle which were fed during the same period of time.

STEERS WINTERED ON RANGE AND COWPEA HAY.

The cattle of lot 3 were fed cowpea hay while running upon the range during the winter. They averaged 724 pounds in weight and lost 9.6 pounds each during the winter, or a daily loss of 0.11 of a pound per steer. When put on pasture the following summer, they made excellent gains. The daily gains made per steer were 1.52 pounds for the steers fed on pasture alone; 2.22 pounds for those fed on pasture plus cottonseed cake; and 1.89 pounds for those fed on pasture plus cold-pressed cottonseed cake.

The average for all steers of lot 3 shows that while they lost but 0.11 of a pound per steer per day during the winter, the summer gain was 1.86 pounds per steer daily, making an average of 1.01 pounds per day for the winter and summer. These steers made better daily gains during the summer than those in lot 2, but when the summer and winter periods are combined, they did not make quite as large daily gains.

The steers of lot 3 made slight losses in weight during the winter, but somewhat larger gains during the summer than did the steers of lot 2. Good bright cowpea hay proved equally as valuable as the cottonseed meal and hulls for wintering cattle, and when meal was worth \$26 per ton and hulls \$6 per ton, cowpea hay proved to be worth \$13 per ton on the farm.

STEERS WINTERED ON RANGE AND DAMAGED HAY.

The cattle of lot 4, which were wintered on range and coarse damaged hay, weighed 680 pounds each in the fall and 616 pounds each in the spring. The daily loss in weight per steer was 0.67 of a pound. During the summer months they made daily gains varying from 1.59 to 2.22 pounds per head, depending upon which supplementary feed they received. The average daily gain for both summer and winter periods amounted to 0.77 of a pound per day for each of the 43 steers in the lot.

The steers of lot 4 lost 64 pounds each in weight during the winter, but when grazed during the summer they made an average daily gain of 1.83 pounds per steer, or slightly larger summer gains than steers wintered on meal and hulls. Their average daily gain for the whole period, however, dropped to 0.77 of a pound each per day, or slightly more than made by steers which received no feed but range during the winter. These steers did not make as large gains on pasture as the steers of lot 1.

STEERS WINTERED ON RANGE AND COTTON SEED.

The winter ration fed to lot 5 was cotton seed, in addition to the winter range. These steers were not fed enough cotton seed to maintain their weight throughout the winter. They averaged 706 pounds in weight when the test started, and lost 40 pounds per head during the winter. However, when turned upon pasture and given supplementary feed, they made exceedingly good gains.

The steers which received pasture alone in summer made 1.84 pounds per day, while the fed steers gained at a rate of 1.76 to 2 pounds per day. The average summer daily gain of each of the 25 steers in the lot was 1.93 pounds, the total gain per steer being 287 pounds. For the combined winter and summer periods each of the steers of lot 5 made an average gain of 1 pound per day.

It is seen that a small amount of cotton seed, about 4.70 pounds, given to every steer on range each day of the winter prevented them from losing 61 pounds in weight. With this small amount of feed the steers of lot 5 lost but 40 pounds each during the winter season. At the time the cotton seed was fed it was worth but $14 per ton and was cheaper to use in that quantity than meal and hulls. The gain made the following summer by these steers was good, being 1.93 pounds per steer per day, which was the highest daily gain made during the summer by any of the lots of steers which had received feed during the winter. The average gain made for the winter and summer was 1 pound per steer per day, or practically the same as made by the steers fed on cowpea hay, but less than that made by cattle wintered on meal and hulls.

The costs of wintering these steers has been discussed in a previous publication, but with the price existing at the time when the work was done, the cowpea hay and the cotton seed proved more profitable than the meal and hulls for wintering cattle.

COMPARISON OF RESULTS UNDER SUMMER METHODS OF FEEDING.

The comparisons which have heretofore been made have been with the various lots of steers which were handled the same way during the winter but finished by different methods on pasture. There is another and more important comparison which should be made, however, in order to properly show the effects of different methods of wintering cattle upon the size of the summer gains. This comparison reverses the former method—that is, the groups are compared which were wintered on different feeds but all of which received similar treatment during the pasture season. For instance, compare the results secured with group A under each of the five separate winter lots of cattle. Each of these groups was fed on a different feed during the winter, but the steers of group A in every case were finisnea .n one pasture on grass alone the following summer. The grass received and the method of handling were therefore just the same for each steer during this period. This method of comparing the results is seen in Table 10, which follows:

TABLE 10.—*Comparison of summer gains resulting from various methods of winter feeding.*

Lot and winter ration (average for 3 years, 1908, 1909, and 1910).	Number of steers in summer group.	Average weight in fall.	Winter gains.[1]		Summer gains.		Combined winter and summer gains.	
			Average total gain per steer.	Average daily gain per steer.	Average total gain per steer.	Average daily gain per steer.	Average total gain per steer.	Average daily gain per steer.
A. STEERS SUMMERED ON PASTURE ALONE.								
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds*	*Pounds.*
Lot 1. Range alone	17	662	− 92	−1.02	225	1.79	133	0.62
Lot 2. Range and cottonseed meal and hulls	18	723	− 14	− .16	194	1.53	180	.83
Lot 3. Range and cowpea hay	9	767	− 21	− .25	170	1.52	149	.76
Lot 4. Range and damaged hay	11	648	− 66	− .70	218	1.59	152	.65
Lot 5. Range and cotton seed	5	657	− 44	− .45	284	1.84	240	.95
Grand average	....	693	− 49	− .54	211	1.64	162	.74
B. STEERS SUMMERED ON PASTURE AND COTTONSEED CAKE (MEDIUM RATION).								
Lot 1. Range alone	25	692	−104	−1.14	282	2.21	178	0.82
Lot 2. Range and cottonseed meal and hulls	21	681	− 8	− .09	244	1.89	236	1.07
Lot 3. Range and cowpea hay	8	678	− 10	− .12	248	2.22	238	1.22
Lot 4. Range and damaged hay	12	643	− 51	− .54	244	1.76	193	.82
Lot 5. Range and cotton seed	9	671	− 47	− .48	301	1.95	253	1.01
Grand average	....	677	− 52	− .56	264	2.02	212	.96
C. STEERS SUMMERED ON PASTURE AND COLD-PRESSED CAKE.								
Lot 1. Range alone	8	723	− 99	−1.18	196	1.74	97	0.49
Lot 2. Range and cottonseed meal and hulls	10	689	− 1	− .01	215	1.92	214	1.09
Lot 3. Range and cowpea hay	7	722	6	.07	212	1.89	218	1.11
Grand average	....	709	− 30	− .36	208	1.85	178	.90
E. STEERS SUMMERED ON PASTURE AND COTTON SEED.								
Lot 1. Range alone	6	709	−117	−1.19	351	2.28	234	0.93
Lot 2. Range and cottonseed meal and hulls	3	675	30	.23	263	1.71	293	1.17
Lot 4. Range and damaged hay	3	731	− 52	− .53	341	2.22	289	1.15
Lot 5. Range and cotton seed	3	717	− 46	− .47	270	1.76	224	.89
Grand average	....	708	− 60	− .63	315	2.05	255	1.01
F. STEERS SUMMERED ON PASTURE AND COTTONSEED CAKE (HEAVY RATION)—SPECIAL GROUP.								
Lot 1. Range alone	12	715	−102	−1.08	267	2.31	165	0.79
Lot 2. Range and cottonseed meal and hulls	13	729	60	.63	208	1.71	268	1.24
Lot 4. Range and damaged hay	17	729	− 63	− .67	228	2.00	165	.79
Lot 5. Range and cotton seed	8	772	− 25	− .26	280	2.00	255	1.07
Grand average	....	733	− 34	− .36	240	1.87	206	.95
E. STEERS SUMMERED ON PASTURE, COTTONSEED CAKE, AND ALFALFA HAY.								
Lot 1. Range alone	4	592	− 93	−0.94	267	2.26	174	0.81
Lot 2. Range and cottonseed meal and hulls	3	571	39	.43	224	1.90	263	1.26
Grand average	....	583	− 36	− .35	249	2.11	212	1.00

[1] A minus sign (−) indicates loss.

STEERS SUMMERED ON PASTURE ALONE.

The steers of group A, lot 1, received range alone in winter and grass alone in the summer and made an average daily loss of 1.02 pounds in winter and a gain of 1.79 pounds in the summer, or a total average daily gain for winter and summer of 0.62 of a pound per steer. The cattle of group A, lot 2, were fed range plus meal and hulls in the winter, and pasture alone in the summer, and made an average daily loss of 0.16 of a pound per steer in the winter and 1.53 pounds gain during the summer, or an average daily gain for summer and winter of 0.83 of a pound per head.

For the cattle in lot 3, the average loss per day in the winter was 0.25 of a pound; a gain of 1.52 pounds was made in the summer, and a gain of 0.76 of a pound for summer and winter. Those of lot 4 lost 0.70 of a pound per day in winter and gained 1.59 pounds in the summer, or gained 0.65 of a pound daily for the whole period. The average daily loss in the winter for each steer of lot 5 was 0.45 of a pound; they gained 1.84 pounds in the summer and 0.95 of a pound for the winter and summer periods taken together.

These figures show very clearly that the steers which were not fed during the winter made larger losses during that time, but they made larger gains during the summer. Further, the larger the losses which were made during the winter, the greater were the gains made during the grazing season to a certain limit. The increased gains made during the summer were not great enough, however, to completely overbalance the excess losses during the winter, so it is seen that the smaller the daily loss per steer, during the winter, the greater is the average daily gain when both the winter and the summer periods are considered as one.

STEERS SUMMERED ON PASTURE AND A MEDIUM RATION OF COTTONSEED CAKE.

The steers which made up group B in each of the lots responded to their winter treatment during the following summer in practically the same way as did the steers of group A. The steers of lot 1, group B, made a heavy loss during the winter, but made very large daily gains during the pasture season.

When lot 2, group B, is compared with lot 3, group B, it is seen that the steers of the latter lot lost but 2 pounds more per steer during the winter than the steers of lot 2, which received cottonseed meal and hulls as the supplementary feed while on range. During the summer the daily gains made by the steers of lots 2 and 3 were 1.89 and 2.22 pounds per steer per day, respectively. This indicates that bright cowpea hay is a better supplementary feed for winter range than hulls and meal with respect to its effect upon the summer gains, but the relative price of cowpea hay and meal and hulls will determine which is the most economical winter feed.

STEERS SUMMERED ON PASTURE AND COLD PRESSED CAKE.

Group C was composed of steers which received cold-pressed cottonseed cake as a summer feed. This was not fed each summer of the 3 years as were some of the other lots, but was fed during 1908 only. This group gave different results from the others mentioned with respect to the steers which made the greatest gains during the summer. For some reason which can not be explained the steers of group C which lost the most in weight during winter made the smallest gains when put on pasture. The steers which were fed during the winter and were as heavy in the spring as in the fall (those of lots 2 and 3) gained more by one-sixth of a pound per steer per day during the grazing season than the steers of lot 1, in this group, which were wintered on range alone.

STEERS SUMMERED ON PASTURE AND COTTON SEED.

The steers of group E were fed during 1909 only. The price of cotton seed since that time has been so high that it has been better policy to trade it for cottonseed meal or cake than to feed the raw seed. During this year, however, the steers which made up group E had been wintered in lots 1, 2, 4, and 5. Those which had been wintered in lot 1 experienced the heaviest winter loss by far, and made the largest daily gains on pasture, but these heavy gains on pasture (2.28 pounds per steer per day) were not great enough to overcome the difference in the winter losses when compared with those of the other lots. In other words, the steers which became so poor during the winter gained much faster during the summer months than the heavier fleshed steers, but at the end of the feeding experiment they were still lighter in weight than the steers which received feed during the winter.

STEERS SUMMERED ON PASTURE AND A HEAVY RATION OF COTTONSEED CAKE.

As has been previously explained, the steers of group F were larger and fleshier than the steers of the other groups. They were selected thus so they could be finished in a shorter time for the market, and were fed a heavier ration of cottonseed cake per day during the summer feeding period. They are, therefore, not strictly comparable with the other groups. The steers in this group which lost the greatest amount of flesh during the winter gained fastest in weight during the summer, but never got as heavy as the steers which lost no flesh during the winter. The steers which had passed the winter on range alone were not nearly as well finished at the time they were sold as were the other steers which had received winter feed. This was more noticeable with this group of steers than with any of the groups which were fed for a longer summer period.

The daily gains per steer for the winter and summer combined were but 0.79 of a pound per day for the steers in this group which subsisted on range alone during the winter, while the average daily gains for those which were fed during the winter were 1.24, 0.79, and 1.07 pounds, respectively. There is no doubt that steers which are to be finished for the early summer market can be profitably wintered by the use of supplementary feeds in conjunction with range. For such steers the use of winter feeds is more economical than permitting them to become thin in flesh by depending upon the open range for their winter feed. The object is to get the steers fat early in the season while prices are still high for fat cattle, and thin steers will not become fat enough for slaughter purposes until late in the summer. At that time prices are usually much lower because of the competition of straight grass cattle.

STEERS SUMMERED ON PASTURE, COTTONSEED CAKE, AND ALFALFA HAY.

The steers of group G which were wintered on range alone lost 93 pounds per head, while those which were given meal and hulls during the winter gained 39 pounds each. During the summer the thin steers gained 267 pounds in weight while those which had increased in weight during the winter gained 224 pounds during the pasture season. When the total gains for the whole period of 7 months are considered, the steers of lot 1 made a total gain of 174 pounds each while those of lot 2 gained 263 pounds each, or the average daily gains per steer for these periods were 0.81 and 1.26 pounds, respectively.

A GRAPHIC PRESENTATION OF THE RESULTS OF THE FEEDING.

The charts, figures 2, 3, and 4, present the results of the work in a different way and bring out some important points in the feeding more forcibly than can be done in tabular form. Each chart represents a year's work, portraying the results secured in the years 1907–8, 1908–9, and 1909–10, respectively.

The heavy dotted horizontal line O represents the dividing line between a gain in weight and a loss in weight. The heavy dotted vertical line represents the dividing line between the winter and the summer work. Each check horizontally represents a period of 20 days. Each check vertically represents a loss of 0.4 of a pound per day in weight for each steer if below the heavy horizontal line, or a gain in weight of 0.4 of a pound per steer per day if above the line.

Each lot of steers fed during the winter is represented by a line to the left of the heavy vertical line. Each diagonal line to the right of the vertical line represents one of the groups of steers which were fed during the summer. In figure 2, therefore, the line O–1 shows the loss in weight made by each steer in lot 1 during the winter of 1907–8. At the end of the winter test the steers of lot 1 were divided among the groups A, B, and C to be finished on grass during the summer.

The gains made by each of these groups of steers are shown by the lines A–1, B–1, C–1, respectively. The distance a line terminates above or below the horizontal line O determines the relative size of the daily gain or loss per steer, as the case may be, with respect to

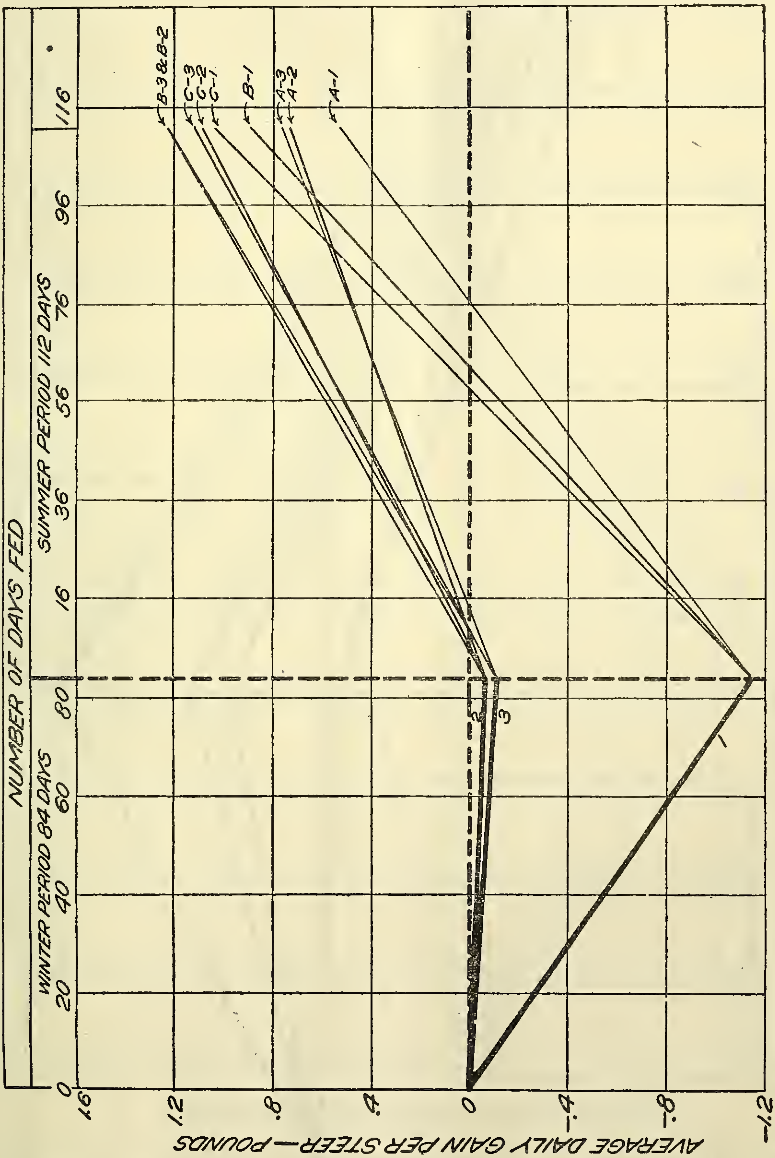


Fig. 2.—Effects of three methods of wintering steers upon the gains made during the winter and the following summer. Work of 1907–1908.

the other lots. The distance the line terminates to the right of the vertical represents the length of the feeding period. The general direction each of these lines takes, therefore, indicates the rapidity of the gains made by the steers of the respective groups.

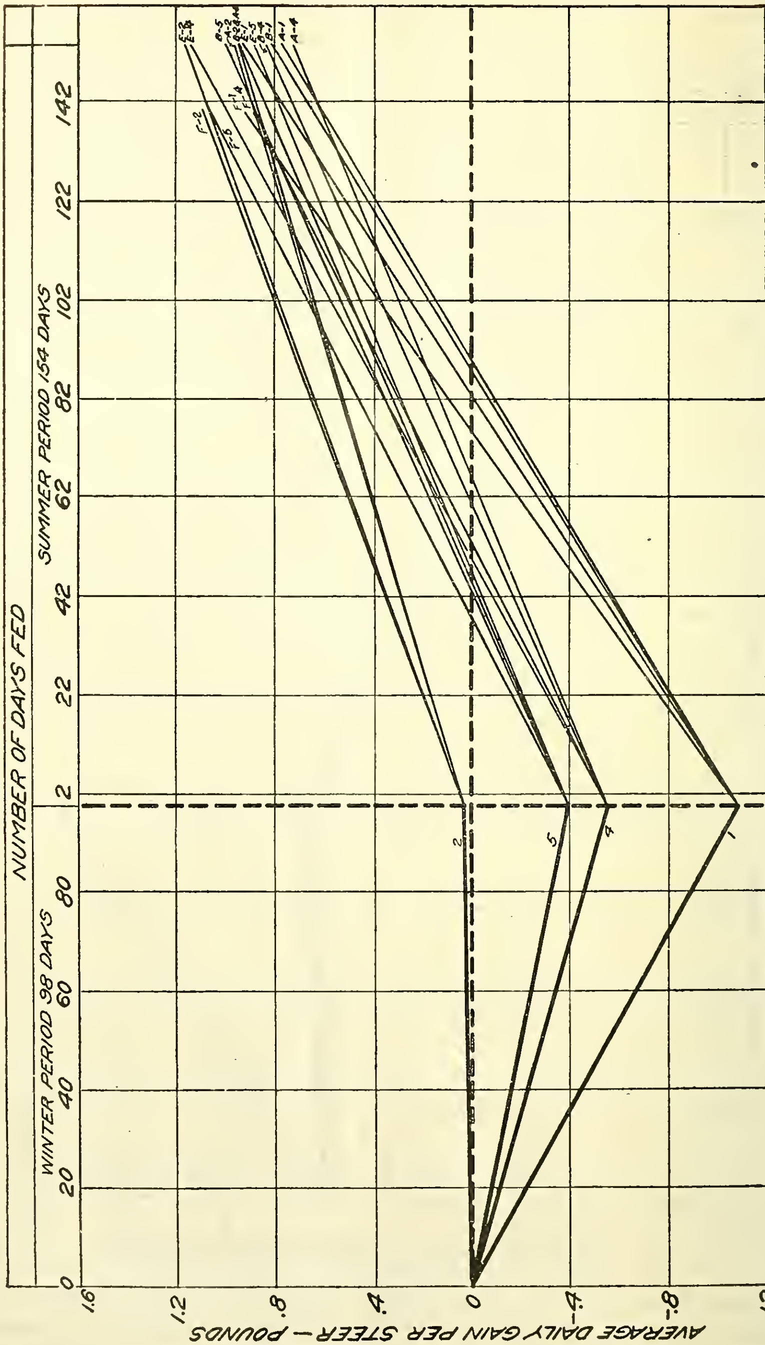


FIG. 3.—Effects of four methods of wintering steers in 1908–1909 upon the gains made during the winter and the following summer.

In figure 2, all of the steers are seen to have been fed the same length of time during the summer. A glance at the 3 charts will show that while some of the winter lots experienced heavy losses in weight, these cattle gained more rapidly during the summer months and

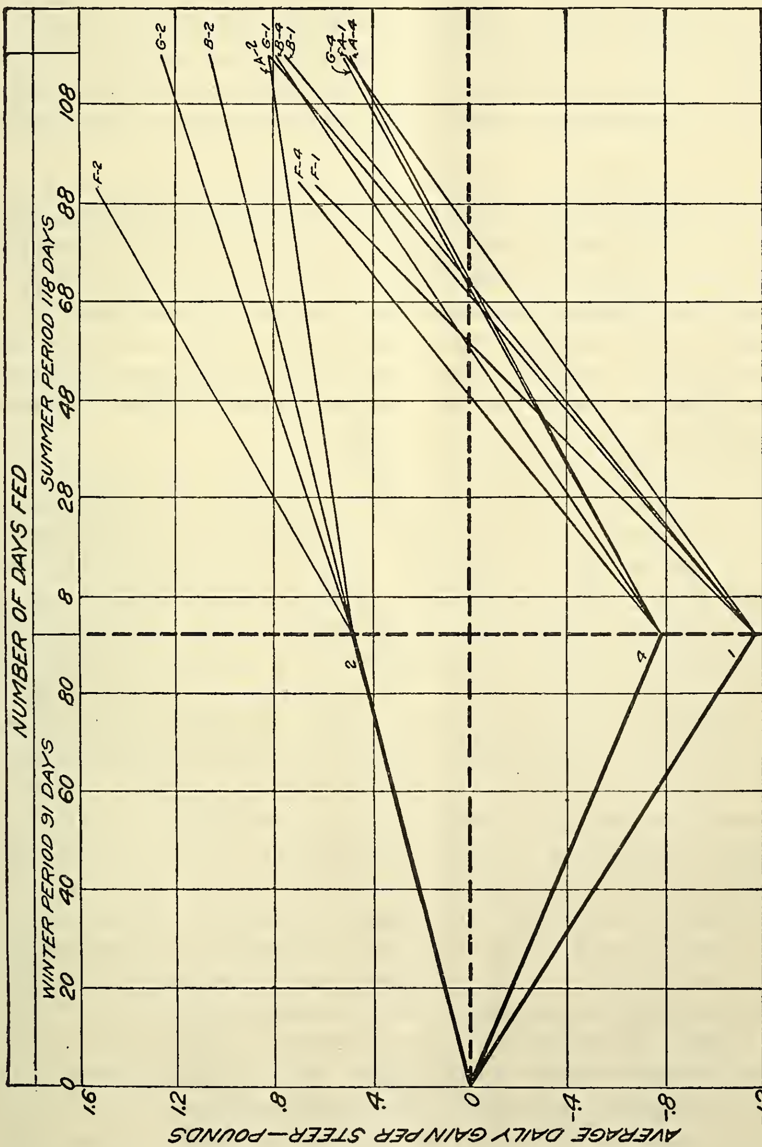


FIG. 4.—Effects of three methods of wintering steers during 1909-1910 upon the gains made during the winter and the following summer.

approached the mean or the average of all lots more rapidly than the steers which lost a smaller amount of flesh during the winter.

The length of the summer-feeding periods for the years 1908, 1909, and 1910 were 112, 154, and 118 days, respectively, for all cattle except those of group F. Figures 2 and 3 clearly show that the longer the summer-feeding period the nearer the total gains in weight approach the mean of all lots; in other words, the longer the summer period the nearer the steers, which made heavy winter losses, overcame these losses and approached the weight of the winter-fed steers. If the feeding periods had been 60 days longer and all steers had continued to increase in weight at the rate they had established during the actual summer-feeding period the total gains at this time would have been practically the same for all lots irrespective of the method of wintering.

The semistarvation of the steers on range alone during the winter in connection with their rapid increase in weight when put on grass the following summer, corresponds to the loss in weight of a human being during a spell of sickness or starvation, and the rapid gains in weight made during and immediately after convalescence on an amount of food which during a normal period would cause him only to maintain his weight, or at most gain very slightly. Like the human being also, after the steer reaches his normal degree of fatness the smaller are the daily gains in weight.

The charts also show that the gains for summer and winter periods combined are more rapid with group F than with any other group of steers for the same, length of time. In other words, the wintering of cattle by the use of feed in addition to the natural range will be both economical and profitable for cattle which are to be fattened early in the summer, but the longer the grazing season the less economical and profitable the winter feeding will be. If the steers in these tests had been grazed until pasture gave out in October, instead of being sold in July and August, it is extremely doubtful if any difference could have been detected between the steers which wintered on range alone and those which received feeds. Consequently, if this had happened, the feeds given during the winter would have been wasted.

Figure 4, presenting the work of 1910, shows that lot 2 made such a large gain in weight during the winter, viz, 43 pounds per head, that by the end of the summer these steers had made much larger total gains than the steers of the other lots. The chart also indicates that if the rate of gains for all the groups had continued in the same direction they showed at the close of the test, all but group F would have reached practically the same point within 60 days—that is, the lines in the chart would have merged. The results are, therefore, in entire keeping with those of the two previous years. Group F can not be compared with the other groups, as these steers were in a different class, being older, heavier, and fleshier at the beginning of the test, and especially selected for quick finishing. All the steers in the other groups were similar.

The results for the three years have been such that the statement seems justified that it will not pay to feed mature steers of medium or inferior quality during the winter if they are to be kept until the end of the following summer, provided the waste lands, old fields, and the stalk fields of the farm will yield enough feed to keep them strong and thrifty until spring comes. This is true even though the steers may become very thin in flesh during the winter. If the fields become depleted, however, before the winter is over, feeding should be resorted to in order that the cattle shall not be lost by starvation.

PROFITABLENESS OF WINTERING CATTLE BY FEEDING.

The question may still be asked, "Was it profitable to feed any of the steers except those of group F during the winter months?" In answer to this the following statements may be made: When no value was placed on the range, as in this case, it cost nothing but the loss in weight to winter the steers. Since the value of each steer will be reckoned by his final summer weight, no charge should be made here for the winter loss in weight. The cost of wintering the other steers ranged from $3.23 per head for the steers wintered on cotton seed and range to $5.63 each for the cattle fed on meal and hulls during 1909. The average cost of the feeding for all winters of lots 2, 3, and 5 was $4.25.

Now, for the entire time the cattle were on feed each fed steer gained about 0.27 of a pound per day more than the range steers, or a total of about 60 pounds more per steer during the combined winter and summer seasons. The winter-fed steers were therefore 60 pounds heavier than the range-fed steers at the end of the summer. As the weight of the range-fed steers was about 850 pounds, the average weight of the others was about 910 pounds. Some southern markets will pay slightly more per pound for the heavier steers than they will for lighter steers of the same quality, while others make little difference in price where the variation is but 60 pounds per steer. There has been secured, then, in return for the cost of wintering 60 pounds of flesh on each steer in addition to the increased selling price per hundredweight in favor of the heavier steers. The cost of wintering in this case was $4.25.

The prices of feeds used in this estimate were $26 per ton for cottonseed meal, $6 per ton for hulls, $10 per ton for cowpea hay, and $14 per ton for cotton seed. Anyone can determine approximately from these statements whether or not it will pay him to winter his stock, providing that he knows about what his steers are worth per pound and what difference his market will make in favor of the heavier steers when sold. The cost given above for wintering steers should be increased about 25 per cent to be in keeping with the present (1913) prices of feeds.

The steers in the experiments sold for about 4½ cents a pound on the farm, so we have the following statement:

To cost of wintering 1 steer	$4.25	
By value of 60 pounds increase in weight, at 4½ cents a pound		$2.70
By increased value of 17 cents per hundredweight on the heavier steers over the lighter ones necessary to break even		1.55
Total	4.25	4.25

From the above it is seen that the winter-fed steers would have to sell for 17 cents per hundred pounds more than the others to pay for the winter feed. A reliable commission man of New Orleans stated that the heavier steers would sell for about 25 cents per hundredweight more on that market, while buyers from Atlanta, Ga., and Meridian, Miss., who purchased some of the steers, stated that for their trade there was not enough difference in weight to cause a variation in price.

SUMMARY.

1. Cattle which became very thin during the winter made larger daily gains the following summer on pasture than steers which were in better flesh at the beginning of the pasture season.

2. Usually the greater the winter loss experienced, the greater was the gain the following summer, and vice versa.

3. Steers which are to be finished for the early summer markets should enter the pastures in good flesh in the spring. Such cattle sell for a premium which justifies the expense of giving them feed in addition to the range during the winter months and a heavy ration of cottonseed cake while on pasture during the summer.

4. Although steers which were wintered on range alone made larger gains during the summer, the total gains made from fall until the steers were sold were usually smaller than those made by steers which were given feed in addition to winter range and subsequently finished on pasture.

5. The difference in live weight amounted to 109 pounds per steer at the beginning of the pasture season and 60 pounds per steer at the time the steers were sold. This difference in weight was in favor of the winter-fed steers.

6. Steers which had been wintered on a half ration of cowpea hay and range made practically the same gains during the combined winter and summer periods as steers that were wintered on a half ration of meal and hulls plus range.

7. When cotton seed is worth but $14 per ton it can be used with greater economy than cotton seed meal and hulls for wintering steers which are to be finished on pasture the following summer. The average daily gain with cotton seed for the combined winter and summer periods was 1 pound per day, or slightly smaller than for steers wintered on cowpea hay or cottonseed meal and hulls.

8. The steers which were wintered on coarse waste hay did not make as good gains on pasture nor as large daily gains for the winter and summer periods combined as the steers of the other lots which received feed.

9. The wintering of cattle by the use of feed in addition to the natural range will be both economical and profitable for cattle which are to be fattened early in the summer, but the longer the summer grazing season the less economical and profitable the previous winter feeding will have been. If the steers in the foregoing tests had been grazed until pasture gave out in October, instead of being sold in July or August, it is extremely doubtful if any difference in fatness could have been detected between the steers which wintered on range alone and those which received feeds.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 111

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 11, 1914.

(PROFESSIONAL PAPER.)

THE SEQUOIA PITCH MOTH, A MENACE TO PINE IN WESTERN MONTANA.

By Josef Brunner,
Agent and Expert, Forest Insect Investigations.

INTRODUCTION.

In the area near and at the divide between Swan River and Clearwater River in Montana and extending, so far as known at present, about 8 miles southeast from that divide, the sequoia pitch moth (*Vespamima sequoia* Hy. Edw.)[1] is at present the most destructive insect. It menaces the lodgepole pine timber, in which it propagates, and all other trees in the vicinity of those attacked are jeopardized by the forest fires fed by the dead timber resulting from the work of its larvæ. The range of its peculiar injury to trees in that region has also been traced by the writer about 6 miles west from the wagon road which unites the Clearwater and the Swan River country from Rainy Lake toward the Mission Range. Roughly, the area in which the insect is a very serious factor in forest destruction is about 12 miles long by as many miles wide and covers about 144 sections of forest land, or more than 90,000 acres.

Control and practical elimination of this insect, as a serious menace to the very existence of the forest growth of this area, depends largely on a knowledge of its habits and life history. Insufficient familiarity with these two points would result in unnecessary waste of time in locating infested trees and in conducting control operations at a time of the year when the result would be out of proportion to the cost.

DESCRIPTION OF THE INSECT.

Vespamima sequoia (fig. 1) is a clear-winged moth in general appearance strongly resembling a hornet or "yellow jacket." This resemblance is so perfect that a truck gardener near Missoula, Mont., evi-

---

[1] Identification by August Busck, as the species which was first found to inhabit the sequoia.

NOTE.—This bulletin is a report on an insect infesting lodgepole pine in the Rocky Mountain region of Montana.

44394°—14

dently familiar with the hornet, refused to believe that a specimen which had just emerged and was being observed on the tree in which it had attained maturity was not a "stinger" until the difference was pointed out to him.

The female is about two-thirds of an inch in length and the male is somewhat smaller. In the female the last three segments, and in the male the last four, are bordered with rich lemon-yellow, which makes the sexes easily distinguishable, even to the uninitiated.

The mature larva is from three-fourths inch (male) to 1½ inches (female) long and is of a dirty white or yellowish color.

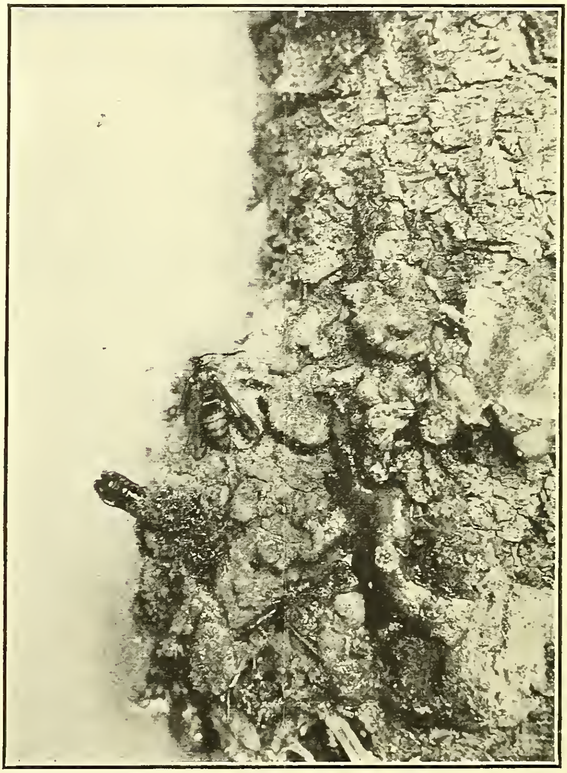


FIG. 1.—Female pitch moth (*Vespamima sequoia*) 15 minutes after emerging. (Original.)

LIFE HISTORY.

Observations on this species in different localities, together with the dates of emergence of adults reared in the laboratory, show that the general flight of the mature insects and oviposition occur between June 25 and July 15, the greater number of them probably flying about July 10. However, variation in latitude and altitude and unusual weather conditions prevailing during the spring of certain years may put the date of this general emergence a few days ahead or behind those given here. The flight and oviposition of the insect are over by August 1.

It appears that the adult insect is rather short-lived, as all the specimens that were reared and observed in captivity died within four days of emergence. Out of 20 females thus under observation only one oviposited, the rest dying without issue. This would show that the female dies, unless she is fertilized, within three days after emergence.

As this species is very active it is reasonable to suppose that it deposits but few eggs in any one place. In fact, it was frequently observed that wherever two larvæ are too close together one of them invariably dies. Wherever an occasional pitch mass is found to contain as many as three larvæ, each one of them occupies an independent tube. This shows that the scattering of the eggs is necessary in order to enable most larvæ to survive the evidently fierce struggle for existence. Exactly how long it takes the eggs to hatch is unknown to the writer, but the injury to the newly infested trees by the young larvæ is quite perceptible by August 15. By the time frost arrests their activity, about October 1, the larvæ, especially the females, have attained considerable size. The following summer is devoted by the larva to lengthening the tunnel and growing, and toward the second winter it drives a rather roomy tunnel into the pitch exudation which, during the following June, it lines with silky thread preparatory to pupation.

During the two months preceding pupation all the larvæ of the same sex are of practically the same size, so that the two generations are almost inseparable. However, one familiar with this and allied species can separate them by the difference in color and density of skin, which is rather white in the younger generation and yellowish, leathery, in the older one.

The length of the pupal stage is 30 days, i. e., the insect remains in the chrysalis for 30 days from the day it transforms into that stage until it emerges as adult. The chrysalis is free in the tunnel, moving back and forth in it at will by means of spines on the body, and is usually found on warm days quite near the surface and far back when it is cold. When ready to emerge the pupa forces about half its length out through the thin shell of pitch at the mouth of the tunnel and the adult insect (fig. 1) emerges by bursting the shell of the chrysalis. This occurs two years after the egg was laid. In other words, the larvæ hatching from the eggs deposited in June and July of one year develop into adults during the same months two years later, thus making the generation biennial.

There seems to be indication of an alternation of seasons of abundance and scarcity of the insect. During late autumn, 1913, the young larvæ were quite scarce in the vicinity of Rainy Lake, especially east of the wagon road from Clearwater to Swan River, while

1-year-old larvæ were abundant. If this observation holds good, the insect being biennial, we should be able to forecast the years when it will be abundant and when scarce. Hence there should be great flights during 1914, 1916, 1918, etc., unless the insect is controlled, and small flights during 1915, 1917, 1919, etc.

RELATION TO THE MOUNTAIN PINE BEETLE.

The only insect which is of any consequence in its relation to the pitch moth in the Clearwater country is *Dendroctonus monticolae* Hopk. This beetle frequently attacks trees infested by the larvæ of the moth. This attack is always fatal to the latter, because Dendroctonus kills the tree almost immediately, and without the flow of sap the larvæ of the moth can not survive. On October 1 every larva of the moth which was found in trees attacked by the beetle after August 1 was dead. Some of the trees had the appearance of having been infested by the beetle only two or three weeks; nevertheless, the moth larvæ were dead, although they were in perfectly fresh condition otherwise.

Vespamima sequoia is apparently little subject to attack by either parasitic or predaceous enemies. In fact, it is less troubled by insect enemies or diseases than any other species known to the writer; and as birds also never seem to pursue it, there is no present evidence that natural agencies might check it in the course of time.

HABITAT.

The insect prefers sunny openings within the forest and slopes where the soil is rather sandy and quick to dry. Ridges along watercourses are also favorite places for it. It avoids the damp and densely shaded bottom lands along streams. It prefers pine, open stands of lodgepole pine, as, for example, within and alongside the big old burn which extends from the wagon road toward and along the Flathead Range, where there are few trees 3 or more inches in diameter that have escaped attack and are not infested now.

HOST TREES, AND CHARACTER OF INJURY.

Lodgepole pine is numerically the principal species of tree in the region and, with the rare exception of the yellow pine, is the species subject to attack by the pitch moth, although the moth attacks almost all kinds of conifers in other localities within its range.

The trees infested by this insect (see fig. 2) are readily located by the never-absent pitch exudation over the tunnel of the larva. This may be readily seen at quite a distance, if the stand of trees is not too young. Even on very small trees of but 1 or 2 inches in diameter the pitch tube is of the size of a walnut the first season of the infestation and more than twice that the second year.

The pitch exudation on the tree shown in figure 3 weighed over 10 pounds, and such trees are so numerous that many tons of pitch could be collected within the comparatively small area infested by this insect.

The trees are all of them attacked at the extreme base, and the exuding pitch flows out from the tree not infrequently a distance of 10 or 12 inches upon the humus which covers the ground.

THE WORK OF THE LARVA.

The larva begins its mine in a crevice in the bark, where the egg was deposited, proceeding through the outer layers until it reaches the cambium. Close to the wood it begins to construct a transverse

FIG. 2.—Lodgepole pine trees infested by the sequoia pitch moth. Trees of all sizes are infested in the Clearwater country of Montana.

mine running in both directions from where it entered. It widens this tunnel at the center, thereby causing the appearance of a central chamber. In small trees the mine is always practically straight across the grain of the wood.

It is a puzzle to the writer how the larva determines how far it can go in the two directions without entirely girdling the tree, thus killing it and thereby depriving itself of sustenance. It is a noteworthy fact that of the great many trees less than 3 inches in diameter examined, all were found girdled to within 1 or 2 inches, and none entirely girdled.

It is evident that the entire girdling of about 0.5 per cent of the older infested trees is accomplished by more than one larva which happen to infest these trees at one and the same time. Each larva evidently tries to get as far away from its neighbor as it can, and thus the tree is girdled. But, as indicated, plural infestation is rare. To test this point experimentally the writer has several times planted in captivity two larvæ on one piece of wood, and invariably one of them left the sustaining slab. On a few occasions when, because

FIG. 3.—A lodgepole pine tree infested by the sequoia pitch moth. The new, flowerlike exudation indicates present infestation. (Original.)

none vacated, the writer supposed he had made a success of "double planting," he found later that one of the larvæ was dead.

Tunnels in trees infested only the second year, as well as those in trees that have been infested by several successive generations of the insect, look as if they had been engraved by the larvæ eating the wood, but such is not the case. The appearance is caused by the larvæ preventing the wood from forming a new layer across the tunnel. Thus the tunnel, in the course of many seasons, gradually becomes deeply embedded in the wood tissues.

In rare cases the tunnel is slightly slanting, running on one side of the center, a few inches below the surface of the ground, while the end of the other side is several inches above ground. Under no circumstances is the tunnel parallel to the grain of the wood.

As stated, the activity of the larvæ within the cambium of the tree causes a heavy flow of pitch toward the exterior, and fresh, flowerlike nodules upon older exudations (fig. 3) are a definite proof that the tree is still infested.

EFFECT OF THE INFESTATION ON TREE GROWTH AND THE FOREST.

It is obvious that with one-half and, in the majority of cases, two-thirds of the circumference of the tree trunk cut off from the root

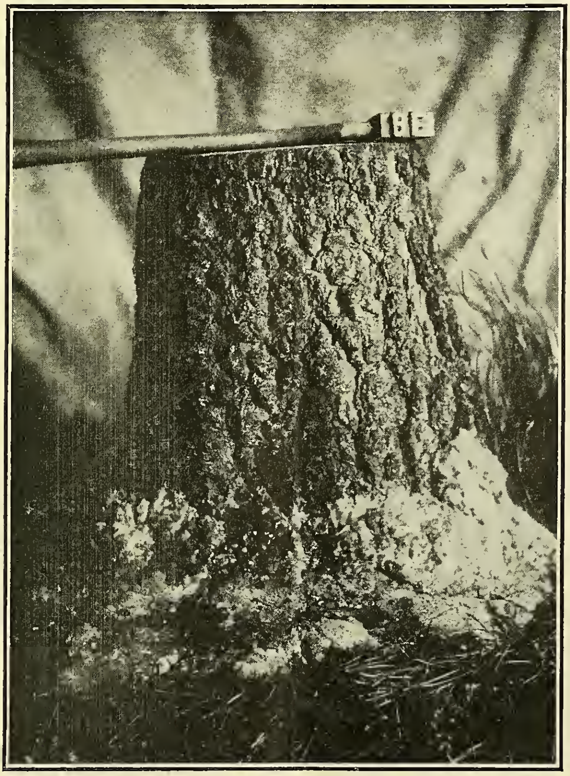


FIG. 4.—Stump of a pine tree 64 years old which grew to be $9\frac{1}{8}$ inches in diameter breast high at 41 years of age and added only seven-eighths inch to this diameter during the last 23 years of its life, owing to attack by the Sequoia pitch moth. (Original.)

system by the dividing tunnel, the growth of the afflicted tree has to suffer. Count of annual rings and measurements on a tree which was considered to be a fair example of the general injury in the area brought out the fact that during the first 41 years of its life and normal health it had added annually about one-fourth inch to its diameter, while it added only about one thirty-second of an inch, or the thickness of an ordinary visiting card, annually during the 23 years it had been infested by the pitch moth. (See fig. 4.)

SECONDARY INJURY BY FIRE.

About one-half of 1 per cent of the trees infested by *Vespamima sequoia* is killed. In case of a slight surface fire in places where, outside of humus, no litter covers the ground, all the infested trees which are not killed outright come through it with the bark on the sides where the pitch exudation is located literally cooked, and for the balance of their existence they display the "fire wounds" (fig. 5), of which the pitch moth was the primary cause. They remain green but add little to their size annually. Subsequent fires fell them

FIG. 5.—Fire wounds on pine tree injured by the Sequoia pitch moth. (Original.)

readily, and their burning injures and kills perfectly healthy trees, which would otherwise have remained unscathed.

There is abundant proof in the area under discussion that unattacked trees, on ground not littered with fallen timber, pass through surface fires with but slight injury. Thousands of such trees are mingled with as many which display "fire wounds" and the tunnel of Vespamima burned indelibly into the base of the latter, thus explaining why it is that some trees are half burned while others, under the same conditions and at the same place, have escaped with scarcely a scar.

Many trees with fire wounds are reinfested on the sound side and killed, thus adding to the material which makes a surface fire in the area really serious. The heat generated by them in burning, either standing or prostrate, injures and kills healthy trees in the immediate vicinity.

During decades fallen timber, primarily caused by insects, accumulates and provides such an amount of inflammable material among the uninjured green trees that finally a fire sweeps such areas clean of all tree growth and enters and destroys adjoining areas which contain healthy trees only.

In the infested zone in the vicinity of Rainy Lake the forest looks much like a checkerboard. There is an area of 50 acres here with a stand of 10-year-old trees on them; adjoining this is a square-cut piece of 200 acres with 40-year-old trees as a cover; next to this are 80 acres on which reforestation started only a few years ago, and so on. This thing has been going on for at least 100 years, so far as can be traced, and probably existed before time was counted. Everyone of these variously aged tree patches is the result of a separate fire. The explanation of the occurrence of so many of them within an area comparatively so small is found in the peculiar meteorological conditions prevailing here.

TOPOGRAPHY OF THE AREA.

Running from the southeast toward the northwest are the rocky walls of the Flathead Range; west and parallel to it lies the Mission Range; and on the divide between Swan River and Clearwater River, extending from the Mission Range toward the wagon road which passes over the lowest elevation, and running from west to east is a high ridge. This ridge forms an effective barrier to storm clouds driven up Swan River between the walls of the Flathead and Mission Ranges. Their only outlet is between that ridge and the Flathead Range over the Rainy Lake territory.

The clouds driven up Swan River, inconsequent though they might be under different conditions, strike the ridge dividing the two water courses and are promptly thrown back upon their own mass by the resistance of the ridge. On the west are the walls of the Mission Range, so there is no escape for them in that direction; thus they drift eastward and toward the outlet over Rainy Lake. Part of them escape there. But the greater part are thrown upon the walls of the Flathead Range, from which they tumble back upon the oncoming mass in a turmoil before this also by and by finds its way to the only avenue of escape. The great numbers of lightning-struck trees in this area abundantly testify to the great rôle played here by lightning.

Remembering that in the comparatively small zone about Rainy Lake infested by the pitch moth there are tens of thousands of trees with heavy pitch exudation at their base which, once ignited, will burn for several days, rain or shine, and that during the violent thunder storms there many trees are struck by lightning and the pitch set on fire, we will have the combination which explains the frequency of fires in that area.

Let us illustrate. Lightning strikes a tree infested by Vespamima and sets it afire. During the storm the ground is soaked sufficiently to prevent the fire from spreading. The pitch, however, owing to its thickness and inflammability, continues to burn. On the following day a clear sky allows the sun to dry the ground cover around the burning pitch sufficiently so that a surface fire is started which will be ended by the next shower. If the stand consists of medium or small sized trees and the area has passed through fires before, everything is killed, and the place, when it has been reforested, will stand out clear in the checkerboard of forest and elemental battles even after half a century or more, as is the actual case in this territory.

As storms are evidently quite frequent there, the patches burned are usually small, ranging from 50 to 200 acres. However, there are also some burns which an accumulation of débris had undoubtedly so augmented that whole sections were swept. All the traceable evidence in the biggest burn in the area points to insect work as the primary cause, just as in the smaller burns where the evidence is more definite and is easier of location.

With a knowledge of these facts, one can not but conclude that the peculiar results of the work of *Vespamima sequoia* are the chief and primary contributing cause of the frequency, we might almost say continuity, of fire damage to forest growth in this area. To eliminate or ameliorate this condition, it is manifestly necessary to eliminate the insect or at least reduce it to such an extent that it loses its menacing aspect.

REMEDY.

Since nature and its agencies are powerless in the control of this insect, the scourge has to be combatted by man through direct action if it is not to continue its injurious activity in the future as it has in the past. There is only one way to reduce the insect, and that is to destroy it while it is in the larval stage.

As is apparent from the portion of this bulletin relating to the life history of the moth, larvæ can be found in the infested trees at any time of the year.

However, in order to destroy the greatest number of them with the same amount of effort, operations should be conducted during the months of September to June, inclusive, when there is no snow on the ground to cover the pitch exudations. During most seasons the snow eliminates November, December, and January as control months.

By September 1 all of the eggs which have not been lost have hatched, and the young larvæ have attained a size sufficient so that they can be seen and destroyed, and up to June 25 hardly any of the second-year larvæ have reached the adult stage.

The statements under "Habitat" suggest where to look for infested trees. To locate the larvæ, separate the pitch exudation from the trees, thereby exposing the larvæ. Killing the larvæ outright, or taking them up for later counting and destruction, or, in other words, hand picking, is really the only thing that can be done to reduce the numbers of the insect.

RECOMMENDATIONS.

If the control work is done without utilization of the pitch, it will be at direct cost; and the taking up of the larvæ, though slower than destruction on finding, is preferable, as it enables a proper checking up of the extent of damage and of the amount of control work accomplished. But if the pitch is of sufficient commercial value to pay the cost of its collecting and shipment, it would be possible to control the insect by utilizing its products.[1] If the pitch is marketed, it is not necessary to keep a close check on the work beyond keeping tab on the weight of the pitch shipped and the returns from the sales.

NOTE.—The statements in this paper, with the exception of those under "Description of insect," "Life history," "Relation to the mountain pine beetle," and, to a certain extent, "Remedy," refer to *Vespamima sequoia* in the Clearwater country of Montana alone and are not applicable in other regions where the destructiveness of the insect is known to assume a different character.

---

[1] Just before going to press analyses of these resins were received from the U. S. Bureau of Chemistry, with the following comment.—A. D. HOPKINS, *in Charge of Forest Insect Investigations.*

"The volatile oils obtained from these two resins are slightly heavier than ordinary oil of turpentine. They show smaller percentages, distilling below 170° C. However, as turpentines as heavy as these will find a market as paint and varnish thinners, it is anticipated that no difficulty would be encountered in disposing of the turpentine produced from this material. Especially is this opinion held since * * * it is more than likely that owing to the size of the sample and the manner of packing, as well as the exposure of the crude gum, the percentage of volatile oil is lower than it would be in material which was collected in the ordinary commercial way.

"The rosins do not appear to differ essentially from the rosin made from longleaf pine, and we have no hesitation in expressing an opinion that it would be entirely suitable for soap-making purposes and would command the ordinary market price according to the grade. Attention may be called to the fact that lighter colored rosins, therefore higher grade rosins, would undoubtedly be made in practice, provided bark, dirt, etc., are kept out of the resin.

"Nothing was observed in this examination which would warrant the opinion that the nature of the product was due to the particular manner of its production. It is believed that essentially the same product would be obtained by the ordinary commercial chipping of the tree except so far as prolonged exposure on the trunk of the trees, as probably took place with these samples, favors volatilization of the light oils and this affects the relative proportions of volatile oils and of rosin and the specific gravity of the oils."—F. P. VEITCH, *Chief of Leather and Paper Laboratory, Bureau of Chemistry.*

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 112[1]

Contribution from the Bureau of Entomology, L. O, Howard, Chief.
August 21, 1914.

THE OAT APHIS.[2]

By J. J. Davis,
Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

Of the three important plant-lice attacking wheat and oats above ground, the oat aphis (*Aphis avenæ* Fab.)[3] is probably the most widely distributed and most common over its area of distribution, and is second in importance as a wheat pest, first rank being held by the so-called "green bug" (*Toxoptera graminum* Rond.), a species well known in the Southwest because of its periodic depredations. Like the "green bug," the insect under discussion is an imported species, and was probably introduced into the United States during the first half of the last century, at least previous to 1851, the date of what appears to be the first published record of its occurrence in this country.[4]

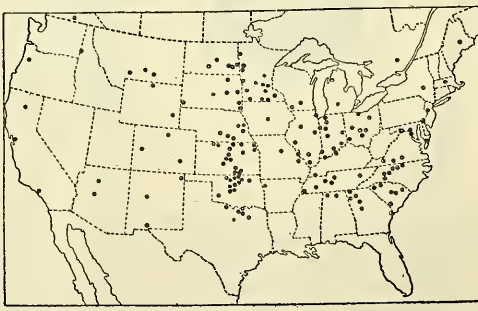


Fig. 1.—Distribution of the oat aphis in the United States. (Original.)

The oat aphis has never been considered a pest of great importance, although observations would lead to the belief that it is worthy of more consideration and study. It does not ordinarily appear suddenly in great swarms as does the "green

[1] This bulletin describes an insect found on the small grains, more especially oats. The bulletin is of interest to growers of cereals.

[2] This common name, used by some of the early writers, is adopted here, since the name European grain-aphis, used by some authors, is scarcely distinctive, all three of the common grain aphides probably being native to Europe.

[3] Specimens labeled *"Aphis avenæ* Fabr.—*A. padi* Kalt. on *Triticum vulgare,* Russia merid.," received from Dr. N. A. Cholodkovsky, of St. Petersburg, agree well with the *Aphis avenæ* of this country.

This species has the following synonyms: *Siphocoryne avenæ* Fabricius, *Siphonophora avenæ* of some authors, *Aphis mali* of some authors, *Aphis annuæ* Oestlund (included as a synonym on the authority of Mr. Theodore Pergande, U. S. Dept. Agr., Div. Ent., Bul. 44, p. 9, 1904), and *Aphis fitchii* Sanderson.

[4] Fitch, Asa. Fourth Ann. Rpt. Regents Univ. N. Y., 1851, p. 65; reprinted in Lintner, J. A., Ninth Rpt. . . . on the insects of N. Y., 1893, p. 405.

45614°—14

bug," although occasionally it may be found in conspicuous and alarming numbers, but it is ever present on wheat; and, especially in the fall, when it occurs at the base of the plant and on the roots, it is easily overlooked by the casual observer. However, there is no doubt that these plant-lice, even though they may not be conspicuous and apparent, weaken the plants and decrease the yield. This decrease in yield is presumably general, but may not as a rule be locally conspicuous as in the case of the "green bug," that is, not enough to be recognizable. On the whole, however, it can hardly be doubted that these little insects are responsible for the loss in this country of thousands of bushels of wheat annually.

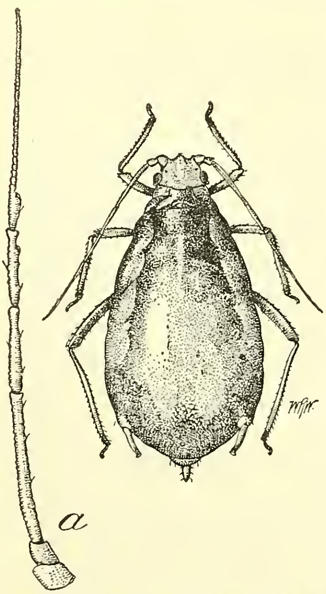


FIG. 2.—The oat aphis (*Aphis avenæ*): Wingless viviparous female, much enlarged. *a*, Antenna of same, still more enlarged. (Original.)

DISTRIBUTION.

The oat aphis is almost cosmopolitan in its distribution, and in this respect rivals such well-known plant-lice as *Macrosiphum pisi* Kalt., *M. granarium*, and *Toxoptera graminum*. It has been found in all parts of Europe, as well as in most of the States of the United States. Quite likely it will also be found to occur in Asia, and probably in Africa, although we believe it has never been reported in literature from these countries up to the present time.

The map (fig. 1), compiled from records made by assistants in the Cereal and Forage-Crop Insect Investigations and from authentic published records, indicates the present known distribution in the United States. It will be observed that the species has not been found in the Gulf region.

DESCRIPTIVE.

On grain two forms of the oat aphis are found—the winged and wingless viviparous females. As will be explained later, it occurs on the apple where there are to be found, in addition, the sexual forms, namely, the wingless oviparous female, the winged male, and eggs. (See fig. 5.)

The *wingless viviparous female* (fig. 2) is yellowish green to olive green, often somewhat mottled. The stem mothers on apple in the spring are more often lighter, with a darker green median longitudinal area, while those found on wheat in the fall of the year are darker, sometimes becoming greenish brown. The bases of the cornicles are surrounded, in the spring forms, with areas yellowish to orange in color, while these areas are larger and are usually orange to dark reddish in the fall and in hibernating individuals. The antennæ are about one-half the length of the body, and the cornicles, or "honey tubes," are slightly vasiform.

The *winged viviparous female* (fig. 3) has a black head and thorax, the abdomen being olive green, sometimes paler, with a row of more or less conspicuous black spots on each side anterior to the cornicles, and usually with a rusty or brownish red area about the base of each cornicle. The antennæ are black and reach a little beyond the middle of the body. The cornicles are black and slightly

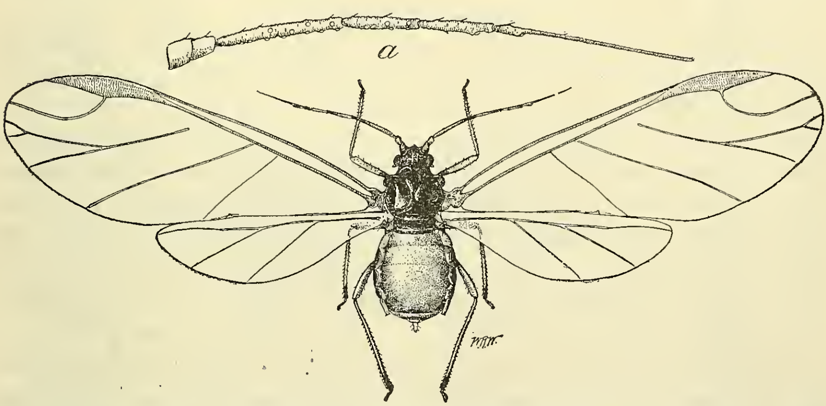


FIG. 3.—The oat aphis: Winged viviparous female, greatly enlarged. *a*, Antenna of same, still more enlarged. (Original.)

vasiform. The last branch of the median vein in the wings branches near the apex of the wing.

The *immature* aphides are paler green, but almost invariably the yellowish to pinkish areas about the bases of the cornicles are quite noticeable, although sometimes faint in very young individuals.

The *winged male* is similar to the winged viviparous female except that it is smaller and has a narrower abdomen, and the color is usually more of a dusky green.

The *wingless oviparous female* is somewhat like the viviparous female, but the abdomen is more tapering toward the tip, and the color is pale yellowish green to greenish dusky, or even has an orange tint. Rather conspicuous orange or reddish areas are present on the abdomen at the bases of the cornicles.

The *eggs* (fig. 5, *a*) are laid in the crevices of the bark or between the leaf bud and twig, and when first deposited are pale greenish, but they soon change to shining black and retain this color until they hatch in the spring.

SPECIES LIKELY TO BE CONFUSED WITH THE OAT APHIS.

This species may be recognized in the grain field by the pinkish, orange, or reddish areas on the abdomen at the bases of the cornicles. It may also be distinguished by the wing venation, by the short, slightly swollen cornicles, by the mottled pattern of coloration of the abdomen, and in the winged form by the rows of black spots on either side. The antennæ also differ from those of other species.

The large green grain-aphis (*Macrosiphum granarium* Kirby) is larger than *Aphis avenæ* and does not have the colored areas at the base of the cornicles. These last are longer, reaching nearly to the tip of the cauda, or tail, and are more cylindrical, and the antennæ are longer in relation to the length of the body.

The spring grain-aphis, or "green bug" (*Toxoptera graminum* Rond.), is more nearly the size of *Aphis avenæ*, but it need not be confused with that species if we remember that it is pale green, about the color of the wheat leaf, and that this coloration is quite uniform over the entire abdomen; that it does not have the orange or reddish areas at the bases of the cornicles; and that the winged female is without the black spots on each side of the body. Further, the venation is ordinarily different in the two species, the median vein of *avenæ* (fig. 3) being twice branched, except in rare instances, while in the "green bug" (fig. 4) it is but once branched.

Aphis avenæ is readily distinguished from other aphides on apple. *Aphis pomi* De G., the most common apple aphis, is quite different, the wingless individuals being uniformly pale apple green with black and rather conspicuous cornicles and no trace of orange or pink on the abdomen about the cornicles. The winged individuals are similar, except that the head and thorax are shining black and the abdomen pale apple green; also the venation of the wing is different, the last branch of the median vein not dividing near the apex of the wing. This aphis spends its entire life cycle on the apple and related trees.

The rosy apple aphis (*Aphis sorbi* Kalt.) varies greatly in color from the greenish blue, pulverulent females hatching from eggs to the more or less pinkish forms. It is slightly larger than the oat aphis and does not have the pinkish or orange areas about the bases of the cornicles, although the distal end of the abdomen may be pinkish, and in some stages, such as the pupal stage of the spring migrants, the entire body may be pinkish or salmon colored. The

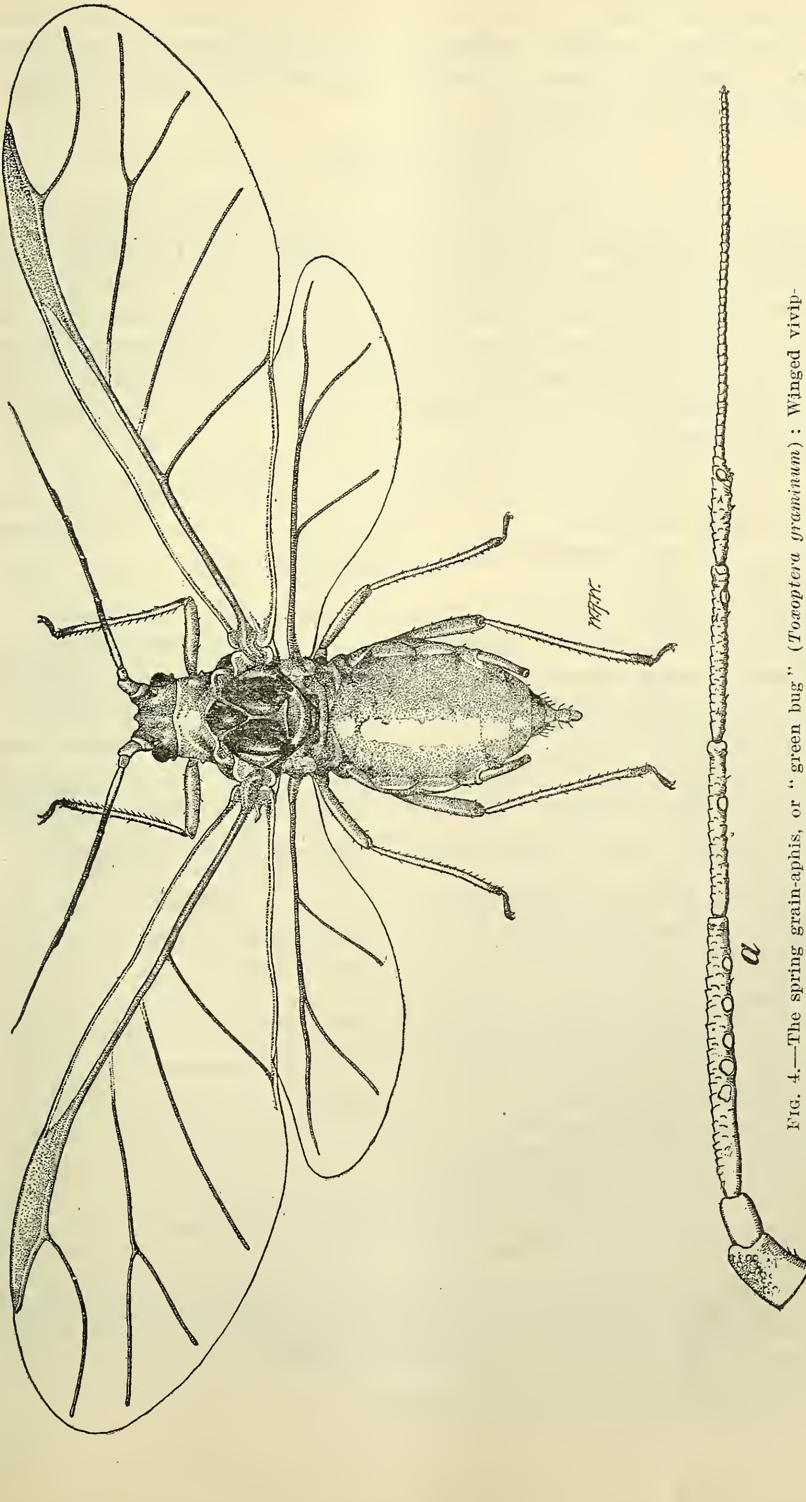


FIG. 4.—The spring grain-aphis, or "green bug" (*Toxoptera graminum*): Winged viviparous female and antenna. Greatly enlarged. (From Webster and Phillips.)

winged female has its wing venation much like that of *Aphis pomi;* the cornicles are black, tapering and reaching almost to the tip of body, and the abdomen is rather conspicuously marked by a large black patch on the dorsum.

HOST PLANTS.

Aphis avenæ has been recorded from a large number of plants, particularly of grasses. Owing to the confusion with the larger grain aphis (*Macrosiphum granarium*) in some of the literature, it is impossible in many cases to determine which species of plant-louse was meant, and consequently the following list includes only those plants in cases where the identity of the aphis is reasonably certain. This list does not include all of the plants upon which this species has been found in Europe.

GRAMINEÆ.

Wheat, *Triticum vulgare*
Triticum dicoccum [1]
Rye, *Secale cereale*
Oat, *Avena sativa*
Wild oat, *Avena fatua* [2]
Tall oat grass, *Arrhenatherum elatius* [3,4]
Barley, *Hordeum vulgare*
Two-rowed barley, *Hordeum distichon* [2]
Wall barley, *Hordeum murinum* [4]
Timothy, *Phleum pratense*
Canada blue grass, *Poa compressa*
Kentucky blue grass, *Poa pratensis*
Annual or dwarf meadow grass, *Poa annua* [1]
Rough-stalked meadow grass, *Poa trivialis*
Crab grass, *Syntherisma sanguinale*
Upright chess, *Bromus racemosus*
Rescue grass, *Bromus unioloides*
Cheat, *Bromus secalinus* [3,4]
Hungarian brome grass, *Bromus inermis* [3,4]
Orchard grass, *Dactylis glomerata*
Italian rye grass, *Lolium multiflorum* [3,4]
Perennial rye grass, *Lolium perenne* [3,4]
Redtop, *Agrostis alba* [3,4]
Red fescue, *Festuca rubra* [3,4]
Sheep's fescue, *Festuca ovina* [3,4]
Meadow fescue, *Festuca pratensis* [=*elatior*] [3,4]

GRAMINEÆ—continued.

Hard fescue, *Festuca ovina duriuscula* [3,4]
Reed canary grass, *Phalaris arundinacea* [3,4]
Melic grass, *Melica bauhini* [1]
Melica penicillaris [1]
Johnson grass, *Andropogon halepensis* [5]
Broom corn, *Andropogon sorghum* var.
Sorghum, *Andropogon sorghum* var.
Koeler's grass, *Koeleria cristata* [1]
Wild rye, *Elymus geniculatus* [=*arenarius*] [1]
Virginia wild rye, *Elymus virginicus* [4]
Nodding wild rye, *Elymus canadensis* [4]
Corn, *Zea mays*
Teosinte (*Euchlaena mexicana*) [3,4]

TYPHACEÆ.

Cat-tail, *Typha latifolia* [4]

AMMIACEÆ.

Celery, *Apium graveolens*

COMPOSITÆ.

Tickseed, *Coreopsis* sp.?

MALACEÆ.

Apple, *Malus malus*

[1] Recorded by Mordwilko as hosts of *Aphis padi* Kalt.—*avenæ* Fabr.

[2] Recorded by Fabricius; so far as known, there is no record on this plant from America.

[3] In 1909 Mr. T. H. Parks, at that time connected with the Bureau of Entomology, confined this species with various plants and found that it would breed contentedly and freely on these plants. Other plants tried, and which the aphides refused, are Muhlenbergia, *Agropyron occidentale, Panicum virgatum,* and *P. bulbosum.*

[4] Recorded here for the first time.

[5] Recorded as hosts of this species by Passerini.

MALACEÆ—continued.

Pear, *Pyrus communis*
Hawthorn, *Cratægus coccinea*, etc.
American mountain ash, *Sorbus americana*
Quince, *Cydonia vulgaris*
Double-flowering crab apple (*Malus* sp.)
Wild crab apple (*Malus* sp.)

ROSACEÆ.

Ninebark, *Opulaster opulifolius*.[1]

AMYGDALACEÆ.

Plum, *Prunus* sp.
Choke cherry, *Padus virginiana*
Wild black cherry—
Padus serotina
Padus padus

In addition to the foregoing list of food plants, Mr. Theodore Pergande lists dogwood (*Cornus* sp.), shepherd's purse (*Bursa bursa-pastoris*), and burdock (*Arctium minus*); but in each case he notes that it is, or evidently is, accidental.

Although this species, as shown, has a large number of available host plants, it is more often to be found in the fall and spring on wheat, blue grass, apple, and pear. In early summer it is frequently found on oats, wheat, blue grass, and, previous to June, on apple and pear, and in later summer on volunteer wheat and oats and on blue grass.

INJURIES AND METHOD OF WORK.

Probably no other species among the plant-lice has been so completely confused in literature as the one under discussion. Numerous reports of injury to apple, wheat, and oats have been made since its discovery in 1851, but in most instances there seems to have been some confusion in the species, and it is impossible in such cases to determine just which of several species may have been responsible for the damage. Thus in 1865 Fitch[2] described and figured a Macrosiphum on wheat, although some of his observations doubtless refer to *Aphis avenæ*. In 1879 Thomas[3] reported a plant-louse which damaged wheat considerably in Illinois in 1866 and again in 1876, but in his description he has confused two species, *Macrosiphum granarium* and *Aphis avenæ*, and there is no means by which the particular species troubling grain in the years mentioned can be identified. Again, Riley in his report for 1889[4] discusses, under the name *Siphonophora avenæ*, at least two species, and the facts relating to life history, injuries, parasites, etc., refer to more than one species; consequently this data must be ignored for the present, although the colored figures and probably most of the data contained in the article refer to *Macrosiphum granarium* rather than to the species under discussion. The same must be said of many other references to grain

[1] Recorded here for the first time.
[2] Sixth report on the insects of N. Y., 1865, p. 91–97. "*Aphis avenæ*, Fabricius."
[3] Eighth report of the State entomologist on the * * * insects of the State of Illinois, 1879, p. 51–55. "*Siphonophora avenæ*, Fab."
[4] U. S. Sec. Agr. Rpt. for 1889 (1889), p. 348.

aphides in which the author has either failed to describe the insect or its habits, or has confused two or more species in his descriptions.

On the other hand, we have one important reference to injury recognizable as that of the true *Aphis avenæ*. In Insect Life [1] Prof. F. M. Webster says:

> The wingless viviparous females of this species flock to the fields [of wheat] and on these [wheat plants] give birth to their young, which at once make their way to the roots, where they continue reproduction, sapping the life from the young plants. On very fertile soils this extraction of the sap from the roots has no very serious effect, but where the soil is not rich, and especially if the weather is dry, this constant drain of vitality soon begins to tell on the plants. Though they are seldom killed outright, these infested plants cease to grow, and later take on a sickly look * * *. It is very seldom that the affected plants fully recover, at least in autumn, and the results must be to reduce their productiveness the following year.

In January, 1891, Mr. Christian Steiffel, of Salem, Ind., reported this plant-louse as injuring wheat, causing it to turn yellow and die out in spots.

Prof. Webster received a report from Wooster, Ohio, of serious injury to wheat in December, 1898, on land subject to overflow. The wheat came up very well and remained green for about a month, after which it began to assume a brownish cast, and the warmer the weather and the more sunshine the plants got, the browner they became. In a letter dated December 4, 1901, to this bureau, Mr. J. D. Hummell, of Carroll, Ohio, writes:

> This plant louse seems to have almost completely destroyed one field of wheat in which it appeared early in the fall, and is not yet dormant, although we have had nights when the temperature was down to 15° F.

November 12, 1908, Mr. E. O. G. Kelly, of this bureau, reported this species abundant on the roots and stems of wheat at Caldwell, Kans., and doing considerable and noticeable injury to the early sown wheat.

Mr. A. A. Cooke, in a letter dated August 21, 1910, reported damage by this aphis to dwarf broom corn at Dale, Union County, N. Mex., the insect covering the plants and causing the foliage to turn a reddish color.

This insect was abundant in western North Carolina in March, 1913, reports of serious damage to wheat, oats, and rye having been received from several parties.

Numerous reports were received by this bureau from Oklahoma and northern Texas in December, 1913, and January, 1914, to the effect that the "green bug," which had ravaged the wheat fields in these areas in 1907, was again abundant and destructive to oats and wheat. Detailed examinations were made by Messrs. W. E. Penning-

---

[1] U. S. Dept. Agr., Div. Ent., Insect Life, v. 6, no. 2, Dec., 1893, p. 152.

ton and H. E. Smith, of this bureau, under directions from Prof. Webster. They found very few of the "green bug," while the oat aphis was present in considerable numbers. After a careful examination of the fields, the conclusions reached were that the injuries were due to one or more of three causes, namely, attacks by the oat aphis, impoverished soils, and weather conditions, particularly excessive rains during the late fall and early winter. Of these, weather conditions seem to have been the cause of the greatest amount of injury, although in certain areas the damage was more probably the result of attacks of the oat aphis. However, the parasites were in noticeable evidence everywhere, so that with normally late winter and spring weather they should prevent the aphides from becoming injuriously abundant.

As described by Prof. Webster in the foregoing quotation, the infested plants take on a yellowish or greenish yellow color, appear sickly, and cease to make any apparent growth, and since the insect works on the lower parts of the plant and is not always easily detected, the cause of the injury may sometimes be overlooked. During the summer this aphis usually feeds on the under surface of the leaves, on the stems, and in the axils of the leaves—seldom in the grain heads, as does *Macrosiphum granarium.*

CAUSES OF OCCASIONAL OUTBREAKS.

Prof. Webster[1] has made clear the reason for periodic outbreaks of the spring grain-aphis (*Toxoptera graminum*), and the usual abundance of the oat aphis in certain years may be attributed to the same cause. As in the case of the spring grain-aphis, the oat aphis breeds and multiplies at a temperature of about 40° F., or above, while the common parasite of these and many other aphides, *Aphidius testaceipes* Cress., is hardly active at a temperature less than 56° F. Consequently, mild winters and cool springs, when the temperature fluctuates between 40° and 56° F., permit the aphis to multiply, uninterrupted by attacks from their common natural enemy.

LIFE HISTORY OF THE INSECT.

The oat aphis occurs on grains and grasses throughout the summer, the spring colonies originating either from viviparous females which passed the winter on wheat, grasses, etc., or from spring migrants from apple and related trees—that is, the progeny of aphides hatching from eggs laid the previous fall on such trees. The plant-lice usually become more abundant toward fall, and as the weather becomes cooler they seek the lower parts or roots of wheat and other

[1] U. S. Dept. Agr., Bur. Ent., Circ. 85, Mar. 29, 1907, and U. S. Dept. Agr., Bur. Ent., Bul. 110, Sept. 6, 1912.

plants of the grass family and here pass the winter as viviparous females; or the winged fall migrants from grain may seek such trees as the apple, where the true sexual forms are produced, the oviparous females of this generation in turn depositing eggs on the twigs and branches, usually in the axils of the dormant buds or in crevices in the bark. (Fig. 5.)

In the latitude of La Fayette, Ind., the species commonly winters either as viviparous females on grains and grasses or in the egg stage on apple. Farther north, and especially in extremely cold winters, this species is probably unable to winter in any but the egg stage, while in the southern parts of the United States, where the winters are moderate, the aphides may live over winter as viviparous females only, no egg stage appearing.

The theory, put forth by Pergande,[1] "that the species is biennial and that the progeny of the spring migrants from the apple subsist almost exclusively upon various grains and grasses until the fall of the second year, when a generation of return migrants makes its appearance," is hardly a correct one. The writer's experience shows that while the apple may be a fall or spring host of *avenæ*, it is not a necessary alternate host, and that the species may subsist indefinitely on grains and grasses, and especially is this probably the rule in the Southern States. The species has been reared through more than 60 consecutive generations, covering a period of over two years, and through three winters on wheat, the warm greenhouse being used to carry the species through the winter months, and the line of viviparous generations could probably have been continued indefinitely but for an accident, the aphides having been killed when the greenhouse was fumigated without the knowledge of the writer.

Continuous-generation experiments were conducted at La Fayette, Ind., in 1909 by Messrs. W. J. Phillips and T. H. Parks and in 1911 and 1912 by the writer. In 1909 and 1911 the summers were unusually hot, and the experiments were not satisfactory, but in 1912 it was possible to get continuous first-born and last-born generation series without breaks. In 1909 Phillips and Parks obtained a maximum of 15 generations from May 15 to October 7 and a minimum of 8 generations in the same length of time. In 1911 a maximum of 18 generations was obtained from April 29 to October 12, and in 1912 a maximum of 23 and a minimum of 9 generations from May 3 to November 13, or a mean average of 16 generations. In the Southern States, where the species may breed throughout the winter months, a much greater number of generations would occur. In the experiments of 1909 the average number of young per female, in the 21 cages where records were kept, was 30.6; in 1911 the average for

---

[1] U. S. Dept. Agr., Div. Ent., Bul. 44, 1904, p. 7.

FIG. 5.—Diagrammatic explanation of the life cycle of the oat aphis. January–February, in egg (*a*) stage on apple and related trees or as wingless females on lower parts and roots of wheat and grasses. March–June, progeny from eggs hatching on apple migrate to grasses and grains. September–November, migrants return to apple, where several forms are produced and eggs laid. Others remain on grasses or migrate to fresh grass hosts, passing the winter as viviparous females. (Original.)

17 mother plant-lice was 22.1 young; and in 1912 the average for 43 individuals was 32.7 young, with a range of from 12 to 65 young per female. There was thus an average for the three years of 32.3 young. The largest number of young produced by a single female was 103, and normally, in the cooler parts of the year, the number ranged between 50 and 60. The number of young produced per day ranged from 1 to 8 per female, and the length of the period from birth to maturity varied from 6 to 15 days and averaged about 8½ days, excepting in late fall, when the length of time was ordinarily much greater. According to the numerous tests the species molts but four times, as do other species.

It will be seen from the foregoing that this species, like many other plant-lice, is quite prolific, although not so prolific as the "green bug" (*Toxoptera graminum*). It is computed that in 15 generations, averaging 30 young per female, the progeny from a single individual, providing all lived and reproduced, would cover almost the entire land area of the world, or, if packed 256 to the square inch and piled 25 high to the inch (6,300 to the cubic inch), would cover the entire State of Texas to a depth of 7 inches. Fortunately plant-lice are delicate insects, being highly susceptible to rains and inclement weather, and are preyed upon by many predaceous and parasitic animals, as well as being subject to fungous diseases.

In 1879 Dr. Cyrus Thomas[1] aptly discusses the winter habits of the wintering viviparous females in the following words:

> When winter appears they move down toward the ground, some of them, at least, entering the soil and feeding upon the sap of the roots. At any rate, I find the apterous ones at this time working upon the roots, but at the same time I find a winged individual above ground. I have also observed them heretofore at the root of the wheat, late in winter, while snow was on the ground; and what somewhat surprised me, I found them busy at work under the snow, and the apterous females bearing well formed larvæ.

There are numerous office records in which the occurrence of this plant-louse is reported on wheat and grasses during the winter months, but the following individual record will substantiate the belief that the insect may survive even rather severe winters as viviparous females. At Wellington, Kans., Mr. T. H. Parks found adult wingless viviparous females of the oat aphis on wheat roots April 9, 1910, and these had undoubtedly passed the winter on wheat, or were the direct progeny of overwintering females. The winter of 1909–10 was an unusually severe one at Wellington, according to Mr. E. O. G. Kelly, the ground becoming frozen early in December, 1909, and remaining frozen until February, 1910, after which

---

[1] Eighth Rept. State Entomologist, Ill., 1879, p. 53.

it alternately froze and thawed until March, 1910, the weather being so severe that 50 to 75 per cent of the wheat in that vicinity was killed by the cold.

Sometimes these winter root forms are attended by ants, as has been observed by Prof. Webster and the writer. The forms which go to apple migrate early in October in the latitude of La Fayette, Ind., and usually fully a month later in the latitude of northern Oklahoma. In the rearing cages it has never been possible to get the forms from wheat to migrate to apple, the failure doubtless resulting from the use of too small cages. On the other hand, there was no difficulty in getting the spring migrants to go to wheat and there continue to reproduce throughout the summer from apple shoots, even in small lantern globe cages.

NATURAL CHECKS.

Like most plant-lice of the genus Aphis, *avenæ* is freely attacked by various parasitic and predaceous animals, principally insects, and doubtless these are responsible for the usual control of this pest.

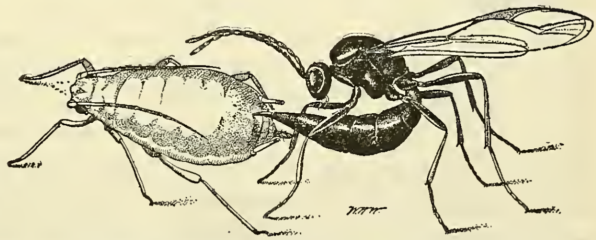


FIG. 6.—*Aphidius testaceipes* ovipositing in the body of the spring grain-aphis. Enlarged. (From Webster.)

Among the internal parasites, Fitch[1] has recorded *Toxares triticaphis* Fitch, (*Praon*) *Aphidius avenaphis* Fitch, and *Allotria tritici* Fitch, but it is probable that he reared these from *Macrosiphum granarium* rather than from *Aphis avenæ* as was supposed by Mr. Pergande.[2] In 1894 F. M. Webster[3] reports rearing *Pachyneuron micans* Howard and (*Lysiphlebus*) *Aphidius testaceipes* Cresson (*tritici* Ashmead). The latter species (figs. 6 and 7) is the one which ordinarily holds the spring grain-aphis (*Toxoptera graminum*) in check, and doubtless is likewise beneficial in preventing undue multiplication in *avenæ*. Mr. Theo. Pergande[4] reared another species of *Aphidius* (*A. nigriceps* Ashmead) in considerable numbers from this aphis.

Among the predaceous insects Pergande[4] has reared a common syrphid fly (*Syrphus americanus* Wiedemann) (fig. 8); the writer has reared a species of Aphidoletes from larvæ feeding on *Aphis*

---

[1] Sixth Rpt. on the noxious and other insects of the State of N. Y., 1865, pp. 98–112.
[2] U. S. Dept. Agr., Div. Ent., Bul. 44, 1904, p. 13.
[3] Ohio Agr. Expt. Sta., Bul. 51, 1894, p. 117.
[4] Op. cit.

avenæ at La Fayette, Ind., and Washburn[1] says that this plant-louse is attacked by a "red mite." Of the ladybird beetles which attack this aphis, Fitch mentions *Hippodamia parenthesis* Say, *Coccinella 9-notata* Herbst, and *Coccinella 5-notata* Kirby, although it seems probable that Fitch was dealing with a different plant-louse, and he may not have observed them feeding on the oat aphis. At different times assistants of the Cereal and Forage-Crop Insect Investigations have observed the following ladybird beetles, or their larvæ, feeding on the oat aphis in various parts of the United States: *Cycloneda munda* Say, *Coccinella 9-notata* Herbst, *Megilla maculata* DeG., *Scymnus* sp., and *Hippodamia convergens* Guér. (fig. 9), the last species being by far the most abundant, and consequently the most useful of the coccinellids in the control of the aphis.

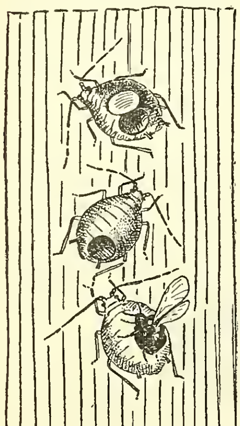


FIG. 7.—Dead aphides, showing holes from which the matured parasites of *Aphidius testaceipes* emerge. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasites emerging. Enlarged. (From Webster.)

In addition to the foregoing enemies, the larvæ of several species of lace-wing flies (Chrysopidæ) are known to feed upon this aphis.

Miss Margaret Morse, of Worcester, Mass., (in litt.) has found that quails eat these aphides in confinement, and while definite field observations are lacking, it is quite probable that the quail, or bobwhite, as well as other birds frequenting grain fields, plays an important part in the control of this and other grain aphides.

Among other natural agencies which assist in holding the aphis in check are fungous diseases. These, like most fungi-attacking insects, thrive best under moist conditions; hence the diseases commonly attacking plant-lice are most prevalent and useful in moist seasons. Rains likewise have a beneficial effect, particularly "driving" rains.

Webster,[2] in his Ohio report, "suspects" two minute insects, *Gonatocerus brunneus* Ashm. [MS.] and *Polynema longipes* Ashm. (*Cosmocena citripes* Ashm.) as destroying eggs of *avenæ*, but this observation has apparently never been authenticated.

REMEDIAL AND PREVENTIVE MEASURES.

As in the case of the well-known spring grain-aphis, or "green bug" (*Toxoptera gramium*), it is practically impossible to control

[1] Twelfth Rpt. State Entomologist of Minn. for 1907 and 1908, Dec., 1908, p. 50.
[2] Op. cit., p. 117.

the oat aphis after it has once gained much headway in numbers and diffusion, but by proper precautions it is possible to prevent serious outbreaks.

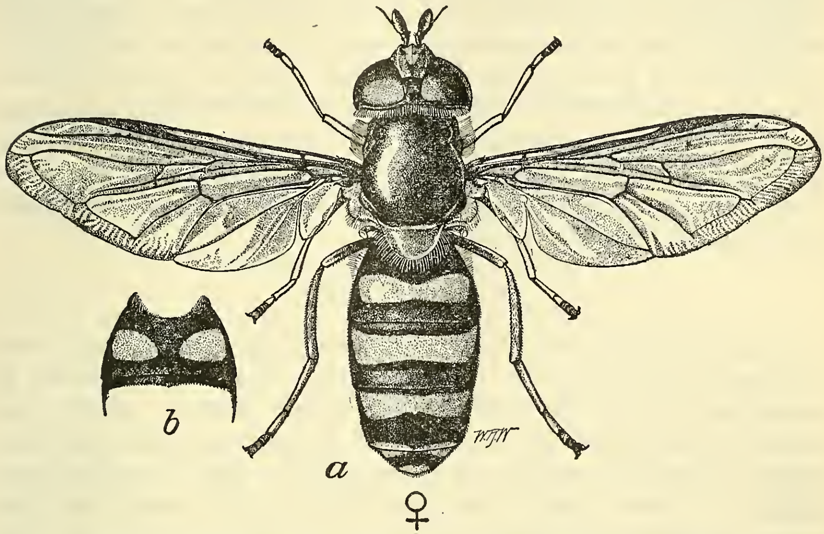


FIG. 8. *Syrphus americanus*, whose larva destroys the oat aphis. *a*, Female fly; *b*, second abdominal segment of male. Enlarged. (From Webster and Phillips.)

DESTRUCTION OF BREEDING PLACES.

As has been observed by the writer and other assistants of the Cereal and Forage-Crop Insect Investigations, the plant-louse under discussion thrives best in rank-growing wheat, for instance in spots where manure piles or straw stacks have stood, as well as in the vicinity of straw stacks where the growth of grain is usually luxuriant. In fact, observations show that the latter place is the usual center of infestation, for during the colder winter months the plant-lice may be found here when it is impossible to locate them elsewhere. Such locations also provide much better protection from inclement weather, and reproduction may continue, more or less, throughout the winter. Therefore it is evident that if the growth about straw

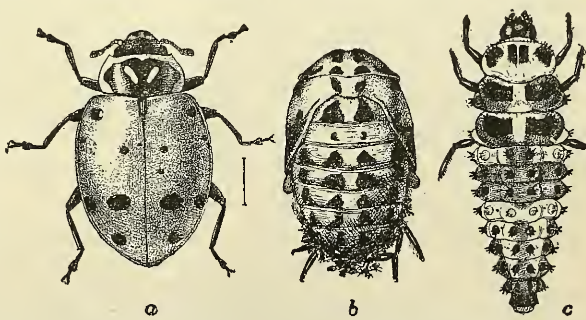


FIG. 9.—The convergent ladybird (*Hippodamia convergens*), an enemy of the oat aphis: *a*, Beetle; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

stacks be plowed under or otherwise destroyed late in fall, the aphides harbored thereon will be destroyed. In some cases it may be desirable to destroy this vegetation even earlier; that is, before the winter wheat is planted or at least before it makes any growth above ground. Likewise the pasturing of cattle in wheat and oat fields in Oklahoma and Texas during the late fall and early winter is desirable; indeed, observations made by Messrs. W. E. Pennington and H. S. Smith, of the Cereal and Forage-Crop Insect Investigations, show that where this procedure had been followed, the grain was practically free from the oat aphis, although adjoining unpastured fields showed rather heavy infestation.

CULTURAL METHODS.

As in the case of many other grain pests, crop rotation is of much importance in the control of this aphis. Wheat fields should be located as far from the previous year's grain fields as possible, and especially should they be planted some distance from standing straw stacks. It is also advisable to plant grain as far as possible from apple and other trees, which harbor the insect during the fall, winter, and spring months.

SPRAYING.

Direct applications are hardly practicable in grain fields, but where only small areas are badly infested spraying with blackleaf-40 at the rate of 1 part of this insecticide to 900 parts of water, plus 1 pound of soap to each 100 gallons of spray liquid, will doubtless prove efficacious, providing the application is thorough.

Another method which might be adopted in localities where the aphides freely migrate and deposit eggs on apple, is spraying such trees early in spring before the eggs hatch, preferably just previous to their hatching and while the trees are yet in a dormant condition, with commercial lime-sulphur mixture at the rate of 1 part of the mixture to 8 parts of water.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 113

Contribution from the Bureau of Entomology, L. O. Howard, Chief

August 22, 1914.

(PROFESSIONAL PAPER.)

THE LESSER BUD-MOTH.

By E. W. Scott and J. H. Paine,

Entomological Assistants, Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the spring of 1912, while engaged in apple spraying experiments at Benton Harbor, Mich., the senior author noticed the work of a small larva in the buds of unsprayed apple trees. The injury inflicted by this minute insect was quite severe in a neglected orchard near the laboratory, and this insect, among others, was the most important factor in the destruction of the entire crop of fruit. From the character of the injury, the attack on the swelling buds, and the tying together of the growing leaves the damage was at once attributed to the eye-spotted bud-moth (*Tmetocera ocellana* Schiff.).

In 1913 a study was made of the life history and habits of this insect, supposedly the eye-spotted bud-moth, and experiments were tried with remedial measures. The first discrepancy noticed between the habits of this insect and those of the eye-spotted bud-moth, as stated in literature, was the fact that the hibernaculæ were not necessarily situated near the buds, but were to be found in any suitable place upon the limbs. Following this, many other even more striking differences in habits were noted during the course of the season, and the fact was soon impressed upon the writers that they had to deal with an insect whose economic importance had not been recorded in the United States.

The adult moths, upon submission to Mr. August Busck, of the Bureau of Entomology, were identified as *Recurvaria cratægella* Busck (1903),[1] a species described by him (with no indication of its life history) in 1903 from material submitted by Mr. William Dietz from Hazleton, Pa., who reared it from hawthorn (*Cratægus tomen-*

[1] Bibliographic citations in parenthesis refer to "Literature cited," pp. 15 and 16.

NOTE.—Describes an imported insect which is very destructive to several kinds of growing fruit and has attained quite wide distribution throughout the Northeastern and North Central States.

tosus) in June. Busck makes the following statement in his description:

> I am, at present, unable to separate this species from a series of authentic European specimens of *R. nanella* Hübner, and I am conscious of the probability of my making a synonym of this species, the life history of which, according to Meyrick's Handbook of British Lepidoptera, is not definitely known. but which is variously said to feed in flowers or the shoots of pear or on lichens growing on the trunk.

However, in the same year Houghton (1903) published a short though complete account of the life history of *Recurvaria nanella*, corresponding in detail to our observations in Michigan. In view of this identity between the life histories as observed in Europe and America, Busck feels certain of the identity of the two insects, as appears in a statement by him in the accompanying footnote.[1]

HISTORY OF THE SPECIES IN EUROPE.

Stephens (1834) records *Recurvaria nanella* as "not very uncommon in gardens within the metropolitan district (London), frequenting the trunks of apple trees in June and the beginning of July."

Stainton (1854) records the larva as feeding in May, in England, on the pear, making a gallery across the flowers with pieces of the petals and stamens interwoven with silk.

Rössler (1871–72) observed the tying together of the young leaves of fruit trees by larvæ of *Recurvaria nanella* and its effect in hindering the development of the new leaves, at Wiesbaden, Prussia. The insect was present in such large numbers as to attract the attention of the public to the deformed trees and to arouse the fear that serious harm would result. In view of the fact that the larva was so small, ate so little, and did not attack the blossoms, Rössler considered that it was not to be feared.

Houghton (1903) published quite a complete though short account of the life history and habits of *Recurvaria nanella* from an economic point of view, as observed by him in England. His attention was directed to the insect in an apricot orchard, where the crop had been practically destroyed by it in previous years. He was the first to note the fact that the larva, after hatching. passes the time before hibernation as a miner in the leaf. He also observed that it was the habit of the larvæ to bore into the swelling buds in the spring. The larvæ appeared in swarms on peaches and apricots and less commonly on cherries and plums. In his description of the larva he men-

[1] *Recurvaria crataegella* Busck (Proc. U. S. Nat. Mus., v. 25, p. 811, 1903) is identical with the European *R. nanella* Hübner, as already suggested in the description. At that time the life history of the species was but fragmentarily known in Europe, and it was deemed the soundest course to give the American form a separate name, even though it was realized that it would probably prove the same as the European species. The subsequent careful study of the life history in Europe by J. T. Houghton and in this country removed all doubt about the synonymy.—A. B.

tions the different colors assumed by the caterpillars as they near maturity, and this observation corresponds with our own.

DISTRIBUTION OF THE SPECIES.

The distribution of *Recurvaria nanella* in Europe is given by Staudinger and Rebel (1901) as follows: Central Europe, Sweden, northern Spain, southern France, central and northern Italy, Dalmatia, and southwestern Russia.

Specimens of *Recurvaria nanella*, all identified by Busck, have been received by the Bureau of Entomology and by the United States National Museum from a number of localities in the United States. As previously stated, the first specimens were received in 1903 from Mr. William Dietz, Hazleton, Pa. Others have been received from Pittsburgh, Pa., collected by Henry Engle; from Denton, Md., collected by Quaintance in April, 1905, on peach; from College Park, Md., by Girault in August, 1905, on apple, "from fruit;" from Bennings, D. C., collected by Girault in May, 1905, "found resting in numbers on trunks and larger limbs, simply swarming on peach trees;" from Albany, N. Y., by Felt; from Hampton, N. H., by Shaw; from Dublin, N. H., by Busck; and from Cleveland, Ohio, by Prior, the larvæ eating apple leaves.

It is improbable that the insect has attained this distribution in the United States through natural means from a single importation from Europe, but it is likely that it has been imported a number of times on nursery stock shipped to various points in this country. In fact, the importation of this insect, which spends six or seven months in hibernation concealed in minute cracks and crevices of the bark, could occur most easily.

FOOD PLANTS.

In the earlier references to *Recurvaria nanella* the pear is usually given as the host plant. Houghton, however, failed to observe it infesting this fruit, but finds it swarming on the apricot, destroying the crop. On the other hand, it is certain from the observations of other authors that the pear is a favorite food plant, for the insect has often been observed frequenting pear trees in the vicinity of London. Other European host plants are apple, peach, plum, cherry, wild plum, and hawthorn. It has been recorded as attacking the peach in swarms. At Benton Harbor, Mich., the insect was reared from apple, peach, pear, plum, and sweet and sour cherries. The infestation was light on plum and cherry. At Hazleton, Pa., it was reared from a wild hawthorn.

It is interesting to note the immunity of the Kieffer pear to the attack of the young larva in the fall or leaf-mining stage. The larvæ, upon hatching, bore into the tissue of the leaves of this variety, showing no discrimination against it; the mines, however, are never developed to any great extent, for the tissue of the leaf about the mine turns dark and apparently hardens, effectually stopping the operations of the insect. Many larvæ must thus meet their death, being unable to secure food. This is another instance illustrating the resistant qualities of the Kieffer variety of pear.

CHARACTER OF THE INJURY.

The first attack by the larvæ of *Recurvaria nanella* in the spring is aimed at the swelling buds (Pl. II, figs. 3 and 4) of both blossoms and leaf. The insect bores into the bud, eating the tender tissues as it goes, showing particular partiality for the young stamens and pistil, if it has been lucky enough to select a blossom bud. As the buds open and the leaves begin to expand the larva ties the tips of the leaves together, spinning about them a tiny silken thread, thus greatly deforming and hindering the succeeding leaves as they develop (Pl. I, fig. 2). It is this injury, when inflicted by countless numbers of this tiny caterpillar on nearly every bud on a tree (Pl. I, fig. 1), that results in a serious, if not almost total, loss of the crop.

SYNONYMY.

Recurvaria nanella.

Tinea nanella (Schiff.) Hübn., 1796 (?), Tineæ, pl. 39, fig. 267.

Euota pruniella Schiff., 1776, Syst. Verz. Schmet., C. 75.

Tinea alcella Fab., 1794, Ent. Syst., v. 3, pt. 2, p. 317.

Recurvaria nana Haw., 1829, Lep. Brit., v. 4, p. 554.

Trichotripis nanella Hübn., 1816, Verz. bek. Schmet., p. 425, No. 4143.

Anacampsis nana (Haw.) Curt., 1827, Brit. Ent., v. 4, pl. 189.

Anacampsis alcella (Fab.) Steph., 1829, Syst. Cat. Brit. Ins., pt. 2, p. 197.

Gelechia nanella (Hübn.) Her.-Schäf., 1853–1855, Syst. Bearb. Schmet., v. 5, No. 416.

Recurvaria nanella (Hübn.) Heinem., 1870, Die Schmet. Deutsch. u. d. Schweiz., Bd. 2, p. 280.

Aphanaula nanella (Hübn.) Meyrk., 1895, Handb. Brit. Lep., p. 580.

Recurvaria cratægella Busck, 1903, *in* Proc. U. S. Nat. Mus., v. 25, p. 811.

DESCRIPTION OF THE LESSER BUD-MOTH.

THE ADULT.

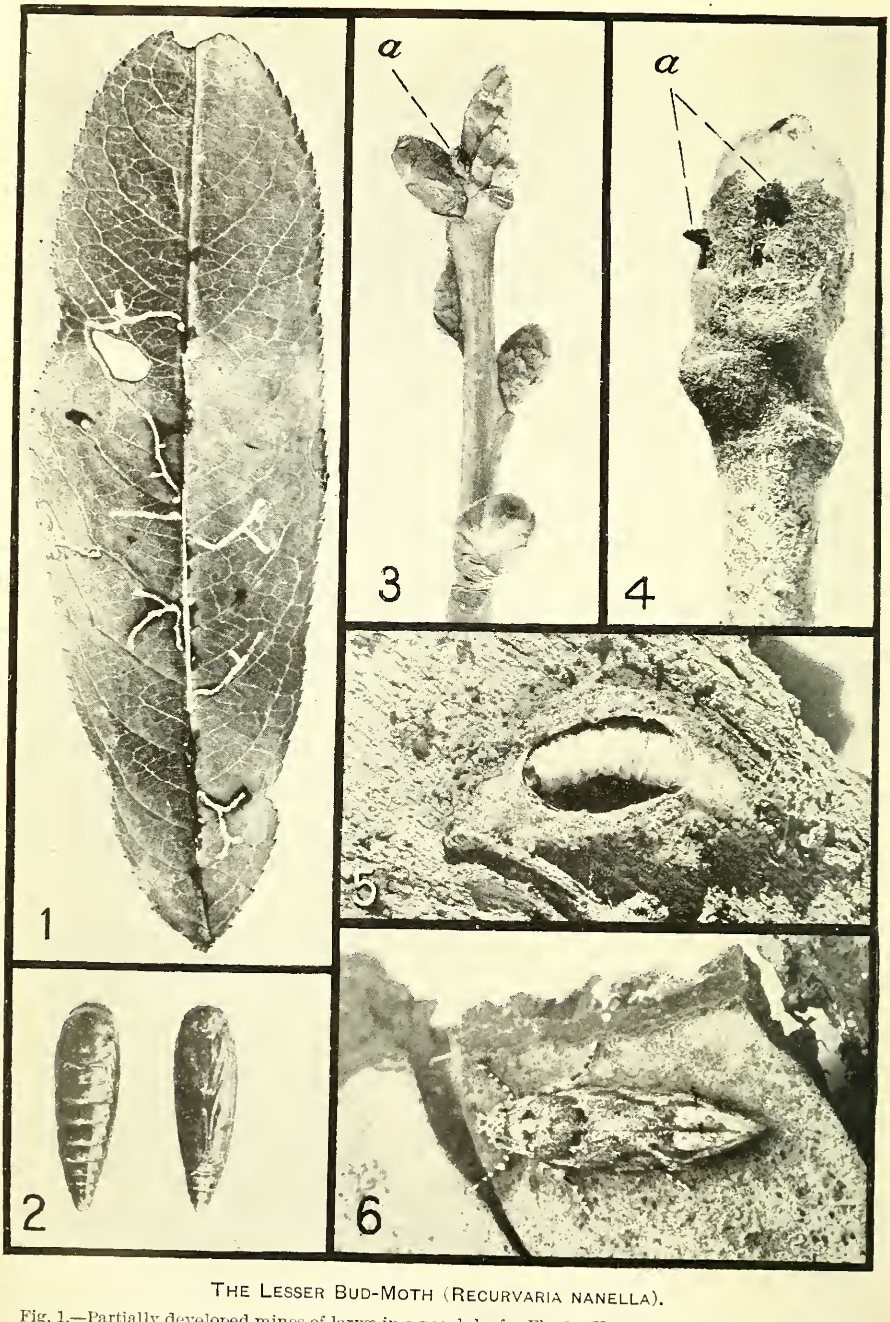
The adult (Pl. II, fig. 6) of *Recurvaria nanella*, or lesser bud-moth, is a very small streaked moth with a wing expanse of half an inch, although as it appears on the tree trunks it is not more than one-fourth of an inch long; the black and white banded legs are quite conspicuous. The following technical description is as given by Busck for *R. cratægella* (1903):

Antennæ whitish, with indistinct, narrow, dark-brown annulations. Labial palpi whitish, with two black annulations on each joint; tip white. Face, head, and thorax white, suffused with fuscous.

Fore wings white, thickly sprinkled with fuscous.. From near the base of the costa is an outwardly directed, oblique, ill-defined black streak, which

WORK OF LARVÆ OF THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Neglected peach trees partially defoliated by larvæ. Fig. 2.—Work of larvæ on pear twigs resulting in the destruction of some of the buds. (Original.)



THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Partially developed mines of larvæ in a peach leaf. Fig. 2.—Upper and lower views of pupa. Fig. 3.—Excrement (*a*) deposited at entrance to larval burrow in cherry bud. Fig. 4.—Apple bud infested with larvæ, showing excrement (*a*) deposited at entrance to burrows. Fig. 5.—Full-grown larva in cocoon on bark removed from trunk of pear tree. Fig. 6.—Moth at rest on bark. Fig. 1, slightly enlarged; figs. 2, 5, 6, about six times enlarged; fig. 4, about twice enlarged; fig. 3, natural size. (Original.)

does not reach the dorsal edge and which is more or less interrupted at the fold and bordered on the outside with white scales. From the middle of the costa is a similar, parallel, interrupted dark streak still less clearly defined. At the end of the cell in the middle of the wing is a short, black, longitudinal streak; below this on the dorsal edge is a small black spot, and on the costal edge are two similar black spots, one at the apical third, the other just before apex. Cilia white, speckled black, and fuscous. Hind wings light silvery fuscous; cilia a shade lighter than wing; male without costal hair pencil.

Abdomen dark fuscous, anal tuft silvery gray; legs white, with black annulations; hairs on posterior tibia silvery white. Alar expanse, 12 mm.

The species is very near the other fuscous species of the genus and is easily confused with *Recurvaria cristatella* Chambers, but besides minor colorational variations, it differs in the lack of the hair pencil at the base of the hind wings in the male.

THE LARVA.

In the larva (Pl. II, fig. 5) the usual characters of Gelechiidæ are exhibited. Up to the time of hibernation the young larvæ are light reddish brown, with the head, a plate on the second segment, a small plate on the anal segment, and the upper surface of the legs vandyke brown. Soon after issuing from their hibernacula in the spring they lose the anal plate, and as they reach their full growth many of them turn from brown to pale green, while others exhibit various shades between the two. This color variation of the larva has no effect on the appearance of the moth, for both brown and green larvæ have been isolated and reared, resulting in adults of a uniform type.

The larva shortly after hatching measures a little over 1 mm., or about one-twentieth of an inch, in length. It grows slowly and at the time of hibernation measures from 2.1 to 2.6 mm., and when full grown from 8 to 10 mm., or about three-eighths of an inch, in length.

THE PUPA.

The pupæ (Pl. II, fig. 2) shortly after the transformation takes place vary in color from brown to green, as do the larvæ; in a few days, however, they all turn brown. They measure 4 or 5 mm., or three-sixteenths of an inch, in length.

LIFE HISTORY AND HABITS.

ADULT STAGE.

The first moths (Pl. II, fig. 6) issued in rearing cages at Benton Harbor, Mich., on June 22. Some individuals may have emerged in the orchards before this date, for they were found there in considerable numbers on June 23. In the rearing cages the maximum emergence took place on June 30, and the last moths to appear issued on July 10; the period of emergence thus covered 19 days. In Table I is given the record of the emerging moths in cages in the rearing shelter and the emergence of hymenopterous parasites of the larvæ. The total number of adults that issued was 383; of larval parasites, 14.

TABLE I.—*Record of emergence of adults and larval parasites of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913.*

Date of emergence.	Number of moths.	Number of larval parasites.	Date of emergence.	Number of moths.	Number of larval parasites.
June 22	5	0	July 2	13	0
23	10	0	3	35	0
24	12	2	4	11	0
25	17	4	5	0	0
26	21	6	6	1	0
27	36	2	7	0	0
28	64	0	8	2	0
29	47	0	9	0	0
30	65	0	10	2	0
July 1	42	0	11	0	0

In figure 1 this record of the emergence of the adults is graphically shown.

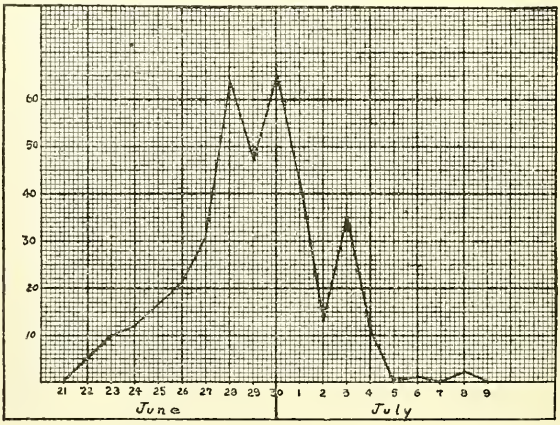


FIG. 1.—Graphic representation of time and relative emergence of adults of the lesser bud-moth in rearing cages at Benton Harbor, Mich. (Original.)

During the first few days of emergence the number of males issuing was greatly in excess of the females; toward the last of the period, however, the reverse was true. Table II shows the proportion of males and females as they issued on successive days.

TABLE II.—*Relative number of males and females of the lesser bud moth issuing in rearing cages at Benton Harbor, Mich., in 1913.*

Date.	Number of males.	Number of females.	Date.	Number of males.	Number of females.
June 24	20	4	June 30	7	15
25	12	3	July 1	3	4
26	10	4	2	6	13
27	12	14			
28	16	17	Total	97	103
29	11	29			

In the field the moths were found in large numbers resting on the trunks of the trees. They remained motionless until touched, and even then often flew only a short distance, taking a new position on the same trunk. As many as 15 were counted on the shady side of the trunk of a small Kieffer pear tree. However, the insects did not confine themselves to the trunks of the trees alone, but were occasionally found resting upon near-by weeds or upon the branches and, in a few cases, upon the leaves.

All attempts to feed the moths in captivity failed. They apparently refused to taste the brown-sugar sirup offered them. Nor were attempts to obtain eggs in confinement more successful, as the insects would not oviposit under the unnatural conditions of the rearing cage.

EGG STAGE.

Although a most diligent search was made for the eggs of the lesser bud-moth, no trace was found of them. This failure is in a measure due to the fact that nothing of the habits of the insects was at that time known to us. The adults were seldom observed anywhere except at rest on the tree trunks, although without doubt they deposit their eggs on the underside of the leaves singly, as evidenced by the location of the entrance opening to the leaf mines. Eggs in the egg tubes of the females were observed when dissected, but nothing of their appearance after oviposition could be surmised.[1]

LARVAL STAGE.

It is in the larval stage that *Recurvaria nanella* spends most of its life. In Benton Harbor the eggs commenced hatching about July 15. The larvæ at this time are very small, measuring scarcely more than 1 mm. in length. They at once bore through the epidermis of the leaf on the underside and commence the construction of a most curiously shaped mine in the inner tissues of the leaf. (See Pl. II, fig. 1.)

The larva first eats its way in a small circle, then constructs a main burrow which soon divides, the branches in turn again dividing, often after the manner of the branching of a tree. The form of these mines, however, is by no means regular, but shows considerable diversity. The insect does not finish the construction of any branch of the mine at once, but feeds at will in all parts, keeping the whole

[1] As this paper is going to press, specimens of eggs of the lesser bud-moth have been received from Mr. E. H. Siegler, of the Bureau of Entomology, who has been successful in obtaining them from moths confined in glass jars, at Benton Harbor, Mich. Some of the eggs received had been loosely deposited among the hairs on the underside of an apple leaf, singly or several sticking together, for the most part along the veins of the leaf. Another lot had been deposited on a twig under the edge of a small scale. The egg is oblong, inclined to be cylindrical, though irregularly so, and is flattened where it comes in contact with another in the cluster. It is minute in size, measuring about 0.32 mm. long by 0.2 mm. broad, and is pale, shining yellow in color.

mine open and ejecting all excrement at the point of entrance. Thus, if the larva, which can be seen through the epidermis, be disturbed, it will rapidly crawl to another part of the mine; and if followed, will escape at the entrance hole.

The larvæ show no preference as to the point of entrance, eating their way into the leaf tissues at any point from the midrib to the edge.

One or many mines may be constructed in a single leaf, according to the degree of infestation. Where the insects are numerous, the mines form a network covering the leaf. It is evident that the adult female in depositing her eggs lays a number at one time on adjacent leaves, as the mines usually appear in groups, several affected leaves occurring on the same twig or neighboring twigs.

Upon the arrival of the first cold days of fall the larvæ begin leaving the mines to construct the small silken hibernacula in which they pass the winter. The desertion of the leaf mines commenced about September 12 (1913), the temperature showing the first considerable drop of the season at that time. By September 17 practically all the larvæ had disappeared from the mines. However, upon picking off small pieces of loosened bark, or lifting up old bud scales, the larvæ were discovered spinning the minute cocoons which were to be their winter shelter.

No preference was shown in the selection of a place for hibernation, the larvæ taking possession of the first available protection. On large trees they confine themselves to the twigs and smaller branches, but on small trees they may be found in abundance on the larger limbs and trunk. The hibernating larvæ on large trees, even where the infestation is severe, are difficult of location, being very small and inconspicuous. However, after a few warm days in the spring the larvæ begin to appear in great numbers, as if spontaneously.

As the weather warms and the buds on the fruit trees swell, one may discover, upon close observation, minute masses of reddish or greenish pellets upon the buds. This is the excrement which the larva within has deposited at the entrance to its burrow (Pl. II, figs. 3 and 4).

The first larvæ at Benton Harbor were observed working in the buds in considerable numbers on April 15, when the buds were just beginning to swell. They probably began emerging in small numbers one or two days before.

The insect appears to show little preference as to the point of its attack on the bud, for it enters either at the side or at the tip. As a rule those entering at the side do so just at the edge of the bud scales, although sometimes one will pierce the scales themselves. In a few cases larvæ were noted entering buds which had not begun to swell, but which were still in a dormant state. Over the entrance to the burrow the caterpillar spins a fine netlike web. The larva burrows to the center of the bud both by means of eating its way, the material passing through its alimentary canal, and by biting off bits and carrying them to the outside. The latter method is used when the insect is piercing the tough outer layers of the bud.

Should the temperature drop after a warm day has tempted the caterpillars to come out of hibernation, but before they have had the opportunity to enter a bud, they will seek shelter under loose bark on the limbs. Many larvæ were found under the bark on April 16, but by April 23 all had apparently entered buds.

As before mentioned, the larva upon entering a bud makes its way directly to the center, there feasting on the tender ovary of the unopened flower, provided the insect has entered a flower bud, which the majority do. It is this habit which does the greatest amount of injury (Pl. I, fig. 1), for often every bud on a large limb will be affected. After consuming the inner portions the larvæ feed upon the leafy tissue of the bud, remaining within until the bud expands and the leaves begin to unfold.

As the first leaves open out, the larva fastens them together, spinning its fine strand of silk as it crawls about (Pl. I, fig. 2). It now constructs for itself a shelter or cocoon of silk, often rolling over the edge of a leaf and constructing it from within, or bringing the tips of several leaves together and spinning it in the midst, or making a combination of the two methods. As a rule, the larvæ during the day are to be found at rest within this cocoon, giving evidence for the supposition that the insects are nocturnal feeders.

On May 15 it was noticed that some of the nests in the leaves were empty, and by the next day a large percentage of the larvæ had disappeared. However, a search revealed the caterpillars under bits of loose bark on the limbs and trunk constructing cocoons in which to pupate (Pl. II, fig 5). On large trees where there is a great deal of roughened bark the cocoons are difficult to locate, but on smaller trees they will be found clustered in the crevices on the trunk; this is especially true on young pear trees, where most of the bark is smooth, affording the insects no shelter. A search among the leaves and débris on the ground beneath the trees revealed a few larvæ transforming in the shelter there afforded.

The last crawling larvæ in the orchard were found on June 19. Thus the larval stage covers an average period of about 10 months.

The number of molts of the larva was not accurately determined, the only data taken on this subject being measurements of the width of the head taken at successive intervals during the development of this stage of the insect. These measurements, arranged numerically, are given in Table III. It is not the writers' opinion that these figures show definitely the number of molts, but they are presented merely for what they are worth. However, a study of Table III seems to warrant the interpretation that there are five instars, or four larval molts. In the last instar considerable variation in the width of the head will be noticed, but as this same variation is found among full-grown larvæ taken from their cocoons, they are all considered as belonging to the same stage.

TABLE III.—*Measurements of width of head of larvæ of the lesser bud-moth taken at intervals throughout their development at Benton Harbor, Mich., in 1913.*

Date.	Width of head.	Stage.
	Mm.	
July 29 (just hatched)	0.12	First instar.
	.12	
	.12	
	.14	
	.15	
	.15	
	.16	
	.16	
	.16	
	.16	
	.16	
August	.16	
	.16	
	.16	
	.16	
	First molt.	
	.19	Second instar.
	.19	
	.19	
	.19	
	.20	
	.21	
	.21	
	.21	
	.21	
	Second molt.	
	.245	Third instar.
	.245	
	.25	
September	.26	
	.275	
	.275	

Date.	Width of head.	Stage.
	Third molt.	
	Mm.	
	0.31	Fourth instar.
	.31	
April 8 (in hibernation).	.34	
	.35	
	.36	
	.36	
	.38	
	.38	
April 18 (in buds)	.38	
	.41	
	.41	
	.43	
	.43	
	.48	
	Fourth molt.	
	.56	Fifth instar.
	.57	
	.57	
	.59	
	.60	
	.62	
	.62	
	.64	
	.64	
	.64	
	.66	
	.86	
	.96	
	1.12	
	.60	
May 27 (in cocoon)	.64	
	1.02	

PUPAL STAGE.

The first pupæ (Pl. II, fig. 2) of the lesser bud-moth were found on May 18 under the loose bark on the trunks of young peach trees, incased in their small, white, silken cocoons. The last larvæ to pupate in the rearing cages did so on June 16. The average time spent as a pupa is about 19 days, varying, however, from 15 to 30 days.

Table IV is a record kept of isolated larvæ, giving dates of pupation and of emergence as adults.

TABLE IV.—*Pupation and emergence record of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913, showing number of days spent as pupæ.*

No. of observation.	Date of—		Days.	No. of observation.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	June 2	June 25	23	19	June 12	June 30	18
2	June 3	June 27	24	20	June 14	...do...	16
3	...do...	...do...	24	21	...do...	...do...	16
4	...do...	July 3	30	22	...do...	...do...	16
5	June 6	June 27	21	23	...do...	...do...	16
6	...do...	...do...	21	24	...do...	July 1	17
7	...do...	...do...	21	25	...do...	July 3	19
8	...do...	...do...	21	26	June 16	July 1	15
9	...do...	...do...	21	27	...do...	...do...	15
10	...do...	June 28	22	28	...do...	...do...	15
11	...do...	...do...	22	29	...do...	July 2	16
12	June 9	June 27	18	30	...do...	...do...	16
13	...do...	June 26	17	31	...do...	July 3	17
14	...do...	June 28	19				
15	June 10	...do...	18	Average			18.9
16	...do...	...do...	18	Maximum			30
17	...do...	...do...	18	Minimum			15
18	June 12	June 30	18				

INSECT ENEMIES.

The following hymenopterous parasites, representing six families and seven genera, were reared from *Recurvaria nanella*, from material collected in the larval and pupal stages, and confined in breeding jars. Braconidæ: *Phanerotoma recurvariæ* Cushman; Ichneumonidæ: *Diadegma* sp. and *Itoplectis* sp.; Pteromalidæ: A broken, undetermined specimen; Encyrtidæ: *Eupelmus* sp.; Eurytomidæ: *Eurytoma* sp.; Chalcididæ: *Dibrachys* sp.

EXPERIMENTS IN CONTROL.

EXPERIMENT I.—A young apple orchard at Benton Harbor, Mich., was used for experimental spraying against the lesser bud-moth. This orchard consisted of 50 trees of the Oldenburg (*Duchess*) variety about 9 years old. Early in the spring, before the buds began to swell, the trees were examined and numerous hibernating larvæ were found under the loose bark, the infestation appearing uniform over the entire orchard. The orchard was divided into eight plats, each plat consisting of not less than eight trees. The material was applied with a hand barrel sprayer equipped with Vermorel nozzles. The results were determined by actual count of all infested and uninfested fruit and leaf buds from five trees of each plat, 10 days after the blossoming period. The results are shown in Table V.

TABLE V.—*Spraying experiments against the lesser bud-moth on apple, Benton Harbor, Mich., 1913.*

Plat No.	Treatment.	Number of buds infested.	Number of buds sound.	Total number of buds.	Total percentage of sound buds.
I	One application of commercial lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	1,638	7,534	9,172	82.14
II	One application of soda-sulphur solution (1 lb. to 5 gals. of water) on Apr. 8. Trees dormant	680	4,228	4,908	86.14
III	One application of unfiltered lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	924	5,918	6,842	86.49
[1] IV	Two applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, and on May 1, when cluster buds opened	956	7,019	7,975	88.01
[1] V	Three applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, on Apr. 24, when cluster buds were half open, and on May 1, when cluster buds were open.	523	8,006	8,529	93.86
VI	Check (unsprayed)	4,949	4,129	9,078	45.48

[1] Lime-sulphur solution, 1½ gallons to 50 gallons of spray, was added in the last application in plats IV and V, mainly for the control of apple scab.

As will be noted, the best results were obtained on Plat V, where three applications of arsenate of lead were used. In this case the buds were kept covered with poison, so that the larvæ had little chance to gain entrance into them. The next best results were obtained where two applications of arsenate of lead were used. However, the application of the lime-sulphur and the soda-sulphur solutions when the trees were dormant, both used at the strength recommended for the San Jose scale, were almost as effective as the arsenate of lead. The action of the sulphur compounds on the larvæ is not known, but they probably act largely as repellents.[1] The larvæ were examined in their hibernacula at various intervals from the time the application was made until they came out to enter the buds, and in all cases they were found unhurt and untouched by the spray. However, this was expected, since their hibernacula were protected from the spray by the loose bark under which they were hidden. Then, too, the hibernacular cases are of such construction that they can not be easily penetrated by spray. When the larvæ emerged, they disappeared, either having been repelled from the tree or killed by the action of the sulphur sprays subsequent to their emergence.

Almost the entire crop of fruit on the check trees was lost on account of the work of the larvæ, there being less than half a dozen apples on each tree, while the crop was unhurt on the sprayed trees.

EXPERIMENT II.—An apple orchard of the Rhode Island Greening variety, consisting of 120 trees about 40 years old, belonging to Mr. W. H. Woodruff, Benton Harbor, Mich., was also used for ex-

[1] Lime-sulphur solution was found to act as a strong repellent against certain other lepidopterous larvæ in other experiments conducted during the season.

perimental spraying against the lesser bud moth in 1913. Previous to that year the orchard had been badly neglected, not having been cultivated, pruned, or thoroughly sprayed for several years. The owner reported that no crop had been harvested from the orchard during the preceding eight years, although it is not known that this was due to the work of the lesser bud moth. However, last season it was noted by the senior author that almost every bud was infested with this insect, resulting in a total loss of the crop. The experimental spraying was done with a gasoline-power sprayer equipped with nozzles of the Vermorel type. The orchard was divided into six plats, each containing not less than 14 trees. The treatments and dates of application are shown in Table VI.

TABLE VI.—*Treatments and dates of applications of sprays for the lesser bud-moth, Mr. W. H. Woodruff's apple orchard, Benton Harbor, Mich, 1913.*

Plat No.	Treatment at—		
	First application, Apr. 7. (Trees dormant.)	Second application, Apr. 12. (Buds swelling.)	Third application, Apr. 29. (Cluster buds open.)
I	Lime-sulphur solution (1 : 8)	None	None.
II	Lime-sulphur solution (1 : 8)	None	Lime-sulphur solution (1½ : 50).
III	Soluble-oil solution (1 : 15)	None	Do.
IV	Blackleaf 40	None	Do.
V	None	Arsenate of lead (2 : 50)	Lime-sulphur solution (1 : 50) and arsenate of lead (2 : 50).
VI	Check (unsprayed)		

As the trees in this orchard were too large for counts to be made of the infested and uninfested buds, the results were determined only by observation and by comparing the amount of the fruit that set on the sprayed and unsprayed trees. While the infestation was not as heavy in this orchard this year as last, the larvæ were numerous enough materially to affect the crop, and at the time of blossoming quite a contrast could be noted between certain sprayed plats and the unsprayed plat.

Entirely satisfactory results were obtained on Plat I, which received only an application of lime-sulphur solution at the rate of 1 gallon to 8 gallons of water when the trees were in the dormant state. Only a few larvæ could be found on these trees at blossoming time, and there was practically no loss of fruit from their work, the trees bearing a good crop. Plat II received the same treatment, with the exception of an additional application of lime-sulphur solution at the rate of 1½ gallons to 50 gallons of water when the cluster buds opened. The results were the same as on Plat I. Plat III, sprayed in the dormant state with soluble oil at the rate of 1 gallon of the oil to 15 gallons of water, and Plat IV, receiving a dormant application of blackleaf 40 at the rate of 1 gallon of this insecticide to 800 gallons of water, gave no noticeable results. Both of these plats received an application of lime-sulphur solution at the rate of $1\frac{1}{2}$ gallons to 50 gallons of water when the cluster buds opened, chiefly for the purpose of controlling apple scab. Plat V received two applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water when the buds were swelling and when the cluster buds opened. The results on this plat were satisfactory, being practically the same as where the dormant application of lime-sulphur solution was used.

More than 50 per cent of the fruit buds on the unsprayed trees were infested with the larvæ, and the trees set less than half a crop of fruit.

Observations were made throughout the vicinity of Benton Harbor, Mich., to determine the extent of infestation of the lesser bud moth. It was noted that practically all unsprayed apple and peach orchards were badly infested, while all apple orchards which were thoroughly sprayed for the San Jose scale in the dormant state and followed up by later sprayings were free from infestation. No apple orchards were found which received only the dormant application, so that the effect of this one spraying could not be determined. However, the peach orchards in this section are sprayed with lime-sulphur late in the spring, just before the buds open, for control of the San Jose scale and leaf-curl, and in only a few cases do they receive any other application of spray. In these orchards, which receive only the dormant application of the lime-sulphur solution, the lesser bud-moth is thoroughly controlled, while unsprayed peach orchards are moderately to badly infested.

RECOMMENDATIONS FOR CONTROL.

The foregoing experiments, as well as general observations made throughout the infested section at Benton Harbor, Mich., show that the lesser bud-moth can be controlled by thoroughly spraying the trees in the dormant state with lime-sulphur solution at 32° Baumé used at the rate of 1 gallon to 8 gallons of water. Lower testing material should be used at increased strengths. The spraying should be done just before the buds swell, or preferably when the buds are swelling. This treatment is especially to be recommended, as it involves no extra application where it is necessary to spray during the dormant season for other insects, such as the San Jose scale, oyster-shell scale, scurfy scale, and blister-mite, and for the peach leaf-curl.

In cases where it is not expedient to use the lime-sulphur solution two early applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water should be made. This should be applied first when the buds are swelling and again when the cluster buds open. This latter application coincides with the first apple-scab treatment. In case of a bad infestation it would be advisable to make another application of arsenate of lead when the buds are half open or bursting. It should be borne in mind that thorough control of this insect by use of an arsenical necessitates keeping the buds covered with poison as nearly as possible from the time they begin to swell until they are open.

LITERATURE CITED.

1776. SCHIFFERMÜLLER, I. Systematisches Verzeichnis der Schmetterlinge der Wiener Gegend, Wien, 1776.

Original description of *Tinea nanella*, C. 68. Original description of *Euota pruniella*, C. 75.

1794. FABRICIUS, J. C. Entomologia Systematica, v. 3, pt. 2, Hafniae, 1794.

Original description of *Tinea aleella*, p. 317.

1796(?) HÜBNER, JACOB. Tineæ, pl. 39, fig. 267.

Figures *Tinea nanella* Schiff., fig. 267; figures *Euota pruniella* Schiff., fig. 175.

1816. HÜBNER, JACOB. Verzeichniss Bekannter Schmetterlinge, Augsburg, 1816.

Lists *Trichotripis nanella* Schiff., p. 425, No. 4143; lists *Euota pruniella* Schiff., p. 408, No. 3930.

1827. CURTIS, J. British Entomology, v. 4, London, 1827.

Lists *Anacampsis nana* from Haworth's MSS., No. 189.

1829. HAWORTH, A. H. Lepidoptera Britannica, v. 4, London, 1829.

Gives *Tinea nanella* Hüb. and *Tinea aleella* as synonyms of *Recurvaria nana* Haw., p. 554.

1829. STEPHENS, J. F. A systematic catalogue of British Insects, pt. 2, London, 1829.

Gives *Tinea nanella* Hüb. and *Recurvaria nana* Haw. as synonyms of *Anacampsis aleella* Steph., p. 197, No. 7214.

1834. STEPHENS, J. F. Illustrations of British Entomology. Haustellata, v. 4, London, 1834.

Noted in gardens on trunks of apple trees in June, p. 215.

1853–1855. HERRICH-SCHÄFFER, G. A. W. Systematische Bearbeitung der Schmetterlinge von Europa, v. 5, Regensburg, 1853–1855.

Lists as *Gelechia nanella* Hüb., p. 167, No. 416.

1854. STAINTON, H. T. Insecta Britannica. Lepidoptera: Tineina, London, 1854.

First account of habit of larva of feeding on pear, p. 129.

1854. WOOD, WILLIAM. Index Entomologicus, London, 1854.

Noted as common in gardens near London in June, p. 176, fig. 1213.

1870. HEINEMANN, H. VON. Die Schmetterlinge Deutschlands und der Schweiz. . . . Zweite Abteilung, Kleinschmetterlinge, Bd. 2., hft. 1, Braunschweig, 1870.

Description of *Recurvaria nanella*, p. 280, No. 417.

1871–72. RÖSSLER, A. Beobachtungen über einige in Gärten vorkommende Kleinschmetterlinge. Jahrb. Nassau. Ver. Naturk., Jahrg. 25/26, p. 424–425, 1871–72.

Describes larvæ attacking fruit trees in large numbers.

1895. MEYRICK, E. A handbook of British Lepidoptera, London, 1895.

Description of adult and larva of *Aphanaula nanella*, p. 580.

1901. STAUDINGER, O., and REBEL, H. Catalog der Lepidopteren des Palaearctischen Faunengebietes, 3. aufl. des. Cataloges der Lepidopteren des Europäischen Faunengebietes, Berlin, 1901.

Distribution of *Recurvaria nanella*, pt. 2, p. 155, No. 2874.

1903. BUSCK, AUGUST. A revision of the American moths of the family Gelechiidæ. Proc. U. S. Nat. Mus., v. 25, p. 767–938, 1903.

Description of *Recurvaria crataegella*, p. 811.

1903. HOUGHTON, J. T. Contribution to the life-history of *Gelechia* (*Recurvaria*) *nanella*, Hb., from an economic point of view. Ent. Mo. Mag., v. 39 (ser. 2, v. 14), p. 219–221.

Most complete account of life-history of the species.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 114

Contribution from Office of Experiment Stations, A. C. True, Director.
July 13, 1914.

(PROFESSIONAL PAPER.)

REPORT UPON THE BLACK AND BOGGY SWAMPS DRAINAGE DISTRICT, HAMPTON AND JASPER COUNTIES, S. C.

By F. G. Eason, *Drainage Engineer.*

INTRODUCTION.

While in some respects all the swamp lands of the Atlantic Coastal Plain are alike, the problems to be met in draining the lands differ somewhat from one section to another. In Georgia and the Carolinas are many areas that have little slope as a whole, but in detail are somewhat rolling. From the higher parts, scattered among the flat open woodlands and the timbered bays and branches in which water stands the greater part of the year, the timber has been cleared and small farms have been established. The watercourses, which are broad, shallow, winding depressions, with no marked channel, are usually filled with growing timber and thick underbrush.

The topographical conditions require that these lands be drained in units of considerable size, necessitating the cooperation of many landowners. In order that a few owners may not prevent a greater number from reclaiming their wet lands, when the few can not be excluded from the district to be formed, most States have passed general laws providing for the organization of drainage districts and an equitable distribution of the cost. In accordance with such a statute enacted in 1911 by the Legislature of South Carolina, the Black and Boggy Swamps drainage district was organized in March, 1912.

Because the Black and Boggy Swamps drainage district is in many respects typical of other areas in the same and bordering States, and because it is the first district organized under the above law, and as the landowners are naturally cautious about beginning an unfamiliar kind of undertaking, Drainage Investigations of the Office of Experiment Stations, United States Department of Agriculture, at the request of the landowners and in cooperation with them, made a

Note.—This paper is intended for engineers and others interested in drainage enterprises in regions where the conditions are similar to those here described; it is suitable for distribution in the South Atlantic States.

survey of the district and prepared plans of the work to be done, together with an estimate of the cost. The survey was begun in August, 1912, and field work was completed in November of the same year. The following report presents a description of the district and of the drainage plan and a brief discussion of the problems involved in such reclamation.

GENERAL DESCRIPTION.

LOCATION.

Black and Boggy Swamps drainage district is located about 75 miles west of Charleston, S. C., 40 miles north of Savannah, Ga., and 100 miles south of Columbia, S. C., in the southern part of Hampton County and the western part of Jasper County, S. C. (See fig. 1.) It includes all the lands drained by Boggy Swamp and Black Swamp, together with the lands in the vicinity of Garnett that are drained by Church Branch, Hog Branch, and King Branch, all extending as far down as high water from the Savannah River; the area is 67,642 acres, or about 106 square miles. In shape the district is approximately a rectangle, 12 miles long northwest and southeast, and 9 miles wide. The Seaboard Air Line Railway and the Columbia-Savannah line of the Southern Railway traverse the district in a northerly and southerly direction, and on these railroads are situated the principal towns in the district, Scotia, Garnett, Furman, and Pineland. Other towns and settlements in the district are Brighton, Shirley, Robertville, Lawtonville, Staffords, and Goethe.

TOPOGRAPHY.

The district is situated 40 to 50 miles from the Atlantic Ocean, and thus lies within the Coastal Plain. There are in the neighborhood, including the Black and Boggy Swamps district, three distinct benches or levels paralleling the Savannah River. First, the river swamp proper; second, a higher level subject to occasional overflow, known locally as "savannas"; and third, the general elevation of lands in the district under consideration. The north, east, and west boundaries of the district are formed by natural watershed lines, but no such natural boundary occurs on the south. The general elevation of the lands in the southern part of the district east of the Seaboard Air Line Railway varies from 50 to 70 feet above sea level until the second bench from the river is reached, where it suddenly falls off about 25 feet. The foot of this slope has been determined upon as the district boundary. The southern part of the district west of the Seaboard Air Line Railway is much flatter and no decided slope is evident, the land rising gradually from the second to the third level, so that the southern boundary of the district should be more accurately established than has yet been done. It should be the limit of high water from the Savannah River.

The general slope of the ground is southward toward the coast and westward toward the Savannah River, which is the outlet for all of

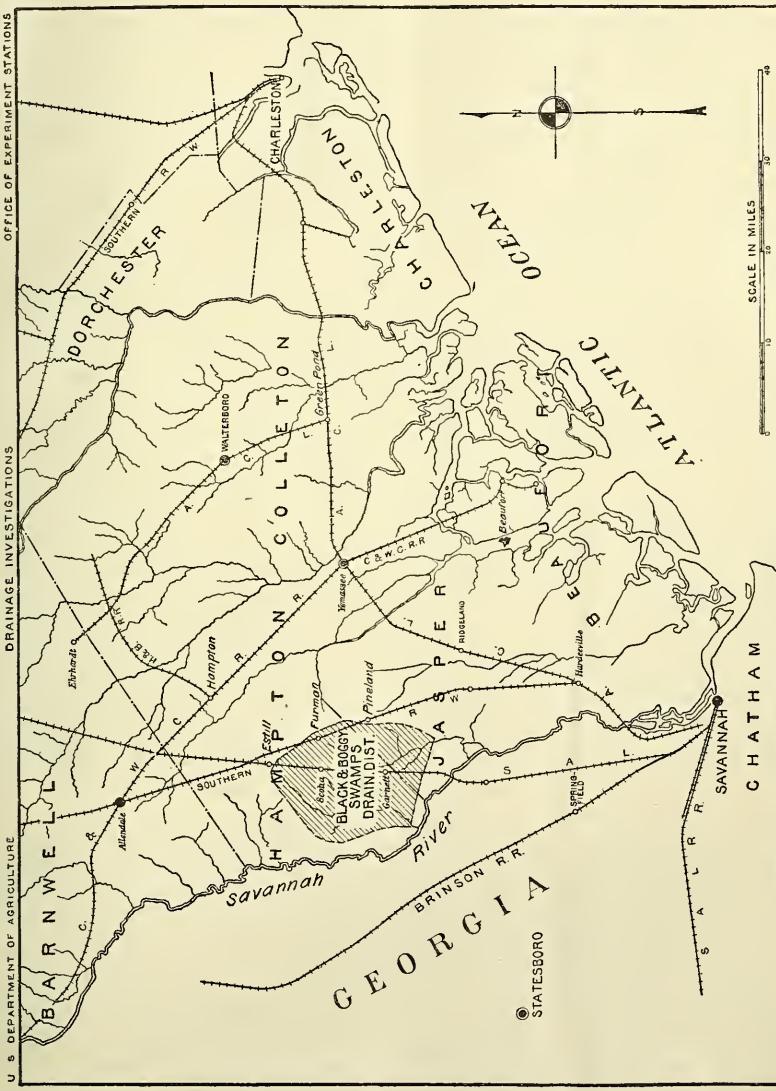


Fig. 1.—Map showing location of Black and Boggy Swamps drainage district.

the drainage of the district. The northern or upper end of the district is much more rolling and hilly than are the southern and western ends. The topography north of Shirley, Scotia, and Furman (see fig. 2) is very irregular, there being considerable stretches of high land now under cultivation, broken by large areas of flat bays and swamps of much lower elevation. These bays usually are the headwaters of the various branches which flow southerly through the district. Practically all of the land in the upper section of the district that can be cultivated under present conditions is now being farmed; the remainder is composed almost entirely of these flat bays and branches, notable examples of which are Rogers Bay, Steep Bottom Bay, Alligator Bay, Green Pond, and Roberts Pond. The section between Scotia, Shirley, and Garnett is much flatter and of an entirely different conformation. This area is a relatively high plain, with marked slopes on three sides to Wolf Bay, Long Branch, Church Branch, Hog Branch, King Branch, Manigault Branch, Hurricane Branch, and Beaver Dam Branch No. 1. In it are found large areas of flat, open pine woods, containing standing water a good portion of the year. The area is badly in need of drainage. The wet condition is due to the lack of proper drainage connection between the shallow depressions on this plain and the branches which surround it. The drainage in the southeastern part of the district is good, owing to the rolling nature of the lands and the large fall from them to the branches.

The western portion of the district, particularly the area west of the Augusta Road, is different from the other parts and should be described separately. There is in the extreme western part a large area called Haskell Baroney Swamp, which is formed by the junction of The Savannas, Rum Branch, Mill Branch, and Boggy Swamp. Haskell Baroney Swamp is about 3 miles long north and south and about 2 miles wide; it is a continuous, flat swamp, much below the general level of the adjoining lands. Between the swamp and the Savannah River is a clay ridge (see fig. 2), the top of which forms the western boundary of the district. There are several breaks in this ridge, and during extreme floods water has been known to flow from the Savannah River through these breaks into the head of "The Savannas," thence through Boggy Swamp back into the river.

The eastern portion of the district is also quite flat, and large areas of flat bays are encountered, especially in the southeastern part, from Robertville toward Pineland, and the watershed is not clearly defined. Many years ago a ditch was constructed which flows into Titi Branch and drains an area in the vicinity of Pineland. To follow the natural course of drainage this land would not be drained northwest to Titi Branch but southeast to Cypress Creek, which stream is not in the district. The present course of drainage is unnatural, and these lands have therefore been excluded from the district.

There are several ponds in the district which, owing to their depth, can not be drained by gravity, but must remain undrained unless pumping is resorted to. The general location of these ponds is the flat land between Scotia and Shirley, but the total area is only a few acres.

The highways of the district are the usual dirt roads, but they have been improved recently by the county and are now in very good condition.

WATERSHEDS.

There are two distinct primary watershed areas in this district, drained respectively by Boggy Swamp and Black Swamp, which are in turn divided into various secondary watersheds drained by the tributary branches or swamps. In addition to the two main watersheds with their tributaries there is included within the district a section of land in the vicinity of Garnett drained by Church Branch, Hog Branch, and King Branch. These branches flow down into the second level of overflowed lands bordering the Savannah River and form what is known as the "Pallachucolla Savannas," which empty farther down into Black Swamp. Thus, while they are in reality tributaries of Black Swamp, they will require separate handling so far as this project is concerned. Similarly, Scott Swamp No. 1, south of Robertville, and two small areas farther west must be considered separately. Black Swamp and its tributaries drain 18,490 acres, Boggy Swamp and its tributaries drain 36,693 acres, and the independent watercourses drain 12,459 acres.

These watershed areas are for the most part fairly rolling, although the portion of the district west of the Augusta Road and that part between Scotia and Garnett are quite flat. The higher and more rolling lands are cultivated to some extent at present, as they have very fair natural drainage, which is aided by some farm drainage; but even on those lands crops fail in wet years, showing the need of a general system of drainage. The swamps and the flatter areas are mostly covered with timber, which is being rapidly cut off by lumber companies.

DRAINAGE CHANNELS.

There is no lack of drainage channels in Black and Boggy Swamps district, yet drainage conditions are bad. The situation is due primarily to two causes—(1) lack of suitable drainage connection between the wet, flat areas and the drainage channels or branches, and (2) the inability of the drainage channels to remove the water after it has reached them. The two main drainage channels for the district are Boggy Swamp and Black Swamp, the former serving the northern and western parts of the district, the latter serving the eastern part, and both finally emptying into the Savannah River, the outlet for all of the water from this district. There are numerous smaller branches or swamps tributary to these, which reach out to the different parts of the district, and which are the outlets for the drainage from their respective watersheds. A general description of these channels will suffice for this discussion, since they are all similar in character and differ only as to size.

In general, the drainage outlets are low, flat branches or swamps, varying in width from 50 to 1,500 feet and having in most instances no discernible channel or "run." Where a branch has a run of appreciable size, the latter will almost invariably be found so choked with fallen logs and trees, bushes, and all manner of débris, as to afford but a poor channel for the water. The branches are overgrown with thick underbrush and water-loving trees, such as cypress, gum, maple, and ash, through which the water finds its way but slowly There being in most places no channel, the water covers the ground from hill to hill, and the swamps, therefore, can not be cultivated. Where the adjoining land lies but little above the level of the swamp it also is affected to a great extent by this water, which seeps the land and thus keeps it wet and sour. While cleaning out these swamps would undoubtedly help conditions considerably, this alone will not give satisfactory drainage, which can result only from lowering the water table by the construction of deep ditches. These swamps are almost continually wet, and in most seasons contain standing water. However, with the exception of those near the Savannah River, they all have large fall and can easily be drained. The bays and ponds where most of these branches have their rise are very flat, and for this reason will be much more difficult to drain.

In places throughout the district ditches have been dug in these branches, and much good has resulted from them. Hurricane Branch and Hog Branch have been improved in this manner, and little additional work on them is necessary, the swamp often being under cultivation right up to the edge of the ditch. These are exceptions, however, and comparatively little work of this character has been done. After having been constructed, these ditches have not always been maintained, and consequently have filled up and fallen into disuse.

SOIL AND CROPS.

The predominating soil of the district is a light sandy loam underlain by a reddish to yellow clay subsoil at depths of 4 to 18 inches. This is the type most generally cultivated in the district at this time. The soil on the flat "piney woods" land is composed of a grayish clay, which is extremely tenacious and is difficult to drain on account of its compact nature. Toward the Savannah River the sandy soil changes to a red clay, which can be seen outcropping in places. The soil of the bays, swamps, and branches is a heavy black muck, several feet thick, which in most places is underlain by a clay, but in some of the bays by a sandy subsoil. While the ditches planned are to be located almost entirely in the muck soil of the swamps and branches, they are to furnish drainage outlets for all the district, as all the soil types need drainage, though the need is not so great for the loam soil as for the others.


Fig. 2
U S DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS
MAP OF
BLACK AND BOGGY SWAMPS DRAINAGE DISTRICT
HAMPTON AND JASPER COUNTIES, S.C.
Showing proposed drainage channels
Prepared to accompany a report upon the drainage of the district by
F. G. Eason, Drainage Engineer
Under the direction of
S H McCrory, Chief of Drainage Investigations
1913
SCALE IN FEET
Magnetic
N
LEGEND
Proposed Ditches
District Boundary
Surface Elevations
Bench Marks
Roads
Watershed Line
Edge of Swamp
High Water Line
Goethe
Furman
Scotia
Shirley
Brighton
Garnett
Pineland
Stafford Cross Roads
Robertville
Roberts Pond
Good Hope Church
Hamilton Ridge Club
BOGGY SWAMP
BLACK SWAMP
Rogers Bay
Beaver Dam
Savannah River Swamp
Second Level (occasionally overflowed by Savannah River)
SEABOARD AIR LINE RR
SOUTHERN
HAMPTON
JASPER
COUNTY
TOWN LIMITS
J. G. HAMFORD DEL.

Fig. 3

U. S. DEPARTMENT OF AGRICULTURE — OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

BLACK & BOGGY SWAMPS DRAINAGE DISTRICT

HAMPTON-JASPER COUNTIES, S. C.

Profiles of Proposed Black Swamp and Boggy Swamp Ditches

SURVEYED 1912

F. G. Eason, Drainage Engineer

SEA LEVEL DATUM

The principal industry of the people of the district is farming; but only a small part of the land available for this purpose is now being utilized, due to the sparsely settled condition. The chief money crop of the district is cotton, and the greater part of the acreage under cultivation is planted to it. The other crops grown are principally corn, oats, hay, and watermelons. Labor conditions in the district are not of the best, but notwithstanding this drawback very good crops are obtained, due to intelligent methods of cultivation and fertilizing. The growing of truck crops might become very profitable by the utilization of artesian water for irrigation. There are already a number of these wells scattered over the district, all of which are bold, flowing wells from 900 to 1,000 feet deep.

THE SURVEY.

The survey was made from camp by a party under the direction of F. G. Eason. Field work was begun August 2, 1912, and completed November 14, 1912. The principal roads of the district were traversed by compass and stadia, ground surface elevations being taken at intervals of about 500 feet. All the branches, swamps, and watercourses were meandered by stadia and compass, and sufficient elevations were taken in them to secure the data necessary for the proper location of the ditches. Levels were run entirely across the district, usually east and west, at intervals of about one-half mile, and these lines were tied to all other level lines crossed. Levels were also run along both railroads.

After the edges of Boggy Swamp and Black Swamp had been surveyed, the locations of the proposed ditches in them were determined by means of compass and steel-tape measurements, except from station 0 to station 150 on Boggy Swamp and from station 0 to station 62 on Black Swamp. On the located lines stakes properly marked were set at intervals of 100 feet; substantial hubs were set about 500 feet apart and at angles in the line; and the trees along the lines were well blazed. Profile levels were run over these lines, elevations being taken every 100 feet. The Black Swamp and Boggy Swamp ditches were the only ones located in the field; the other ditch lines shown on the map were not surveyed.

The datum for the levels is sea level as secured from the Seaboard Air Line Railway, taking the elevation of top of rail at Scotia and running all levels from that point. Bench marks were set along the main roads and at other prominent points, usually on roots of trees suitably inscribed. Three standard iron and bronze Drainage Investigations bench marks were set, one each at Scotia, Brighton, and Robertville. The data secured in the survey are shown on the accompanying map and profile (figs. 2 and 3).

RUN-OFF.

The "run-off" from a natural drainage basin is generally understood to be that water which flows from the area through the surface outlet channel. In designing drainage improvements, consideration must be given to the maximum rate of run-off for which provision should be made rather than to the total quantity to be removed. The principal factors affecting this rate in the Black and Boggy Swamps drainage district are rainfall, soil, and topography.

RAINFALL.

There are no stations of the United States Weather Bureau within this district, although it is well surrounded by stations at which continuous precipitation records have been kept for years. From a study of the records secured at Allendale, Walterboro, and Yemassee, S. C., and Statesboro, Ga. (see fig. 1), the rainfall in the Black and Boggy Swamps district can be learned with sufficient accuracy. These daily records for the years 1903 to 1912, inclusive, have been carefully compared with each other and with the daily records secured at Whiteville, N. C., for comparing this district with the Chadbourn and Lyon Swamp districts as explained in the following paragraphs.

PROBABLE RATE OF RUN-OFF.

Drainage districts where conditions are similar to those in the Black and Boggy Swamps drainage district have been completed in southeastern North Carolina and have been in operation for sometime, but no measurements of flood run-off from these ditches have been made. These districts, however, afford the best guide in designing the ditches for this district. At Chadbourn, N. C., the rainfall, topography, evaporation and transpiration of plants, climate and seasons, the natural reservoir and storage capacities of the streams, and the nature of the vegetable growth are very nearly the same as in the district under discussion. Several ditches which drain areas varying in size from 400 to 2,150 acres have been constructed in that locality and have been in operation for about two years. The principal difference between conditions at Chadbourn and in Black and Boggy Swamps district is that the soil at Chadbourn is a sandy loam 3 to 8 inches deep underlain by a clay or clayey sand that is quite permeable and which will absorb water very readily; this, as compared with the soil in the district under discussion, will give a low run-off. The ditches at Chadbourn were designed to remove 1 inch in depth of water from the entire watershed in 24 hours when running bank full. Where those ditches were constructed as designed they are working satisfactorily.

In Bladen and Pender Counties, N. C., the Lyon Swamp Canal, which drains an area of about 18,000 acres, has been completed for a year or more. Conditions in the Lyon Swamp district are practically the same as at Chadbourn, and the chief difference, so far as run-off factors are concerned, between that district and the Black and Boggy Swamps drainage district lies in the character of the soil. The drainage area of the Lyon Swamp district consists of 6,000 acres of dark brown and black loam from 3 to 5 feet deep underlain by a coarse sand, which gradually changes to a fine sand, and about 12,000 acres of sand ridges and bays, the latter varying in size from 1 acre to 2,000 acres. The soil of the sand ridges consists of a very coarse white sand, which absorbs the heaviest rainfalls with great rapidity. That of the bays consists of a very fine white sand near the surface, which also absorbs water quite readily. The entire area is underlain by blue marl at a depth of from 15 to 20 feet below the surface. The Lyon Swamp ditch was designed to remove one-half inch in depth of water from the entire area in 24 hours. The soil in this district, taken as a whole, will give a considerably lower run-off than that of the Black and Boggy Swamps drainage district.

From the preceding description of the several districts it will be seen that the chief difference is in the character of the soil, that of the Black and Boggy Swamps drainage district being of such a character as to give a somewhat higher run-off than either of the other districts. Therefore it would appear that the main outlet ditch for Boggy Swamp should be designed to remove a run-off of three-fourths inch depth in 24 hours from its entire watershed of 36,693 acres and 1 inch depth from areas less than 20,000 acres. On the same basis the main outlet ditch for Black Swamp should be designed to remove 1 inch of depth of run-off from its entire watershed area, 18,490 acres.

PLAN OF IMPROVEMENT.

The plan recommended for reclaiming the lands of Black and Boggy Swamps drainage district consists of a system of open ditches. These ditches, as a general rule, are planned to lie in the lowest parts of the swamps and are as straight as can be made without leaving the swamp. In only a few instances have the swamps been departed from, the object in these cases being to make cut-offs across the adjoining lands where they are low, thus reducing the distance. The complete plan involves the construction of 68 miles of dredged ditches and 98 miles of handmade ditches, a total of 166 miles for the district. On the two lines located in the field all changes of direction have been shown by angles, which in construction should be replaced by curves of suitable radius so that the flow of water will not be retarded by abrupt changes of direction. In the following paragraphs some of the principal features of ditch construction as applicable to this district are taken up.

SIZES OF DITCHES.

The computations of the ditch capacities have been based on the Chezy formula for flow in open channels, $V=C\sqrt{RS}$, in which C was determined by Kutter's formula, using 0.030 as the value of the roughness coefficient "n." Except at the lower end of Boggy Swamp and Black Swamp, however, the controlling feature in determining the sizes of the ditches has been the method of construction rather than the required capacity of the waterway.

Experience has shown that in heavily timbered lands such as these the best type of machine to use is the floating dipper dredge; but to float a machine of this kind frequently requires a larger ditch than would be necessary to take care of the maximum run-off. In lieu of the dredge the only practicable methods of construction will be hand labor or explosives; by the former method a ditch of just the required size could be constructed, but at a price per cubic yard very much greater than for dredge work, so a ditch roughly two and one half times the required size, provided it is no smaller than the minimum dredge ditch, could be constructed by the dredge for the same cost as by hand labor and in a much shorter time. The construction of ditches with explosives is comparatively new, and has met with varying degrees of success. It might be well to experiment with this method on some of the smaller ditches, which are of a size best adapted to its use.

The smallest ditch that can be constructed with a dipper dredge of sufficient power to remove the stumps and sunken timbers is one with a 14-foot bottom width, 6-foot depth, and side slopes ½ horizontal to 1 vertical. Such a ditch would have a top width of 20 feet. However, to afford proper drainage the depths of the dredged ditches should in this case be not less than 7 feet, and therefore wherever in this report the phrase "minimum dredge ditch" is used it refers to a ditch with 14-foot bottom width, 7-foot depth, and ½ to 1 side slopes. Ditches of this character are proposed for all of the main tributary branches except Hurricane Branch, Scott Swamp No. 1, Ballifore Branch, Rose Hill Branch, Titi Branch, Causeys Branch, Long Branch, and Lyas Bay, which streams are too short to warrant putting in a dredge. On some of the tributaries the upper mile of each ditch should be excavated by hand, as such channels will have sufficient capacity and will cost considerably less than minimum dredge ditches. The ditches to be constructed by hand labor, with one exception, are recommended to have 3-foot bottom widths, 5-foot depths, and ½ to 1 side slopes; such a ditch has an 8-foot top width. This kind of ditch will be referred to in this report as a "handmade ditch," as all of the ditches not constructed with dredges are recommended to be of this size except the upper end of Boggy Swamp, which should be 6 feet deep. The excavation for a minimum dredge ditch is 4.54 cubic yards per linear foot of channel, and for a handmade ditch it is approximately 1 cubic yard per foot.

BERMS.

In order not to put undue weight on the ditch banks and to keep the waste material from refilling the ditches, a clear berm of 8 feet between the edge of the ditch and the toe of the spoil bank should be left on each side of all the dredged channels, and similar berms 3 feet wide should be left along the handmade ditches.

RIGHT OF WAY.

It is necessary that a right of way be cleared through the swamps for all the ditches and that it be purchased and owned by the drainage district. The width of the right of way should be determined according to the bottom width of the ditch, since the depth of cut does not vary greatly, as follows: For 3-foot ditch, 30-foot right of way; for 14-foot ditch, 80-foot right of way; for 16 to 20 foot ditch, 90-foot right of way; for 22-foot ditch, 100-foot right of way; and for 28 to 30 foot ditch, 120-foot right of way. The improvements recommended in this report will require a total of 1,043 acres right of way.

It is suggested that an effort be made to secure easements for the right of way instead of purchasing it, as has been done by some drainage districts. Such easements give the district complete control of the land so long as it is used for drainage works; otherwise the land reverts to the owner.

BRIDGES.

The State law requires that the drainage district construct all public highway bridges that are made necessary by the construction of a ditch. Steel bridges with concrete abutments are recommended, although costing more than wooden structures, because the cost of maintenance will be much less. In making the estimate of cost, bridges have been included for all public road crossings. It is assumed that in most cases 30-foot bridges will be suitable for ditches with 14-foot bases, and 15-foot bridges for ditches with 3-foot bases.

IMPROVEMENTS IN BOGGY SWAMP WATERSHED.

Boggy Swamp is the longest stream in the district, and drains the largest area. The swamp along the upper 2½ miles of this stream is not over 100 feet wide; then it increases to about one-half mile wide, continuing so to the Orangeburg Road. From there to the Morrison Road it narrows to as little as 50 feet in places, having occasional arms or branching bays. Between Morrison Road and Haskell Baroney Swamp the width varies from 200 to 1,500 feet, averaging about 500, and from a mile above Hamilton Ridge Road to the river swamp the width is about 700 feet. The upper part of the drainage area is comparatively well drained, and largely under cultivation. It is rolling, with good fall to the swamp. Below the Orangeburg Road the land is much flatter, with little fall to the swamp above the Morrison Road, but with a break of 10 to 25 feet to the swamp level below that road. The largest cultivated tracts are along the main swamps where drainage is better than on higher land farther back. The chief need of this section is better drainage channels to bring the water to the main streams.

The proposed improvement in Boggy Swamp consists of a ditch throughout the length of the swamp. (See figs. 2 and 3.) From station 0, the upper end, to station 130, the ditch should be constructed by hand labor, with 3-foot bottom width, 6-foot depth, and side slopes ½ to 1, giving a top width of 9 feet. From station 130 to station 758, the lower end, the ditch is to be constructed with a floating dipper dredge. At the upper end of this portion there will be a minimum dredge ditch, and the bottom width will gradually increase to 30 feet at the lower end. The total fall in Boggy Swamp is 100 feet, varying from 17 feet per mile at the upper end, to 1.8 feet per mile at the lower end. (See fig. 3.) The Boggy Swamp ditch is not carried on to the Savannah River Swamp, but ends about 1½ miles below the Hamilton Ridge Road. Below the end of the proposed ditch the water will overflow the swamp, but the lands adjoining this portion of the swamp are much higher and will not be damaged, while the swamp itself is subject to overflow from the Savannah River and will be of little value for agriculture.

The following table summarizes the data and hydraulic computations for the proposed Boggy Swamp ditch:

TABLE 1.—*Data and computations for Boggy Swamp ditch.*

[Side slopes of ditch, ½ to 1.]

Stations.		Depth.	Bottom width.	Fall.		Computed velocity.	Watershed.		Computed ditch capacity.
From—	To—						Area.	Run-off.	
		Feet.	*Feet.*	*Ft. per foot.*	*Feet per mile.*	*Feet per second.*	*Acres.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
00	40	6	3	0.00225	11.88	....	600	....	....
40	80	6	3	.00325	17.16	....	1,150	....	....
80	130	6	3	.00206	10.88	3.6	1,800	....	130
130	143	7	14	.00206	10.88	3.7	2,000	....	700
143	260	7	14	.00051	2.69	2.9	3,300	....	360
260	355	7	14	.00171	9.03	5.15	4,175	....	630
355	423	7	14	.00171	9.03	5.15	8,000	....	630
423	440	7	14	.00171	9.03	5.15	14,800	620	630
440	531	7	20	.00087	4.61	4.1	15,875	665	675
531	570	7	22	.00087	4.61	4.15	17,025	715	740
570	628	7	24	.00087	4.61	4.25	19,850	835	815
628	660	7	28	.00087	4.61	4.35	29,475	930	960
660	758	7	30	.00034	1.80	2.8	31,900	1,005	655

The estimate of the amount of excavation for this ditch was computed in 2,000-foot sections from the profile data secured. Six highway bridges will be required, three of 30 feet span, and one each of 15, 35, and 45 feet span.

Beaver Dam Branch No. 1 is the largest tributary of Boggy Swamp, being about 8 miles long. It has numerous tributaries, in which small ditches should be constructed. The swamp along this branch is very narrow, except the portion southwest of Scotia, which is about 2,000 feet wide, and formerly was cultivated in rice. The upper portion of the drainage area is rolling, and is practically all under cultivation except in the several bays. The lower part is much flatter and contains large areas of flat woods which are badly in need of drainage. The proposed improvements on Beaver Dam Branch No. 1 consist of a handmade ditch for the upper 7,550 feet, above the Seaboard Air Line Railway, and a minimum dredge ditch from the railroad down to Boggy Swamp, a total length of 38,500 feet. The fall is 37 feet in 7.3 miles, or 5 feet to the mile, but very little of it occurs in the upper mile. Two 30-foot highway bridges will be required.

Beaver Dam Branch No. 2 has a swamp that varies much in width, from 100 feet in some places to a half-mile in others. The watershed area comprises mostly good rolling land, much of which is under cultivation at the present time, although there is a large area of flat bays and ponds covered with a thick growth of timber. The proposed improvements consist of a minimum dredge ditch for its whole length of 25,420 feet, except the upper mile which should be a handmade ditch. The fall is about 35 feet in 5 miles. One 30-foot bridge will be required.

Manigault Branch heads in a series of flats and ponds between Shirley and Scotia, and joins Boggy Swamp where the swamps are subject to overflow from the Savannah River. For the first 2 miles, in the flats and ponds, the swamp is about one-fourth mile wide, but it narrows below the Augusta Road to about 100 feet, widening out again lower down to about 500 feet. The watershed area of Manigault Branch is for the most part fairly flat, with large stretches of flat pine woods and a small percentage of land under cultivation. The proposed improvements on this branch consist of a minimum dredge ditch 33,150 feet long. The fall in the upper 2 miles of the branch is slight, but below Augusta Road it is 44 feet in 3.6 miles. The lower mile of Manigault Branch is subject to overflow from the Savannah River, and while it is not absolutely necessary that the improvements extend down to Boggy Swamp, it is recommended that they be carried to that point, as this will provide a better outlet for the lands above. One 30-foot highway bridge will be needed.

Mill Branch Swamp, between the flat bay in which the branch rises and Haskell Baroney Swamp, averages hardly more than 100 feet wide.

The fall on this branch amounts to 38 feet in 4.8 miles, or about 8 feet to the mile. The watershed area is quite rolling, with marked differences in elevation between the highlands and the bays, and nearly all of the former are now under cultivation. The proposed improvements on this branch consist of a handmade ditch for the 6,700 feet above the Mill Road, and the minimum dredge ditch for the remainder of the 25,240 feet total length. Two 30-foot bridges will be required.

The Savannas lie in the flattest section of the district, nearest the Savannah River. The area drained, except that tributary to Rum Branch, is extremely flat for the most part, being composed almost entirely of flat swamp covered with an excellent growth of timber. The soil is very rich and could be converted into valuable farm land. The Savannas are several hundred feet wide, with no discernible channel or run. The vegetation in the upper part of this swamp is quite different from that in the other branches, for the others are covered with thick growths of timber and brush, while the Savannas are comparatively open, having a thick growth of grass and rushes about 3 feet high and only an occasional bush. The fall in the Savannas is only 6 feet in 3.8 miles. The proposed improvement consists of a dredge ditch of minimum section for the entire length of 19,950 feet. No new bridges will be needed.

To prevent the occasional overflow from the Savannah River, the breaks in the clay ridge on the west boundary of the district should be closed by low dikes. The amount and cost of this work has not been estimated.

Rum Branch drains an area consisting mostly of good rolling land now under cultivation, but including Rogers Bay and several other large bays. The upper end of the swamp along this branch is about 800 feet wide, but it soon narrows to about 100 feet, which width is maintained for about 2 miles; below this the width becomes very irregular. Neither the bays nor the lower end of the swamp is under cultivation. The fall of this branch is ample for its whole length, being 54.5 feet in 6.4 miles, or 8.5 feet to the mile. The proposed improvements consist of a handmade ditch for the upper 5,400 feet and a minimum dredge ditch through the remainder of the branch, which has a total length of 34,200 feet. Two new 30-foot bridges will be required.

Hurricane Branch drains about 1 square mile of fairly high and slightly rolling ground, practically all under cultivation. The swamp is very narrow the whole length of the branch. The fall amounts to 23.5 feet in 2.1 miles. There is at present a good ditch throughout the length of Hurricane Branch, 4 to 10 feet in top width, 3 to 4 feet in bottom width, and 2½ to 6 feet deep. This ditch has a good flow of water, but it could be improved by cleaning and straightening, which improvements are the only ones recommended on this branch. The length of the ditch is 11,150 feet.

IMPROVEMENTS IN BLACK SWAMP WATERSHED.

The watershed area of Black Swamp is comparatively flat, except the lower or southern portion, which is more rolling, with a good fall toward the swamp. A large part of the flat land is under cultivation, while the remainder is mostly flat bays and ponds with a thick covering of bushes and trees.

The swamp or wet land along this stream is 100 to 300 feet wide for the first few miles below the source, then 400 to 600 feet for a few miles, and finally reaches 800 to 1,000 feet width at the lower end. There is no well-defined channel, and during wet seasons the entire swamp is covered with water several feet deep. The growth in this swamp is a thick, tangled mass of vines, briars, canes, and bushes, with a fairly heavy growth of timber. The total fall is 79 feet, quite sufficient to give good drainage to these lands, and for the greater portion of the swamp it is quite uniform, as may be seen from the profile (fig. 3). It varies from 12.5 feet per mile at the upper end to 1.3 feet per mile for a short distance at the lower end.

The proposed improvements on Black Swamp consist, as shown in figures 2 and 3, of a dredge ditch starting at the Southern Railway just south of Furman and continuing down the swamp until overflow water from the Savannah River is encountered. This will require a ditch about 10 miles long. The depth should be 7 feet, with side slopes of ½ to 1. The ditch should start with a 14-foot bottom width, increasing to 30 feet. At the lower end the estimated capacity of the ditch is less than the calculated run-off, and consequently some flooding is to be expected. No harm will result from this, however, as the lower end of the swamp will be flooded by exteme high water in the Savannah River, and the lands bordering the swamp lie 15 to 20 feet above its level and have good natural drainage. The table below summarizes the data and computations for the Black Swamp ditch.

TABLE 2.—*Data and computations for Black Swamp ditch.*

(Side slopes of ditch, ½ to 1.)

Station.		Depth.	Bottom width.	Fall.		Computed velocity.	Watershed.		Computed ditch capacity.
From—	To—						Area.	Run-off.	
		Feet.	*Feet.*	*Feet per foot.*	*Feet per mile.*	*Feet per second.*	*Acres.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
00	80	7	14	0.00237	12.51	....	2,000	....	....
80	102	7	14	.00200	10.56	....	2,175	....	....
102	169	7	14	.00200	10.56	....	3,575	....	....
169	180	7	14	.00200	10.56	....	7,050	....	....
180	240	7	14	.00127	6.71	4.55	7,850	....	555
240	299	7	14	.00127	6.71	4.55	10,775	453	555
299	320	7	14	.00127	6.71	4.55	12,600	529	555
320	339	7	16	.00095	5.02	4.1	12,900	542	560
339	407	7	20	.00095	5.02	4.3	16,650	700	710
407	432	7	22	.00095	5.02	4.35	17,425	732	775
432	460	7	22	.00095	5.02	4.35	17,925	753	775
460	526	7	30	.00023	1.31	2.4	18,500	777	565

The estimate of material to be excavated for this ditch was calculated in 2,000-foot sections, from the profile data. Three highway bridges will be required at the points where the proposed ditch crosses the public roads, one of 35 feet span and two of 30 feet.

Wolf Bay lies in the flat woods section of the district. Only a small part of the basin drained is under cultivation, the greater part being flats and bays covered with timber and brush. It has two forks, along both of which the swamp varies greatly in width but averages about 300 feet. The fall on this branch, from the head of the east fork, is about 35 feet in 4.6 miles. The proposed improvements on the east fork of this branch consist of a minimum dredge ditch for its entire length of 24,250 feet, except that the upper mile should be a handmade ditch, while the west fork should have a smaller ditch and is considered as lateral ditch No. 10. Four new bridges will be required, one span of 15 feet and three of 30 feet.

Causeys Branch has two outlets, part of the water going direct to Black Swamp through Shumans Bay and part flowing south through Titi Branch. Most of the drainage area is rolling land under cultivation. The swamp along Causeys Branch is quite narrow at the upper end, about 600 feet wide from the railway to Shumans Bay, where it widens to about 1,000 feet, then it rapidly narrows before reaching Black Swamp. The fall on the branch is comparatively large, 44 feet in 3.3 miles, or 13.3 feet to the mile. It is proposed to carry all the water by the more direct route through Shumans Bay, the improvement to consist of a handmade ditch throughout the entire length of 18,425 feet. Two new 15-foot bridges will be needed.

Titi Branch drains an area largely under cultivation, with rather rolling topography and a good fall from the adjoining lands to the branch. The swamp along this branch varies much in width, the upper end and middle section being wide, while the lower end is narrow. The fall on Titi Branch is quite large, amounting to 43 feet in 3 miles. The improvement proposed for this branch consists of a handmade ditch 16,275 feet long. One 15-foot bridge will be required.

Long Branch is the drainage outlet for a basin quite flat and covered with timber at the upper end, but a little more rolling and largely under cultivation at the lower end. The swamp along this branch averages about 200 feet in width, and it has a fall of about 28 feet in 3.2 miles. The proposed improvement consists of a handmade ditch through the entire branch, a distance of 17,900 feet. Three 15-foot bridges will be required.

Lyas Bay drains good, rolling land, a large part of which is now under cultivation. The swamp averages about 700 feet wide. The proposed improvement is a handmade ditch 9,900 feet long, running from the Southern Railway southwest to the bay, thence through it to Black Swamp. The fall will be 22 feet in 1.9 miles. Two 15-foot bridges will be required.

Ballifore Branch heads in the flat woods southeast of Robertville. The watershed area is slightly rolling and is well under cultivation. The swamp averages about 100 feet wide, and the fall on the branch is 26 feet in 1.3 miles. The improvement proposed consists of a handmade ditch for the entire length of 7,000 feet. One 15-foot bridge will be required.

Rose Hill Branch drains an area that is fairly rolling, and a large part of which is cultivated. The swamp along this branch is rather wide at the upper end, but gradually decreases to not more than 50 feet at the lower end. The fall is about 16 feet to the mile. The proposed improvement is a handmade ditch for the entire length of 7,600 feet. One 15-foot bridge will be required.

IMPROVEMENTS IN INDEPENDENT WATERSHEDS.

Church Branch joins Black Swamp outside the drainage district. The upper end of the watershed area is quite flat and consists of open pine woods and grass, but the lower end is very rolling, with good natural drainage; nearly all of the land is under cultivation. The swamp along Church Branch is only 50 to 100 feet wide at the upper end, but it gradually increases until at the lower end it is about 500 feet wide. The fall on this branch amounts to 40 feet in 3.9 miles. The proposed improvement consists of a minimum dredge ditch 20,400 feet long. Five bridges of 30-foot span will be required.

Hog Branch joins King Branch and empties into the Pallachucolla Savannas, finally reaching Black Swamp lower down. The upper end of the watershed is very flat, composed almost entirely of flat woods, with occasional ponds and bays, all in timber. This section needs drainage outlets badly, as water stands several inches deep on it for long periods after heavy rains. The lower section of the watershed is more rolling, and fair natural drainage is secured by reason of a marked drop from the adjoining lands to the branch. A large portion of this section is under cultivation. The swamp along Hog Branch is very narrow at the upper end, but toward the lower end it widens to about 300 feet. The total fall on this branch is 46.5 feet in 6.1 miles, the slope increasing somewhat from the upper to the lower end. The proposed improvement consists of a ditch throughout Hog Branch and extending 2½ miles northward into the flat woods. The upper mile will be a handmade ditch, and the remainder a dredge ditch of minimum size, the total length being 32,150 feet. There is at present in the branch a small ditch in fair condition, but so small that it has not been considered in estimating the excavation. Two 30-foot bridges will be needed.

King Branch watershed consists of flat woods in the upper portion, and rolling land in the lower portion, which has fair natural drainage and is mostly under cultivation. The swamp along King Branch, like others in this part of the district, is narrow at the upper end and gradually widens toward the outlet. The fall is 40 feet in 5.6 miles, being greater at the lower end than at the upper. A minimum dredge ditch is recommended below the Orangeburg Road, and a handmade ditch extending north for about 1 mile into the flat woods to give those lands a drainage outlet. The ditch would have a total length of 29,490 feet. Two 30-foot bridges will be required.

Scott Swamp No. 1 drains rolling land principally, and most of the lower end of the area is cultivated. At the upper end the swamp is wide and flat, but it narrows rapidly toward the outlet. The fall is 39 feet in 2.4 miles. The proposed improvement is a handmade ditch 12,700 feet long. An existing small ditch about a mile long in the upper part of the swamp will reduce the necessary excavation by about 1,000 cubic yards. Two 15-foot bridges will be needed.

LATERAL DITCHES.

In addition to the ditches that have been described, practically all of which lie in the larger watercourses, 66 laterals should be constructed as indicated and numbered on the map (fig. 2). These will extend out from the main channels at all the low places, to provide drainage connection between the flat lands and the larger ditches. Owing to the lack of machinery suitable for constructing small ditches in wooded land, the laterals have been estimated as handmade ditches, 3 feet in bottom width, 5 feet deep, with ½ to 1 side slopes. The excavation has been computed as 1 cubic yard per linear foot of ditch. Where these laterals are crossed by public roads 23 bridges will be required, each 15 feet long. The following table shows the length and excavation for the lateral ditches:

TABLE 3.—*Length and excavation for lateral ditches.*

[Excavation=1 cubic yard per linear foot of ditch.]

Lateral No.	Tributary to—	Length and excavation.	Lateral No.	Tributary to—	Length and excavation.
		Ft. and cu. yds.			*Ft. and cu. yds.*
1	Boggy Swamp	3,600	16	Boggy Swamp	4,100
2	do	5,900	17	do	2,800
3	Beaver Dam No. 1	12,200	18	do	4,400
4	do	3,100	19	Beaver Dam No. 2	9,600
5	do	4,800	20	Rum Branch	3,300
6	do	12,300	21	do	4,700
7	Lateral No. 6	2,900	22	do	5,100
8	(Eliminated.)		23	Lateral No. 22	2,100
9	Beaver Dam No. 1	6,900	24	do	2,200
10	Wolf Bay	6,875	25	Lateral No. 26	3,600
11	Black Swamp	4,100	26	Rum Branch	11,650
12	do	5,300	27	do	7,800
13	Church Branch	8,400	28	The Savannas	7,700
14	Beaver Dam No. 1	4,500	29	Rum Branch	6,900
15	Beaver Dam No. 2	5,300	30	Mill Branch	6,600

TABLE 3.—*Length and excavation for lateral ditches*—Continued.

Lateral No.	Tributary to—	Length and excavation.	Lateral No.	Tributary to—	Length and excavation.
		Ft. and cu. yds.			*Ft. and cu. yds.*
31	The Savannas	7,200	51	Black Swamp	2,800
32	Boggy Swamp	4,700	52	Independent	3,900
33	.....do	5,150	53	.....do	8,000
34	.....do	15,200	54	Titi Branch	2,500
35	Manigault Branch	8,800	55	Beaver Dam No. 1	4,200
36	King Branch	3,900	56	Wolf Bay	3,200
37	Manigault Branch	7,000	57	Black Swamp	4,000
38	Independent	5,400	58	Hog Branch	3,000
39	Causeys Branch	3,900	59	Lateral No. 30	8,300
40	Titi Branch	7,200	60	Manigault Branch	5,850
41	Black Swamp	5,200	61	Lateral No. 37	3,000
42	.....do	4,900	62	Lateral No. 38	3,900
43	.....do	7,200	63	.....do	2,750
44	Long Branch	4,900	64	Boggy Swamp	6,000
45	Black Swamp	8,300	65	Lateral No. 64	1,300
46	.....do	7,050	66	Mill Branch	2,300
47	Lateral No. 46	2,900	67	Black Swamp	2,950
48	Black Swamp	2,900			
49	Church Branch	8,000		Total	359,475
50	Lateral No. 49	3,000			

ESTIMATE OF COST.

Owing to the arrangement of the swamps and branches in Black and Boggy Swamps drainage district the excavation will necessarily be slow, as the dredges will have to be rebuilt several times. The cost of excavation by dredge in the two main swamps has been estimated at 8 cents per cubic yard and in the tributaries at 10 cents per cubic yard. These figures are based on contracts in different localities, where conditions are similar to those in this district. The handwork has been estimated at 25 cents per cubic yard. The cost of clearing the right of way is included in the unit price for excavation; the purchase cost has been estimated at $10 per acre. Bridges have been estimated at $20 per foot of span, plus $200. A summarized estimate of the costs for the whole district is given in the following table:

TABLE 4.—*Summary of cost data.*

BOGGY SWAMP WATERSHED.

Ditch.	Excavation.				Bridges.	Right of way, at $10 per acre.	Engineering and legal, at 10 per cent.	Total.
	Cubic yards, at 8 cents.	Cubic yards, at 10 cents.	Cubic yards, at 25 cents.	Cost.				
Boggy Swamp	369,540	....	9,440	$31,923	$4,900	$1,430	$3,825	$42,078
Beaver Dam No. 1	....	140,510	7,550	15,939	1,600	620	1,816	19,975
Beaver Dam No. 2	....	91,440	5,280	10,464	800	410	1,167	12,841
Manigault Branch	....	150,500	....	15,050	800	610	1,646	18,106
Mill Branch	....	84,170	6,700	10,092	1,600	390	1,208	13,290
The Savannas	....	90,570	....	9,057	....	370	943	10,370
Rum Branch	....	130,750	5,400	14,425	1,600	570	1,660	18,255
Hurricane Branch	(Cleaning and straightening.)			1,050	....	80	113	1,243
Laterals (38)	....	....	223,050	55,762	5,500	1,540	6,280	69,082
Total for Boggy Swamp watershed	....	....	....	163,762	16,800	6,020	18,658	205,240

TABLE 4.—*Summary of cost data*—Continued.

BLACK SWAMP WATERSHED.

Ditch.	Excavation.				Bridges.	Right of way, at $10 per acre.	Engineering and legal, at 10 per cent.	Total.
	Cubic yards, at 8 cents.	Cubic yards, at 10 cents.	Cubic yards, at 25 cents.	Cost.				
Black Swamp	261,170			$20,894	$2,500	$1,070	$2,446	$26,910
Wolf Bay		86,120	5,280	9,932	2,900	390	1,322	14,544
Causeys Branch			18,425	4,606	1,000	130	574	6,310
Titi Branch			16,275	4,069	500	110	468	5,147
Long Branch			17,900	4,475	1,500	120	610	6,705
Lyas Bay			9,900	2,475	1,000	70	355	3,900
Ballifore Branch			7,000	1,750	500	50	230	2,530
Rose Hill Branch			7,600	1,900	500	50	245	2,695
Laterals (18)			86,175	21,544	5,000	590	2,713	29,847
Total for Black Swamp watershed				71,645	15,400	2,580	8,963	98,588

INDEPENDENT WATERSHEDS.

Ditch.	Cubic yards, at 8 cents.	Cubic yards, at 10 cents.	Cubic yards, at 25 cents.	Cost.	Bridges.	Right of way, at $10 per acre.	Engineering and legal, at 10 per cent.	Total.
Church Branch		92,620		$9,262	$4,000	$380	$1,364	$15,006
Hog Branch		121,990	5,280	13,519	1,600	530	1,565	17,214
King Branch		109,910	5,280	12,311	1,600	480	1,439	15,830
Scott Swamp No. 1			11,700	2,925	1,000	90	402	4,417
Laterals (10)			50,250	12,562	1,000	350	1,391	15,303
Total for independent watersheds				50,579	9,200	1,830	6,161	67,770

Total for the drainage district, $371,598.
Number of acres in district, 67,642.
Average cost per acre, $5.50.

The total cost of the 66 lateral ditches has been estimated above as $114,232. Omitting these, the cost of ditching only the two main swamps and the principal tributaries would be, as estimated, $257,366, or $3.80 per acre. It is strongly recommended, however, that the laterals be constructed, as well as the main ditches.

MAINTENANCE.

Not much work should be required to keep the ditches in condition after they are constructed. The velocity of flow due to large fall in most of the ditches will assist materially in keeping down the growth of vegetation in the channels. However, an organized method of inspection should be adopted in the district whereby each ditch will be examined at least once each year, preferably just before the rainy season. Any obstructions should be removed and any damage to the ditches should be repaired as soon as noted. If maintenance work is given prompt attention, the defects can be remedied with comparatively little expense; but if it is neglected, the task will become a formidable one, and in the meantime the efficiency of the drainage system will be reduced.

CONCLUSIONS.

Anyone who is at all familiar with the agricultural conditions existing in the Black and Boggy Swamps drainage district at the time this survey was made, could not but be impressed with the need for artificial drainage. Large areas of land are at present yielding no revenue whatever, yet all apparently have such natural qualities as would make them excellent farming lands if they could be relieved of excess water. The plans presented in this report provide for such relief, which should be secured at an average cost of about $5.50 per acre and would be worth many times that amount, although to realize the fullest possibilities of the soil in many parts of the district tile drainage also should be installed. The ditches have been designed of ample depth to serve as outlets for the tile drains.

Besides the financial advantage of increased crop production due to drainage, there is the benefit to the general health of the community, which is none the less real and important because it is less easily measured in money values. The decrease of malaria, which now exists in certain parts of the district, by removing the breeding places of mosquitoes, will make those parts more desirable for residence and thereby add to their commercial value.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
△

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 115

Contribution from the Office of Experiment Stations, A. C. True, Director.
September 1, 1914.

(PROFESSIONAL PAPER.)

GATE STRUCTURES FOR IRRIGATION CANALS.

By Fred C. Scobey,
Irrigation Engineer, Irrigation Investigations.

INTRODUCTION.

A study of the irrigated regions of the West shows that the designs and special features of structures have been copied and adapted one from another, but usually within the bounds of one locality. Two sections with quite similar conditions show great divergencies in structures used for the same purposes. This is true largely for the reason that those who design the structures have neither the time nor the means to travel and learn how others are handling similar situations. The purpose of this bulletin is to bring together designs adapted to many localities, in order that the practice of the whole country may be available to those who design structures.

The purpose of all gates considered in this bulletin is the control of the flow of water in ditches or canal systems. Headgates and floodgates regulate the water entering the system from the source of supply; check gates regulate the water while within the canal; sand and waste gates control the water which is to be turned out and wasted; and branch canal, lateral, and delivery gates regulate the water turned out to branches of the system or to users. Bifurcation works and division gates usually serve the combined purposes of check gates and branch canal or lateral gates, and are used to regulate the flow of water in the main canal and also of that passing into branches or laterals.

For the most part small and medium-size structures are dealt with, as it is believed that most of the problems confronting the engineer located in isolated parts of the West relate to structures of this class. The bulletin should also be of value to directors of mutual water companies, who are themselves irrigators and who are called upon to pass on questions of construction and maintenance.

Note.—This paper will be of interest to engineers and directors of farmers' canal companies in the irrigated sections of the West.

Since the bulletin is prepared for engineers and others who are familiar with gates and gate structures, it does not attempt to treat the subject fully, but merely gives examples of structures which serve the purpose for which they are intended better than many others in common use. Local conditions control many features of gate structures, and the descriptions given relate to existing structures in actual use, which it is believed will prove suggestive and can be readily adapted to other conditions by local engineers and ditch owners.

MATERIALS USED.

A few years ago most of the structures in American canals were of wood, but more recently concrete, both plain and reinforced, has come into common use. Wood has the advantages of cheapness and ease of handling and the disadvantage of rapid depreciation. Concrete has the advantage of permanence, but is costly. In determining which to use, these points must be taken into consideration. The most prominent facts in connection with recent irrigation development under both public and private agencies have been the high cost of water rights and the inability of settlers to make the payments required. In view of these facts there is much to be said in favor of the cheaper wooden structures for original construction with a view to their replacement with more permanent structures of concrete as the wood decays. This will lessen first cost and bring the heavier cost after the lands have been put under cultivation and the expenses incident to the establishment of new farms have been met. The use of wood has the further advantage that any mistakes in either the type of structures or their location are not so costly. It frequently happens that structures are found to be placed too high or too low, or to be too small or not of the best type for the purpose to be served. A few years' experience in their operation will demonstrate these facts, after which permanent structures may be put in with an assurance that they are what is needed.

Another condition to be taken into consideration in determining the material to be used for structures is the damage which is likely to be done in case of failure. If the failure of a structure will result in great damage to the canal system, or to crops or other property below, only the most nearly permanent construction should be used. If, on the other hand, failure will mean merely the replacement of the structure itself, cheaper construction may be used.

Probably the best practice is to make combined wood and concrete structures, using concrete for the parts which are inaccessible and not easily replaced and wood for the accessible parts which can be replaced easily. Local conditions affecting the relative price of wood and concrete will also help to determine which material should be used.

TYPES OF GATE SHUTTERS.

The openings or vents in gate structures generally are regulated by either slot shutters, comprising flashboards and wooden and metal slide gates; radial gates; or shear gates. There are also several styles of collapsible gates, roller curtains, needles, butterfly gates, and other devices, but their use is very limited in this country, and for that reason they are omitted from this publication.

SLOT SHUTTERS.

The type of slot shutters in most common use is a wood or metal shutter sliding in grooves or slots. This arrangement does very well for small gates, but where the opening is so large that there is any great amount of pressure against the gate the friction becomes so great as to render the operation of the shutter difficult. Sometimes this sliding friction is reduced by inserting a roller bearing between the shutter and the guide.

Wooden gate shutters are the most common of all types. Various types of wooden shutters are shown in Plate I. Slides for openings up to about 4 feet wide are made wholly of wood, as a rule. Larger shutters are usually braced with iron, and those 8 to 12 feet in width commonly are furnished with a metal shoe which slides against the guide. Small gates are usually nailed together, but it is better to use bolts freely on gates wider than 3 feet.

If redwood lumber is used gates up to 3 feet wide may be made of 1-inch stuff single thickness, but above that it is recommended that at least 2-inch stuff be used, or, better still, double 1 or 1½ inch, with the two layers at right angles to each other. Tightness may be secured by placing a layer of tar paper between the two layers of wood. Gates of pine and of any timber other than redwood, except very small ones, should not be made less than 2 inches in thickness. If built of double material they will be more nearly water-tight and stiffer than if built of a single thickness.

Most of the much-used metal slide gates are made by foundries and machine shops that specialize in this work and issue very complete catalogues that describe in detail each kind of gate. Most of them are included in one of three types: Gates for pipe deliveries through the banks, gates for rectangular tubes of wood or masonry through the banks, or gates for open channels. The first type consists of a sheet-steel or cast-iron slide over a cast-iron face orifice with angle iron or steel standards and the necessary lugs to attach the gate to the bell, and of a cast-iron, vitrified-clay, cement, or corrugated-iron pipe. In the trade nomenclature the size of the gate agrees with the size of the pipe to which the gate is to be attached; that is, an 8-inch gate is ordered to fit a pipe 8 inches inside diameter.

Practically all gates of this type are fitted with screw and wheel lift and locking devices. The locking device usually consists of some form of cast-iron nut turning on the thread of the gate stem under the crosshead. As the stem does not turn around but is lifted simply by the threads in the wheel it is necessary only to screw the loose nut to any desired point and lock it to a chain or bar connecting with one standard. This prevents it being turned in either direction, and when the stem is raised until the nut reaches the crosshead, the shutter is locked as regards further opening, but may be closed partially or wholly by the consumer. Other devices used lock the gate so that it can not be either opened or closed except under action of the key. (See fig. 11, p. 42.)

Most of the standards of this type of gate come in lengths of 6 feet unless ordered otherwise, but the writer noticed many cases throughout the West where a material saving could have been exercised by ordering shorter lengths of standard.

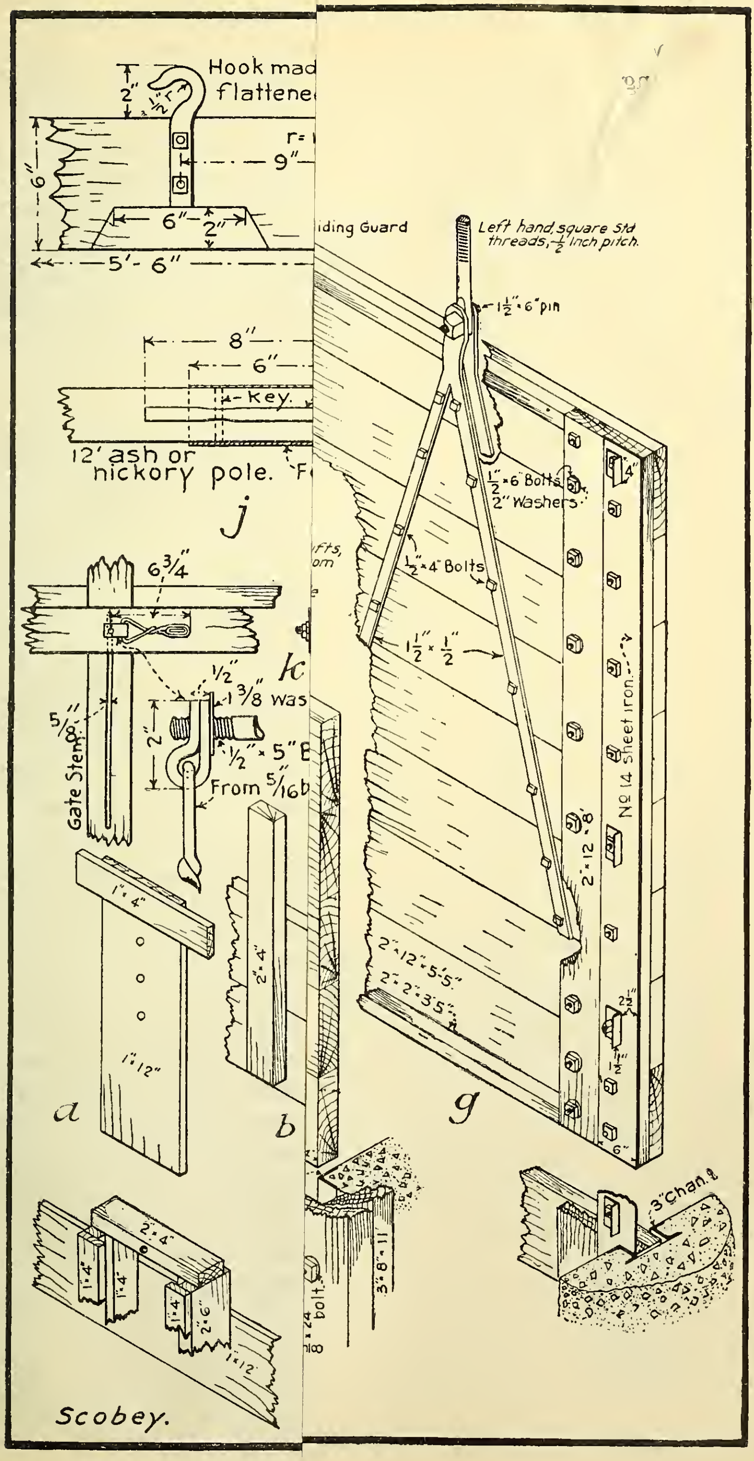
The standards may be made so that they will be at right angles to the connection for the pipe or at an angle of 60° or 75° with the pipe. In most cases the 75° angle probably will give better results, as the face then will be more nearly in conformity with the slope of the bank. One manufacturer even makes a type with a slope of 45° with the pipe.

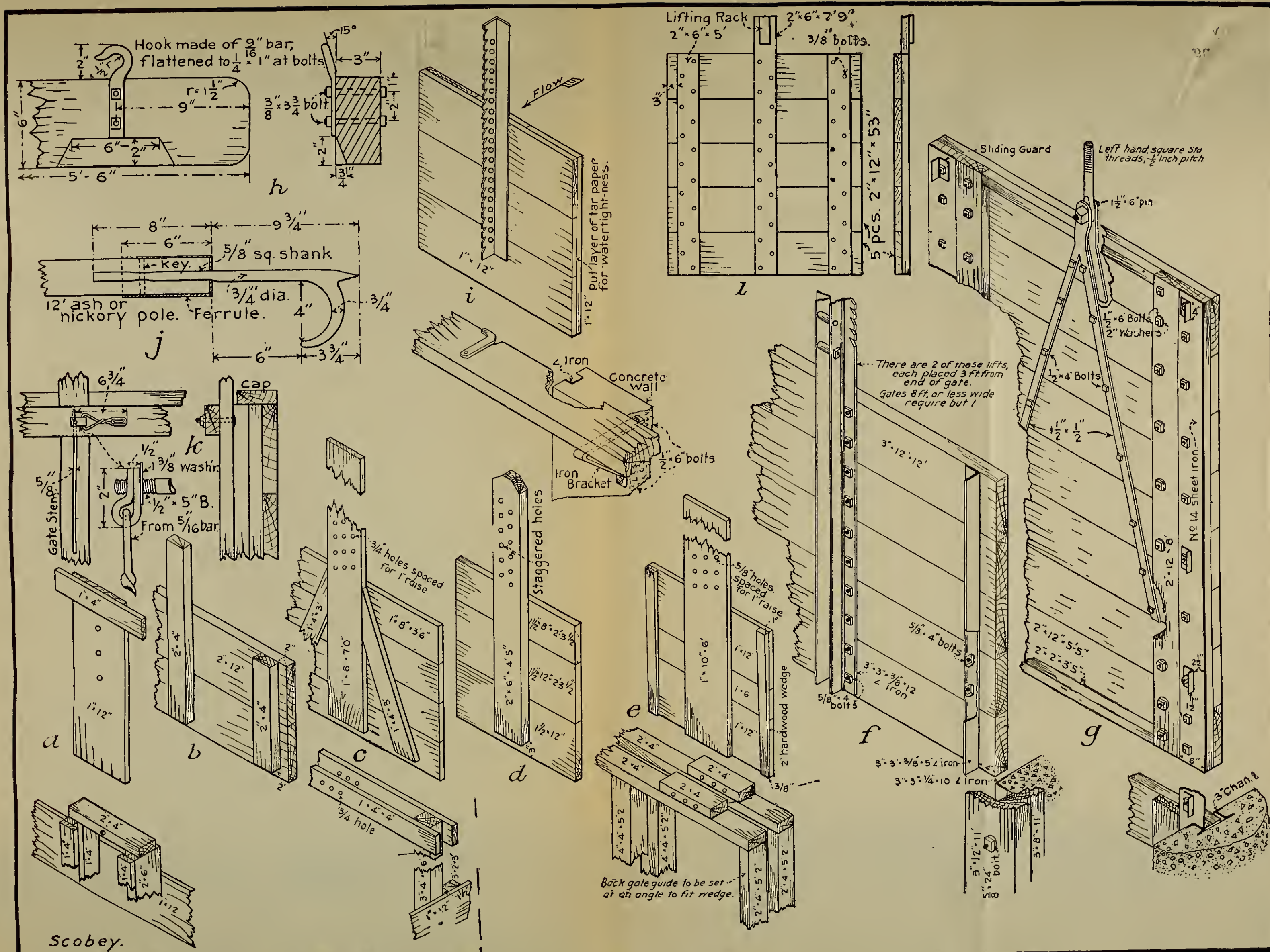
Most makers step up the gate sizes to conform to the sizes of standard vitrified-clay pipe beginning at 6 inches and going to 24 inches. Some makers have gates for 30 and 36 inch pipe, but as a rule the type is changed.

Gates with connections for rectangular openings are for use with timber or masonry tubes larger than standard sizes of pipes, as a rule. The standards, locking devices, etc., are the same as on the gates for pipes. These gates run in various sizes from 6 by 6 inches up to several feet in either dimension. The stems and lifts vary all the way from a simple handle and bar up to powerful geared rack-and-pinion or screw lifts.

The third type of gates consists of sheet-steel or cast-iron slides with metal guides. They come in sizes up to about 12 feet wide and may be built up from a single panel to a battery of several openings. Where the masonry structure is divided into vents by masonry piers each gate is a unit independent of the others. They also are designed in batteries for installation as a metal unit in a gate structure with walls and floor of concrete or rubble masonry. This class has a structural steel frame securely anchored by bolts to the floor and walls. An example of this type of gate is shown in Plate V, figure 2.

The rack-and-pinion lift is the most common type for this class of gates. On the more simple ones the lever acts directly on the pinion, the gate being held by a pawl. More power is secured by inserting a train of gears between the lever and the rack.


Hook mad
flattene
2"
1/2"
r=
9"
6"
6"
2"
5'-6"
iding Guard
Left hand, square std threads, 1/2 inch pitch.
1 1/2" × 6" pin
8"
6"
Key.
12' ash or hickory pole.
j
1/2" × 6" Bolts
2" Washers
1/2" × 4" Bolts
1 1/2" × 1/2"
No 14 sheet iron.
2" × 12" × 8'
6 3/4
1/2"
1 3/8 was
k
5/8"
Gate Stem
2"
1/2" × 5" B
From 5/16 b
1" × 4"
1" × 12"
a
2" × 4"
b
2" × 12" × 5'-5"
2" × 2" × 3'-5"
g
2 1/2"
1 1/2"
6"
3" Chan.
2" × 4"
1" × 4"
1" × 4"
1" × 4"
2" × 6"
1" × 12"
bolt.
3" × 8" × 11
Scobey.



Wooden Gate Shutters and Accessories.

Large cast gates are lifted by powerful one or two man gate stands, or, in some cases, by electric or water power. These stands are equipped with ball-bearing wheel and screw, bevel gearing and screw, or worm and wheel and screw. The waste gates on the Milner dam in Idaho are regulated by a traveling hoist equipped with electric power and running on a track set back of the gate guides. This device is used in many cases where there is a battery of gates, but one hoisting apparatus being provided. This is transferred from one stem to another and the adjustments made. The hoist may then be removed entirely and locked in a near-by tool house, thus preventing passers-by from tampering with the gates.

FLASHBOARDS.

The flashboard is the form most used for an overflow gate, such as most check and some types of waste gates. With boards a definite crest is maintained over which any excess water will pass. Alterations in this crest height may be made in steps gaged by the width of the boards. Where there are several panels in a gate structure the general water level may be regulated by flashboards and more delicate adjustments made by a solid gate shutter of either the groove or radial form.

Primarily a set of flashboards should be used only where leakage is of little or no consequence unless measures to prevent leakage are adopted. In California double sets of flashboards sometimes are used for floodgates and the spaces between them are packed with mud during such times of the year as they are not being adjusted. The water issues from a structure regulated by flashboards with less velocity than it does from an undershot gate, and the resulting erosion below the structure is less. One advantage of the type shown in figure 8 (p. 37) is that the whole shutter may be lifted by the stem, giving the advantage of more delicate adjustment and still allow some water to pour over the upper flashboards. This water will fall on and tend to break the force of whatever water is passing under the gate.

The disadvantage of flashboards lies in the difficulty of operation and the time this requires. The jamming of a board may be reduced by rounding off the corners of each board as shown in Plate I, *h*.

Where used in a check gate flashboards develop a very bad feature of maintenance. If a delivery of water is not being made above the check, then all of the vents should be " pulled " and the water allowed to flow as nearly as possible in the same manner that it does when there are no gates in the canal, thus scouring out any deposit which has accumulated while the water was checked up. Unless the ditch tender is exceptionally conscientious he will " pull " one or two vents, causing an excessive scour through the openings pulled, and leaving the silt deposit above the others. Of course this same condition must be guarded against where other forms of shutter are used, but it is much easier to pull all vents, if it can be done at one operation for each opening, than to fish out one flashboard at a time, with perhaps 8 or 10 boards in each vent.

This objection does not apply where boards are used to establish the crest of such a structure as a waste gate, designed for practically all of the water above the level of the crest to pass off and leave the canal. The water in the canal continually scours past the waste gate, keeping out the silt, and, as a rule, there are not many adjustments on such a gate throughout the irrigation season, there being a very material saving in the cost of gate lifts, which would be used only a few times in the season.

If flashboards are made loose enough so that they will operate with comparative ease, then there also is danger that they will float if the slots are made vertical. If the slots are inclined, the friction against the upper side of the slot counteracts the floating action of the water. Inclined slots also place the shutter so as to carry the thrust of water downward through the floor of the structure rather than tend to overturn it. The inclined slot requires more material for a shutter of a given height than does a vertical slot. Flashboards in an inclined set of slots can be more easily made water-tight by packing with mud than those in vertical slots.

SHEAR GATES.

During the past few years the shear gate has come into use on irrigation systems. It consists of a round cast disk turning on a pin through a hole at the edge of the disk. At the side opposite the pin is attached an iron rod for a handle. When the gate is closed the disk covers the end of a tube which is cemented to a cast-iron orifice plate. By means of the rod the disk is turned on the pin until the desired amount of water is delivered through the opening made as the end of the pipe is uncovered. In closing, the disk drops down between wedging lugs which bind the disk tightly to the face plate, making a comparatively water-tight connection. This gate costs but a fraction of the amount necessary for a metal slide gate, and could have been used in many cases where a slide gate has been installed.

To provide a locking device for this type of gate, the iron handle bar may be flattened and bored with slots to pass like a hasp over a staple set in the wall of the gate structure. The bar then may be slipped over the staple at the notch nearest the desired position and a padlock put through the staple.

RADIAL GATES.

The use of the radial gate is comparatively new in this country. It is essentially a gate raised and lowered by revolving on a horizontal axle, to which the face is attached by arms centering at the axle. (Pl. II, fig. 1.) In practice the face of the gates has been made of simple planking nailed or bolted to ribs, or of sheet steel riveted to metal ribs. There have been a few cases where the face was built of reinforced concrete. In Canada a very simple type of this shutter has a perfectly flat face of planks attached to wooden arms. The practice in this country is for the face to form the segment of a cylinder. The arms of small gates may be made of wood, but the usual practice is to make the arms of angle or channel iron, even where the face is wood. The axles may be either sections of pipe or bars extending completely across the openings, or pins extending through the side walls adjoining the openings. Simple galvanized pipe makes a good axle for economical construction if the conditions at the gate structure are such that there is no danger of débris catching on the axle and bending it or washing it out. The more finished construction, which does not tend to obstruct the channel, consists of a steel pin set in a tube cast in the wall of the structure.

There are two great advantages in this type of shutter. First, friction is changed from sliding friction in the guideways, as usually used for gate shutters, to axle friction, with a lever arm the length of the gate arms. The second feature in favor of this gate lies in the form of lift. The usual stem-gate lift requires that the point of application be approximately twice the height of the opening above the bottom of the gate in order to lift the shutter clear of the opening. In nearly every case there is a waste of material in securing the elevation for the lift. This argument does not apply to most river gates, for the reason that the additional elevation is of benefit and is necessary in some form to give a high bulkhead to prevent flood water in the stream topping and destroying the structure. But there is an advantage in the case of other gates where the height of the levee is the controlling factor, and all the material above that height is so much that does not add any benefits to the structure. Since the cable or other form of lift can be attached to the very bottom of the radial gate, the winch may be set approximately on the level of the gate top when the latter is closed and the cable wound up by the winch, lifting the radial gate until the bottom is approximately level with the drum. As the radial gate requires no guides, it extends up into the air without other support than the axle, and there is no loss of material for lift standards, as is the case for most stem lifts.

The great factor against the radial gate always has been that the only discharge through it was undershot, but there is no reason why this should be, as the face does not need to be a single unit. It may be made of two or more sections, the upper ones hinging on axles carried by the radial arms of the lower section or all centering on a common axle. With this arrangement water may be taken under, over, or between sections of the shutter. This allows heavy silted water to be held back in the stream and the lighter waters taken over the top of one or more sections of the shutter. The sectional construction also allows the upper sections to be lifted out of the way. so that the lower section may be partly raised and still have a low upper crest. This may be used as a wasteway to prevent floods from topping the levees. The ordinary radial-gate panels are closed at the top when the shutter is partly raised. The greatest use for this modification of the old radial gate is probably in river gates for canals and in crest gates regulating the water above a diverting weir. The solid type of radial gate probably will remain standard as a gate for a sand sluice where the scour at the bottom is necessary, and for all other gates than the river gates the character of the water and the manner of discharge will dictate the desirability of using the sectional type.

Very large openings probably are more easily regulated by the radial gates than by any other form of shutter used in this country at present, and for this reason they lend themselves readily to places where the openings must pass cakes of ice or small débris. On the other hand, large pieces of driftwood are a continual source of annoyance during flood times. This is true especially where the water is carried through submerged orifices, as the arms of the gate in such a case are within reach of the driftwood, which easily clogs in the irons of the gate.

If it is desired that a radial gate be made comparatively watertight, a strip of rubber belting on each side and at the top may be used. The bottom of the gate may close on a strip of wood set in the concrete floor, or it may close behind a shoulder of wood or concrete.

There are various ways of balancing a gate of this type so that the net amount of labor necessary to raise it may be reduced, although it is desirable that there be plenty of weight in favor of the gate in order that it may close of its own weight, as a cable or chain, the usual type of lift, can not be used to push the gate down as can a wooden or iron stem.

Since the pressure on the face of the gate is normal to the surface, then, if the face is a true segment of a cylinder, with the axle at the center, the pressure is transmitted directly to the axle, but if the axle is set below the center there will be developed a pressure passing over the axle and tending to raise the gate. This same effect may be obtained by spiraling the face of the gate so that the resultant pressure passes above the axle.

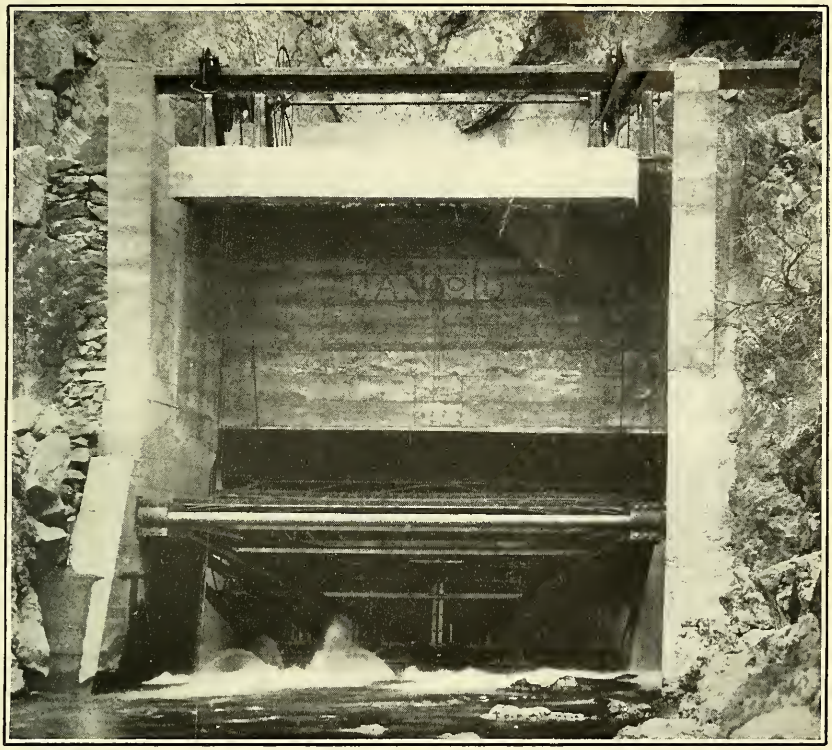


FIG. 1.—RADIAL GATE WITH CONCRETE COUNTERWEIGHT. LOWER END OF INLET TUNNEL, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

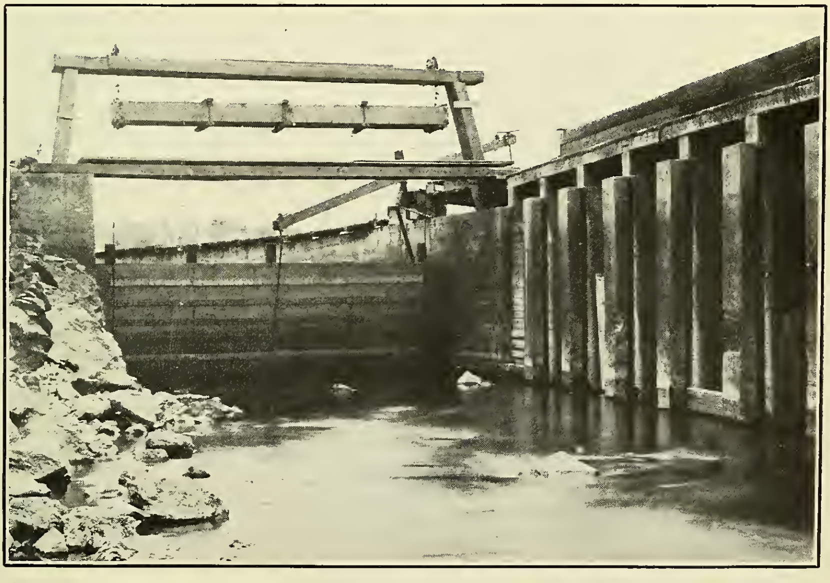


FIG. 2.—AUTOMATIC RADIAL REGULATOR GATE WITH SINGLE LEVER TO MAINTAIN CONSTANT VOLUME BELOW GATE. AT THE RIGHT FLASHBOARD WASTEWAY INTO TUOLUMNE RIVER, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

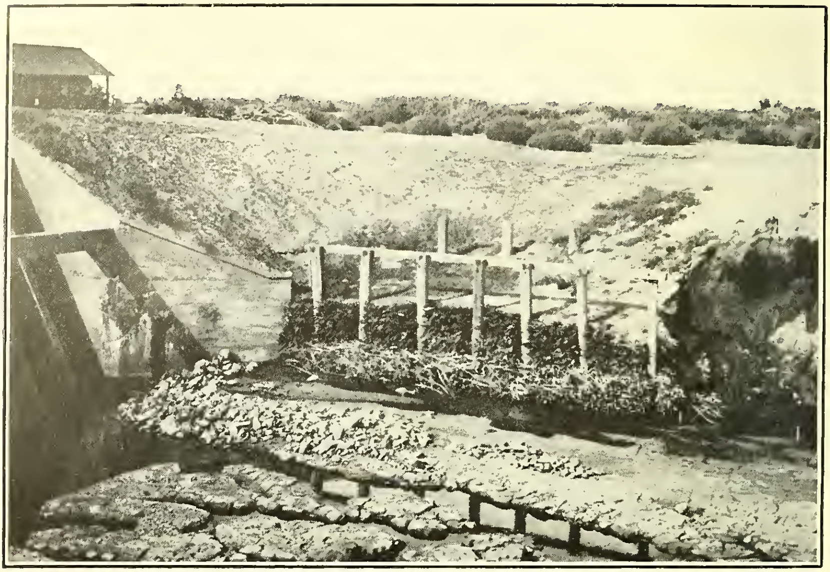


FIG. 1.—BRUSH RIPRAP BELOW ROSITAS WASTEWAY, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

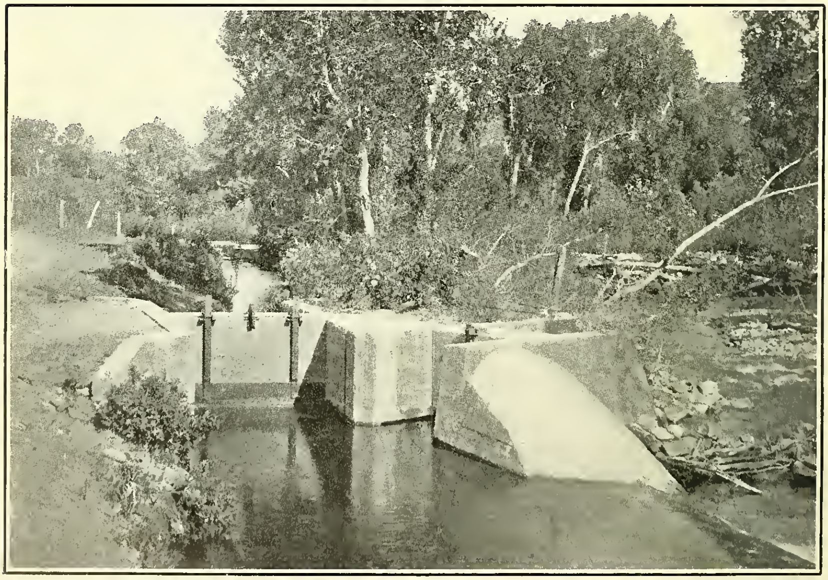


FIG. 2.—DIVERSION WEIR, SAND GATE, AND HEADGATE OF THE JACKSON DITCH NEAR FORT COLLINS, COLO.

GATE STEMS AND LIFTING DEVICES.

For very small gates using wooden shutters, the simple stem with staggered holes is recommended. (See Pl. I, *c*, *d*, *e*.)

For small iron shutters and wooden shutters up to 5 feet wide and 5 feet high a screw stem and wheel lift are recommended, for the reasons that they permit of adjustment to any desired point and are not controlled by the position of holes, notches, or other stepped devices (Pl. I, *g*). They exert a steady and gradual pull on the shutter, and do not jerk the gate to pieces. They may be used to force the shutter down as well as up, but it is recommended that they be placed in a pipe to prevent buckling if they are longer than twice the height of the shutter. The disadvantages are that the threads become bruised and corroded; that a screw can not jerk the gate where silt piles up against it when closed temporarily; that they are slow for large gates; and that the usual position is such that they require great physical effort to start and operate as compared with long-lever lifts, where a man simply may hang his weight on the end of the lever rather than use muscular force in turning the wheel.

For large sliding wooden gates a double stem with lever lift is recommended wherever they are known. The general construction of this type is shown in Plate I, *f*. This type is especially adapted to situations where a jerk may be necessary to start a gate. The lever may be used to force the gate either up or down. The disadvantages mentioned, which can be corrected easily, are that the stem crowds away from the fulcrum under the action of the lever; that a pawl is not reliable in holding the gate up; and that the lever is easily lost. By simply running the stem through a cast frame with a roller behind the stem, the latter may be held firmly up to the fulcrum. An even simpler method is to bolt a heavy timber to the head beam with a space for the stem between the timbers, as shown in Plate VI, figure 2. The pawl is used in the Arkansas Valley to hold this type of lift, and seems to give satisfaction. The lever may be chained to the structure. The double-stem lift does not have any complicated unit in its makeup, and all the necessary parts that go into the construction can be purchased at any hardware store. For this reason a broken piece can be replaced in a short time. A winch is recommended as a powerful hoist, but the great disadvantage is that it exerts tension only on the cable and can not be used to force down a gate. This practically precludes its use for any type but the radial gate, which has so little friction that it will close of its own weight where hung true and settling does not occur.

The rack-and-pinion lift is used a great deal throughout northern Colorado for gates of all sizes except the very smallest delivery gates.

It is fast, permits accurate and close adjustment, and the position of the lever operating the pinion permits a man to use his weight rather than his strength in adjusting the gate. The main disadvantage occurs in case of a broken casting, as no makeshift can be substituted easily, and the gate may be out of use until a new casting can be secured. This is one of the types of gate stem held by a pawl, and as such is criticized for the reason that the space between the notches controls the steps between the possible positions of the shutter.

As to the comparative advantages of wood, cast-iron, and sheet-steel gates, wood, of course, is the cheapest in first cost. It may be cut and adjusted easily to suit a gate structure that has settled or otherwise gotten out of line; it is elastic and will yield to prying where a cast gate will break. Ice does not freeze as tightly to wood as it does to iron or steel. On the other hand, the life of a timber shutter is much less than that of a metal gate and, as ordinarily constructed, it is less water-tight. Ice bulges wooden gates out of shape and will spring a sheet-steel shutter, but the latter can be pounded back into shape. A cast gate neither bulges nor springs but simply breaks.

Cast and sheet-metal gates cost more in the first place, but last a lifetime unless broken. Silt does not stick tightly to metal, especially a smooth, vertical side of sheet metal; such gates are practically water-tight, present a better appearance, and for this reason add to the project from a land-selling standpoint. The disadvantages are that they are liable to rust shut and break unless faced with brass. When they break the repair must come from a distance, taking time and money, while wooden gates can be repaired on the ground with lumber that can be obtained at any town. A cast gate is more easily broken by the action of a crowbar on a stuck gate or by a log in the stream than is either a sheet metal or a wood shutter.

PAVING AND RIPRAP.

The channel immediately above large gate structures may be eroded by the action of racing water, while new banks below nearly all structures become badly washed by the eddies of the issuing stream. The entry channel may be protected by a lining of concrete 3 to 6 inches thick or by a riprap of hand-laid bowlders or broken stone. This is sometimes grouted with cement mortar, forming a comparatively smooth, solid surface.

The erosion below a structure is far more difficult to handle than that above it and is more liable to cause the failure of the structure unless watched and checked in time. A short, smooth lining is only partially successful, as the high velocity in the water is not materially diminished and the erosion is only postponed until the water reaches the end of the lined section, sometimes as far as 100 feet below a gate.

Canals near mountain streams having a bottom paving of bowlders may be protected by the liberal use of these bowlders laid as simple riprap or formed into rubble concrete paving by the use of cement mortar. A rough surface, gradually becoming about as smooth as the earth channel below it, will aid the water to secure its "balance" and to pass quietly into the unlined section.

In parts of the West far removed from bowlders in quantity but near sage-covered lands, this protection is secured by the use of bundles of sagebrush securely wired to posts driven deep into the canal bottom, while the California Development Co., in the Imperial Valley, has made a remarkably efficient riprap of greasewood. Where greasewood is scarce this company uses arrow weed or young willows, but these are not as durable as the greasewood. A structure protected in this manner is shown in Plate III, figure 1. The general procedure is as follows: The erosion of the bank below the gate is allowed to proceed, but carefully watched by the ditch tenders until the extent of the erosion up and down the canal and the depth have been determined. As a rule, the erosion is quite rapid until a certain shape is washed out, when it stops so long as conditions remain the same. The sides and bottom of the hole are then trimmed neatly, the former vertical in some cases, but as a rule on a slope of about $\frac{1}{2}$ to 1. Vertical posts or light piles then are driven 2 to 5 feet apart and about 6 inches back from the proposed water edge of the channel. Sometimes a few posts are driven near the bank side of the hole. The brush then is cut into uniform lengths and bound with wire into bundles about 6 inches in diameter. These are packed into the trimmed holes in layers, with their butt ends forming an even wall in the channel. Each layer of brush is brought to a smooth surface by puddling in wet earth, and is securely fastened by wires to the posts or piles previously driven, the butt ends extending about 6 inches into the channel beyond the line of posts. One layer after another is thus placed until the level of the protection is well above that of high water in the canal. In a heavily silted water this mass of brush rapidly gathers a coating of waxy mud within the interstices at the water ends of the bundles and in this condition lasts for years, some in this locality being five or six years old and still in good condition.

GATE STRUCTURES IN OPEN CHANNELS.

By far the most important, and in many cases the only structure on a ditch, is the gate placed near the point where water is diverted from the stream. In nearly all of the Western States such a gate is required by law.

DIVERSION OR RIVER GATES.

As much depends on the diversion gate and it is close to the river, whose performance is always more or less uncertain, it is recommended that a substantial and, if possible, permanent structure be built as soon as possible. Even where the general policy of the constructors is to hold the initial expenditures down to the lowest limit, it has come to be recognized that a substantial river gate inspires a feeling of confidence in the system. As long as the control remains at the river the canal below the diversion gate is not subject to ruin from floods. Local storms may injure portions of the banks, but should the river gate fail there is not much limit to the damage that can result through the lack of this control. The trouble from the Colorado River in the Imperial Valley during the years prior to 1907 was caused by this lack of control at the river.

LOCATION OF THE GATE.

Most diversion gates are located in one of the four following topographic situations:

(1) At the point where the center line of the excavated canal intersects the river bank; (2) out in the main river channel, with a built-up canal bed between the gate and upper end of the true excavated canal; (3) some distance down the canal from the point where the latter leaves the stream, with open channel between the stream water and the gate; (4) at the upper end of the canal where it intersects the bank of a secondary channel of the stream.

Variations in local conditions surrounding the sites of such gates preclude the adoption of any plans as standard, but some of the suggestions in the plans shown will be of benefit in the designing of gates under conditions which approximate those of the gate shown.

Headgate at the bank of a stream.—If the conditions of topography, anchorage, and stream flow permit, it is customary to install the diversion gate at the true excavated head of the canal. As a rule, this should be at a point where the main current of the river, especially at low-water stages, will sweep past the gate openings and carry much of the silt not in suspension on down the stream. This is partially effected by means of sand sluices adjoining the canal openings, but the results with gates built on this principle show that the designer should not expect to rid the canal of all sand at this point. There are too many whirls and eddies to insure all the sand being on the bottom of the stream, and for this reason some of it will enter the canal.

Gates placed at the original line of the river bank are not, as a rule, subject to the full force of the current during high water. Nevertheless, the general factor of safety should be much higher than for other structures farther down in the canals of the system. The greatest factor in favor of the safety of such a structure lies in the design and construction of the upper wings and cut-off walls. If water tops, goes around, or under these there is little chance of saving the gate unless it is paved on top, so that unusual floods may pass over it harmlessly.

Headgate out in the stream channel.—Where the bed of a stream is very wide and the low-water discharge very small as compared with the floods which have determined the location of the main stream banks, it may be necessary to place the river gate out in the stream bed. It is then protected from above and below by more or less extensive cribbing or rock riprap. A canal bed, well protected on the river side by riprap, is then built up from the gate to the point where the canal line intersects the main bank of the stream.

This kind of construction also is resorted to in some cases where the river bank is more or less precipitous; it is not practicable to install a high diversion weir, and the desired canal grade intersects the river above the line of flow in time of low water. In this combination of conditions, which is quite common throughout the West, it is the usual practice to continue the grade of the ditch or canal on up the river bed, usually just under the bank of the stream, until the grade of the ditch approximates that of the stream, at which point the gate may be installed.

Headgate below upper end of the canal.—The condition spoken of in the last paragraph usually is met by constructing the ditch up the river bed as just described, but installing the gate at the point where the artificially-built bed of the ditch intersects the main bank of the stream, at which point a waste gate forms an "L" with the river gate and the surplus water is turned back into the stream.

The conditions of anchorage and foundation may not be favorable at the point where the line of the canal intersects the main stream bank and then the headgate is installed at some distance down the canal with open channel between it and the river water.

In connection with such a river gate it is most advisable to install waste gates of such capacity that the water in the channel leading to them will have sufficient velocity to keep the silt moving and not choke up the intake channel.

Headgate on bank of secondary channel.—Some of the most satisfactory structures in the West are built at the banks of secondary channels to main streams. In most of such cases the water enters from the head of the channel and is regulated roughly by logs and brush or bowlders at the point where the secondary channel leaves the main stream. In other cases the water is made to back up from the lower end of the secondary channel and in this way much of the silt and sand is confined to the main channel of the stream. The structure shown in Plate V, figure 2, is from a secondary channel and shows a great saving in material, for the reason that the amount of water entering the channel leading to the gate can be so easily controlled that there is little danger of failure from freshets, and no excessive amount of money was necessary to build expensive wings and a high bulkhead.

In the following pages the diversion works of several systems, illustrating both the simple and more elaborate types of structures, are described.

DIVERSION WORKS OF THE SOUTH SAN JOAQUIN AND OAKDALE IRRIGATION DISTRICTS.

The combined structures shown in Plate IV furnish a general idea of arrangement for an efficient method of handling of water at the head of a canal. The joint headworks of the South San Joaquin and Oakdale irrigation districts are located in the canyon of the Stanislaus River about 18 miles above Oakdale, Cal.

The river has a maximum flood flow, as shown by two floods within six years, of 62,000 second-feet. The low-water flow is about 100 second-feet. Of the 1,500 second-feet which the structure is designed to take from the river but 1,370 feet will be delivered into the head of the canal below the lower gates, the surplus being wasted over the spillway or out through the sand and waste gate, back into the canyon below the diversion dam.

The complete heading consists of the diversion dam of two arch spans with an intervening buttress, 466 feet in crest length, and a maximum height of 78 feet, and the joint headworks on the north end of the dam and of the separate Oakdale headworks on the south end. The following description is confined to the joint headworks:

The joint headworks are built of concrete, part plain and part reinforced, installed upon and against solid rock foundations.

There are four principal elements in the headworks: First, the head wall, with five openings designed to be closed with stop logs in case of accident to the gates below; water covering the diversion dam more than 3 feet in depth tops this head wall. Second, a gravity dam placed on a tangent to the curve of the diversion dam, diverging about 16° from a right angle with the center line of the canal. There are three gate openings at right angles to the line of the canal, each 6 by 9 feet, regulated by massive cast-iron gates raised by screw stems through geared hoists located on top of the gravity dam. The top of the gravity dam is 25 feet above the crest of the diversion dam and careful estimates show that maximum flood crests will top the diversion dam about 23 feet. Third, an automatic spillway about 30 feet long just below the gravity dam at an elevation of 1½ feet below the crest of the diversion dam, and a sand and waste gate just downstream from the spillway. Fourth, three gates, each 6 feet wide by 9½ feet high, set in suitable piers at the head of the joint canal, which shapes up after a transition section about 20 feet long into a concrete-lined channel 10.33 feet in total depth, 13.5 feet wide on the bottom, with side slopes of ½ horizontal to 1 vertical. The designed ultimate capacity of the canal will not be reached until some time in the future when the lower bank is raised and lined about 2 feet higher.

It is expected that the larger portion of silt will be prevented from entering the canal by the sluice-way trough in front of the river openings. The water will be further cleared of sand by the covered ducts below the gravity dam. The floor across the channel in a line 16½ feet above the lower gate piers slants down 2½ feet in 4 feet, while curved ribs carrying reinforced-concrete slab covers form ducts for carrying the sand out through the waste gate into the canyon.

The underlying ideas in these headworks are as follows: The velocity of the water through the structure is raised from 5 to 9 feet per second, with as little commotion as possible, by lowering the floor and curving the outside wall and lower ends of the piers so as to interfere no more than is necessary with parallel filaments of water. The wall is curved on the formula of a cubic parabola. The canal is protected from the entry of flood water by the high gravity section at the dam. The automatic spillway, waste gate, and sand sluice permit the removal of excess water and such sand as passes the upper sluice way. The lower gates accurately determine the quantity of water finally entering the canal.

In all portions of the headworks, depths, widths, and shapes were adjusted as carefully as practicable to prevent losses of head. Assuming the water level in the river to be the crest of the dam at elevation 350 feet, 1,500 second-feet of water enters at a velocity of 5 feet per second, the bottom of the head-wall openings being at elevation 341. Five feet above the lower gates this elevation has lowered 1.42 feet at the river side and one-half foot less on the bank side. The floor now falls rapidly to a uniform elevation of 338.59 feet. The velocity has increased to 9 feet per second. The floor from the upper gates falls 0.71 foot in a distance of 35 feet.

The upper sand sluiceway designed to catch sand, bowlders, etc., is at present regulated by stop logs, but it is the plan eventually to install an ordinary vertical sluice gate.

The contract price for concrete work in this heading runs from $14 to $15 per cubic yard on the basis of payment in bonds worth 80 cents, or less than $12 per cubic yard on a cash basis. The total cost will be about $40,000 in bonds. The structure was completed in November, 1912. The floors are made of a 1:3:6 mixture of cement, sand, and gravel, while most of the balance of the structure is made a 1:2½:5 mixture.

JACKSON DITCH HEADING, COLORADO.

The concrete and steel structure shown in Plate III, figure 2, was constructed in 1909, 8 miles above Fort Collins, Colo., on the Cache la Poudre River. A low diversion dam raises the river water high enough to supply the demands of the Jackson Ditch, which carries about 75 second-feet of water. The gate shutter is of sheet steel operated by double rack stems, connected by a bar which turns both pinions at once. In front of the slots for this gate is a set of auxiliary slots for the insertion of flashboards in case it is necessary to remove the steel gates for repairs during the operating season. This feature can be adopted to advantage in many gates. The sand sluice adjoins the ditch gate. The operators state that it works well but is supplemented by another sand gate a few rods below the diversion gate. In other parts of the West an installation similar to this has been more cheaply constructed by making the sand sluice merely a depression in the diversion weir, controlled with flashboards, which may be pulled during high water and replaced when the full height of the weir is needed, which occurs at a time when less sand is running in the stream. The total cost of the weir and gate structure was about $600. The concrete was mixed by hand in a ratio of one part cement to six parts of sand and gravel mixed.

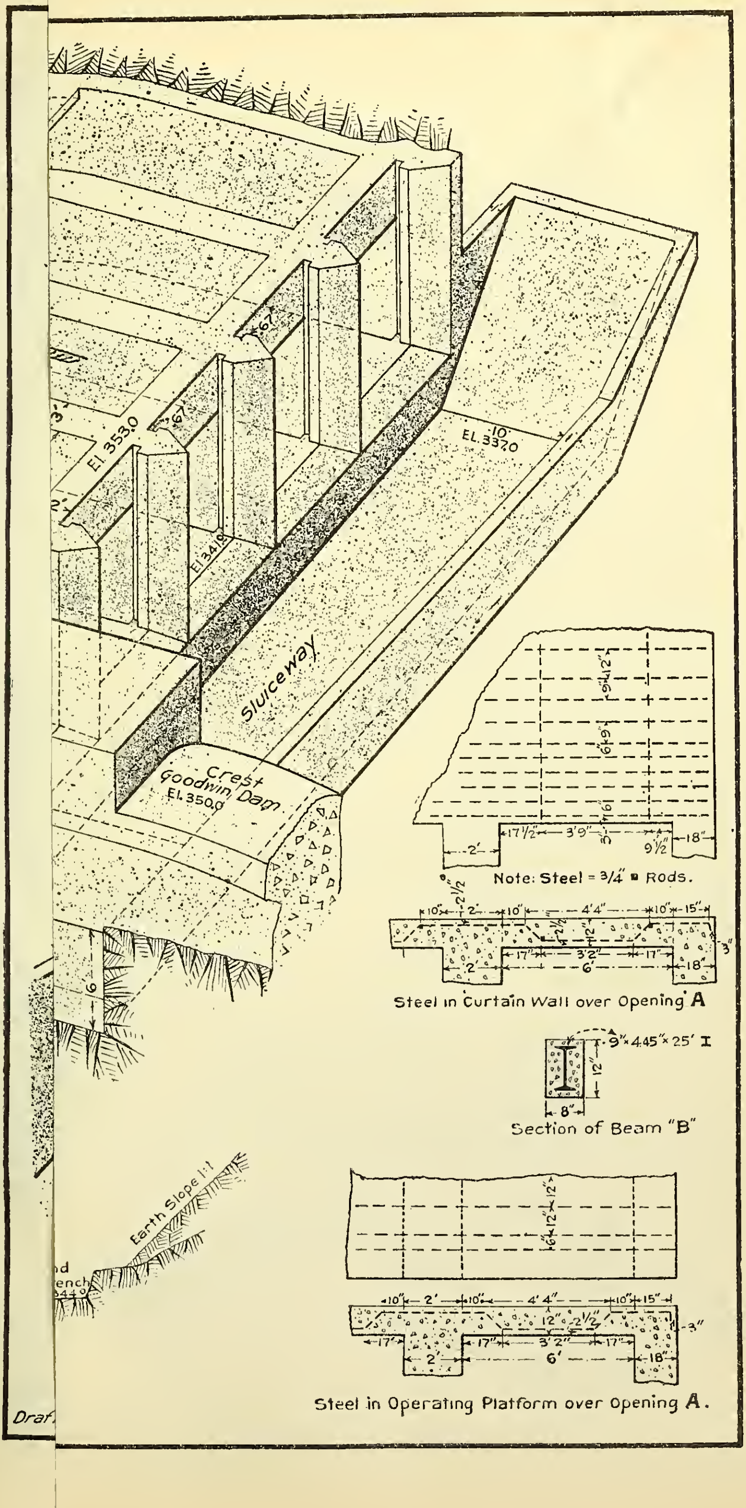
NAPESTA DITCH & RESERVOIR CO. HEADING, COLORADO.

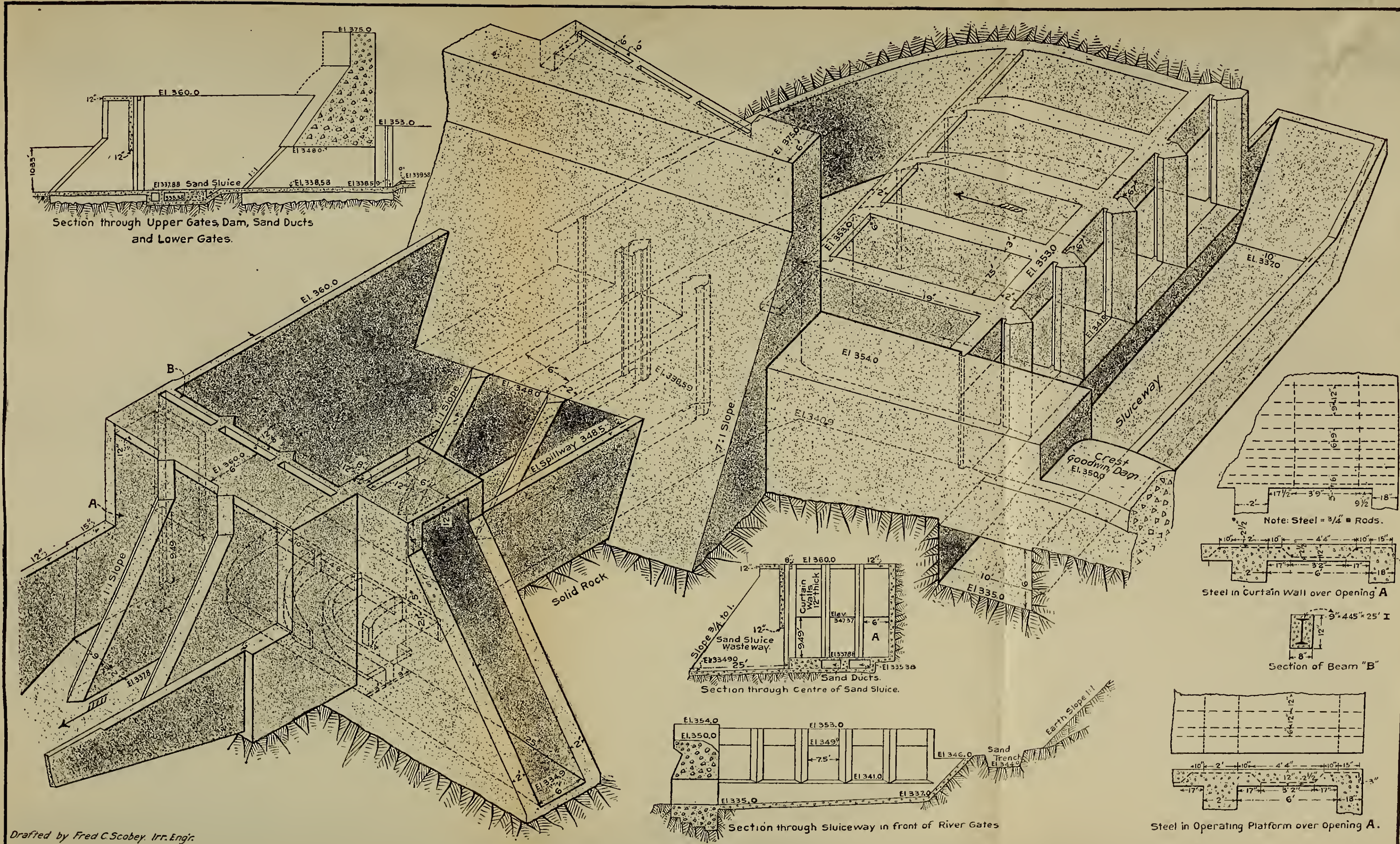
The heading of the Doyle Arroyo feeder of the Napesta Ditch & Reservoir Co., located on Doyle Arroyo, in Pueblo County, Colo., is out on the plains 24 miles below Pueblo (fig. 1).

These arroyos in the vicinity of Pueblo are subject to sudden and very violent rushes of water, being dry for months at a time and then carrying a river of water for a short period. The only possible use of such water from an irrigation standpoint is to divert a large head for a short time and store the water in a reservoir. The object of this heading was to divert 850 second-feet of water from a vertical-sided wash, or arroyo as it is known locally. The sides and bottom of this wash are in shale where there is little danger of seepage under the structure, but it was necessary to protect the bottom of the wash above and the canal below the gate by a concrete apron, as the water was to be delivered under a head of several feet, through undershot gates, where the resulting velocity and scour would be very heavy.

There are no sand sluices in connection with this heading, as there is little or no sand in the water, but the water is very heavy with adobe silt in suspension, which is carried on into the reservoir.

As shown in figure 1, water is checked up by a low-diversion dam extending across the arroyo. As the spring and flood flow of this wash is estimated at 3,000 second-feet and it is only 50 feet wide,


El. 353.0
6.7'
El. 341.0
El. 337.0
10'
Sluiceway
Crest Goodwin Dam
El. 350.0
Earth Slope 1:1
Note: Steel = 3/4" ■ Rods.
Steel in Curtain Wall over Opening A
9"×4.45"×25' I
Section of Beam "B"
Steel in Operating Platform over Opening A.
Draf



JOINT HEADING OF SOUTH SAN JOAQUIN AND OAKDALE IRRIGATION DISTRICTS ON STANISLAUS RIVER, CAL.

it was necessary to build high curtain walls above the openings in order to bulkhead out the surplus waters. The canal below the structure is 20 feet wide on the bottom, carries water 6 feet deep, and has side slopes 1 to 1. The structure as shown contains 197 cubic yards of concrete, hand-mixed in a ratio of one part cement to seven parts river gravel taken bank run. The unit cost of the concrete was about $9.50 per cubic yard. The cement cost $1.50 per barrel f. o. b. Pueblo, while the cost of the gravel was practically nothing but the digging and the hauling. Earth and shale excavation cost 40 cents per cubic yard for 110 yards.

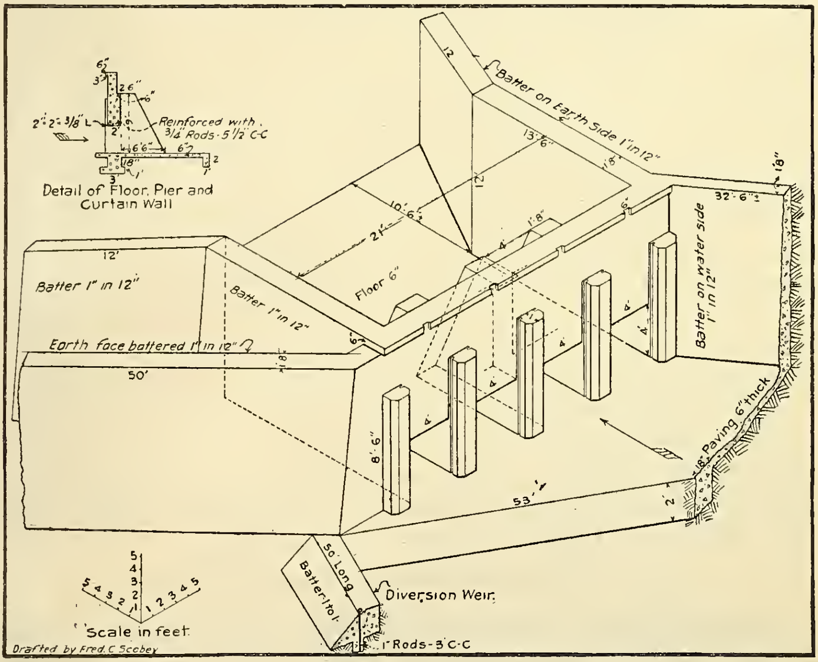


FIG. 1.—Headgate, Doyle Arroyo feeder, Napesta Ditch & Reservoir Co., Colorado.

The total cost of the structure, including the steel gates, which were made in Pueblo, was about $2,500. The lifting device is the double stem, bolted together with spool spreaders, a type which is much used in southeastern Colorado.

HEADWORKS, NORTH LARAMIE LAND CO. CANAL, WYOMING.

A good example of modern construction for a headgate serving a small canal is that of the North Laramie Land Co. (Pl. V, fig. 1.) A simple and efficient form of temporary diversion dam raises the water sufficiently to secure the desired discharge into the canal. This canal is 14 feet wide at the water line, 8 feet wide on the bottom, and will carry water 3 feet deep on a grade of 4.2 feet per mile. The gate structure has two openings regulated by steel gates, with a rack-and-pinion lift. The crest of the wings and the curtain wall above the openings are such that the maximum flood known to the stream can pass over the dam without topping the structure. The ditch below the gate is separated from the creek by a stepped concrete wall. When the writer saw this structure in May, 1912, there was about 1 foot of water passing over the weir, developing sufficient pressure on the openings to induce a velocity of 7 or 8 feet (estimated) per second in the upper reaches of the canal. As only a small amount of water was needed in the canal the gates were opened but a few inches. The high velocity caused scouring of the canal sides for about 100 feet below the gate. This condition suggested that the water might be delivered to the canal much more gently by casting some flash-board grooves in the sides of the gate structure downstream from the openings so that boards might be inserted in these grooves and the elevation of the water below the gate kept at such a height that the shutters could be opened wide and the velocity of the entering water correspondingly reduced. The water would fall over the flashboards in a vertical drop and the velocity of the water below the structure cause no damage. If the full capacity of the canal should be desired, the flashboards would be pulled and the elevation of the water in the canal would prevent high velocity at the upper end.

At the time the photograph shown in Plate V, figure 1, was taken all of the water not entering the canal was passed through the sluice-way in the diversion dam. This not only serves to carry most of the sand down the stream, but also makes it possible to draw off the water below the crest of the dam in order to make repairs.

HEAD GATE, UINTA COUNTY IRRIGATION CO., WYOMING.

A good example of modern construction of a river gate for a canal diverting water from a secondary channel of the stream is furnished at the head of the Cottonwood Canal in Uinta County, Wyo. (Pl. V, fig. 2.)

Ball Island separates the stream into two branches and the gate is installed on one of these. The amount of water flowing in the branch supplying this gate can be regulated roughly by logs and brush in the channel at the head of the island. This regulation prevents the heavy flood flow of the stream from coming with full force against the gate structure and the saving in construction, due to this safe position, is evident from the view shown. It will be noted that the wing walls do not rise far above the natural surface of the bottom land.

This gate supplies a canal 20 feet wide on the bottom with water 3 feet deep. The carrying capacity is 140 second-feet. The gate is set in a cut in cemented gravel 5 feet deep. The canal below the structure is in this same class of material, so that it forms a natural paving which does not erode easily.

The Uinta County Irrigation Co. constructed this system under the conditions of the Carey Act. This particular structure was built by force account in 1911. The steel gates proper and fittings, which were made in Denver, Colo., weigh 5,700 pounds. Cement cost 80 cents per hundred pounds f. o. b. Opal, a station on the Oregon Short Line 60 miles by wagon from the work. Sand, water, and gravel

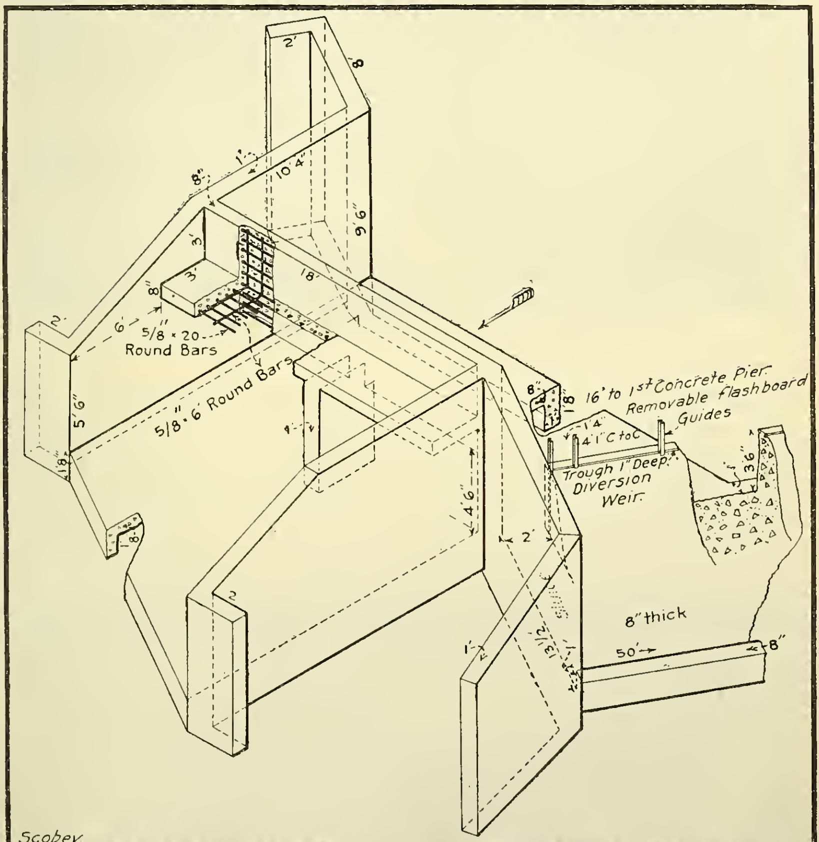


FIG. 2.—Concrete portion of headgate, Highland Ditch Co., Colorado.

were close at hand and cost nothing but the labor of one handling. The cost of the structure was $820.

HEADING, THE HIGHLAND DITCH CO., COLORADO.

The heading for the inlet ditch of the Foothills Reservoir, located in Boulder County, Colo., about 10 miles from Longmont, is a good example of a diversion from a stream which is plentifully paved with heavy cobblestones. (Fig. 2.) This paving forms a natural riprap, effectually preventing scouring of the bottom above and below the structure, which eventually would cause the failure of the gate through undermining but for these cobbles. On this particular structure, as shown in figure 2, the cut-off walls extend but 12 inches below the bottom of the floor. The ditch headed by this gate is 14 feet wide on the bottom and has a maximum carrying capacity of 400 second-feet, to be diverted from St. Vrain Creek, which has a normal flood flow of about 1,100 second-feet.

In order to raise the crest of the diversion dam in times of very low water, a set of flashboard guides is loosely placed in tin-lined holes in the concrete dam proper, the tin acting as the form for the holes when cast. The original plans called for a concrete footwalk over the weir, from which it was possible to pull the flashboards and also the guides in times of very high water, so that the obstruction offered by the weir could be reduced to a minimum. These plans were afterwards changed and a plank walk loosely bolted to the piers was substituted. A flood of sufficient size to cause damage to the structure would break these boards, and there would be no obstruction to the passage of trees and heavy débris, with the exception of the piers, which are placed so that a net opening width of 16 feet remains between them.

This structure was built in 1911. Including the bridge in connection, it contains 90 yards of concrete, reinforced with five-eighths inch twisted bars. The concrete was machine mixed in a ratio of 1:3:5 cement, sand, and river gravel. The construction was carried on by force account, and the total cost of the structure, excepting the iron work of the gates proper, was $450. Cement cost $1.75 per barrel at Hygiene, on the Burlington Railroad, 4 miles distant. The foreman was paid $100 per month, and common labor cost $2.25 per day. The total engineering charge against the structure was $40. The iron gates cost $75, in addition to the $450.

HEADWORKS, SOUTH BOULDER AND COAL CREEK DITCH, COLORADO.

A short distance above the town of Eldorado Springs, on South Boulder Creek, Colorado, the South Boulder and Coal Creek Ditch diverts 53.55 second-feet of water. As shown in Plate VI, figure 1, the creek at this point has a very rapid fall in a canyon. The bottom is strewn with bowlders from the size of a cobblestone to that of a small house.

The diversion dam is a makeshift of boards spiked to a heavy cross timber which is braced against the bowlders of the creek, the whole structure being weighted with a sloping pile of loose cobblestones.

The gate structure has 8-inch concrete side walls 10 feet long which bond with the bowlders of the canyon, in effect merely squaring up the face of the bowlders. Two vents are formed by a central

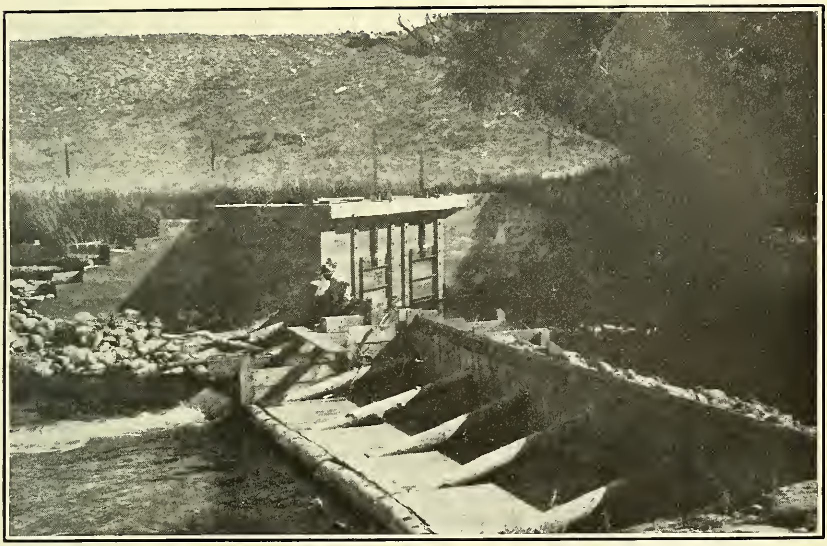


FIG. 1.—DIVERSION DAM AND HEADGATE, NORTH LARAMIE LAND CO. CANAL, WYOMING.

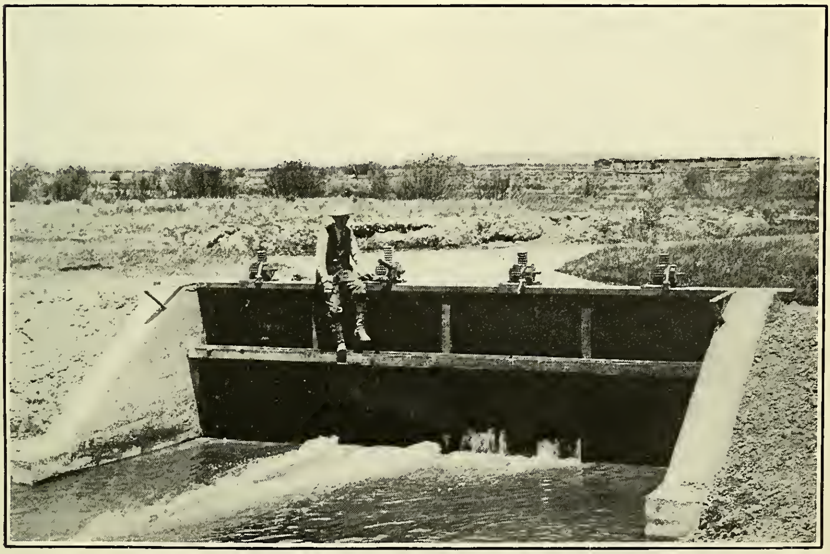


FIG. 2.—HEADGATE, COTTONWOOD CANAL, UINTA COUNTY, WYO.

FIG. 1.—HEADWORKS, SOUTH BOULDER AND COAL CREEK DITCH, COLORADO.

FIG. 2.—BIFURCATION WORKS, HOLBROOK IRRIGATION DISTRICT, COLORADO.

concrete division wall 8 inches thick. The gate shutters are each 2 feet 4 inches wide, sliding in 2 by 3 inch grooves. The individual boards are of 2-inch stuff firmly bolted to a wide gate stem of the same thickness, which is bound around the edge securely with an iron strap. Small bolts pass completely through the gate stem edgewise and hold the strap to the stem. The outside gate slots are cast in the concrete, while the inside slots are built up of timber secured to the division wall by anchor bolts. The 4 by 4 inch cap for the locking device is secured to the side and division walls by anchor bolts. Staggered holes for the locking pin are bored in the stem shutter and cap. The concrete is a mixture of one part cement to six parts sand and gravel found near the site. The total cost was $225. The items were not obtainable.

As the canyon is subject to very rough flood waters which may overtop the gate at any time it was desirable to keep the superstructure as low as possible, so that the gate standards were not set high enough for the locking holes to be bored in the stem alone, which would leave the shutter proper a solid panel. In order to secure a locking position for the shutters when wide open, it was necessary to bore the holes nearly to the bottom of the gate, and these cause a bad leakage when the gate is closed. A better construction to secure the low superstructure probably would have been a wooden radial gate extending from one side wall to the other, omitting the division wall; or, if desirable to use a slide gate, the use of the angle-iron stem shown in Plate I, *i*. The double concrete flume below the shutters is covered with a timber footbridge for a trail leading up the canyon.

BIFURCATION WORKS.

These structures are used to divide the water of one canal or lateral between two or more canals or laterals. This division may be on a proportionate basis or otherwise. A structure may be used to divide water all of which is handled by one company, or it may be used to segregate for one company water which has been carried in the canal of another company up to the point of bifurcation. If the conditions of water rights and the arrangements between the companies call for a proportionate division of whatever flow is in the supplying canal, then the openings should be so arranged that any change in the head of water will affect the discharge of both proportionately.

Where the division of water is to be nearly equal and the topography permits, it is usual practice to design a twin structure placed symmetrically with regard to the supply canal. In this way each gate is affected equally by the various factors of approach velocity, contraction, etc. If one division is to receive only a small portion of the water, the usual practice is to hold the alignment of the supply canal for the larger of the two canals and change the direction of the smaller channel. This involves about the same construction as a check gate and a lateral delivery, the check serving as the head gate of the larger of the two divisions and the lateral gate as the head gate of the smaller division.

The relations between the two companies receiving water from a structure of this class may be such that the designer is called on to attach locking devices to either or both of the division gates. This condition may involve a more expensive form of gate shutter than would be required if the water is to be divided between two canals of the same organization.

BIFURCATION GATES, HOLBROOK IRRIGATION DISTRICT, COLORADO.

About 9 miles below the head of the Lake Canal of the Holbrook irrigation district, in Otero County, Colo., the inlet canal to supply

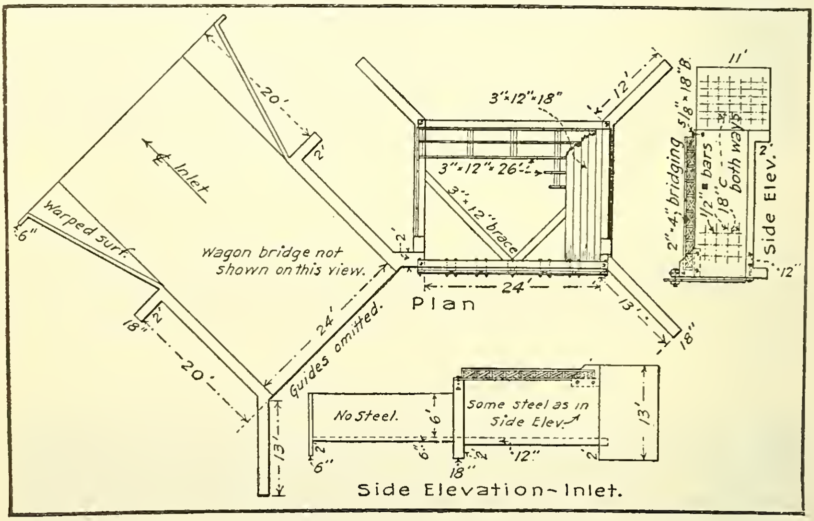


FIG. 3.—Bifurcation works on Lake Canal, Holbrook irrigation district, Colorado.

Dye Reservoir leaves the main canal. The regulation of water between these two is effected by means of the twin structure shown in Plate VI, figure 2. This structure illustrates very well the general practice in Colorado of combining wood and concrete. It is noted that the wings, floor, and side walls are of concrete, while the gate shutters—shown in detail in Plate I, *f*—the front guides, and the whole bridge structure are of wood (fig. 3). As these parts are all bolted to the concrete they may be replaced as they rot out, whereas the portions most difficult of access are made permanent.

The canal leading to the structure is 30 feet wide on the bottom, 7 feet deep at the water line, and has a capacity of 1,000 second-feet.

The gates in the main canal are placed at right angles thereto and the gate leading into the reservoir inlet canal is set at an angle of 45° with the main canal and at right angles to the inlet canal.

The use of a wooden slide gate for openings of this width, 12 feet, is rather unusual, and the writer would suggest the use of wood or steel radial gates in adapting these same general plans if the regulation to a great degree of accuracy is not required, and there is to be very much changing of the gates. Many bifurcations of this sort—supplying a reservoir—do not require to be changed more than once or twice in the course of the year, all the water being turned to the reservoir during the winter and early spring and then the inlet to the reservoir closed for the balance of the season and the main canal gates left open. In such cases economy in gate shutters at the expense of time and labor for one or two operations a season may be recommended.

This structure was constructed by contract at a time when common labor cost $2 and teams $4 per day. Water was close at hand; sand and gravel were hauled 1½ miles and cement and lumber 3 miles. The district furnished at the site all steel, hardware, and lumber except forms that went into the structure. Cement was furnished, mixed, and placed by the contractor. The successful bid was as follows:

For concrete in place, including the setting of all anchor bolts and placing steel reinforcements, $8.65 per cubic yard.

For labor, framing, and completing gates (shutters), bridges, etc., $12.75 per thousand.

For all excavation required for concrete, not included in inlet ditch, $0.34 per cubic yard. (The above quoted from contract.)

The total cost was $2,685.48.

DIVISION GATES.

Bifurcation works on a small scale are usually called division gates or division boxes. As a rule, they divide water between two small laterals, between one consumer and all others below him on a lateral, or very small ones are used by a single consumer to distribute the water in his head ditch to various parts of his land, the various shutters being used alternately as check and delivery gates, depending on where the water is to be sent.

DIVISION BOX, SHELL CANAL, WYOMING.

Plate VII, figure 1, shows the type of construction used to divide the water of a lateral 8 or 10 feet wide between two smaller laterals. The water in the foreground is turned to one or the other or both of the small laterals leading to the right and left of the picture. Simple flashboards are inserted in the slots as shown. Where the laterals are very small, the velocity low, and the possible pressure head not more than 2 feet an "L" structure of a simple wall of concrete might be used, with one leg of the "L" at right angles to each of the smaller laterals with slots in the ends of the walls where the water openings occur.

COMBINATION DELIVERY GATE, DIVISION BOX, AND MEASURING WEIR, CONSOLIDATED LOWER BOULDER RESERVOIR & DITCH CO., COLORADO.

There has been designed and installed for the Consolidated Lower Boulder Reservoir & Ditch Co., of Longmont, a small concrete and iron structure which takes the place of a delivery gate, with an adjustable shutter, lockable at the various positions of the gate shutter. This shutter is shaped and placed under conditions approximately correct for the Cipolletti weir, which gives a very close measuring device through the orifice of the gate.

The plans shown in figure 4 are for a box to be placed at the lower end of a small lateral, the water to enter the structure as shown by the arrow. The three weir openings allow water to be delivered to any one or more of these farmer's ditches, one leading from the box in the same direction as the flow of water toward the box in the lateral and the other two leading off to either side.

A modification of this structure allows a delivery to one side only, the continuation of the lateral leading off from the structure either at the other side or at the end opposite that through which the water entered.

The construction where a delivery is to be made to either side and the lateral continued from the box is similar to the first case taken above. Each of the openings leading from the box is provided with an adjustable cast and wrought iron Cipolletti weir, as shown in the details of the drawings. There are two equal and symmetrical cast-iron plates each three-eighths inch in thickness, sliding between wrought-iron guides. The inside edges of these plates have a slope of $\frac{1}{4}$ to 1, and give the correct conditions for the Cipolletti weir, aside from any velocity of approach, which must be guarded against. When the plates are wide open the weir is 3 feet long on the cast-iron crest. The latter is stationary, and set 15 inches above the bottom of the box. On the assumption that the depth of water over a weir should neither exceed one-half the distance from the weir crest to the bottom of the supply channel nor one-half the distance from the ends of the weir crest to the sides of the supply channel the maximum allowable depth over the weir is $7\frac{1}{2}$ inches.

A delivery to the maximum of 5 second-feet may be made to any one of the branches and still use the measuring device. As the slides are closed the weir condition changes from that of a Cipolletti weir to a "V" notch, and the opening finally is closed completely when the slides lap each other to the extent of 3 inches. As the weir is shortened the discharge increases over the formula discharge as soon as the depth exceeds about one-fourth the length.

The stationary weir plate A is bolted into the concrete wall of the box and extends 3 inches inside the edge of the concrete at both

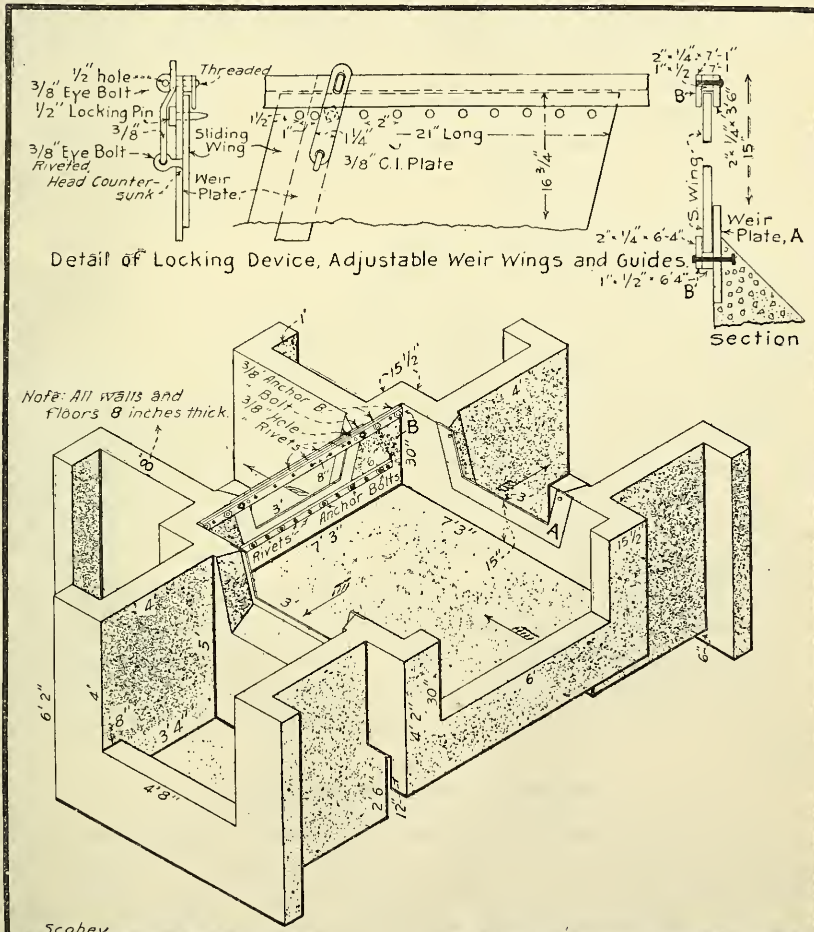


FIG. 4.—Three-way division box of Consolidated Lower Boulder Reservoir & Ditch Co., Colorado.

sides and at the bottom. Bolted to the wall and extending across the box are two guides—B–B—formed of pieces of wrought iron, the upper one 7 feet 1 inch long and the lower 6 feet 4 inches long. Each is 2 inches wide and one-quarter inch thick. The guideways are formed by riveting the above pieces to a filler piece of wrought iron of the same length as B–B, but 1 inch wide and one-half inch thick. The rivets are countersunk on the side coming against the concrete.

The gate shutters or slides are 16¾ inches high and 21 inches long, the back end being cut parallel to the front end. Near the top of these shutter pieces is bored a series of holes five-eighths inch in diameter. These holes come just under the lower edge of the upper guide and pass corresponding holes of the same size in the stationary plate. Either slide is locked in any desired position by passing a pin through the proper hole in the slide and fastening it there, as shown in the drawing. This forms a positive locking device, and the slide can be moved only under action of the key. If the ditch regulations on a system desiring to adopt such a device as this are such that the consumer is allowed to open his gate to a certain point, determined by the lock, but can close it at will, a modification of the structure may be effected as follows:

Cast two flashboard grooves in the side walls of the outlets below each weir so that boards inserted therein will close up the opening leading from the weir. By adjusting these the consumer can close out any part of the water and yet he can not take water to exceed the capacity of the locked weir. Of course it is to be understood that any gate which allows the consumer to turn water back into the ditch causes that much more water to come against the succeeding gates, with an increase in the discharge through these other gates. If flashboards are undesirable then a simple wooden slide gate may be made to fit the grooves.

This construction as installed by the company, made under force account, costs about $8 per cubic yard for concrete of a 1:3:5 mixture of cement, sand, and river gravel. Cement costs $1.85 per barrel. A structure with 3-foot weirs costs about $32, while one with 4-foot weirs costs about $40. These prices include the shutters and locking devices.

WOODEN DIVISION BOX, MONTANA.

In parts of Montana the division box shown in figure 5 is used to turn all or any part of the water in one small ditch into a head ditch or field lateral leading from the supply ditch. In the gate shown 2-inch material is used for the most part, but in sections of the West where redwood is available 1-inch stuff would do almost as well for the flashboards, sides, bottom, wings, and cut-offs, using 2 by 4 inch redwood or Oregon pine for the posts, sills, and caps. If it is not desirable to use flashboards one of the simple wooden shutters shown in Plate I may be adapted to fit. The gate shown is for a one-way division from the supply. For a two-way division the structure is made symmetrical, both deliveries being made like the one delivery shown.

PROPORTIONAL DIVISION BOXES.

In parts of Utah and northern Colorado and in other places in the West a type of structure is used which is supposed to divide whatever water there is in a ditch in a proportional manner. As a rule this division box is used on rather small ditches, owned by a few men as partners or a small group of men organized as a cooperative company. The general manner of division is the same in either case. Assume the organization to be a small cooperative company in which a share of stock entitles the holder to the same proportion of what-

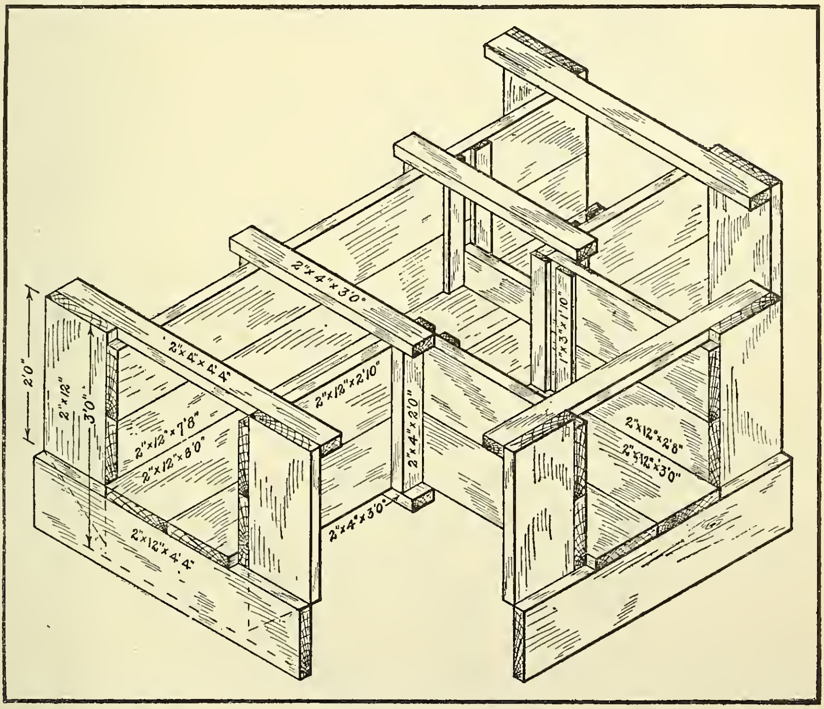


Fig. 5.—Wooden division box, Montana.

ever water is turned into the ditch as one share bears to the total number of shares in the company. Assume the total number of shares of stock to be 36 and that the first stockholder on the ditch has 11 shares and the second one 8 shares. The first division box, therefore, is to turn out eleven-thirty-sixths of whatever water is in the ditch, and the second box is to turn out eight-twenty-fifths of the remaining water. The denominator becomes 25 for the reason that after delivering water to the 11 shares the water remaining in the ditch represents 36 less 11, or 25 shares. This procedure is carried out to the end of the ditch.

Suggested design for proportional division box.—The structure shown in Plate VII, figure 2, is a very common and very faulty type of installation. The division board is set so as to divide the check board in the box in the same proportion as the water right of

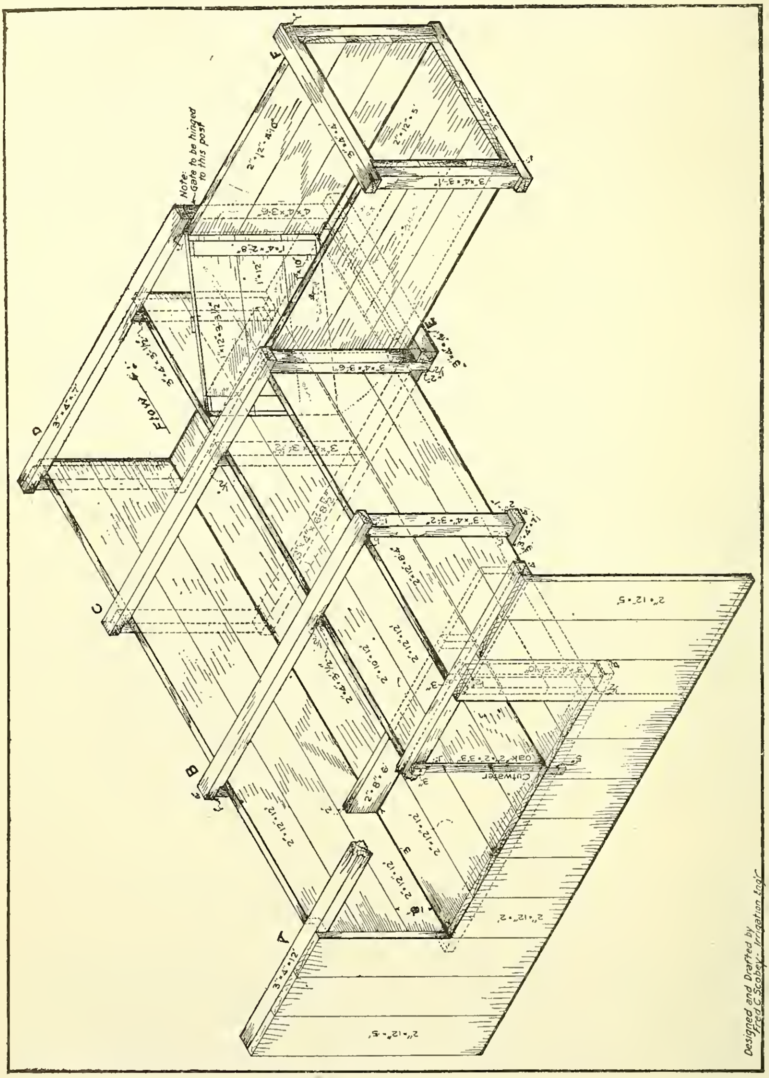


Fig. 6.—Design for proportional division box.

the consumer taking water through the small opening at the left of the box bears to the total water in the ditch. The area of the cross sections of the water in the two portions of the box may be proportional in the correct ratio, but the discharge through each part of the box equals the area multiplied by the velocity, and the latter is so retarded along the edge of the ditch by grass, rocks, and other friction elements that in the case photographed the water flowing out of the small division at the left of the box had a velocity about one-fifth that at the middle of the box. Also in the case shown in the plate, the conditions of contraction are not such that the discharge over the check or weir board is proportional to the length. The division board should have been extended as far upstream from the check board as the side walls so that the contraction of the current would be completely suppressed by the time the water reached the board, and then the discharge would be proportional to the length, provided the velocity is uniform across the weir or check board. To secure this last condition it is better to pool the water above the box by widening and deepening the ditch or by installing baffle boards in some form. The nearer still the water is above the box the more nearly accurate is the division.

As usually installed there is a very appreciable velocity toward the box, and the diverted water is less than the figured proportion for the reason that it is diverted at the side of the ditch while the greatest velocity is near the middle. The only thing that can be said in favor of this erroneous division is that the consumers at the head get less water than they are entitled to, and in this way involuntarily contribute water to the ditch to help pay for the losses by seepage and evaporation below their gates. If the division were brought about exactly as intended, then the stockholders at the lower end of the ditch would have to stand the brunt of the losses. The best way, from a theoretical standpoint, is to determine what the losses in transmission actually are and take them into consideration in determining the position of any particular division wall. Figure 6 shows a wooden division box designed to apportion out water quite accurately provided the water has but a very low velocity toward the box.

The box as designed by the writer and shown in figure 6 will deliver water to 11 shares of stock out of a total of 36 shares. That is, the net opening leading to the delivery box bears the same ratio to the total width of opening as 11 bears to 36. Assuming the division wall to be of 2-inch lumber, then the total width of opening is 70 inches. On this basis the position of the division wall is found by the following proportion:

$$\frac{x}{70}=\frac{11}{36}$$

where x is the desired width of the opening leading to the delivery box, expressed in inches. Therefore

$$x=\frac{70\times 11}{36} \text{ or } \frac{770}{36}$$

which equals 21.39, or $21\frac{3}{8}$ inches expressed to the nearest sixteenth of an inch. Therefore on the plans as shown the width of opening for the smaller channel would be $21\frac{3}{8}$ inches; then comes the 2-inch division board and then the remainder of the 6-foot width of main box, or $48\frac{5}{8}$ inches.

Assuming that the width of the ditch remains about the same and that the next consumer has 8 of the 36 shares of stock, after passing the first box the water represents 36 shares less 11 shares, or 25 shares, and the width of the opening leading to the delivery box becomes

$$\frac{x}{70}=\frac{8}{25} \text{ or } x=22.4 \text{ or } 22\tfrac{3}{8} \text{ inches.}$$

Note that all of the posts supporting the division wall are set in the larger channel for the reason that any influence due to these posts would affect the larger channel less in proportion than the smaller one. These posts go through the floor but are not set into the sill as are the outside posts. The check or weir board goes completely across both channels and the lower board of the division wall is cut to set down over the check board. For a large division box on this plan, or where the soil of the channel below the box is eroded easily, a lower cut-off wall and a wing on the side opposite to the delivery box should be added to the structure.

The siding and floor of this structure are given as 2-inch stuff. In southern California, where densely fibered redwood is obtainable, 1-inch stuff would suffice. The thickness of the boards may be altered to suit the local lumber.

The only piece of hardwood in the structure is the cutwater, which should be of oak or it will not last long. It should be screwed into the ends of the division wall boards and tightly screwed to the cap and to the sill. This construction saves the use of any side posts above the weir board, which posts would alter the proportionate division of water. Thin strips of sheet iron may be fastened to each side of the division wall with stove bolts to strengthen it. The upstream side of the cutwater is beveled to a knife edge, as shown, from the floor to the cap. It is to be noted that the width of the division board is deducted from the total width of the main box; that is, 2 inches is deducted from 72 inches, leaving 70 inches to be divided proportionally.

The weir board is placed 3 feet down the channel of the box in order to suppress the contraction and make the flow over the board approximately proportional to the length between walls. This box is designed to be used where there is not sufficient fall to the land to make a clean drop in the ditch at the division box, but this board will reduce the influence of the water below the board so that the flow is divided as nearly proportional as the expense will justify. Greater refinements of division mean greater cost to the device in length of channel, baffle boards, etc. The weir board need not be made sharp for this kind of a box, as the discharge over the square edge is quite proportional to the length of the crest. Even though partially submerged, the two discharges will hold the true proportion quite closely.

When it is desired that no water be turned to the delivery box, then the gate is closed on its hinges and the water passes through the box and back into the channel below the box, keeping both sides of the division wall clear of silt. The crack under the gate, left so that the gate may swing freely, is closed by a stop board nailed across the channel of the delivery box, as shown. The box contains about 650 feet b. m. of lumber.

LATERAL HEADGATES.

It is a difficult matter to draw the line between a lateral headgate on one system and a delivery gate on another. In this publication structures will be classed for the most part in the way they were classed by the companies using the plans in question, but the reader should understand that most of the comments on the conditions of divergence for a lateral gate are applicable also to a delivery gate, turnout, or whatever this class of structures may be called in the particular part of the country in which they are made.

Lateral headgates divide themselves naturally into two distinct classes—those having essentially a tube of some form through the bank, and those which take an open-box culvert form. The first type preserves the continuity of the surface of the levee for road or other purposes, and the second breaks the levee surface and must be bridged if the levee is to be used for a continuous road. Small laterals may be served by either type, but as a rule very large laterals receive their water through the open-box type.

Another important factor entering the decision as to which type to use, is the relationship between the top of the bank and the canal water. Where the bank crest is more than 5 or 6 feet above the water to be diverted it is better to use the tube type for comparatively small laterals, as the height of the side walls, with the added detrimental feature of the break in the canal bank, causes greater expense than would be required of a tube delivery.

The tube form is desirable, especially in cases where the canal occupies a supported position along a hillside and a drop of some form is necessary between the canal and the general level of the land which must support the lateral after it leaves the canal.

The open type of gate replaces the levee for the width of the gate, and it must be prepared, therefore, to withstand all of the conditions of variation in water level in the canal that are required of the levee. The front, wing, and side walls need not be any higher than the crest of the levee adjoining the structure. On the other hand, if they are lower, then the high-water line in the canal is lowered accordingly. It may be desired to have the lateral gate act as a spillway for surplus water to pass from the canal into the lateral and on into some natural drainage. Such a condition as this may be met by so designing the front of the lateral gate structure that water may top it and be collected in the culvert below without damaging the anchorage within the wing walls.

The same thing may be said of the tightness of the shutters in a lateral gate as of a check gate. If the shutters act as regulators only and there is always more or less water being delivered into the lateral, then there is no necessity for the gate to be water-tight, but if the lateral is of such small size or the conditions of delivery are such that water is turned out for intervals, then it is desirable that the structure be made water-tight. This is true particularly when the water carries silt in suspension.

Experience has shown that it is very desirable to design a structure leading from a canal so that the general shape of the canal bank is changed as little as possible. This is comparatively easy to do when a lateral gate is designed to be placed in the bank after the canal has been operated for some years and the bank has assumed the general form which will remain and which may be called one of the individualities of the canal at that particular point. This change in the shape of the levees or banks is very marked in most systems. When first constructed the loose earth usually takes a slope of $1\frac{1}{2}$ or 2 to 1, but after some years grass and weeds appear on the levees and the bank near the water line stands nearly vertical, overhung with earth and grass in many cases, while the slope near the bottom becomes flatter than it was in the initial construction. When this final position of the canal banks can be determined, then the face of a delivery structure may be made to conform to and be flush with the steeper slope, and if the shutters are set well to the front of the gate structure there will be very little break in the canal bank and the cost and trouble of maintenance due to the deposits caused by eddies and quiet water in nooks in the canal bank will be reduced to the minimum.

The system of delivery through a lateral gate may be such that a constant quantity is desired regardless of fluctuations in the surface of the water in the canal, or it may be such that it is desired that any fluctuation in the water of the canal be shared in proportion by the lateral.

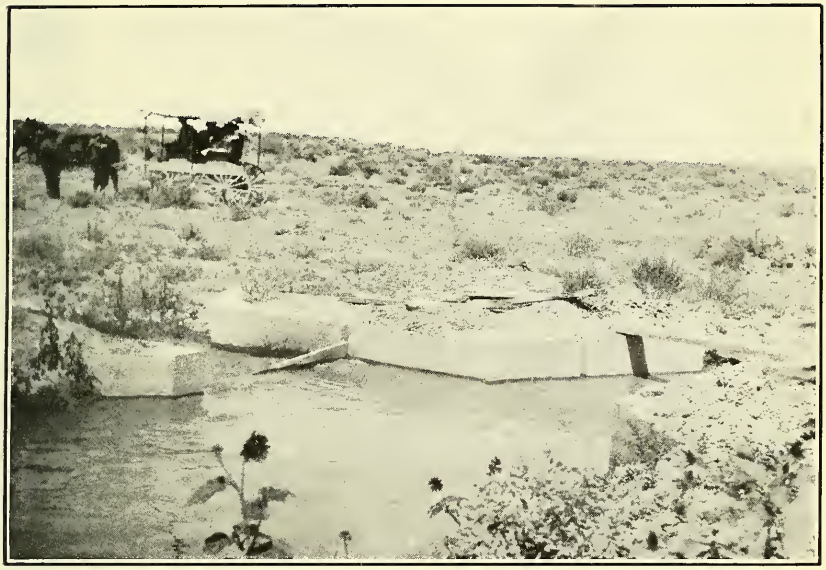


FIG. 1.—DIVISION BOX, SHELL CANAL, WYOMING.

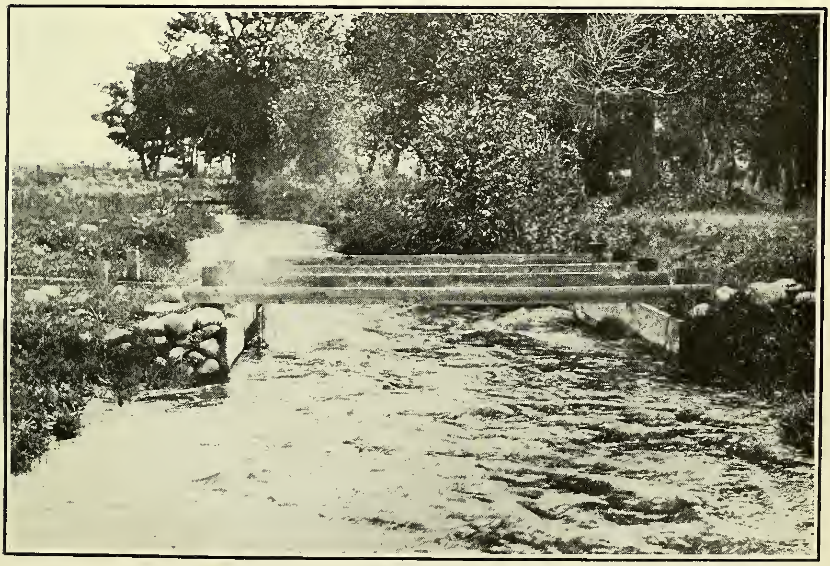


FIG. 2.—FAULTY PROPORTIONAL DIVISION BOX.

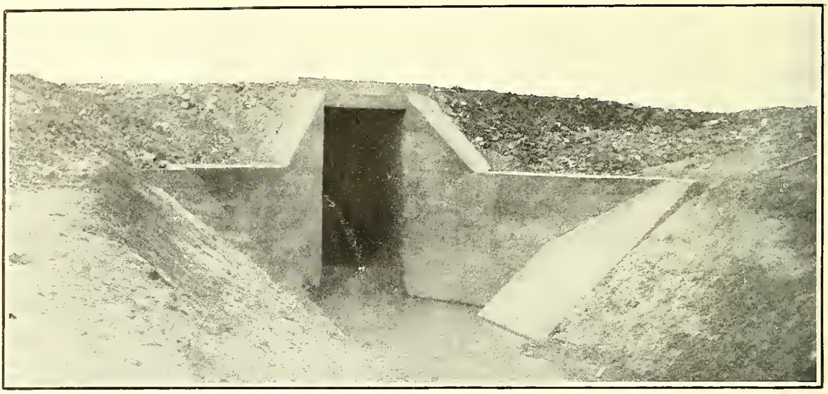


FIG. 1.—HEADGATE, LOW LINE LATERAL, ROCK CREEK CONSERVATION CO., WYOMING.

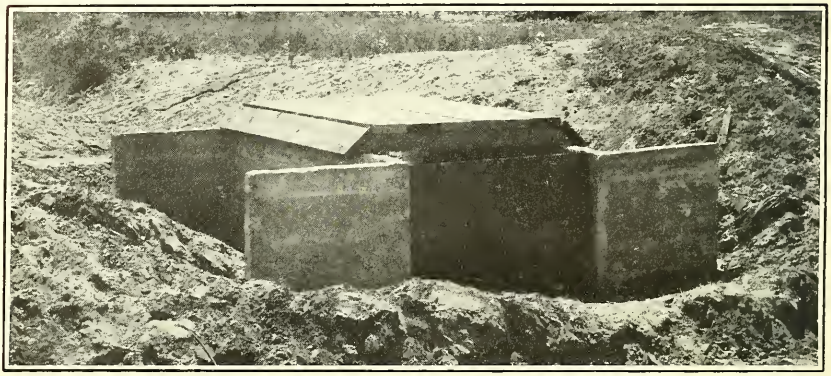


FIG. 2.—RADIAL DELIVERY GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

FIG. 3.—DELIVERY GATES ON NORTH POUDRE CANAL, COLORADO.

If the first condition holds, then it is easier to maintain a constant delivery by an undershot gate, as the discharge through such a gate varies as the square root of the head on the opening, while the discharge over a crest varies as the cube of the square root of the head. Thus, the best combination of check and delivery for the purpose of delivering a constant head is to check the water up to pass over a crest, the wider the better, and to pass the delivered water under a gate. If the second condition holds, then it is desirable to deliver the water in the same way as the water passes the check; that is, if the check has an undershot discharge, then the water should be deliv-

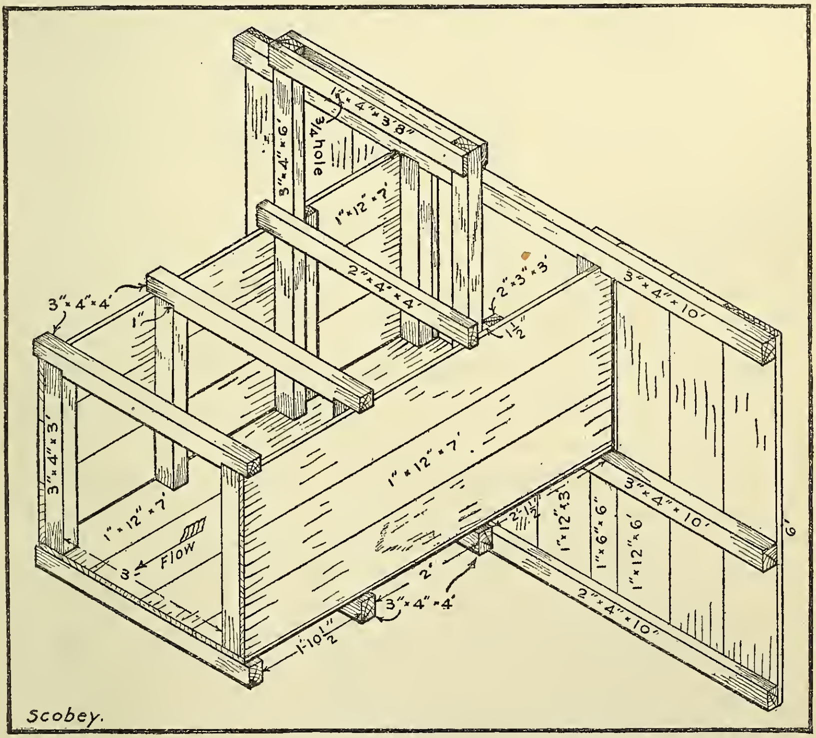


FIG. 7.—Small lateral headgate or delivery gate, Imperial Valley, California.

ered under the gate, but if the check is a crest device, the water delivered should then be passed the same way and the ratio of the crest lengths should be in the same proportion as the desired ratio of delivered water to volume allowed to pass on down the canal over the check, the crests being set in the side walls so that the contraction is practically suppressed.

SMALL LATERAL HEAD GATE OR DELIVERY GATE.

The water companies in the Imperial Valley, Cal., use a box on the general plans of the one shown in figure 7. This is a modification of a similar gate designed by the engineers of the California Development Co. The joists, floor, wings, cut-off, and walls are of redwood, and the other members are of Oregon pine. The whole structure, including the shutter—similar to the one in Plate I, *c*—contains 222 feet b. m. of lumber. These gates cost $20 to $25 in place. Two-inch material for the floor, sides, and sheet piling, instead of 1-inch, will be necessary for most lumber obtainable in States where redwood is not handled. The cracks should be battened for clear water, but the plans shown are for silted water. If the ground is eroded easily a cut-off and wings similar to but smaller than the front ones should be added at the lower end. Some of the water companies add an 8-inch weir board under the gate shutter to develop partial contraction and then measure the delivered water as an open-air or submerged orifice, as the case may be, using a coefficient of 0.62, but nearly all the gates deliver more than the rated amount of water, due to velocity of approach and imperfect contraction.

On the gate as shown the floor extends under the side walls. A better practice is to let the side walls come outside of the floor. In such case the settling of the floor boards to a slight extent does not develop a crack through which water escapes and does damage.

HEADGATE, LOW LINE LATERAL, ROCK CREEK CONSERVATION CO.

The Low Line lateral of the Rock Creek Conservation Co. of Rock River, Wyo., receives water from the Bosler No. 3 ditch. It is 10 miles long, 8 feet wide on the bottom at the head, and carries water 4 feet deep on a grade of 2.64 feet per mile. The rated capacity of the lateral is 135 second-feet, to serve 10,000 acres of land.

The structure, built in 1911, at the head of the lateral, also serves as a wagon bridge. (Pl. VIII, fig. 1.) No check structure is placed in the main ditch, as the lateral starts out down a slope so steep that drops are necessary, and it was desirable that the lateral headgate be placed as low in the main ditch as possible. The structure is of concrete with steel gate shutter and lift.

The shutter is placed in a vertical position at the line of the water side of the bank crest. A penstock 5 feet wide, with side walls 18 inches thick sloping down on the top from the height of the bank to 4 feet above the floor, leads from the main ditch bottom to the shutter. The floor slants down 2 feet from the grade line of the ditch to the gate opening. The latter is 3 feet $7\frac{3}{4}$ inches high and 3 feet 4 inches wide under a curtain wall 1 foot thick.

The floor extends 15 feet downstream from the gate shutter and then drops 4 feet vertically into a water cushion 10 feet long. At the lower end of the latter a vertical raise of 2 feet makes the net drop in the structure 2 feet. The side walls through the bank are 5 feet apart and 18 inches thick, carrying a bridge slab 6 inches thick for a roadway 6 feet wide. This slab is reinforced the short way with half-inch rods placed 6 inches on centers. Below the bridge the lower wings, which are 6 inches thick, slope down from the bank-crest height to 6 feet above the floor.

The vertical sides of the water cushion are 10 feet high, 18 inches thick, and flare at an angle of 30° with the axis of the ditch. Below the cushion the lateral is lined for a distance of 10 feet with 6 inches of concrete, the sides sloping up at $\frac{1}{2}$ to 1 from a bottom width of 8 feet. The earth section below the lining shows signs of erosion for a short distance, so it probably would have been better to construct the water cushion about 5 feet longer or line the lateral 8 or 10 feet more.

There is a 4-foot cut-off at the canal end of the structure and a 3-foot cut-off at the lower end. Each of these is 1 foot thick. The gate proper is of sheet steel with a rack-and-pinion lift.

This structure contains 111.7 cubic yards of concrete mixed in a $1:2\frac{1}{2}:5$ proportion for plain and $1:2:4$ proportion for reinforced concrete. The material in the concrete cost $9 per yard and the labor of concreting, excluding the excavation, was $2.29 per yard. Form lumber, on a basis of using it four times, cost 57 cents per yard. The excavation was in wet material, about one-half being cemented gravel. Water and cement were hauled one mile. The itemized cost is as follows:

Itemized cost data for low line lateral headgate.

Item.	Time or quantity.	Rate.	Amount.
Excavation:			
Foreman	50 hours	35 cents per hour	$17.50
Laborers	276 hours	25 cents per hour	69.00
Team	15 hours	50 cents per hour	7.50
Carpenters	5 hours	40 cents per hour	2.00
Material:			
Cement	133 barrels	$2.10 per barrel	279.30
Lumber	5,000 feet b. m.	$5.50 per thousand	27.50
Sand	46 cubic yards	$4.80 per yard	220.80
Gravel	60 cubic yards	$6.70 per yard	402.00
Rock plums	42 cubic yards	$1 per yard	42.00
Gravel [1]	6 cubic yards	$1 per yard	6.00
Steel	160 pounds	2 cents per pound	3.20
Hauling			25.00
Concreting:			
Foreman	80 hours	40 cents per hour	32.00
Laborers	540 hours	25 cents per hour	135.00
Carpenters	160 hours	40 cents per hour	64.00
Helper	90 hours	27½ cents per hour	24.75
Concrete structure			1,357.55
Steel gate			100.00
Total cost of structure			1,457.55

[1] Screening some old gravel at site.

LATERAL HEADGATE, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

The engineers of the California Development Co. have designed standard plans for a reinforced concrete branch canal or lateral headgate. These plans are based on their experience of 10 years with wooden structures which these are designed to replace. The plans (fig. 8) show a gate with a minimum amount of concrete, heavily reinforced with steel to give the required strength. Unusual local conditions render great economy in concrete necessary in this region, as it costs as high as $48 per cubic yard. For this reason much time was spent in making a theoretically economic design. The form work would be relatively expensive for this structure, and in adapting the plans for a region where unit cost of concrete would not be so great the cost of forms may be reduced by altering the plans slightly. For instance, the division walls, now made of reinforced posts braced by similar members, could be made solid pier walls; the arched supports for the operating platform might be made slightly heavier of a reinforced rectangular-section slab; the counterfort walls under the front wings might slope directly from the upper edge to the floor, omitting the reentrant angle at the back.

The cut-off walls of this gate are of wooden sheet piling extending 12 feet into the bed of the canals. In adapting the plans, light concrete cut-off walls may be used. The depth would be determined by local conditions. For a canal well lined with cobblestones, therefore not in danger from erosion below the gate, a very shallow cut-off will suffice. A good anchorage already is secured by the weight of earth filling on the floor outside the walls and wings.

The girdered floor and the counterfort supports to the side and wing walls are features which may be adopted to advantage in the design of other gates. The girders and counterforts are reinforced to take the tension, thus enabling the intervening slabs to be made much lighter than if the girders and counterforts were omitted.

The shutters are of wood, constructed so that the main regulation is effected with flashboards, but a similar board is attached to the lower end of a stem so that the whole panel may be lifted as a single unit by a rack-and-pinion or other lifting device. This allows the water to be delivered either under or over the shutter or both. The plans shown are for a 3-bay gate, while the bill of material includes quantities for 3, 4, 5, and 7 bay structures.

The development company delivers 30 to 150 second-feet of water through these gates to the branch canals or laterals of the mutual water companies of the Imperial Valley, who purchase water by wholesale from the development company. All structures below the headgate in the lateral are owned and operated by the mutual companies.

Most of these gates are not calibrated nor is any attempt now made to use a standard formula for discharge through them, as the silt changes conditions quite rapidly, but current-meter measurements in

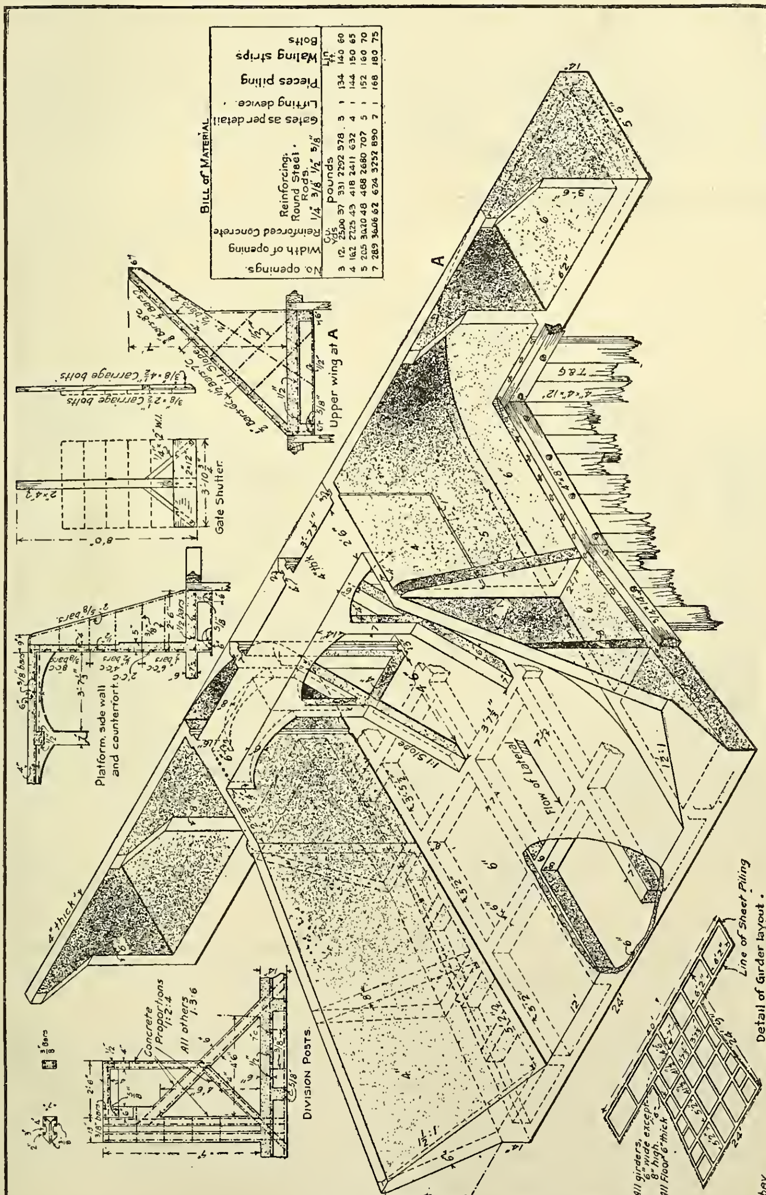


Fig. 8.—Branch canal or lateral headgate, California Development Co.

the canals below the gates, in some cases made several times a day, are made the basis of the charge for water against the mutual companies.

"A"-FRAME GATES.

A great many of the wooden lateral and check gates of the West have utilized the "A" frame in the setting of all posts and braces in the main channel of the flume forming the body of the structure.

The gross opening between side walls is broken up into bays by "A" frames embracing the guides for the shutters and the necessary braces to support the closed shutters. These frames also carry the operating platform or footwalk which acts as a strut in taking the

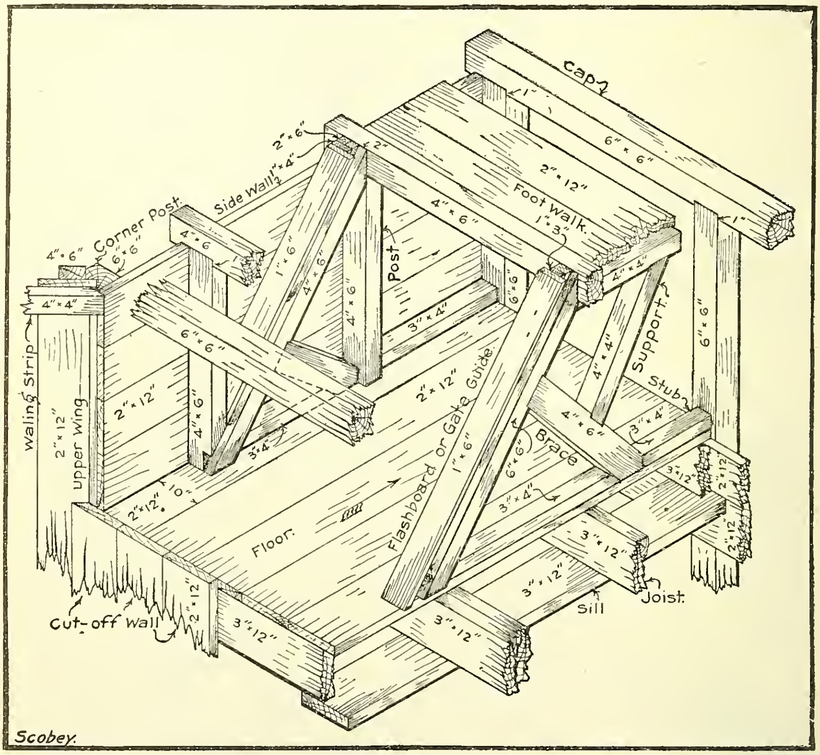


FIG. 9.—A typical "A" frame construction for headgate or checkgate as connected to drop, California Development Co., California.

thrust of the side walls and helps to maintain the spacing of the frames at the top. A typical construction of the frames and details of the general arrangement of members are shown in figure 9. The pressure of the water is transmitted downward to the floor, braces being set normal to the gate face and bearing against stubs. The larger structures have the floor spiked to joists which rest on mud sills as shown in figure 9. Small ones have the floor spiked direct to the sills. For such gates the braces go through the floor and are spiked to the sill. The "A" frames against the side walls are modified. The top of the gate guide rests against the top of a side post and the brace is carried from the angle between the floor and the bottom of the post up to the gate guide and at right angles to the latter.

The sheeting of the wings and cut-offs usually is set vertical and spiked or bolted through a waling strip. On small gates this sheeting is made of a single thickness. On large ones it is made triple thickness, each set of three boards being spiked together. The middle board is offset so as to form a tongue-and-groove joint. This "Wakefield" piling, as it is called, may then be driven with a maul or light pile hammer. The lower end of each piling is slightly sharpened at the exposed edge. This causes it to crowd closely to the preceding pile and make a tight joint.

The depth to which it was necessary to carry the cut-offs depends a great deal on the height to which the water is to be held up by the structure. If the water above and below the gate will be on approximately the same level, say within 1 or 2 feet, then it is not necessary to go more than one-half the depth below grade that the side walls extend above grade, but if more than that amount of pressure is developed the wings and cut-offs should extend as far below grade as the side walls do above.

High side walls that are separated too far to carry caps as struts are braced diagonally from the floor at about the line of the first division wall. High "A" frames have several diagonal braces, with horizontal sashes to prevent buckling.

The "A" frame catches trash easily and the water pounds violently if under much pressure, but both these defects may be much remedied by sheeting all the "A" frames on both sides with light boards. If used as a simple lateral headgate or check the upper and lower wings and cut-offs are identical, but if there is a drop in the grade line at the structure the lower posts are carried to the bottom of the water cushion and sheeted horizontally on the earth side as shown in figure 9.

DELIVERY GATES.

The same general discussion applies to delivery gates as to lateral gates. In addition it is generally necessary to have some form of locking device. Many companies place a device such as this on all gates, but do not use it unless it is found that the consumer under the delivery gate is abusing the confidence placed in him. In deciding upon a locking device for a delivery gate the designer must know the system of delivery of water. Some companies allow the consumer to shut the gate after he has received what water he wishes for that particular irrigation. For such a consumer a lock must be used which permits the gate to be opened to a certain point, determined by the position of the lock, but permits the gate shutter to be closed at will. Most of the locks on standard sheet-steel gates are of this pattern. Other companies do not allow their consumers either to open or close the delivery gates. For such a gate there must be a positive lock which holds the gate shutter in the set position as determined by the ditch tender.

As stated before, water issuing under a gate shutter may be held more nearly constant than that passing over a crest. On the other hand, the amount of water delivered may be altered by the consumer in spite of locks if the orifice is submerged. If the consumer has a division box located close to the gate and the conditions of grade and velocity of water in the various ditches leading from this division box are such that the same amount of water in the head ditch flows away more rapidly in one direction than in another, then the back water against the delivery gate, and consequently the amount of water passing the gate, may be altered by the consumer by shifting the slides in his division box. This condition does not hold if the water issues under a delivery gate shutter into the open air, as there is no back water to be influenced by the consumer. An open-air delivery is possible only where there is sufficient difference in elevation between the canal and the head ditch to sacrifice some of it so as to secure the result desired.

DELIVERY GATE, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

Figure 10 shows a good example of economical design for a reinforced concrete delivery box of the open-culvert form. Water is diverted from a permanent canal where failure would cause much damage, aside from the immediate cost of replacement so that the upper wing walls extend farther into the bank than might be necessary for most installations of this sort. It is to be noted that the slots for the gate are placed slightly in front of the foot slab. The reinforcement does not extend down into the cut-off wall, the latter being used solely for the purpose of stopping seepage water.

This gate was built in the fall of 1910. The 7.6 cubic yards of concrete is a one to seven proportion of cement and gravel. A small concrete pedestal is bolted in the four holes shown on the top of the operating platform and to this pedestal is bolted the lever-lifting device for the rack-and-pinion lift. The cast-iron rack is bolted to the back of the gate stem.

RADIAL DELIVERY GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

The deliveries to the consumers from the main laterals of the Turlock irrigation district are now being made through simple concrete-box structures regulated with wooden radial gates. Plate VIII, figure 2, shows one of these gates before the canal bank has been completed. The roofing over the box will serve as a bridge. The wings of these gates extend at right angles to the flume a distance equal to the height of the flume. The upper wings and the cut-off wall under the upper end of the floor extend 2 feet below the floor, as a rule, but this dimension is adjusted to suit local conditions. The flume is 12 feet long, 4 feet or more high, and between 4 and 10 feet wide. The radial gate face is made of a double thickness of 1-inch redwood, the wooden radial arms carrying the thrust of the water from near the center of pressure on the gate when the canal is full to the 4-inch galvanized iron pipe axle extending across the flume

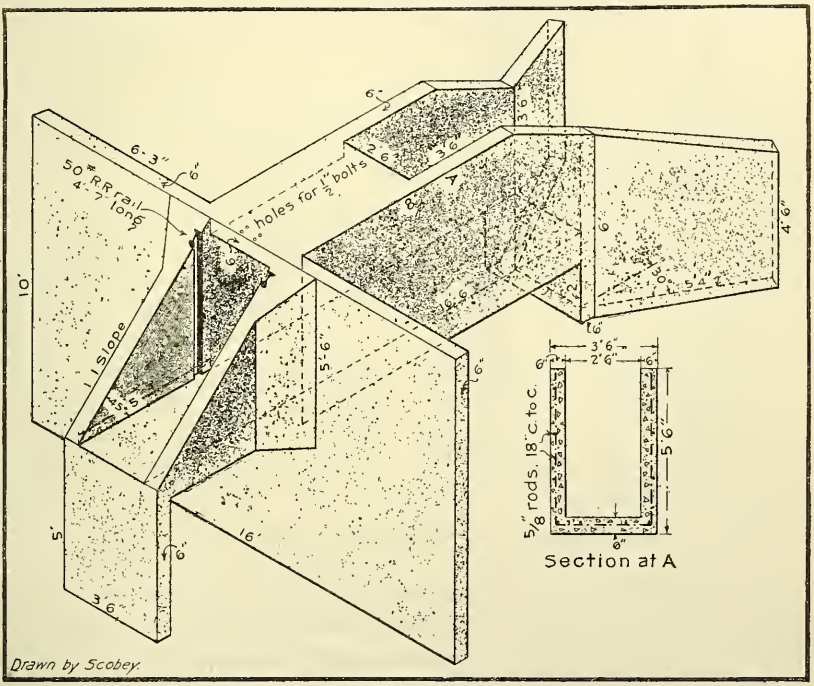


Fig. 10.—Reinforced concrete delivery gate from main canal, California Development Co., California.

about 2 feet in front of the rear end of the flume. This gate is more easily lifted when the water is in the canal than when there is no water, as the hydraulic pressure thrusts the gate against the axle and tends to float the gate. An iron bar with a handle at the free end is attached to the gate so that the latter may be lifted easily and locked in position by locking the bar over a hasp loop.

This type of construction might be readily adapted to lateral and even branch canal gates, as the forms are extremely simple, yet the structure is remarkably efficient.

TYPICAL TUBE DELIVERY WITH IRON GATES.

In the extensively irrigated region around Greeley and Fort Collins, and in the Arkansas Valley, in Colorado, a particular type of delivery gate has been used for a number of years and its use is spreading gradually to other States of the West. This is essentially a tube through the bank, with a cast-iron or sheet-iron gate at the canal end. Figure 11 shows this type of gate as used by one of the companies in northern Colorado. After a careful study of a great many installations of this type it is believed that the gate set at an angle of 75° with the pipe line gives the best results. This

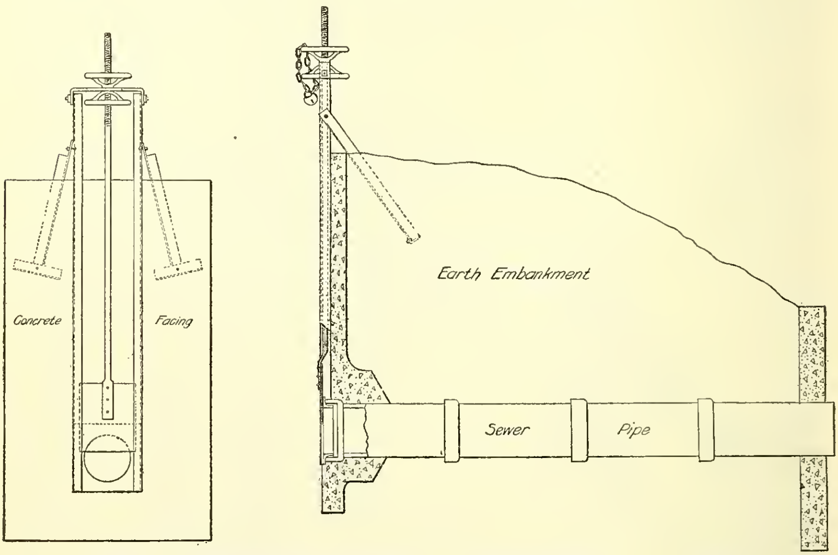


FIG. 11.—Tube delivery used by North Poudre Irrigation Co., Colorado.

slope will agree quite closely with the slope assumed by the banks of canals which have been in service for years, becoming overhung with grass and weeds. This slope allows a light concrete or masonry face to rest against the bank, more as a lining around the pipe opening than as a retaining wall, which it would be if the face were made vertical.

If the centers of the gates delivering water from above the same check all are set at the same elevation, and the grade of the pipe outlets is made the same, then all the deliveries will vary in approximately the same proportion when the head changes.

If it is not desirable to use check gates and hold the water against the delivery gates, then the latter should be set so that the bottoms of the tubes are approximately level with the bottom of the canal. Various grades are used for the laying of the pipes, but if the topography of the country permits, a grade of about $1\frac{1}{2}$ inches to the rod, or about 9 inches to 100 feet, is desirable. As a rule, the pipe tubes are 20 to 30 feet long.

The concrete or masonry face in which the gate is set should extend 1 to 3 feet below the bottom of the tube, between 2 and 5 feet on either side, and at the top from 1 foot to above the surface of water in the canal when the latter is running to capacity. In new construction where there is little or no vegetation to prevent erosion, or in light soil with relatively high velocities in the canal, the larger face should be used, but where a gate is being installed in an old well-set canal, with the banks well sodded and the permanent side of the canal well established, the smaller dimensions may be used safely. Such questions as these must always be finally determined on the ground.

The most difficult question and the one that must be settled satisfactorily in order to keep down maintenance charges is the general position of the face and iron gate. This is not so hard to determine on old ditches, but most construction is done at a time when the canal banks have not yet assumed their permanent form, and the tendency is to place the gate face snugly back in the bank so that a recess results when the banks become set. Here a quiet pool is formed where much silt is deposited, requiring a great deal of cleaning in addition to the annual cleaning of the system. This construction usually results in keeping down the initial cost to the extent of saving one or two joints of pipe, but the maintenance charges more than make up for the amount saved.

When a new gate is installed in an old canal, the face and gate should be set at such a point that the bank of the canal is disturbed as little as possible, as any irregularities in the bank cause the deposition of silt at some place near by. All things being considered, it probably is better to install the face too far into the canal rather than not far enough.

The construction at the outlet end of the tube is governed by many of the same conditions that held for the other end. A delivery from an old canal into a well-sodded head ditch will require little or no concrete or other protection around the outlet end of the pipe, but a delivery into a raw earth channel should be protected by concrete or rock riprap.

The picture shown in Plate VIII, figure 3, was taken at a time when practically all the water was out of the canal and the clean condition in front of the gates indicates that the position of the masonry face is about right with relation to the general bank of the canal. In this installation it is noticed that the face is set too far into the canal rather than not far enough, as is usually the case.

The average cost of vitrified-clay deliveries with iron gates, as given by the chief engineer of the Holbrook irrigation district, near La Junta, Colo., is as follows: 8-inch pipe and gate, $27.70; 10-inch, $30; 12-inch, $35, 15-inch, $40.

DELIVERY GATE, SUNNYSIDE UNIT OF YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

The intake of a tube delivery or turnout gate unless set at just the right point is a great source of annoyance because of the silt and sand that gathers just in front of the gate when it is not in use. To obviate this condition, remove the tendency of the eddies in the entering water to scour the canal bank, and preserve as much as possible the unbroken side of the canal the United States Reclamation Serv-

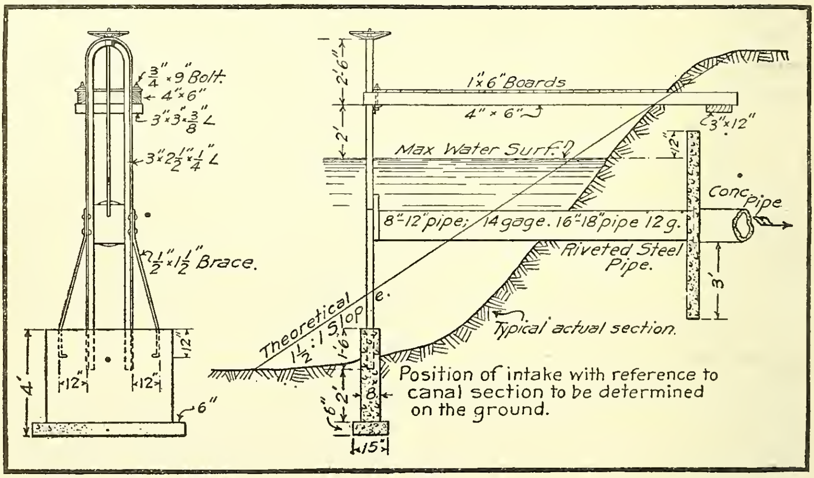


FIG. 12.—Tube delivery extending into canal, Sunnyside unit, Yakima project, United States Reclamation Service.

ice is using a system of installation on the Sunnyside Canal in Washington which is very favorable to canal operation.

A riveted-steel pipe extends out into the water of the canal, as shown in figure 12, being supported at the front end by the gate standards which are carried down to a footing wall. The steel pipe is carried a short distance into the bank where it meets a concrete pipe in a concrete cut-off collar. This installation does away with a wood or concrete face slab at the entrance to a tube outlet when set flush with the bank and also removes the opening in the tube from danger of becoming clogged with silt and trash.

The only place that comes to the writer's mind where such a construction, cost permitting, might not be used, would be where it is necessary to dredge silt out of the canal or lateral. In such cases the dredge would be liable to tear out the gate end of the construction.

Various modifications in the kind of pipe will suggest themselves, depending on the relative cost and the use. The principle will be the same.

CHECK GATES.

In a flat country where there is very little fall to the laterals and to the head ditches leading from them, it may be necessary to raise the water at the point of diversion from the canal and raise the upper end of the diverting ditch above the surface of the surrounding country. In this manner grade enough is developed for the diverted water to maintain some semblance of velocity. This condition is met by building a check gate or "check," as it commonly is called, across the canal supplying the water, below the lateral or delivery headgate. This check serves as a bulkhead to check up or completely stop the water in the canal and turn it through the side gate.

Some companies maintain a system of deliveries, especially in the smaller canals and laterals, by which the ditch tender makes the first delivery to the consumer farthest down the canal. When his run of water is completed it is desired to turn all the water to the consumer next above him. This is accomplished by the use of checks in the supplying canal below the points of diversion to the consumers.

Another use for this device is found in the latter part of the season, when there is comparatively little water in the canals. The vents in the check are closed enough so that the level of the water above them is raised and it is possible to deliver the desired volume of water.

Where the supply of water in the canal from which water is being diverted is subject to great fluctuation, it is possible to assure the level of the water always reaching a known height at least by the insertion of flashboards in a check. This is sometimes accomplished by closing some of the panels with flashboards and some with solid gate shutters, allowing water to flow under the latter. The level of the water above a check which is discharging water over a crest is held more nearly constant in spite of fluctuations than is possible in a check where the water is discharged under gate shutters, for the reason that the discharge over the crest varies as the cube of the square root of the head on the crest, while the discharge through the openings under the shutter varies as the square root of the head over the opening. In other words, a given fluctuation in the supply will be more quickly cared for over a crest than through an orifice, and the elevation of the water will change less.

This is a rather important question in the operation of a system, so a case in point may not be out of order. Assume a discharge of 3.5 second-feet to be passed through a check. With a submerged orifice 3 inches high and 4 feet wide the pressure head required will be about 6 inches. If this discharge be increased to 5.5 second-feet, then the pressure head on the same opening will be about 14 inches. If the same volume of water is passing over a crest—giving approximate weir conditions—of the same width (4 feet), then the head on the weir will increase only from 5 to about 6½ inches. Therefore this given fluctuation raised the level of the water in front of a given submerged orifice 8 inches, while the same amount of fluctuation raised the level on a crest but 1½ inches.

The great factor against securing all of the control of the water above a check by means of crest discharge is that the stilled water tends to cause the deposit of all sedimentary matter in the water, and if the check is not "pulled" regularly this deposit will become the cause of trouble and expense. On the other hand, water discharging through an undershot gate issues from the structure in a very turbulent condition and tends to cause damage by erosion of the banks below the gate. In the opinion of the writer the form of shutter shown in figure 8 (p. 37) gives the best general solution for a cheap check shutter. The loose flashboards allow for crest regulation, and the fact that the shutter may be lifted as a unit by the stem attached to the lowest board of the series allows the opening to be "pulled" and the silt scoured out. This operation is not tedious or so liable to be shirked as is the case if ordinary flashboards are used.

The elevation of the crests of various checks on a system is a matter of great importance. It is usual to design the extreme top of the structure at least 6 inches above the maximum height to which water is to be checked. Some companies mark a line on the structure as the limit of safe operation, because, as a rule, the levees above the check are made to conform to the height of the check or, as a matter of safety, 6 inches above the check.

In an uneven flat country the cost of developing in detail contours of small interval is so great and so much time is necessary to accomplish this that it is a very common sight in such irrigated regions to see a great number of checks which have been built up a foot or two in order to check up the water to reach high knolls which were not noticed during the original construction. On the other hand, it is quite common to see checks on which the high-water mark shows that there was more material put into the structure than was necessary. In other words, a check gate is one of the structures of which a careful study must be made in order to determine whether it would not be better to install wood in the initial construction and replace with concrete when the wood decays. By this time the ditch tenders handling this structure will know exactly what height the permanent gate should reach, and it can be designed accordingly. If concrete is used in the beginning, then it is difficult to add to the height without great expense and a patched appearance, and if the structure is already too high, then the extra material is wasted.

Most checks are for the sole purpose of controlling the level of the water above the structure, and the question of tightness does not enter into their design. However, if for any reason it is desired that all the water be stopped at a check and delivered to a side gate, then the shutters must be made tight by closer joints, tar or other roofing paper, or in some such manner.

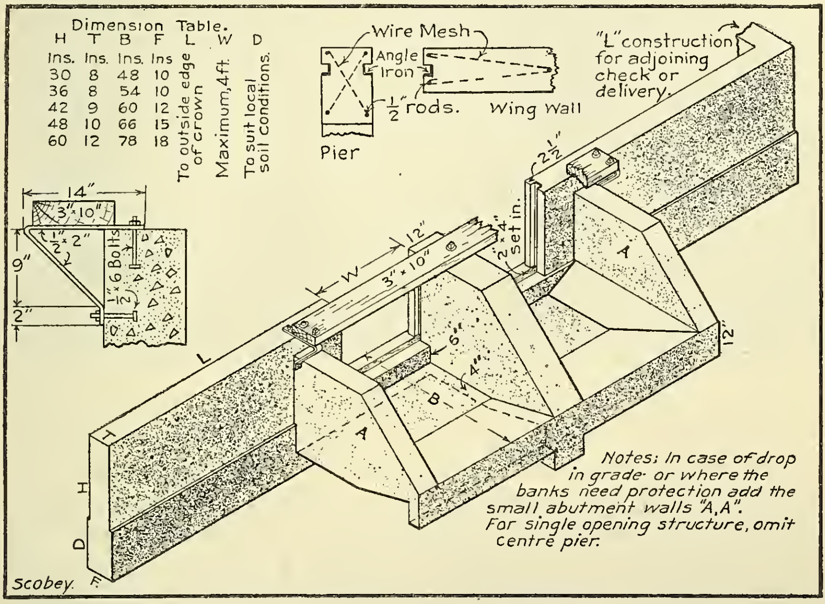


FIG. 13.—Concrete check, lateral headgate or delivery gate, Sacramento Valley Irrigation Co., California.

CHECK GATES, SACRAMENTO VALLEY IRRIGATION CO., CALIFORNIA.

The Sacramento Valley Irrigation Co. has adopted a set of standard plans which may be used in many other parts of the West. The check-gate structure shown in figure 13 can be used also as a lateral headgate or a delivery gate. In fact this is done by the simple L construction which is so well adapted to a combination of check and delivery. The general construction of this gate is adapted either to flashboards or a stem gate. The latter is used most commonly by this company. As shown on the detail view in Plate I, *i*, this stem permits of holes through it far below the top of the shutter without causing leakage through the latter, and it is not necessary for the standards to be raised above the crest of the wing walls in order to secure elevation sufficient to raise the shutter.

It will be noted from the plans that this is practically a sheet structure with a small basin attached to the back to withstand the erosion and pound of the falling water. The buttress construction of this basin also braces the front walls. The plans show a double 3-foot opening check with small buttress walls at the sides of the basin, used where there is drop in grade or the material of the banks requires protection. For double openings the middle buttress wall is not omitted, even though the conditions do not require the smaller side buttresses. The constant dimensions for all this class of structures are given in figures, while the variable ones are lettered and refer to the figures in the table under the letter given.

Plate IX, figure 1, shows a combination of check and delivery structures as used by the Sacramento Valley Irrigation Co. Note the inset panel cast in the concrete, upon which the number of the structure is carried. One gate has been numbered and the panel on another gate is shown in blank.

CHECK GATES, IMPERIAL WATER CO. NO. 1, CALIFORNIA.

Plate IX, figure 2, shows a typical wooden check as used on the main laterals, carrying 30 to 150 second-feet. This particular gate has three bays, the two on the outside regulated by flashboards and the middle one by a simple slide gate, with holes for a pin, which may be locked. The upper and lower wings are identical, as are the cut-off walls at both ends of the floor. Wings and cut-offs extend as far below grade as the side walls extend above. Replacements on a well-set ditch may be modified to the extent of making the depth of these walls about one-half the height of the side walls above grade. The floor usually is set 1 foot below the bottom grade line. The companies in the Imperial Valley use 1-inch redwood for the sheeting on this class of structures, while the posts and sills are made either of redwood or Oregon pine (Douglas fir). These gates last 6 to 10 years.

Note that the posts are all on the waterside. They pass through the floor and are spiked direct to the sills. Diagonal braces extend from the upper ends of the guideposts at both ends of the slide gate down to the foot of the posts shown under the lower cap. No battens are used, as this silted water closes all cracks rapidly, and in addition the gates are puddled in most thoroughly before water is run commercially. In the foreground of the picture is seen a good example of the use of brush riprap, described on page 11 for the protection against eddying water. The structures of this company are numbered with an ordinary, cheap grade of metal house numbers, which remain bright and are easily set on a wooden gate.

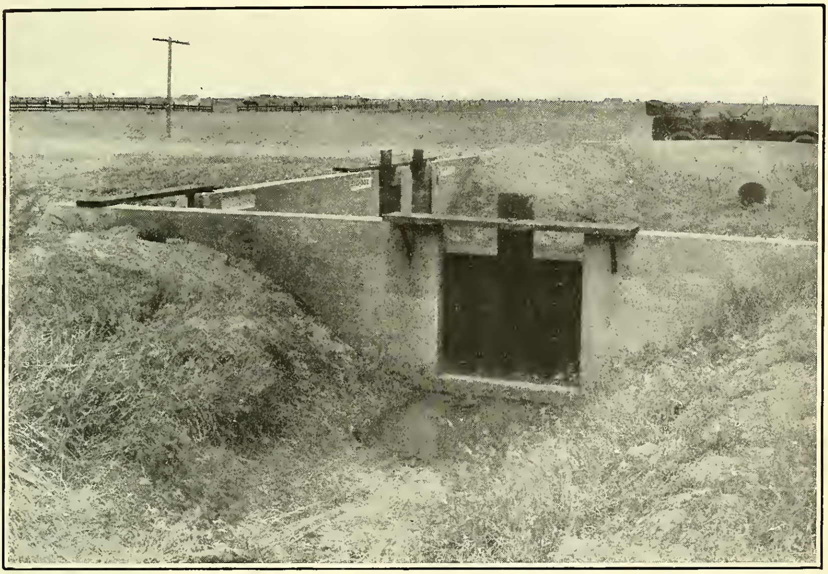


FIG. 1.—COMBINATION CHECK AND DELIVERY STRUCTURE, SACRAMENTO VALLEY IRRIGATION CO., CALIFORNIA.

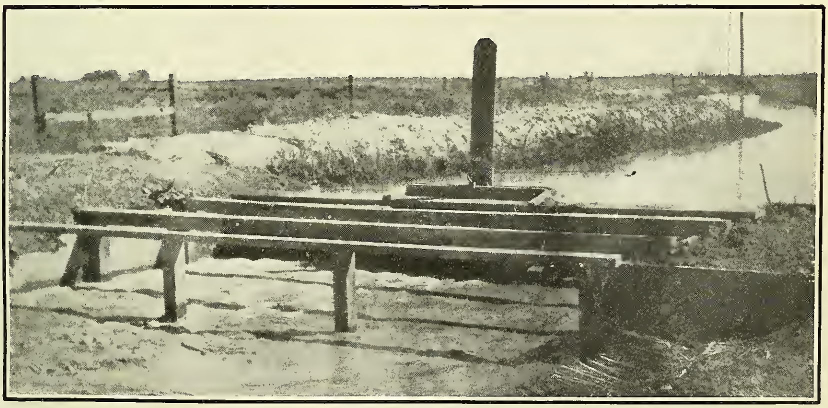


FIG. 2.—WOODEN CHECK GATE, IMPERIAL WATER CO., NO. 1, CALIFORNIA.

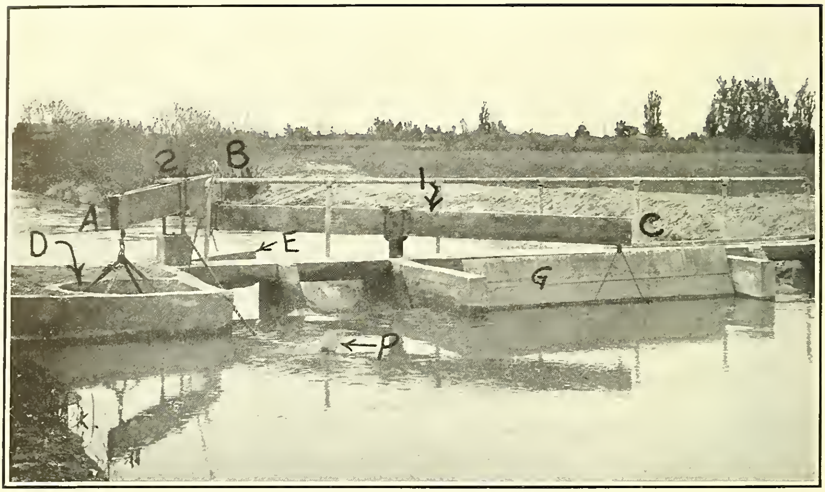


FIG. 1.—AUTOMATIC CHECK GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

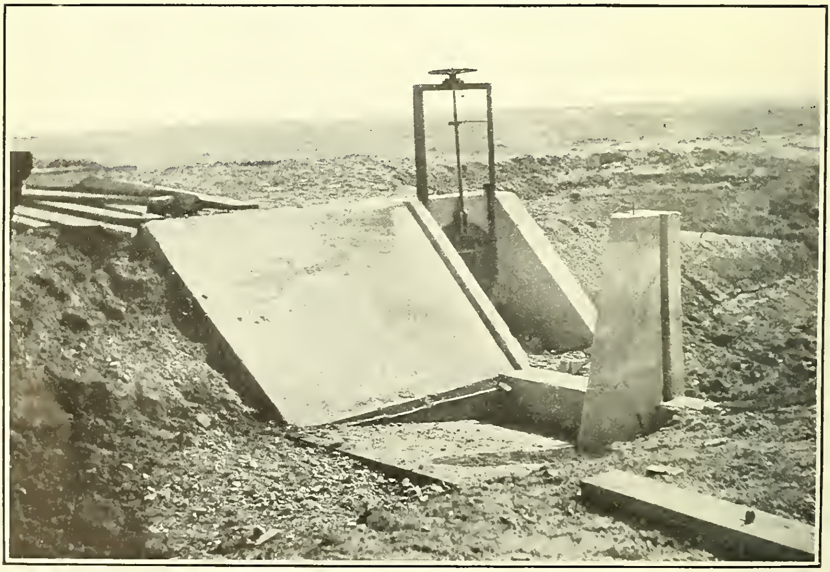


FIG. 2.—COMBINED CHECK AND DELIVERY STRUCTURE, ROCK CREEK CONSERVATION CO., WYOMING.

AUTOMATIC CHECK GATE, TURLOCK IRRIGATION DISTRICT.

The Turlock irrigation district of California is using for all new constructions and all replacements of worn-out wooden checks a patented automatic gate, which holds the water above it to a constant level (fig. 14).

The essential features of this check are: A wooden-faced gate with wood or iron radial arms attached to an axle shaft; a concrete well cast in one wing of the structure, with an inlet pipe from the water whose level it is desired to hold constant; an outlet pipe emerging from near the bottom of the well into the water below the check gate. The level of the water into which the outlet pipe discharges must be lower than the level of the water which the device is to hold constant; a tank float in the well (D) (Pl. X, fig. 1), hung by a chain to the end A of lever 2, which is connected to lever 1 at B. To the end C of lever 1 is attached the chain lifting the radial gate. The fulcrums of the levers are placed at the centers. A counterweight (E) of concrete is hung from the intersection of the two levers at B. The tank is partially filled with water, the amount adjusted to fit each gate after it is in operation.

The operation of the gate is as follows: Assuming there is no water in the canal and the gate (G) is shut, the free end of the inlet pipe (P) is placed at the level to which it is desired to hold the water, the free end of the outlet pipe being placed lower than the opening in the inlet pipe. As the water comes down the canal the closed gate causes it to rise until it enters the well through the inlet pipe. As it rises in the well the weighted bucket or tank is floated, the levers at B are both pulled down by the counterweight, and the gate lifted, allowing water to pass under it, establishing equilibrium again. The water in the well flows out slowly through the outlet pipe, tending to lower the tank, raise the weight at B, lower the gate, raise water above the gate which flows into the inlet pipe, and thus keep up a circulation of water in the well. It requires about an 8-inch head of water on the gate for it to adjust automatically.

If water has been running in the canal several days, always maintained at the same elevation, and an unexpected rise in the water occurs, the depth of water above the gate increases rapidly, submerging the inlet pipe and quickly raising the water in the well, which as quickly lifts the float, lowers the counterweight, and raises the gate to allow the unexpected volume of water to pass by until equilibrium is again established, always at the level of the opening to the inlet pipe.

In the same way, if the volume in the canal is diminished, the water level falls below the opening in the inlet pipe, the water in the well lowers gradually through the outlet pipe, the tank settles down, raising the counterweight and shutting the gate until the water is sufficiently checked to enter the inlet pipe again.

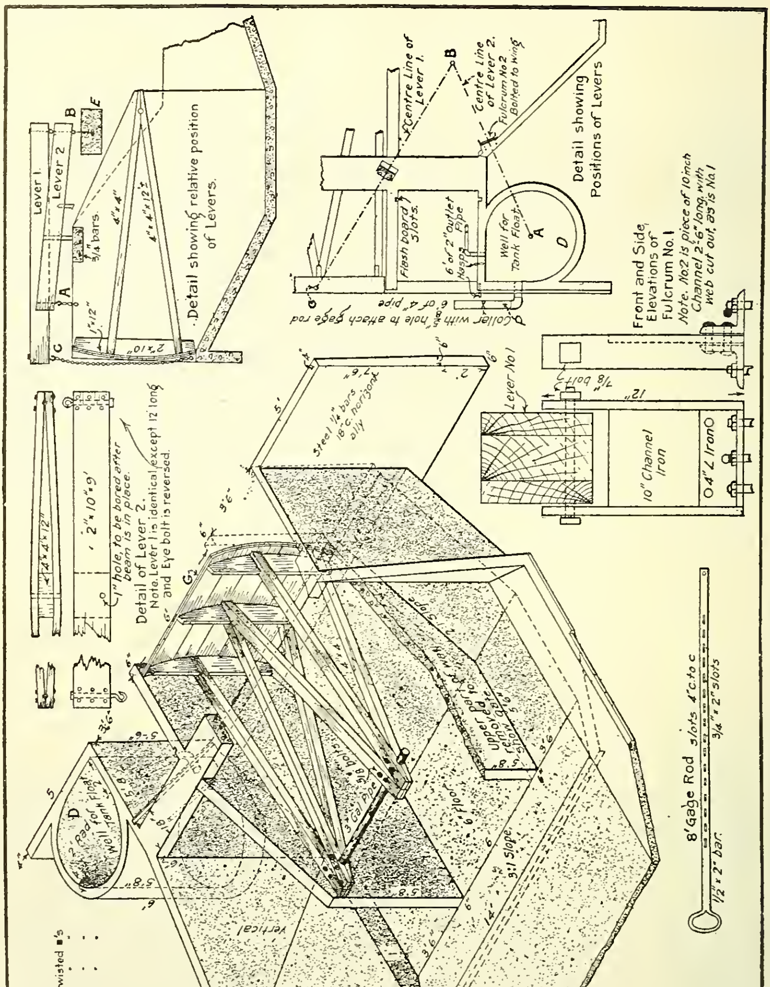


FIG. 14.—Automatic check drop on lateral of Turlock irrigation district.

Numerous modifications of this principle are practicable. Where it is desired that a certain fixed volume enter the headgate of a canal, regardless of moderate fluctuations in the supplying stream, the inlet pipe is set below the headgate and the outlet carried to a lower level. This is possible only where a diversion dam of some sort is used and the outlet pipe discharges into the stream below the diversion dam, and where this water is lower than the proposed water in the canal below the gate. Only one lever is used, connected to the gate at one end and the counterweighted tank at the other. When more water than is desired enters the canal it fills the well through the inlet pipe, raises the tank, and lowers the gate until equilibrium is established. If the supply falls then the water in the well gradually passes out through the outlet pipe, the tank falls, raising the gate, and thus allowing more water to enter.

The operation of these gates in the Turlock district is practically instantaneous and allows the canals to be run with larger heads of water than would otherwise be safe.

Where the level of the water, and consequently the volume, in a side lateral or consumer's delivery is to be held constant the inlet pipe is placed at the desired level in the lateral, but the double system of levers operates on the check gate as before. This system could be used to insure uniform deliveries to consumers and would protect the banks above the check also, because the rising water above the check would increase the delivery to the side lateral, flow into the well, raise the tank, lower the counterweight, and lift the check gate sufficiently for the excess water to pass on down the canal.

The particular structure shown in figure 14 combines both an automatic check and a drop located on lateral No. 7, which carries about 200 second-feet of water. The height of the open ends of both inlet and outlet pipes may be adjusted, as they can be swung about on the threads of the elbows. About two-thirds of the way up these two pipes the gage rods are attached. The slots in the rods are slipped over staples set in the concrete walls near the top and padlocks through the staples over the bars lock the device.

The bucket or tank hanging in the well is made of No. 16 galvanized iron, 44 inches in diameter and 3 feet high, the top lapping over a $\frac{1}{2}$-inch round pipe stiffener and riveted thereto. Two straps of $\frac{1}{4}$ by $1\frac{1}{2}$ inch iron pass completely around the bucket at right angles to each other and are brought together 2 feet above the rim.

The concrete counterweight hung below the intersection of the lines of the two levers is of convenient shape and weighs about 300 pounds more than that portion of the gate to be lifted by it.

The automatic radial gate is built up of double 1-inch Oregon pine. Before being set in the concrete the ends of the pipe axle are bored and 12-inch pins thrust through them, which prevent the axle turning in the concrete.

Where the concrete is mixed by hand on structures like the one described, the Turlock district finds it costs $20 to $22 per cubic yard, while machine-mixed concrete on large structures runs about $13 per cubic yard. The mix used is one part cement to three parts sand and five parts broken stone. Cement costs $2.75 per barrel f. o. b. Turlock, and sand usually is close at hand. Stone costs $1.75 per cubic yard and the hauling 17 cents per mile per yard additional. The reinforcing bars cost 3¼ cents per pound at San Francisco. The total cost of a structure like the one in figure 14 is about $300.

Where a similar design is used for a simple check gate, a lateral headgate, or a drop of less than 2 feet, the pier walls are carried level on top, the slope being omitted, and the axle set 3 inches higher and 3 inches farther back from the face of the gate; also the lower 12 inches of the gate shutter is replaced by a 12-inch weir board. Where used as a waste gate or in any place where tightness is desirable the shutter is made water-tight by placing waterproof roofing paper between the two layers of the double face and rubber belting is placed at the edges.

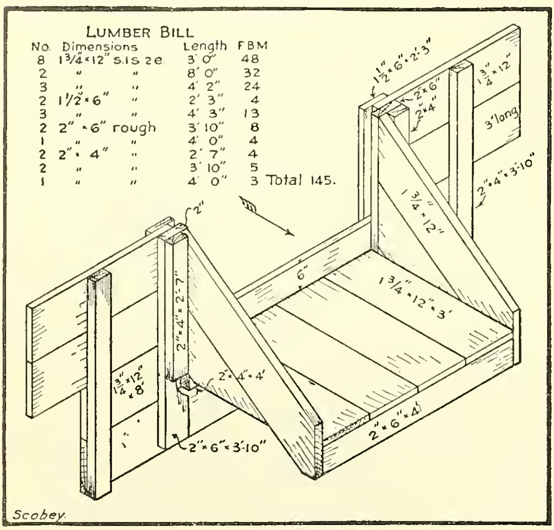


FIG. 15.—Sublateral check, Tieton unit, Yakima project, United States Reclamation Service.

SUBLATERAL CHECK, TIETON UNIT, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

A check which is well adapted to withstand a fall of water behind it is shown in figure 15. It is used for small laterals, and is adapted to the temporary construction which contemplates a permanent structure similar to the one shown in figure 13, page 47.

COMBINED CHECK AND DELIVERY STRUCTURE, ROCK CREEK CONSERVATION CO., WYOMING.

The "L" construction of check and delivery gates is well exemplified in the view (Pl. X, fig. 2) taken on one of the main laterals of the Rock Creek Conservation Co., in Wyoming.

The concrete and iron work is complete while the anchor-bolt to hold the wood foot plank, just back of the flashboard slots, is shown on top of the pier wall. The canal below the structure is lined for a short distance, sloping rapidly on the bottom to form a water cushion. A shallow cut-off wall extends vertically downward at the end of the lining to prevent undercutting of the eddying water. Sufficient cut-off should be provided under the flashboard sill and across the front of the turnout gate to prevent percolation and failure due to the hydraulic head developed when water is checked up. As shown the delivery gate is vertical. A more economical con-

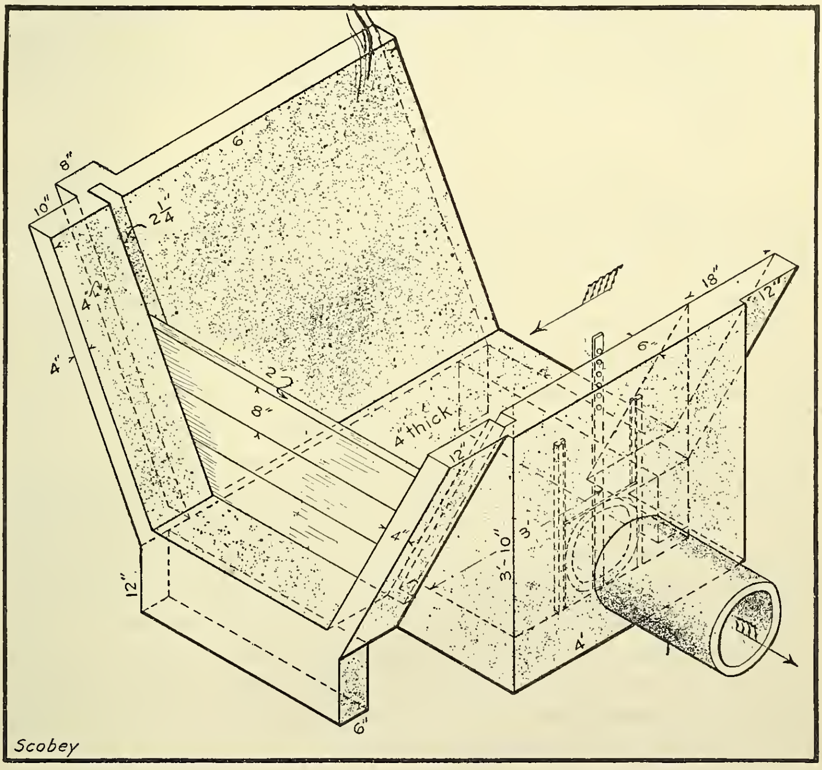


FIG. 16.—Combined check and delivery structure of Beaver Water & Irrigation Co., Colorado.

struction would be to use the 45° connection as manufactured and slope the gate to conform to the 1 to 1 slope of the lining below the check. This would remove the recess, in which silt will gather when the delivery gate is closed.

COMBINED CHECK AND DELIVERY GATE, BEAVER WATER & IRRIGATION CO., COLORADO.

A very economical, neat, and effective structure is used for the deliveries from small, open ditch channels of this company (fig. 16).

It amounts to a lined section of canal with a shallow cut-off wall at each end and a delivery tube through the bank, regulated by a sheet-iron gate. Débris is kept out of the delivery by a screen extending across the recess in which the gate is set. For most systems this screening would not be necessary. If the water in a lateral using this type of structure is to be checked up more than 2 feet above the bottom it would be well to extend the lined section farther down the channel and carry the lower cut-off deeper into the bed of the ditch. This depth will be determined in all cases by the material of the bed.

In adopting this plan a cheaper installation is made by omitting the recess for the gate shutter, allowing both banks of the lined section to slope uniformly to the bottom of the ditch. The gate shutter can be set on this slope, using the connections and gates as made by the manufacturers for a connection with a tube at 45° or 60° with the gate standards.

SAND GATES.

Some designers attempt to exclude the sand before it enters the canal by installing a sluice gate with a sill below the intake of the canal, adjoining the river gates on the downstream side, but as a rule the water is so agitated at the heading that only the heavier sand remains on the bottom and the lighter particles, whirling about in the water, are passed on through the gate to settle in the canal at some point lower down where the velocity is reduced to such an extent that the sand is no longer rolled along the bottom.

It is probably much better to install a separate sand structure far enough below the head of the canal so that the latter will have gained enough elevation over the bed of the stream to obtain a good flushing velocity, and scour out the sand deposit from time to time as water is available. If the water rights on the stream are such that there are other consumers on the stream below the sand gate entitled to water at all times, then an arrangement may be effected so that a surplus amount of water can be run and the sand gates left open throughout the season, returning the surplus water to the stream. Kansas recognizes this benefit by legislation in its favor.

THE SUMP GATE.

There are three general types of gates to remove the sand below the headgate of a canal system. The first consists of a sump connected to a discharge ditch or natural channel by gates located below the normal grade of the canal. This construction makes a combination sand and waste gate. Such a gate as this may be partly opened all the time or it may be closed completely except when a flushing head is available and then opened wide and all the water in the canal used for a short period to wash out the sand which has accumulated. The crest of the gate shutters of this type of structure usually furnishes a good opportunity to waste excess water in the canal by simply adjusting the crest height of the closed gates to the water line deemed a safe elevation. The radial gate offers a good opportunity in this class of structures, the scouring action coming at the bottom where it is desired.

THE TRENCH GATE.

The second type is used only on small ditches and is a modification of the first. It consists of a channel or groove set in the floor of the ditch across the line of the latter. A sliding gate is set in the end of this channel, opening out through the lower bank. A check board or strip of iron is fastened to the floor of the ditch immediately below the channel. This serves to stop the sand and drop it into the channel, from which it is flushed by a continuous stream passing out through the gate. In the opinion of the writer it is best to build the channel across the bottom of the ditch at an angle, with the gate at the lower end. This would cause the filaments of current in the ditch to take the direction of the channel and help carry out the sand.

A sand gate in the South Boulder and Coal Creek Canal, a small ditch diverting water from South Boulder Creek at the town of El Dorado Springs, Colo., has a channel set in the bottom of a section of wooden flume, opening over the side of the ditch into the creek. This channel is about 5 inches wide and 6 inches deep, with a check board made of simple 2 by 4 inch lumber set on edge immediately below the lower edge of the channel. This channel is at right angles to the flume.

This type of gate is easily clogged with trash, the channel being so small that a little stick could effectually commence the clogging of the opening. This may be prevented by putting in a grating of bars, slanting very gradually up from the floor above the channel to the top of the check board. The gentle incline to the bars will cause débris to be pushed on over the check board rather than "glue" to the grate, while the sand is admitted readily between the bars.

THE "LAND" GATE.

The third type of sand gate, and the one commonly used in the Arkansas Valley of Colorado, was first built by Mr. Gordon Land, of Denver, Colo., and has been known as the Land gate. This structure is essentially a check and waste gate with a double floor above the check, the upper floor being on the normal grade of the canal, while the space between the floors is separated by ribs into ducts. These ribs carry the upper floor and are curved so that the stalls between them guide the sand around into a direction at right angles to the flow in the canal and discharge it out through the waste gate forming an L with the check gate. One of these gates is included in the joint head works spoken of on page 14.

SAND GATE, MAXWELL LAND & IRRIGATION CO., MAXWELL, N. MEX.

After trying out a wooden structure, the Maxwell Land & Irrigation Co. has designed a concrete gate to eliminate the sand and coal dirt from its water, 700 feet below the river headgate. At this point an arroyo leads back into the river.

The canal, which is 32 feet wide on the bottom, carrying water 7 feet deep, with the top of the levees 3 feet above high-water mark, is lined with 6 inches of concrete for a distance of 400 feet above the gates. This lining (fig. 17) commences at the normal grade of the canal and slopes on a grade of 1 foot per 100 feet on the side next to the river and 3 inches per 100 feet on the other. This slope forms a long pit having a maximum depth of 4 feet directly in front of the gates, and it is expected that even a small head of water in the canal will effectually sluice out all silt deposited on the concrete lining. The end of the pit terminates in a vertical wall, crested with a rectangular weir, which serves the double purpose of deepening the pit by the height of the weir and giving an approximate measurement of the water in the canal, after the proper bottom-contraction conditions are effected by sluicing out the deposit above the weir.

The shutters are simple wooden slides with double stems separated by iron bolts and spreaders, on the principle of the one on Plate I, *f*. An iron-mounted lever 12 feet long gives a fast and effective lift when inserted under the bolts. The silt above such gates causes them to stick, and some lift is necessary which will jerk the gate, rather than to exert a steady pull. For this reason the lever is better than a screw lift.

Bids for the concrete construction varied from $3 to $3.60 per cubic yard, the company to furnish the material at the site. Bids on the excavation for the structure were 14 and 18 cents per yard. This will make the total cost of the concrete in place $10.50 to $11.25 per yard.

SAND AND WASTE GATE, AMITY CANAL, COLORADO.

One of the best examples of the modern construction and use of the "Land" sand gate is the concrete sand and waste gate installed on the Amity Canal by the Arkansas Valley Sugar-Beet & Irrigated Land Co. This structure (as shown on Plate XI, fig. 1) forms an L, one leg of which extends across the canal and acts as a check gate, while the other leg contains the openings of the sand ducts at

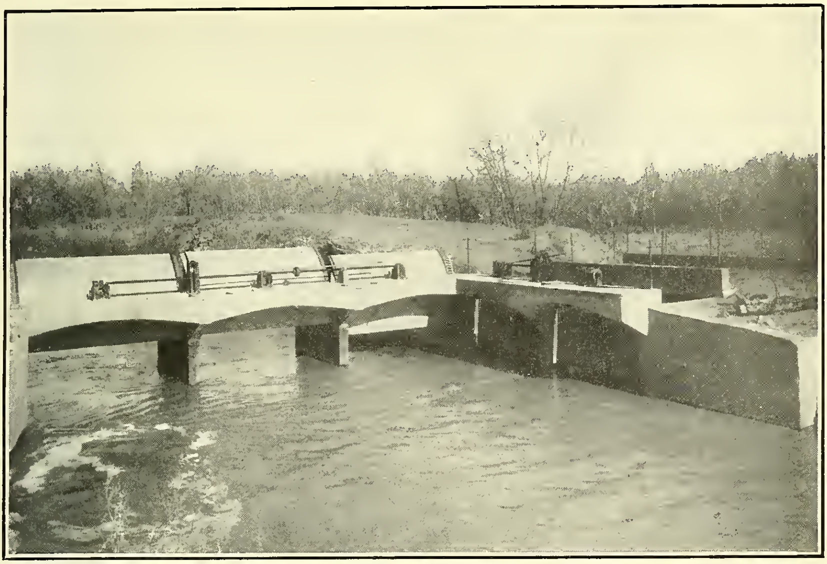


FIG. 1.—SAND AND WASTE GATE, AMITY CANAL, COLORADO.

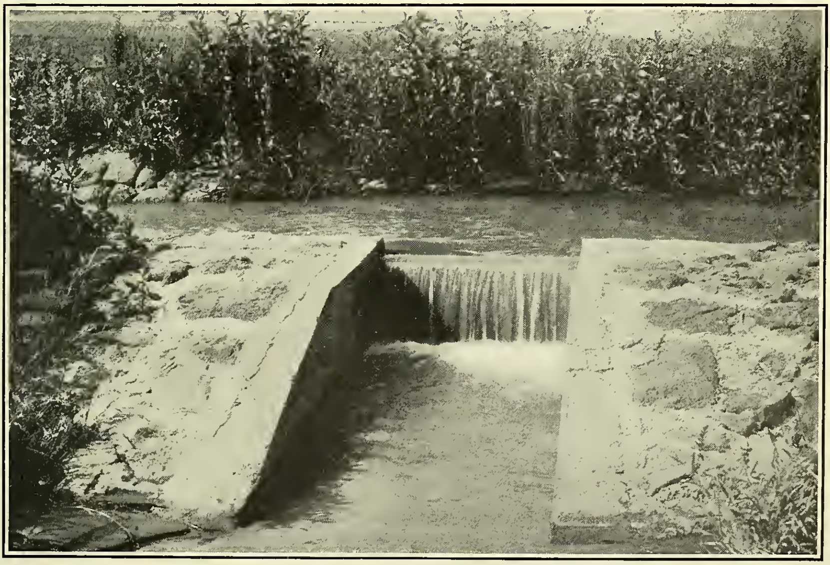


FIG. 2.—WASTE GATE ON SMALL LATERAL, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE.

FIG. 1.—WASTE GATE ON LAKEVIEW IRRIGATION CO. CANAL, WYOMING.

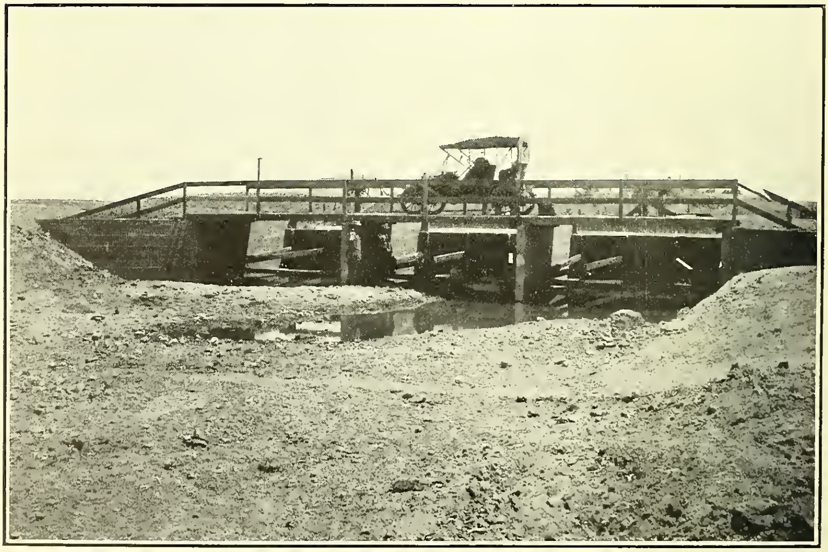


FIG. 2.—WASTE GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

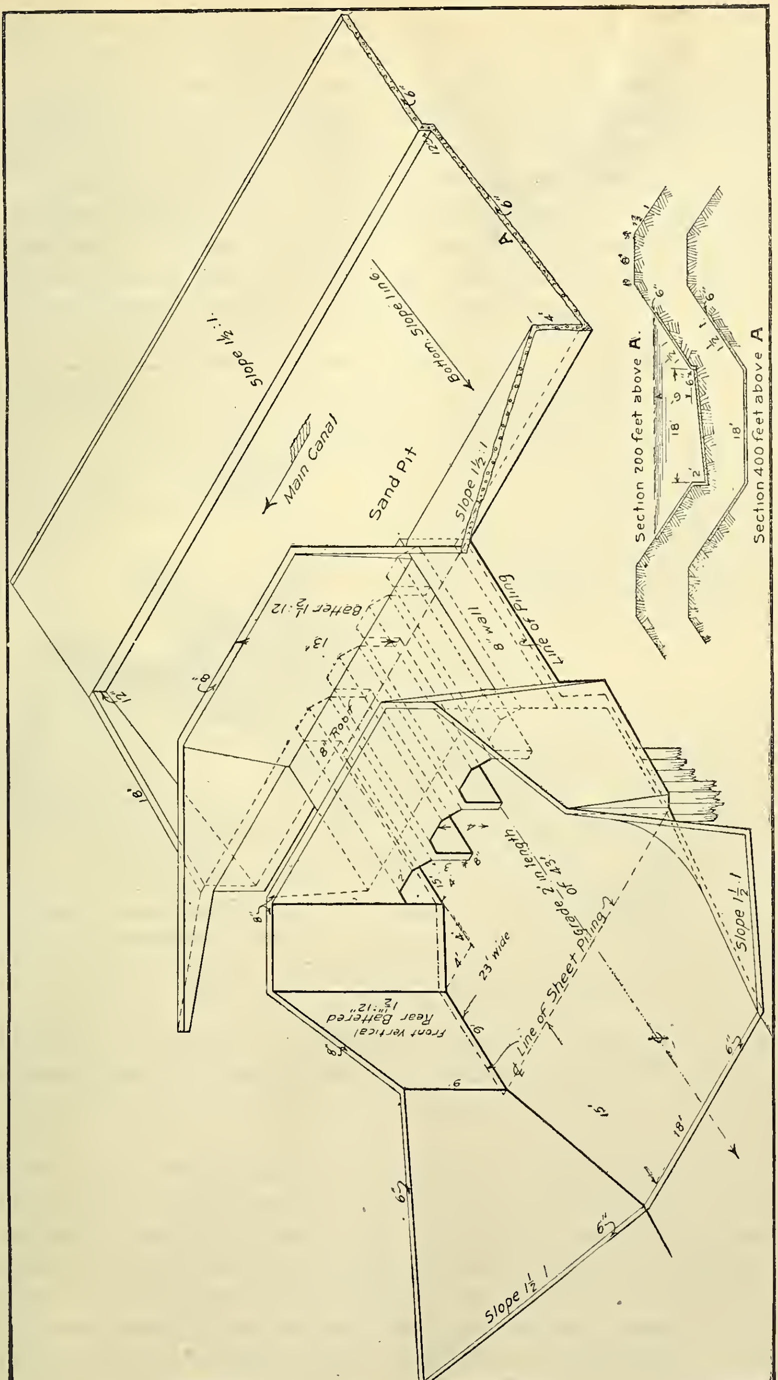


FIG. 17.—Proposed sand gate of Maxwell Land & Irrigation Co., New Mexico.

the bottom of one bay and also serves to waste excess water by raising the radial gates above the upper cover to the sand ducts.

The waste structure is designed to pass all the water the canal can carry to it; that is, 870 second-feet. The check structure consists of three 12-foot openings, regulated by radial gates attached to cables wound around small drums through worm-and-wheel leverage.

The distinctive feature of this structure, as explained under the general description of the " Land " sand gate, page 55, is the double floor with sand ducts between (fig. 18). On the assumption that most of the sand is close to the bottom, two distinct currents are in-

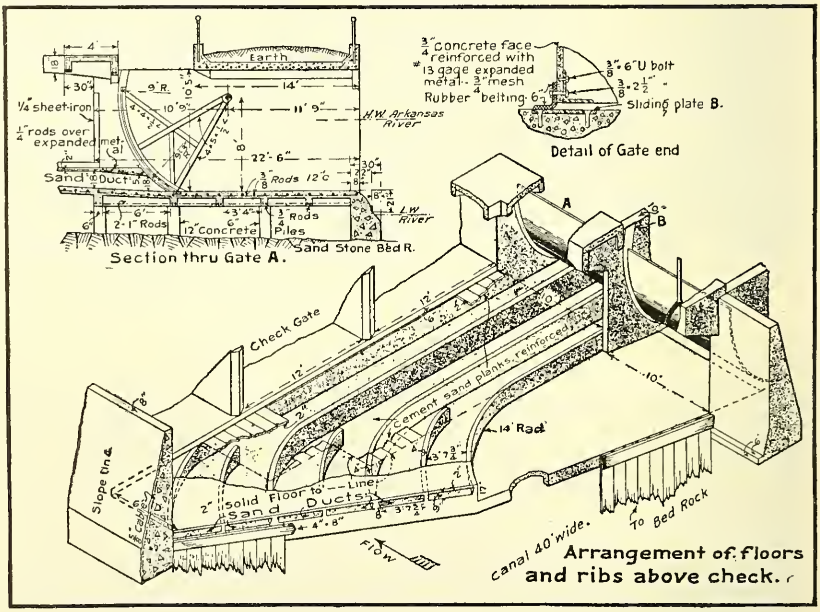


FIG. 18.—Portions of sand and waste gate on Amity Canal, Colorado.

duced in the canal by covering the ducts for some distance above the check gate. When the sand gate is open the steep grade of the ducts causes a high velocity, uninfluenced by any slow water above the floor.

In order to facilitate the cleaning of clogged ducts, a portion of the upper floor is made of reinforced cement mortar planks. The various ribs forming the ducts serve a double purpose. They not only support the upper floor, but divide the water under the upper floor into several streams so that the sand is carried off in a more general and even manner than would be the case if there were only one large opening under the floor. If the latter condition existed, there would be an excess of " draw " and velocity near the waste gate, but no influence from the waste would be felt by the water at the other side of the canal.

Concerning the operation of these gates the chief engineer of the company states that the ducts do not clog so long as they are operated continuously, but if completely closed for a period, the openings may become clogged with sand and trash and must be cleaned out with a trash hook (shown on top of the check gate in the photograph) before they will start carrying off the sand. He adds that the gates do not remove all of the sand from the canal, but do materially assist in keeping the canal clear.

The complete structure, comprising both the sand and the check gates, contain 135 cubic yards of plain concrete and 95 cubic yards of reinforced concrete. The total cost was $5,388.60, divided as follows, the detail items not being obtainable:

Excavation, concrete work, back filling	$4,160.08
Structural steel for radial gates	953.52
Hoisting device for radial gates	275.00
Total cost	5,388.60

WASTE GATES.

USES OF WASTE GATES.

The waste gate is used on canal systems for two distinct purposes: First, it may be simply a safety valve, carrying off excess water which enters the canal during storms or which is turned back into the canal unexpectedly by consumers. Second, it may be located near the head of the canal with a view of running excess water from the river, relieving the pressure on the headgate in times of flood, and reducing maintenance charges by using the large volume of water to develop a high velocity in the upper reaches of the canal, scouring out sediment. It then becomes a combination of waste and sand gate. In fact, it is very often a hard matter to differentiate between a waste gate and a sand gate. A refinement of the second use is found on systems which are running water to the full capacity of the canal and the rough adjustments at the river gate would allow such fluctuation in the volume in the canal that the banks would be endangered part of the time and the canal not run to capacity at other times. The check below the waste gate on such a system acts as a secondary headgate and the discharge through the check is adjusted to supply the canal to capacity, while excess water is wasted out the gate in the bank adjoining the secondary headgate, the upper headgate being set to discharge more water than would be done if the secondary gate did not exist. The main canal of the Turlock irrigation district (Pl. II, fig. 2, p. 8), and the joint heading spoken of on page 14 are equipped in such a manner.

TYPES OF WASTE GATES.

There are two general types of wastes. The first comprises those acting purely as spillways, having a crest height deemed the controlling elevation of the safe high-water line of the canal. Excess water reaching the waste tops the crest wall and is carried off in a natural watercourse or an auxiliary ditch constructed for the purpose. If the canal is located along a hillside, with no levee on the upper bank, thus allowing surface storm water to come directly into the canal, it is advisable to make the crest wall of such a waste gate of sufficient length that a heavy increase in the water may top the waste and not flow past it. The crest of the above type is sometimes made stationary and sometimes adjustable, being altered by flashboards inserted in slots. Obviously, this type of gate is not adapted to wasting all of the water in the canal. The siphon principle has been successfully used to increase the discharge and decrease the crest length.

The second type of gate has an adjustable opening extending down to or below the grade line of the canal, permitting all of the water to be turned out if necessary. It is quite common practice now to construct such a waste gate with the tops of the shutters below the crest of the side and wing walls so that when the gate is closed completely it still acts as a waste gate of the first type, discharging water from the canal when the water level tops the crest of the shutters. The radial gate is readily adaptable to this form of combination gate, and sand gates operated with radial shutters usually are made so that waste water can top their crests. This is easily done by simply omitting the curtain wall between the piers for a sufficient height to allow of a waste way over the tops of the shutters.

WASTE GATES, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

Plate XI, figure 2, shows an easily adaptable waste way for small laterals or ditches subject to sudden increases of water. Where the ditch crosses a natural drainage way a concrete waterway is set in the levee on the lower side and the levee up and down stream for a short distance is paved with rubble laid in cement. This should have a level crest so that water will top it in an even sheet. Slots are set near the front of the waterway so that flashboards may be set and the general level of the water in the ditch adjusted by them, or they may be "pulled" and all the water wasted. An increase of water which would endanger the ditch or a structure below the waste gate passes completely over the whole structure into the drainage channel.

WASTE GATE, LAKEVIEW IRRIGATION CO. CANAL, WYOMING.

Plate XII, figure 1, shows a small waste gate set in the lower levee of the canal. The crest of the solid wall is set as determined to be the safe or desirable limit for a high-water line in the canal. Excess water within limits, due to storms, passes safely off into the natural drainage way to which the waste is connected. The side walls prevent the erosion and washing out of the bank.

WASTE GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

The use of very cheaply-built wooden radial gates is brought out in the view of a waste gate shown in Plate XII, figure 2. This gate opens into a short canal with a capacity of 1,000 second-feet. This great discharge is obtained with but three openings. Note that the winches are located only a few inches above the tops of the shutters and that no high gate standards are required. Although the water in the main canal at the time this view was taken was nearly even with the top of the gates, there was absolutely no leakage noticeable at the sides of the shutters, the water in the foreground being either seepage or that remaining from the last run of water through the gate. Note also that this construction provides a crest waste way which will pass off excess water in case the water level in the canal reaches the tops of the gate shutters.

The face of these gates is simple wooden planking, spiked to joists, from which the thrust of the water is carried by wooden arms to a galvanized pipe axle extending completely across the openings. This construction is shown in figure 14, page 50.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 116

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
June 24, 1914.

(PROFESSIONAL PAPER.)

NEW FACTS CONCERNING THE WHITE-PINE BLISTER RUST.[1]

By Perley Spaulding,

Pathological Inspector, Federal Horticultural Board (formerly Pathologist, Office of Investigations in Forest Pathology).

INTRODUCTION.

In a recent publication[2] the writer gave the latest information regarding the white-pine blister rust up to the spring of 1913. The past season has brought forth several additional developments, which are of great importance.

THE SITUATION AT GENEVA.

Since 1906, when Stewart first discovered the presence of *Cronartium ribicola* upon Ribes at Geneva, N. Y., the disease has been found there in several different years.[3] This occurred in spite of the total destruction of the Ribes found affected in 1906 and the apparent absence of the æcial stage of the fungus on the neighboring white pines.[3] In the spring of 1913 the New York State department of agriculture took up the matter, and a special effort was made to locate and examine every white-pine tree within the diseased area, with the result that two trees about 15 years old were found by Inspector Maney bearing the fruiting bodies of the fungus. They were promptly destroyed. These evidently had been diseased for a long time, probably since they were 3 or 4 years old. No definite

[1] This paper is intended to supplement the previous publication, Bureau of Plant Industry Bulletin 206, entitled "The Blister Rust of White Pine." It is, therefore, as brief as possible, and care has been taken not to duplicate statements made in that publication. These two bulletins are necessary in order to secure complete information regarding this disease.

[2] Spaulding, Perley. The present status of the white-pine blister rust. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 129, p. 9-20, 6 fig. 1913.

[3] Stewart, F. C. Pine blister rust and currant felt rust. *In* West. N. Y. Hort. Soc. Proc. 58th Ann. Meeting, p. 122-124. 1912.

Stewart, F. C., and Rankin, W. H. Can Cronartium ribicola overwinter on the currant? *In* Phytopathology, v. 4, no. 1, p. 43. 1914.

Jordan, W. H. Director's report for 1906. N. Y. State Agr. Exp. Sta. Bul. 284, p. 341-342. 1906. Director's report for 1912. N. Y. State Agr. Exp. Sta. Bul. 356, p. 559. 1912.

Note.—This paper contains additional information concerning the white-pine blister rust that was collected during the season of 1913. It is of interest to foresters, tree experts, nurserymen, and owners of ornamental and forest plantations of 5-leaved pines.

45612°—Bull. 116—14

information concerning their origin could be obtained, but it is believed that they were imported when 3 or 4 years old, that the disease came with them, and that they have been serving ever since as a center of infection each season for the Ribes in that vicinity. During the season of 1913 the disease appeared on but few Ribes bushes near the two trees above mentioned. The pines of the vicinity are to be held in quarantine and inspected each spring. In spite of the recent pessimistic opinion of those most directly concerned in the matter,[1] there is every reason to believe that the disease will soon be eradicated at this point, now that the center of infection is finally located. The conclusion that "complete eradication of the disease is no longer possible" is apparently meant to apply to the entire country and is based on the fact that blister rust was established at Geneva and the supposition that it was established in other places in New York, Massachusetts, and Connecticut. Now that the disease is well in hand in the Geneva area (the most dangerous one known at that time in the entire country[2]), there seems to be no sufficient reason for giving up the fight against as dangerous a disease as this promises to become if unchecked. This is especially true in view of earlier statements as to the seriousness of this disease.[3]

NEW OUTBREAKS.

Early in July the writer received specimens of white pine affected with blister rust from a point in northern Vermont which had not been previously known as harboring the disease. Inquiry showed that it was present upon native trees in that vicinity, this being the first known instance in this country. A visit was immediately made to determine the facts in the case, and the disease was found in the ornamental plantings of a large private estate. The original source of infection is unknown. It is quite possible that a few imported white-pine trees were obtained years ago, although it is definitely known that most of the trees in the vicinity are native and grew in the near-by woods. At any rate, the disease has been in some of the trees about 10 years, judging from the location of the cankers and their general appearance. Of the total number of white-pine trees in that vicinity, about 150 in all, more than 50 were found to be visibly affected by the disease. How many may later develop blister rust is, of course, unknown, but probably 5 or 10 per cent will do so. Already about 33⅓ per cent have it, which should be sufficient to convince the occasional skeptic that this will be a serious disease[4] if allowed to run its course in this country.

---

[1] Stewart, F. C., and Rankin, W. H. Cronartium ribicola and the proscription of Ribes nigrum. (Abstract.) *In* Phytopathology, v. 3, no. 1, p. 73. 1913.

[2] Stewart, F. C., loc. cit.

[3] Stewart, F. C., loc. cit.; Jordan, W. H., loc. cit., 1912.

[4] Clinton, G. P. Notes on plant diseases of Connecticut. *In* Conn. Agr. Exp. Sta. Rpt., 1909-10, p. 733. 1911.

The disease had evidently reached a stage at this place where its future spread would be much more rapid than it has been in the past. About 100 feet from the apparent original center of infection was a single black-currant bush (*Ribes nigrum*),[1] some 50 to 75 red-currant bushes (*Ribes vulgare*), and about 30 gooseberry bushes (*Ribes grossularia*). The leaves of the black currant were covered with telia and uredinia of *Cronartium ribicola*, but only a very few sori were found on the red currants and none on the gooseberry leaves. Evidently the conditions have been extremely favorable for the propagation and spread of the fungus ever since the Ribes were set in that locality. All of the Ribes have been removed and destroyed, and the diseased trees and parts of trees are being cut out and destroyed.

Late in the fall of 1912 the writer received a specimen of blister rust on leaves of Ribes from Ipswich, Mass. In the spring of 1913 two small white pines which bore fruiting bodies of the fungus were found by the State nursery inspector near the diseased Ribes bushes. These were destroyed, and it was believed that the disease had been eradicated. It appeared later, however, about half a mile away, on leaves of *Ribes nigrum* and of *Ribes vulgare* of the variety Red Cross. The abundance of the fungus led the writer to suspect the center of infection to be near by. An examination promptly revealed evidences of the disease on neighboring white pines of about 10 and 18 years of age. Steps are being taken to remove the diseased trees and branches and also the black currants.

In 1913 Clinton [2] reported an outbreak of this fungus on the leaves of black currants near Meriden, Conn., late in 1912. He examined the vicinity, but could find no infected white pines in that locality. The origin of this outbreak is still unknown, and for this reason the situation is perhaps more dangerous than that in any other locality where the disease is now known to occur.

SERIOUSNESS OF THE DISEASE.

In the Vermont locality mentioned one large white pine about 2 feet in diameter and quite mature from the lumberman's standpoint was found to have the disease scattered throughout the top. Branches of all sizes up to 4 inches in diameter were thus affected. From the condition of this tree it was very easy to understand how a large tree may be killed by very severe attacks of this fungus, since it is a mere matter of time before an attacked branch or tree trunk is killed above the point of infection. One tree about 20 years of age, which had been infected in the trunk about 10 feet from the ground,

---

[1] The three Ribes mentioned are cultivated species which have been introduced into this country from Europe. The last (*Ribes grossularia*) is usually placed in a different subgenus than are the two first; by some authors it is placed in a separate genus.

[2] Clinton, G. P. Notes on plant diseases of Connecticut. *In* Conn. Agr. Exp. Sta. Rpt., 1912, p. 347–348. 1913.

had its top entirely dead above that point. Numerous small branches were found on other trees in a similar condition. A number of other trees of the same age apparently have been killed in a similar way, as they have been dying for years and have had to be removed, one or two at a time. While it takes a long time for the destructiveness of this disease to reach its climax in any given locality, there can be no doubt that if it finally becomes established and generally distributed in our forests it will be the worst enemy the white pine has here, as is stated to be the case in certain European countries.[1] It has become so thoroughly established in Europe that there is no hope of eradicating it there, but there is yet time to suppress it here if the danger is once generally realized. Even with conditions as they are in Europe, one of the most prominent plant pathologists of Germany recommends the energetic fighting of this disease.[2] If such action is advisable in Europe, even more drastic action is certainly proper in this country.

CAN THIS DISEASE WINTER OVER ON RIBES?

Late in 1912 F. C. Stewart asked the writer to take part in a cooperative experiment to try to determine whether this disease can winter over on dormant Ribes stock and thus be carried from one place to another in stock which has previously been diseased. Two hundred 2-year-old *Ribes nigrum* plants which had been heavily rusted by *Cronartium ribicola* in the late summer and early fall of 1912 were sent to the writer at Washington, D. C., about December 1. They were promptly heeled in out of doors until February 1, when, according to agreement, they were potted and brought into the greenhouse. They started quickly and made a very vigorous growth. They were examined several times for the presence of *Cronartium ribicola,* but none was found. The experiment was concluded about May 20 because of the writer's absence after that date. Parallel tests were made at Geneva and Ithaca, N. Y., Lafayette, Ind., Amherst, Mass., and New Haven, Conn., 300 plants being used.[3] The results were entirely negative. The evidence furnished by the

---

[1] Bos, J. Ritzema. Phytopathologisch laboratorium Willie Commelin Scholten. Verslag over de inlichtingen gegeven in 1900. *In* Landbouwk. Tijdschr., jaar 9, p. 77. 1901.

Fisher, W. R. Experimental plantations at Coopers Hill. *In* Quart. Jour. Forest., v. 3, no. 3, p. 229. 1909.

Fron, Georges. Nouvelles observations sur quelques maladies des jeunes plants de Conifères. *In* Bul. Soc. Mycol. France, t. 27, no. 4, p. 476–481. 1911.

Lind, Jens. Danish fungi as represented in the herbarium of E. Rostrup, p. 281–283. Copenhagen, 1913

Neger, F. W. Die Nadelhölzer . . . p. 110–111. Leipzig, 1907.

Somerville, W. Peridermium strobi, the blister of Weymouth pine. *In* Quart. Jour. Forest., v. 3, no. 3, p. 232–236. 1909.

Watson, J. G. The Woburn forests. *In* Gard. Chron., s. 3, v. 52, p. 422. 1912.

[2] Tubeuf, Carl von. Über die Verbreitung von Baumkrankheiten beim Pflanzenhandel. *In* Mitt. Deut. Dendrol. Gesell., p. 156–163, 1904.

[3] Stewart, F. C., and Rankin, W. H. Can Cronartium ribicola overwinter on the currant? *In* Phytopathology, v. 4, no. 1, p. 43. 1914.

natural occurrence of the disease shows that dormant Ribes stock does not harbor the fungus. But all the evidence is negative (except that mentioned earlier by the writer) [1] and is subject to certain limitations, as is all negative evidence, when general conclusions are drawn from it. That is, it does not effectually dispose of possible rare exceptions, which may occur only once in thousands of cases. The practical conclusion is that Ribes plants do not carry the fungus over winter and that an outbreak of this disease on Ribes is to be attributed to the presence of neighboring white pines which have the blister rust. Hence, when the disease is found on Ribes leaves a special effort should be made to locate and destroy infected trees.[2] Ewert [3] has recently published a paper showing that thorough spraying with Bordeaux mixture, with special care to cover the lower surface of the leaves, will almost completely control this fungus upon *Ribes nigrum.* It is suggested that in the future when diseased pine trees are found early in the summer, any Ribes in the vicinity be promptly sprayed on both sides of the leaves, in order to reduce the resulting infections and the outbreak of the uredo stage. Spraying should not be resorted to except as a temporary expedient, as just indicated.

About May 15, 1913, several plants of *Ribes nigrum* were isolated and an attempt was made to inoculate them with telial material furnished by Stewart which had been kept out of doors all winter. This attempt was unsuccessful, as was also a similar one made by the writer in 1912 with fresh teliospores.

CULTIVATED VERSUS WILD RIBES.

A statement has been made implying that the cultivated species of Ribes are not dangerous factors in connection with this disease.[4] All of our experience in this country shows that the contrary is true. In no known case has the disease been discovered on native wild species of Ribes, while it has been found in a number of cases on the cultivated species of *Ribes nigrum* and *Ribes vulgare.* The evidence shows that our native wild *Ribes cynosbati* and *Ribes prostratum* are resistant to the fungus, while *Ribes nigrum* is exceedingly susceptible, and some varieties of *Ribes vulgare* are quite susceptible. The variety Red Cross has been found in one instance to be seriously diseased. *Ribes grossularia* has been immune. The cultivated Ribes are much

---

[1] Spaulding, Perley. Notes upon Cronartium ribicola. *In* Science, n. s., v. 35, no. 891, p. 146–147. 1912.
——— The present status of the white-pine blister rust. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 129, p. 17. 1913.

[2] Spaulding, Perley. Notes on the white-pine blister rust. (Abstract.) *In* Phytopathology, v. 4, no. 1, p. 41–42. 1914.

[3] Ewert, R. Erfolgreiche Bekämpfung des Cronartium-Rostes auf der schwarzen Johannisbeere. *In.* Ztschr. Pflanzenkrank., Bd. 23, Heft 8, p. 463–476, 2 fig. 1913.

[4] Clinton, G. P. Notes on plant diseases of Connecticut. *In* Conn. Agr. Exp. Sta. Rpt., 1909–10, p. 732 1911.

more dangerous than are the native wild plants, because many white-pine plantations are made on deserted farms. In such places the former garden currants persist for years, and the inspector often finds them in the midst of a plantation of imported pines. Moreover, nurserymen often keep stocks of white pines and Ribes in proximity to each other, which is dangerous if either has the disease. These facts do not mean that wild species of Ribes can be disregarded, but that both wild and cultivated species must be considered when control measures are undertaken.

PINUS EXCELSA A HOST.

In a recent publication Lind[1] mentions the Himalayan pine (*Pinus excelsa*) as a known host of the white-pine blister rust in Denmark. The writer is informed that the disease was found in 1913 upon young trees of *Pinus excelsa* in Massachusetts. Unfortunately, no specimens of it were saved, but there seems to be no doubt that *Pinus excelsa* is a host of this fungus and is liable to be affected by it in this country. This is the first time that the white-pine blister rust has been found here on any other species of pine than *Pinus strobus*.

AGE OF DISEASED WHITE-PINE TREES.

White-pine trees from 3 to about 75 years old having the blister rust have been seen. From 3 to 15 years the series was almost uninterrupted; then the ages were approximately 18, 20, 25, and 75 years. The trees of 25 and 75 years were diseased on the branches and not on the main stem, but below 25 nearly all have been affected on the main stem. The evidence seems to show that this disease has been present on small numbers of imported pine trees in this country since 1888, and perhaps longer.[2]

DISTRIBUTION OF SPORES OF CRONARTIUM RIBICOLA.

In 1912 the writer made some observations on the distribution of the spores of *Cronartium comptoniae* from *Pinus rigida* to *Comptonia asplenfolia*.[3] The æciospores are so similar in size and shape to those of the blister rust on white pine that it seems probable that one would be distributed as far as the other under the same conditions. It was found that the æciospores of *Cronartium comptoniae* were blown about 30 feet from their point of origin. This led the writer to suspect that the æciospores of the white-pine blister rust would also be blown relatively short distances. Such has been the case in all those

[1] Lind, Jens. Danish fungi as represented in the herbarium of E. Rostrup, p. 281-283. Copenhagen, 1913.

[2] Spaulding, Perley. The blister rust of white pine. U. S. Dept. Agr., Bur. Plant Indus. Bul. 206, p. 36. 1911.

[3] Spaulding, Perley. Notes on Cronartium comptoniae. *In* Phytopathology, v. 3, no. 1, p. 62. 1913.

not so much in the total number of diseased trees present as it does instances that the writer has had an opportunity to investigate personally and where the origin of the spores has been determined. Two instances, on the other hand, where no diseased pines were found, seem to indicate that the æciospores were blown long distances, though this is by no means a certainty. In the three instances examined by the writer in 1913, the Ribes were about 100 feet from the diseased pines. There is every reason to believe that the uredospores of the white-pine blister rust may be blown half a mile or more.[1]

GENERAL RESULTS OF INSPECTIONS.

Some of the general results of the annual inspections made for the white-pine blister rust, beginning in 1909 and continued to the present time, are of interest. In the States north and east of Washington, D. C., about 4,000,000 white pines are known to have been imported since 1900. Probably 500,000 more have been privately imported, about which nothing is known, making a total of about 4,500,000 trees imported into these States. Of this number 1,725,000 are known to have been destroyed before they reached the hands of private individuals, leaving 2,775,000 which have been set out in lots ranging from 500 to several hundred thousand trees. The number of such known lots is approximately 200. The inspection of these trees has varied much, some having been inspected once, some carefully inspected for the first time in 1913, and still others carefully inspected each year since the discovery of the disease on pines in this country in 1909. The figures given in Table I cover only those plantations that have been continuously under inspection from the beginning.

TABLE I.—*Results of the continuous inspection of infected lots of white-pine trees.*

No.	Item.	Number.
1	Total trees inspected	910,000
2	Total trees found diseased	8,177
3	Total trees found with fruiting bodies of the fungus (data available for but 560,000 trees).	938
4	Lots of trees inspected	150
5	Lots of trees where disease was found	88
6	Lots of trees where fruiting bodies of the fungus were found	45

In Table I, item 6 includes none of the lots counted in item 5, and the same is true of items 2 and 3. The same is also true of similar items in Table II.

In considering these results it must be remembered that a single tree with fruiting bodies of the fungus and in proximity to a currant bush may start an epidemic of the disease which may continue for years and may spread over an area of several square miles. In fact, this is practically what happened at Geneva, N. Y. The danger lies

[1] Stewart, F. C., and Rankin, W. H. Cronartium ribicola and the proscription of Ribes nigrum. (Abstract.) *In* Phytopathology, v. 3, no. 1, p. 73. 1913.

in their wideness of distribution. The fact that 938 trees bearing fruiting bodies of the fungus were found within a certain area is of no special significance unless we note that they were found in about thirty different localities which are scattered well over that entire area of thousands of square miles. Then we perceive that it is inevitable that the disease will become established in one or more of those localities unless efficient control measures are taken and faithfully continued until the disease is eradicated. As already indicated, this is not being done everywhere.

TABLE II.—*Results of inspections of 80 lots of infected white-pine trees.*

No.	Item.	Lots.
1	Trees found bearing fruiting bodies in 1910 and not afterwards	15
2	Trees found bearing fruiting bodies in 1911 and not in 1910 or 1912	3
3	Trees found bearing fruiting bodies one year and also each year afterwards	3
4	Trees bearing fruiting bodies not found at first, but which were discovered later	5
5	Diseased trees found at first, but not in later years	21
6	Diseased trees found continuously	12
7	Diseased trees found irregularly (does not include those in item 5)	10

Items 1 and 2 show that in one-fifth of the lots the inspector apparently removed all the trees bearing fruiting bodies of the fungus in a single year, but in every such case trees were found thereafter which were diseased, but did not bear the spores of the fungus. In a single instance only, all of the diseased trees were apparently removed by the first inspection. Our experience to date decidedly discourages the idea that a single inspection is efficient in eradicating this disease. Item 5 apparently contradicts this statement, but these lots may easily have been cases where the inspector took everything showing any abnormality and reported it as suspicious, when the disease was really absent.

In a previous paper [1] the writer mentioned the apparent effect of cool weather in regulating the formation of telia of *Cronartium ribicola* in the greenhouse at Washington. This experience has been repeated the present season. Apparently, farther north, where the nights are relatively cool, this inhibition does not occur, as telia were found in northern Vermont on July 23.

In a recent publication,[2] which received limited distribution, the writer showed the inefficiency of inspection, except as a temporary expedient, in trying to eradicate this disease. The total destruction of infected lots of white pines was urged as being the only safe course. This means a considerable present loss, which, however, will be very slight when compared with the loss that will result if the blister rust is allowed to become established and to spread.

[1] Spaulding, Perley. Notes upon Cronartium ribicola. *In* Science, n. s., v. 35, no. 891, p. 146–147. 1912.

[2] Spaulding, Perley. The present status of the white-pine blister rust. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ 129, p. 9–20, 6 fig. 1913.

O

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 117

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 24, 1914.

PROFITS IN FARMING ON IRRIGATED AREAS IN UTAH LAKE VALLEY.

By E. H. Thomson, *Agriculturist*, and H. M. Dixon, *Scientific Assistant*, *Office of Farm Management*.

INTRODUCTION.[1]

The aim of the work in this farm-management survey was (1) to determine the profits that farmers receive in the irrigated areas and (2) to analyze the farm business and thereby to determine what factors apparently control their income. Data were also needed in respect to certain farm enterprises to determine the feasibility of developing these on the new areas that are to be opened up by the Strawberry irrigation project. Such investigations are particularly desirable at this time in view of the fact that this project, which it is estimated will furnish water for 60,000 acres of land, is now nearing completion.

Much of the area included in this project is now dry farmed or only partially irrigated. With the large quantity of water available at its completion it becomes important that the farms on the new areas be carefully organized, so as to insure a proper and safe development of the entire agricultural district. It is necessary to know the size of the farm and the type of agriculture that will succeed under the conditions existing in the valley where the project is situated.

All data included in this bulletin have been obtained by personal interviews with farmers in the area considered. Although the information in many cases is based on the farmers' estimates, it is believed that the results are reasonably accurate for all practical purposes. The field studies were made in October, 1913. The results, therefore, pertain to the crop season of that year.

[1] Acknowledgment is due to R. J. Evans and D. W. Working, who assisted in collecting the data presented in this bulletin. Valuable aid was received from the report of a soil survey of Provo area, Utah, published in 1903 by the Bureau of Soils of the United States Department of Agriculture. Thanks are extended to the many farmers in the regions studied through whose courtesy this work was made possible.

Note.—This bulletin deals with the results of a farm-management survey of about 100 irrigated farms in Utah Lake Valley in Utah.

DESCRIPTION OF THE REGION.

The region studied is the Utah Lake Valley in the vicinity of Provo, Springville, Spanish Fork, Payson, and Lehi. (See fig. 1.) In general there are two prominent physiographic features: (1) An area of sloping land adjacent to the base of the mountains and usually above the present systems of irrigation and (2) a larger and more nearly level area farther removed from the mountains and generally under irrigation.

The first area consists chiefly of coarse material, sand, gravel, stones, and bowlders, and the surface is usually rough and uneven. It is derived chiefly from the adjacent mountains and has been brought into the valley by inflowing streams and rains. These higher areas are commonly called bench lands. Many orchards have been planted on them, for the reason that the location renders the fruit less liable to frost injury because of better air drainage (fig. 2). The soil is very porous in character and seemingly not as rich as that at the lower levels.

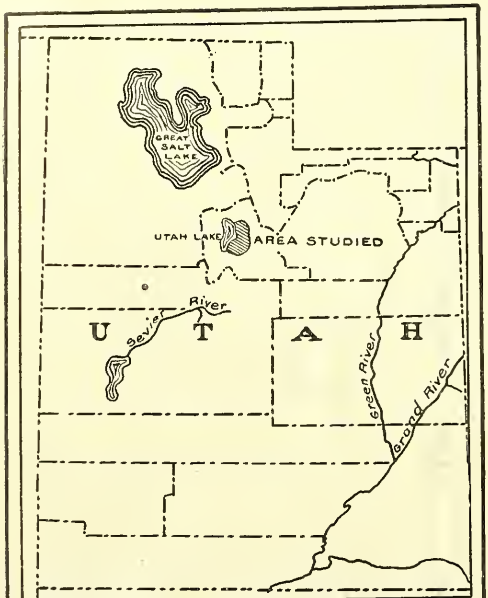


FIG. 1.—Sketch map of the State of Utah, showing the location of the region studied near Utah Lake.

The second area is made of the finer sediments deposited by ancient Lake Bonneville, and since its subsidence these sediments have been considerably modified by inflowing streams and weathering. This area occupies the lower levels extending down to the shore of Utah Lake, which forms its western boundary. Utah Lake is a shallow body of fresh water having an outlet through the Jordan River into the Great Salt Lake. Much of this lower type of land is used only for pasture, the water table being within a few feet of the surface. Where saturated for any great length of time, the alkaline conditions become so bad that cultivated crops are no longer possible. Sugar beets constitute the important crop on these lower and heavier soils.

SOILS OF THE REGION.

Throughout the entire region more or less alkali is found. Most of this occurs on the lower levels. The higher lands are of a porous nature; hence, the drainage is much better. In some sections the soil is very badly affected with alkali, so strongly as to prohibit the cultivation of crops. In many places this condition is the result of seepage of irrigation waters used on the bench lands near the base of the mountains (fig. 3). Over many of the lower areas the alkaline conditions result from rapid evaporation, due to the surface of the soil being within capillary reach of the ground water. This feature of the situation is discussed in the report of the Bureau of Soils on the soil survey of the Provo area.

HISTORY OF AGRICULTURAL DEVELOPMENT.

The first settlers of Utah Lake Valley came from Illinois, halting on their journey for a year at Salt Lake City. The first company,

FIG. 2.—Peach and apple orchards planted at the bases of mountains or near the mouths of canyons, to insure good air drainage.

consisting of 30 families, came early in March, 1849, and settled close to the site of Provo. By the middle of March they had built a fort, consisting of log houses surrounded by a stockade, from the center of which, overlooking all, arose a long parapet upon which was mounted one or more cannon for protection against possible attacks from the Indians.

Meantime the settlers had taken up land along Provo River, near the present site of Provo, and had plowed, fenced, and planted with corn, wheat, and rye the greater part of a field consisting of 225 acres of land. Soon afterwards 10 more families joined them, and the field was divided into 40 lots and 1 lot given to each family.

Immediately upon planting their crops the settlers began to use the water of the stream for irrigation. A number of farmers joined together and by their united labors constructed a canal that brought water to their farms. These were among the first steps toward irrigation in the West.

The first attempt at agriculture by the new settlers was not very successful, as Indian troubles during this time were frequent and the men could not give their crops the attention which they required. The second year was more successful, and good crops of wheat, corn,

FIG. 3.—A wide irrigation ditch, entailing much waste of water.

rye, and barley were obtained. In the years that followed, more settlers came into the country, taking up land in different parts of the valley. For many years corn, wheat, barley, and potatoes were the principal products.

By far the most important crop in the valley at the present time is the sugar beet, this industry having started about 20 years ago. Fruit growing, especially apples and peaches, is of more recent introduction, having had a great impetus about five years ago. The farms as a rule are small in area and are intensively worked. Large numbers of owners live in town and have land on the outskirts of the village.

Nearly all of the settlers in this valley are affiliated with the same church, to which they are deeply loyal, and it is difficult to measure the influence this factor has had in the agricultural development of the district. The children, naturally wishing to retain their church connections, have stayed at home. This has resulted in the subdivision of many of the larger farms into small areas, which has unquestionably been one of the reasons for the development of the intensive type of agriculture prevailing in this section.

PROFITS IN FARMING IN THIS REGION.

CLASSIFICATION OF FARMS BY GROUPS.

Financial statements of the year's business were obtained from 118 farms. In this study the farmers whose records appear were divided into the following classes: (1) Owners, (2) owners renting additional land, and (3) tenants. Of the 118 records received, 69 were from farms operated by owners, 23 from farms operated by owners renting additional land, and 3 from farms operated by tenants. A few records that were not considered complete and accurate were discarded. Records from farmers 50 per cent of whose total receipts came from work done outside the farm were also omitted. All records have been checked carefully, and the 95 used in this report should represent with fair accuracy the agricultural conditions in the valley.

In order to present the data clearly, certain terms which will be used throughout the discussion are here defined. It is important that the reader thoroughly understand them, for such knowledge will materially assist in the interpretation of the results.

Farm capital.—The farm capital is the average at the beginning and at the end of the year of the value of all real estate, improvements, machinery, live stock, feed and supplies, and cash necessary to carry on the farm business. It includes the value of the farmhouse but not of the household furnishings.

Receipts.—The farm receipts include the amount received from the sale of all farm products and also the receipts from outside labor, rent of buildings, etc. If the value of buildings, stock, produce, or equipment is greater at the end of the year than at the beginning, the difference is considered a receipt.

Expenses.—The farm expenses represent the amount of money paid out during the year to carry on the farm business. If the value of buildings, stock, produce, or equipment at the end of the year is less than at the beginning, this decrease is considered an expense. Household or personal expenses are not included, except the value of board furnished to hired help.

Farm income.—The farm income is the difference between the receipts and expenses. It represents the amount of money available for the farmer's living, provided he has no interest to pay on mortgages or other debts.

Labor income.—The labor income is the amount that the farm operator has left for his labor after 5 per cent interest on the average capital is deducted from the farm income. It represents what he earned as a result of his year's labor after the earning power of his capital has been deducted. In addition to the labor income the operator received a house to live in, fuel (when cut from the farm), garden products, milk, butter, eggs, etc. The labor income corresponds to what a hired man receives when he is given so much wages in cash, together with board and room.

DISTRIBUTION OF FARM AND LABOR INCOMES.

For the purpose of this study the 69 records from farm owners were divided into three groups, as shown in Table I. The first group represents fruit and truck farms, each of which has a cultivated area usually of less than 25 acres. The main crops are beets, fruit, and truck, as more than one-half of the receipts come from these crops.

The second group comprises those general farms each of which has an area in crops exceeding 25 acres. Their owners grow practically the same kinds of crops as those on the small farms, but a larger proportion of their crop receipts are from sugar beets, grain, and hay. Over two-thirds of their entire farm receipts come from the sale of crops.

The third group, only four in number, includes grain and live-stock farms. Less than one-third of the receipts on these farms comes from the sale of crops, while more than one-half is from the sale of live stock and live-stock products.

TABLE I.—*Average area, capital, receipts, expenses, farm income, and labor income on 69 farms operated by their owners in Utah.*

Items of inquiry (averages).	First group, 35 small farms.	Second group, 30 fruit and beet farms.	Third group, 4 grain and live-stock farms.	Average for all 69 farms.
Size of farms....acres..	20.5	59.6	178	46.6
Crop area....do....	16.5	42.1	73.6	30.9
Capital....	$5,684	$11,802	$16,989	$9,000
Receipts....	954	1,969	2,420	1,480
Expenses....	423	790	951	613
Farm income....	531	1,179	1,469	867
Labor income....	247	589	620	417

Table I shows that the average size of the 35 small farms is 20½ acres, with 16½ acres in crops. The average labor income of this group is $247. This amount represents the farmer's wages for his year's work. In addition to the $247, he had the use of the house to live in and those products which the farm furnished toward his living. If he had to pay no interest on a mortgage, he had the total amount of the farm income, which is $531, to use for savings and living expenses. Of the 35 farms in this group, one-fifth of them failed to make a plus income. Two-thirds received less than $300 for their year's work.

The second group of farms, 30 in number, is of the same general type, but they are much larger in size, the average area being nearly 60 acres. Their capital is about double and their labor income of $589 is more than twice that of the average small farm. Over two-thirds of those in this group had a labor income of more than $300, and over half made more than $500.

The four grain and live-stock farmers received a labor income of \$620 on the average, which sum is in keeping with the larger area and capital used. The average labor income of all the farm owners studied was \$417, from an average investment of \$9,000 per farm.

In Table II are given the results from the 23 farms where the operator owns a small area and rents additional land. These have been divided into 13 general farms and 10 small farms.

TABLE II.—*Average area, receipts, expenses, farm income, and labor income on 23 farms operated by owners renting additional land in Utah.*

Items of inquiry (averages).	First group, 10 small farms.	Second group, 13 general farms.	Average for 23 farms.
Farm area owned....acres..	12.4	39.0	27.4
Additional area rented....do....	10.3	19.6	15.6
Crop area....do....	19.3	47.7	32.8
Capital....	\$4,085	\$7,871	\$6,225
Receipts....	880	1,639	1,309
Expenses....	445	691	584
Farm income....	435	948	725
Labor income....	231	554	414

With a third less capital these men made practically the same labor income as those shown in Table I. Their crop area, including that owned and rented, was about 2 acres greater than the average of those farmers who operated their own farms. By this method the farmer having small capital (in most cases only enough to own a house and a few acres of land) was able to increase his income very effectively with a small increase in capital. This method represents an intermediate step between tenant and owner, and is becoming very common in many of our agricultural districts where land is high priced.

Crop conditions, as well as the prices of farm products, were fairly satisfactory in 1913, much more so than in 1912. It is possible that the figures here given are above the normal, and this fact should be carefully considered when studying these results. This may be illustrated by the peach crop, as the data show that 15 per cent of the crop sales on small farms, or 8 per cent on all farms, is from peaches. These were worse than a total failure in this valley in 1912 on account of the low price received in the eastern markets.

Out of the total number of farms covered by the records, only three were operated by tenants. On one of these farms the tenant gave one-third of the crops as rent and made a labor income of \$273 and a return of 4.1 per cent to the landlord for his capital invested. This was the smallest farm of the three, having only 35 acres. The second man gave one-half of the crops as rent and received \$756 for his labor income. The landlord received 7.3 per cent. The other farm was leased on a straight half-share system, the landlord furnishing the land, one-half the working capital, paying one-half of all the expenses, and receiving a half share of all the farm sales. In this case the operator had a labor income of $1,528 and the landlord had a return of 7.4 per cent for his capital invested.

Table III shows the average size, crop area, capital, receipts, expenses, farm income, tenant's labor income, and landlord's percentage on investment on the three rented farms.

TABLE III.—*Average capital, receipts, expenses, farm income, tenant's labor income, and landlord's percentage on investment on three rented farms in Utah.*

[Average area of farms, 54.3 acres; average crop area, 38.7 acres.]

Items of inquiry for three rented farms (averages).	Tenant.	Landlord.
Capital	$1,271	$13,145
Receipts	1,490	1,226
Expenses	574	323
Farm income	916	903
Labor income	852	
Percentage on investment		6.9

The average labor income received by these tenants was $852, while the landlords received 6.9 per cent on an investment of $13,145.

DISTRIBUTION OF FARM RECEIPTS.

In Table IV is given the distribution of receipts on 69 farms managed by their owners.

TABLE IV.—*Distribution of farm receipts on 69 farms operated by their owners.*

Source of receipts (averages).	First group, 35 small farms.	Second group, 30 fruit and beet farms.	Third group, 4 grain and live-stock farms.	Average for all 69 farms.
Crops	$617	$1,325	$741	$932
Stock	89	126	1,094	163
Stock products	95	150	138	122
Miscellaneous	44	126	0	77
Increase of inventory (less decrease)	109	242	447	186
Total	954	1,969	2,420	1,480

Table IV shows that two-thirds of the total receipts come from the sale of crops, about one-fifth from stock and stock products, and the remainder from miscellaneous sources. This proportion is very nearly the same on both classes of farms other than the grain and live-stock farms, where the proportion of receipts from crops is only about one-third of the total. That the receipts from the farms whose owners rent additional crop areas are distributed in practically the same proportion is shown in Table V, which gives an analysis of the crop receipts on farms operated by their owners and on farms whose owners rent additional land.

TABLE V.—*Distribution of crop receipts on farms operated by their owners and on farms whose owners rent additional land.*

Source of receipts (averages).	On 69 farms operated by their owners.								On 23 farms whose owners rent additional land.					
	First group, 35 small farms.		Second group, 30 fruit and beet farms.		Third group, 4 grain and live-stock farms.		Average for all 69 farms.		First group, 10 small farms.		Second group, 13 general farms.		Average for all 23 farms.	
	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Pec ent.	Per farm.	Per cent.
Corn	......	......	$7	1	......	......	$3	......	......	......	$1	......	$1	......
Potatoes	$44	7	39	3	$10	1	40	4	$60	9	21	2	38	5
Wheat	10	2	39	3	37	5	25	3	8	1	51	5	32	4
Oats	......	......	39	3	86	12	22	2	5	1	22	2	15	2
Barley	4	1	43	3	......	......	21	2	......	......	18	2	10	1
Hay	28	4	125	9	170	23	78	8	27	4	112	12	75	9
Beets	188	30	746	56	438	59	445	48	498	77	674	72	598	74
Truck crops	23	4	84	6	......	......	48	5	......	......	13	2	7	1
Apples	85	14	48	4	......	......	63	7	2	......	14	2	9	1
Peaches	88	14	60	5	......	......	71	8	23	4	5	1	13	2
Other fruit	145	24	86	6	......	......	111	12	23	4	1	......	10	1
Miscellaneous crops	2	......	9	1	......	......	5	1	......	......	2	......	1	......
Total	617	100	1,325	100	741	100	932	100	646	100	934	100	809	100

Table V shows that the sugar beet constitutes the important cash crop on farms of every group, forming as it does nearly 50 per cent of the total crop sales (fig. 4). In the case of those farmers renting additional land it forms nearly three-fourths of the total crop sales.

In riding through this valley one would be likely to infer that fruit constitutes a large proportion of the crop receipts. That such is not the case is shown by the data in Table V. Peaches, although occupying a place of importance, constitute only 7.6 per cent of the total crop receipts, apples a little less, while other fruits, mostly berries, constitute 12 per cent.

Previous to the introduction of the sugar-beet industry, potatoes formed one of the main cash crops on many of the farms in the valley. In recent years, however, the price of potatoes has been very uncertain, and this, with blight trouble, has been the cause of most farmers discontinuing this crop. If the farmers were assured of a reasonable price for potatoes, no doubt this crop would compete strongly with sugar beets as a cash enterprise.

DISTRIBUTION OF FARM EXPENSES.

Table VI shows the distribution of expenses on the three groups of farms operated by their owners and also on the two groups whose owners rent additional land.

FIG. 4.—Views showing the harvesting of sugar beets in one of the largest fields in the Utah Lake Valley.

TABLE VI.—*Distribution of farm expenses on 92 farms in Utah.*

Distribution of expenses (averages).	On 69 farms operated by their owners.								On 23 farms whose owners rent additional land.					
	First group, 35 small farms.		Second group, 30 fruit and beet farms.		Third group, 4 grain and live-stock farms.		Average for 69 farms.		First group, 10 small farms.		Second group, 13 general farms.		Average for 23 farms.	
	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.	Per farm.	Per cent.
Paid labor and board	$109	25.8	$171	21.6	$85	8.9	$135	22.0	$65	14.4	$112	16.2	$92	15.8
Family labor	72	17.0	264	33.4	312	32.8	169	27.6	116	26.1	186	26.9	156	26.7
Improvements and new equipment	39	9.2	49	6.2	39	4.1	43	7.0	28	6.3	60	8.9	46	7.9
Repairs (machinery, buildings, etc.)	14	3.3	21	2.7	28	2.9	18	2.9	11	2.5	18	2.6	15	2.6
Feed	49	11.6	19	2.4	108	11.5	39	6.4	46	10.4	18	2.6	30	5.1
Horseshoeing, etc	14	3.3	22	2.8	27	2.8	18	2.9	19	4.3	32	4.6	26	4.5
Seed and fertilizers	11	2.6	29	3.7	7	.7	19	3.1	16	3.6	23	3.3	20	3.4
Insurance, taxes, etc	58	13.7	111	14.0	173	18.2	88	14.4	125	28.1	161	23.3	145	24.8
Stock purchased	28	6.6	64	8.1	127	13.4	49	8.0	5	1.1	59	8.5	35	6.0
Miscellaneous	29	6.9	40	5.1	45	4.7	35	5.7	14	3.2	22	3.1	19	3.2
Total	423	100.0	790	100.0	951	100.0	613	100.0	445	100.0	691	100.0	584	100.0

Table VI develops the interesting point that the total labor expense constitutes nearly 50 per cent of the total farm expenses. This is in a large measure due to the intensive type of agriculture followed in that district. Of this labor less than half is hired. This is the only region in which farm-management surveys have been made where the expense of unpaid family labor is greater than that for hired labor. The sugar-beet industry may account for this condition. Taxes are high throughout the entire region and form over 15 per cent of the total farm expense.

SUGAR-BEET GROWING ON SMALL FARMS.

In Table VII data are given for 25 small farms on which sugar beets are the leading cash crop, no fruit being grown. Sixteen of these farms were operated by their owners; the other nine were farms whose owners rented additional land. There was an average of 5.2 acres of beets per farm on those operated by owners, while the other nine farms had an average of 7.6 acres. It is exceedingly interesting to note that these nine owners had almost identically the same area in crops, but had $2,000 less capital. Their total farm receipts were nearly the same, expenses the same, and labor income practically the same. One thing is certain, that the man with small capital should rent rather than buy in that area.

Table VII.—*The raising of sugar beets on small farms.*

Items of inquiry (averages).	First group, 16 farms operated by owners.	Second group, 9 farms operated by owners renting additional land.
Farm area owned ... acres	22.8	12.7
Additional area rented ... do	...	11
Area cropped ... do	19.1	20
Area in sugar beets ... do	5.2	7.6
Capital	$6,103	$4,038
Receipts	995	900
Expenses	426	457
Farm income	569	443
Labor income	264	241

The results in Table VII are also interesting in that they show what can be expected of a small 20-acre farm devoted to sugar-beet raising. Only nominal wages are received by the owner following this type of farming. Of the farm owners, 11 received less than $300 as a labor income. Only one man received over $1,000 labor income, he having a few acres of beets in connection with a special poultry farm. Even if these small farmers have no mortgage to pay and have the entire amount of their farm income to live on, their savings and funds for living expenses are small.

It has been estimated from investigations in some of the large cities that the minimum amount necessary annually for a workingman's family of five persons is at least $800. If we allow these small sugar-beet growers their full farm income, which in the case of farm owners is $569, and the value of their family labor, which is $79, we have a total of $648. This, with a house to live in, garden, milk, and other products furnished by the farm, represents their total living. In view of these facts it is very doubtful whether farmers could pay $250 to $300 an acre, the price at which this sugar-beet land is valued, go in debt for the greater part of the purchase price, and be able to complete their payments for the property. Through hard work and very careful saving they might be able to succeed, particularly if one or more members of the family worked at other employment during part of the year. The trouble with a small farm of this nature is that there is not enough work to keep the members of the family busy, even if the crops grown do pay a high rate of income for the labor performed. Outside employment becomes almost a necessity when farms are reduced to such areas as those found in this region.

THE FARMER'S AGE AND OTHER FACTORS.

In connection with the bearing upon his success, the facts shown in Table VIII in regard to the farmer's age, the size of his family, and the amount of the mortgage on his farm are exceedingly interesting.

TABLE VIII.—*The age of the farmer, amount of mortgages, and size of family on farms operated by their owners and on farms whose owners rent additional land.*

Farm groups.	On 69 farms operated by their owners.				On 23 farms whose owners rent additional land.			
	Number of farms.	Age of operator (years).	Amount of mortgage.	Number in family.	Number of farms.	Age of operator (years).	Amount of mortgage.	Number in family.
Small	35	51.2	$57	4.6	10	45.7	$200	5.9
General and fruit	30	49.4	967	6	13	44.8	179	5.9
Grain and live stock	4	56	2,000	5				
Total or average	69	50.7	565	5.2	23	45.5	188	5.9

This table gives the age of the operator, the amount of mortgage per farm, and the number in the family. The families are somewhat larger than is shown by similar data for other agricultural regions. The age of the farmer, particularly the farm owner, is 50.7 years, practically the same as found in every region studied thus far. In the case of those men who owned small areas and worked additional land, the average age was about 5 years less. This would be expected, in that these men represented the transitory step between tenant and owner. It was also noted that on the average the owner had been a tenant 1 year, an owner for 22 years, and an owner of his present farm for 19 years.

In the case of the owners who rent additional land they had been tenants 2 years, owners 18 years, and owners of their present farms 15 years. The average value of the farmhouse was $859; other buildings, $237 per farm.

EFFICIENCY OF WORK HORSES ON SMALL FARMS.

Table IX gives the number of work horses per farm and the average crop area per horse, arranged by type of farming. One work horse to 10 acres is the average for all the farms in this district, the larger farms being the most efficient in this respect. Good authorities estimate that the annual cost of keeping a horse ranges from $80 to $120 a year; hence, each acre in crops must bear an annual charge of at least $8.

TABLE IX.—*Number of work horses and crop area per horse.*

Farm groups.	Number of farms.	Number of work horses.	Crop area per horse.
			Acres.
Small	45	2.0	8.3
General and fruit	43	3.9	11.2
Grain and live stock	4	6.1	12.0
Total or average	92	3.1	10.3

Comparing this with similar studies,[1] it is seen that work horses, as utilized on the small farms in Utah, are only 50 per cent as efficient as those on farms of 80 acres or more.

Aside from survey studies showing the labor incomes of the farmers visited, many data were gathered in respect to the cost of producing certain crops in that area. These data were obtained in the same way as the other facts presented here and not by cost-accounting records.

CROPS GROWN IN UTAH LAKE VALLEY.

SUGAR BEETS.

For the last 20 years sugar beets have constituted an important crop in this valley. They have been grown with success and are

[1] Thomson, E. H., and Dixon, H. M. A farm-management survey of three representative areas in Indiana, Illinois, and Iowa. U. S. Department of Agriculture Bulletin 41, 42 p., 10 fig. 1914.

Warren, G. F., and Livermore, K. C., assisted by Bennett, C. M., Kutschbach, H. N., Thomson, E. H., Robertson, F. E., and Baker, E. L. An agricultural survey in Tompkins County, New York. Cornell University Agricultural Experiment Station of the College of Agriculture, Department of Farm Management, Bulletin 295, p. 375-569, 56 fig. 1911.

looked upon by the farmer as the one dependable crop, providing the money from which he can pay taxes and buy the necessaries of life. It is generally agreed that there are no big profits in sugar-beet growing, yet its adaptability to local conditions and to intensive agriculture places it foremost as a cash crop on a large number of farms. The large amount of labor needed and its wide distribution through the growing season make the sugar beet one of the best crops for the utilization of the farm labor. In many instances the owner's family can do all the work required on several acres of beets; hence, a reasonably large income can be had with no cash outlay.

From $48 to $60 per acre, exclusive of land rental, is given as the approximate cost of growing an acre of beets under normal conditions in the Utah Lake Valley. With yields ranging from 15 to 20 tons, at a price of $4.50 to $5 per ton, it is evident that there is no large margin of profit between the cost and the price received. Yet in view of the fact that a large part of the cost of production is made up of labor which can be performed by the farmer and his family, the farmer can afford to grow beets even if only day wages are earned at such work.

Of course, the profit per acre will vary a great deal on different farms, depending upon the practice followed, the yield, and the sugar content. It is plain, however, that the price per ton paid by the sugar-beet factory can not be decreased to any great extent without causing the total income from an acre to fall below the cost of production. Of late years several growers have had difficulty with blight and also with low sugar content. Many of these troubles can be remedied by more thought to rotation and care in growing the crop.

TOMATOES.

Under an intensive system of agriculture such as that followed in this region, it would seem that the canning factory should have a place. As yet this industry has not developed to any great extent, there being three small canning factories, one each at Provo, Springville, and Spanish Fork. Tomatoes constitute one of the main crops grown for canning. Table X gives the cost of growing an acre of tomatoes as determined from three good growers in that district. The cost per ton, as found on the three farms averaged in Table X, was remarkably uniform considering the wide variation in yields on these farms. Under careful supervision and with a reasonable price for this crop, the growing of tomatoes promises to be a fairly satisfactory enterprise. One serious trouble is in obtaining a variety which can be planted late enough in the spring to escape late frosts and yet mature early enough to escape frost in the autumn.

TABLE X.—*Cost and yield of an acre of tomatoes, average of three farms in the Utah Lake Valley.*

[Yield: Tons, 15.9; receipts therefrom, $166.65.]

Items of cost.	Man hours.	Horse hours.	Cost.
Labor operations:[1]			
Manuring	1.77	3.54	$0.71
Plowing	7.30	14.60	2.92
Disking	1.26	3.02	.55
Spike-tooth harrowing	2.00	4.00	.80
Spring-tooth harrowing	4.65	13.95	2.33
Leveling	1.58	3.53	.67
Marking	1.02	2.05	.41
Trenching	.84	.84	.25
Watering	11.34		2.27
Planting (partly by contract)	10.88		3.46
Cultivating	12.47	12.47	3.74
Hoeing	8.37		1.67
Replanting	.28		.06
Bugging	1.67		.33
Picking (partly by contract)	106.98		30.70
Hauling	25.40	50.79	10.15
Total labor	197.81	108.79	61.02
Items other than labor:			
Manure			.93
Plants			10.18
Crates			1.95
Water			3.26
Interest and taxes on land at 6 per cent			16.88
Equipment			3.91
Total cost other than labor			37.11
Total cost			98.13

SUMMARY.

Account.	Total.	Per ton.	Per bushel.
Income	$166.65	$10.48	$0.26
Cost	98.13	6.17	.15
Profit	68.52	4.31	.11

[1] Rates per hour: Man labor, 20 cents; horse labor, 10 cents.

POTATOES.

The cost of growing potatoes is about the same as that of sugar beets, or a little less. As previously stated, uncertain prices at harvest time and trouble with blight have been the cause of most farmers discontinuing this crop as one of their main cash enterprises.

APPLES.

The history of apple growing in this area is in some respects the same as that in some of the fruit districts in the Pacific Northwest. Many farmers have planted a few acres of apples, but only a small number have made this their entire farm business. Sugar beets, small fruits, potatoes, and peaches have been grown extensively in the young orchards, so that the expense of bringing the orchards into bearing is not nearly so heavy as where the entire farm is set to apple trees and clean tillage is practiced (fig. 5). If in the future the marketing of apples in the western fruit districts can be made a success in competition with the extensive orchards in the East, then it would seem that these Utah growers have acted wisely in setting a few acres of orchard, as it will help diversify their farm business. Another fact in their favor is that most of the orchards are set to strictly standard varieties. The local market for apples in this region is not sufficient to warrant an acreage of any considerable size; hence, eastern markets must be depended upon.

PEACHES.

The history of the peach industry in this region is an exceedingly interesting one. In the vicinity of Provo several orchards were planted

FIG. 5.—Sugar beets growing in a young orchard.

from six to eight years ago, or about the time that many of the large peach districts were beginning to develop in other Western States; but most of the peach orchards here are the result of an extensive boom started about five or six years ago. In one district at least, the big return in one year from a single acre of old trees, coupled with the promotion scheme of a few growers, started a boom in peach growing which resulted in many hundreds of acres being planted in the two years following.

At present there are many 4, 5, and 6 year old peach orchards in this district. In the vicinity of Springville, at the mouth of one of the small canyons, there is a large area which has been set almost exclusively to peaches. Much of this area, which was originally devoted to general farming, was bought at $75 to $150 an acre, planted with peaches, and then valued in some cases at $300 to $400 an acre. The soil on which these orchards are located apparently is well adapted to this fruit. The location is also good, being well protected from frost.

Since these orchards have been set out there has been no year in which the peach business has been a success financially, owing mainly to the low prices received. Many of these growers are discouraged, and some of them are pulling out first-class 5-year-old peach trees to make the land available for growing sugar beets and other general farm crops. Figure 6 is from a photograph of hogs in a peach orchard. On this particular place the owner had a big crop in 1912. He incurred heavy expenses in picking, packing, and shipping, only to have the returns amount to practically nothing. In 1913 he also had

FIG. 6.—Hogs turned into a peach orchard to harvest the crop.

a good crop, but was not willing to take the chances of picking, packing, and hauling the fruit, so a large number of hogs were purchased in the early summer and the entire crop was fed to them.

It is estimated by several growers in the vicinity that the value of orchard land has depreciated about 40 per cent in the last four years. The estimated cost of producing a crate of peaches is 30 to 34 cents. This estimate was obtained from a number of reliable peach growers. It includes the cost of caring for the orchard, picking, packing, and hauling to the station. No charge for interest on land is included in this figure. Many years the price of peaches has fallen far below 30 cents a crate (22 pounds). The cost of growing the orchard is high and crops are occasionally poor. These are some of the factors that have made the peach industry a losing one.

It would seem that there ought to be some way of taking care of these peaches other than shipping them to far eastern markets in crates. In the practice now followed there is a heavy expense for boxes, and as each peach has to be wrapped in paper the packing cost is high. Furthermore, only the best grade of fruit is packed, and the loss resulting from no returns from all medium and inferior fruit is enormous. Some method whereby these other grades of peaches, and apples as well, could be utilized would result in a great saving for these growers.

SMALL FRUITS.

The small-fruit industry is represented by strawberries, blackberries, raspberries, etc., and apparently is a much more stable one than peach growing. In the first place, it is developed on a more safe and sane basis, not being overdeveloped, as are the peach and apple enterprises. The market for these fruits, however, is small and the outlook not at all promising, unless there is some means of canning or preserving them for shipment. These fruits seem to do very well in this region and could be produced to advantage on the small farms. The whole question is one of a suitable market. A few men haul these fruits a distance of 40 miles to Salt Lake City. Some growers give the price of raspberries as 85 cents per case of 6 quarts and of strawberries 65 cents per case. A yield of 300 to 400 cases per acre is considered very good for both of these berries.

At Provo there is a canning factory which paid during the year 1913 the following prices for berries, fruits, and truck crops:

Strawberries . . per pound . .	$0.04½		Grapes . . . . per pound . .	$0.01
Cherries . . . . do	$0.05 to	.06	Prunes . . . . do	.01
Plums . . . . do		.01	Peaches . . . . per ton . .	12.50
Pears . . . . do	.01 to	.01½	Apples (no wormy ones) . . . . do	12.50
Apricots . . . . do		.01¼	Tomatoes . . . . do	10.00

ALFALFA HAY AND SEED.

In the past, considerable alfalfa hay and seed have been grown in this region, but of late years serious trouble with the weevil has hurt this industry. At the present time the quarantine against the seed from this district has stopped its production. Good stands of alfalfa hay are also seriously injured by the weevil in some localities, as little attention has been given to preventive measures. Alfalfa hay is grown mostly for home consumption, the distance to outside markets being too great to permit shipment at a profit. Hence, the quantity of hay that can be grown profitably will depend entirely upon the development of the immediate area (fig. 7). In some instances range men bring their cattle and sheep from the mountains in the fall for feeding through the winter in the valley. This supplies a good market for considerable hay and grain. The beet pulp from the sugar factories is also utilized by feeding it to range steers.

STRAWBERRY VALLEY IRRIGATION PROJECT.

The land to be opened up by the Strawberry irrigation project is apparently of the same nature and subject to the same conditions as the areas already irrigated. Much of it is rather low and will have to be handled carefully to prevent alkaline conditions resulting. At present this dry land, practically all of which is owned privately, is held at prices ranging from $50 to $100 an acre. In some instances even higher prices are being asked.

The water rights, as obtained from the irrigation project, will cost from $60 to $80 an acre. After this there will be a large expense for putting the land in shape for good cultivation. Many ditches will have to be constructed, the land broken up, buildings and fences

FIG. 7.—Harvesting alfalfa hay on irrigated lands.

erected, and, if the future is to be thought of, drains should be constructed. Summing up all of these costs, there will be a very heavy charge per acre to the settler on these new areas. Good results are seldom obtained the first year with the ordinary farm crops. Whether this land can be purchased at this price and paid for under the existing conditions, as judged from the experience of men now in the valley, is a question. At the best it will call for very efficient farm organization and first-class management.

FARM ORGANIZATION.

It is exceedingly important that the farms be not too small in area, so that the owner will have a moderate-sized business and one which can be efficiently operated. It is also important that the right crops, those which will meet the economic conditions, be selected. This is a problem of great difficulty, for the reason that the conditions change so rapidly from year to year that certain enterprises which may be good at this particular time may be unfitted to the conditions five years hence.

To illustrate: Suppose the price paid by the factories for sugar beets should decrease materially. This would be a serious blow to the agricultural development of the entire region, as sugar beets constitute the chief money crop. It would seem that special attention should be given to the development of canning factories, fruit evaporators, and other similar agencies whereby crops suitable to intensive cultivation can be grown annually without being subject to heavy losses resulting from violent fluctuations in prices in the eastern markets.

When we consider the distance of this region from the great consuming centers, it is doubtful whether truck farming and certain types of fruit growing should ever be undertaken here. Agricultural areas developed at such high costs are under a severe handicap in competing with cheaper lands equally productive that lie close to the great markets of this country.

It would appear that the development of such types of farming in such a region should be limited largely to supplying the local demand for the products grown. With the immense areas of fertile soil that are still farmed extensively close to our big cities, it would seem that the time is not yet ripe for a highly intensive type of agriculture on lands so far removed from those markets.

SUMMARY.

The results of the preliminary farm-management survey made in the irrigated areas in the Utah Lake Valley near Provo and Spanish Fork show—

(1) That an intensive type of agriculture has been developed in certain areas that have been under irrigation for a long period of years. This intensiveness is largely in the form of sugar-beet growing.

(2) The average labor income on 35 small farms with 16.5 acres in crops was $247; on 30 general fruit and sugar-beet farms with 42 crop acres the labor income was $589; and on 4 grain and live-stock farms with 74 crop acres the labor income was $620.

(3) The profits received are largely influenced by the size of the farm business, the type of farming followed, and the diversity of the income. Many farms are so small in magnitude of business that the owner can not possibly make a comfortable living without outside employment. Of the 54 farmers who had less than 40 acres, only 2 men made over $1,000 labor income. More than 60 per cent of them made less than $300. Of 25 small sugar-beet growers, only 1 made over $800 as a labor income.

(4) Sugar beets form 33.4 per cent of the total farm receipts on the 92 farms operated by owners. They are the one crop on which the farmer depends for money to pay taxes and living expenses.

(5) The growing of other crops, such as small fruits and vegetables, which are suited to intensive agriculture, is seriously limited by market conditions, as a large quantity of these products creates a surplus on the markets in the near-by cities and towns.

(6) Peach growing was boomed very highly about four to six years ago. This has proved to be decidedly unprofitable except in a few instances. Several farmers estimated that the value of peach land has depreciated 40 per cent in the last four years.

(7) The possibility of the soil becoming alkaline, due to seepage of irrigation waters and to capillary attraction when the water table is near the surface, makes this a serious question on the lower areas.

(8) The high initial cost of land, plus the cost of water rights, plus the cost of improvements, all combine to make such a heavy investment that intensive agriculture becomes almost imperative, even though such a form is wholly unsuited in its market relations.

(9) In most successful forms of intensive agriculture diversification of enterprises is important. The limited markets in this region are in this way a severe handicap to the most efficient farm organization.

(10) Summing up the situation, it will be very difficult to make either an extensive or an intensive form of agriculture really successful in this region, by reason of the fact that the one needs cheaper land than is to be had, while the other demands a larger and more accessible market than is available. It is plain that on the whole a fairly extensive type embodying staple crops must prevail, for the time is not yet ripe for a highly intensive form of agriculture.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 118.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 14, 1914.

(PROFESSIONAL PAPER.)

EXPERIMENTS IN THE DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

By F. C. Cook, *Physiological Chemist, Bureau of Chemistry*, R. H. Hutchison, *Scientific Assistant, Bureau of Entomology*, and F. M. Scales, *Assistant Mycologist, Bureau of Plant Industry.*

INTRODUCTION.

The great activity in antifly campaigns in recent years, together with the recognition of the fly as a disease carrier, has created such widespread demand for some means of destroying the fly that this investigation has been undertaken for the purpose of finding a chemical that would destroy this pest in its principal breeding place, namely, horse manure, without injuring the bacteria or reducing the fertilizing value of the manure. This work was undertaken in 1913 at the suggestion of Dr. L. O. Howard to Dr. C. L. Alsberg, who has heartily cooperated in this study and secured the cooperation of Dr. W. A. Taylor. The entomological work was done under the direction of Mr. W. D. Hunter and the bacteriological work in cooperation with the laboratory of Mr. K. F. Kellerman. It is the purpose of this paper to review some recent experiments, the results of which point to an economical, practical, and effective way of destroying fly larvæ by the chemical treatment of manure. A consideration of the larvicidal powers of a number of chemicals more or less effective as larvicides, together with an account of their effects on the value of manure so far as may be estimated by chemical and bacteriological analyses, is included.

HISTORICAL.

American workers were the first to attack the problem of the chemical treatment of manure with a view to destroying fly larvæ. Pioneer work of this nature was begun in 1897 by Dr. L. O. Howard, who showed that kerosene emulsion, while effective with small amounts of manure, was not practical for use on a large scale. Chlorid of lime, however, was found to be a good maggot killer, but its action on the bacteria was not studied. Dr. Howard (1911)[1] published an account of his own experiments and of the work of other investigators.

Prof. S. A. Forbes (Howard, 1911, p. 197), State entomologist of Illinois, found that lime, borax, borax and sodium arsenate mixture, iron sulphate, and carbon bisulphid—the last in closed-box tests—were effective larvicides.

Herms (1910) claims that many of the common insecticides are more or less effective if used in proper concentrations and amounts, but none of these can be applied with safety, as they are poisonous, inflammable, or corrosive.

In 1912 Prof. R. I. Smith (Smith, 1912, p. 64), then State entomologist of North Carolina, found that 2 gallons of kerosene sprinkled over 25 square feet of a manure pile gave no indication of any larvicidal action. Acid phosphate proved entirely worthless from the standpoint of killing the maggots, even when used at the rate of 400 pounds to every 2,000 pounds of manure. Finely ground phosphate rock (floats) had no effect on the larvæ. A 4 per cent formaldehyde solution thoroughly applied to heavily infested manure piles did not destroy any maggots.

This seems to be the extent of the experimental work, as reported in the literature, up to the year 1913. It is evident that the chemical treatment of manure has not received the attention which it deserves. Moreover, Dr. Howard (1911) has pointed out that all these experiments have left unanswered the question as to what effect the treatment will have on the manure itself. No analyses were made to determine how the chemical composition of the manure was affected by the larvicides; nor were any field experiments carried out to ascertain whether the fertilizing value of the manure was altered in any way.

MANURE: ITS RÔLE IN FLY BREEDING.

As stable manure is one of the most valuable fertilizers known, a large number of investigations have been carried on to determine the best means of utilizing as well as preserving it. In addition to its content of nitrogen, phosphorus, and potash the value of manure depends on the number and species of bacteria present, as well as on its content of organic material which the bacteria convert into plant food. Manure, when undergoing fermentation in the open, loses some of its valuable nitrogenous constituents, especially ammonia and

---

[1] Authors and dates in parentheses refer to "Literature cited," p. 26.

gaseous nitrogen, the extent of the loss depending on the nature of the fermentation, the aerobic fermentation, due to the rapidity of combustion, producing a greater loss than the anaerobic. To prevent this loss of plant food in the course of fermentation, various chemicals have been used, either to retard bacterial action or to fix the volatile constituents. Among the various substances used for this purpose may be mentioned ground phosphate rock (floats), kainit, various lime compounds, carbon bisulphid, formaldehyde, and ferrous sulphate.

The house fly is attracted to horse manure, possibly by its odor, and on alighting crawls an inch or so under the surface and there lays its eggs. On account of the temperature of the manure the eggs hatch within one day. The larval or maggot stage continues from four to five days, during which the larvæ migrate to the sides of the pile and toward the base, feeding on the manure during their journey. The pupæ are found, after a few days, congregated in the outer edges of the manure near the ground, as seen in Plate I. It is therefore about 10 days from the time the eggs are laid until the mature fly emerges.

GENERAL PLAN OF EXPERIMENTAL WORK.

Experiments were carried out at the Experimental Farm of the Bureau of Plant Industry at Arlington, Va., and continued during the autumn at the Experiment Station at Audubon Park, New Orleans, La., under a cooperative arrangement entered into by the Bureau of Entomology, the Bureau of Chemistry, and the Bureau of Plant Industry.

CAGE EXPERIMENTS.

An idea of the structure of the 15 cages, which were designed by Mr. W. D. Pierce, of the Bureau of Entomology, may be gained from the accompanying photograph (Pl. II). Each cage has an inside measurement of 2 by 2 by 4 feet. The bottom of the cage consists of a galvanized-iron pan 1 foot high. Above this pan bronzed wire screening (16 meshes to the inch) is tacked both on the inside and outside of the framework. These two layers of screening are 2 inches apart. In this way manure once put into the cages was protected from further infestation from the outside. In order to prevent the larvæ from escaping from the sides of the cages through this screening it was found necessary to fasten sheets of tin on the inside above the galvanized-iron base. These strips are 1 foot high, and thus there was afforded a space of 8 cubic feet from which larvæ had little chance to escape. In the bottom of the cage nine small holes were made which permitted excess liquids to drain off. Some larvæ found their way out through them, but these were caught in the pan below and a record kept of the numbers thus escaping.

The top of the cage is a wooden door which is fastened down tightly with hinges and hasps. In the center of this door is an opening 5 inches in diameter and above this a board provided with two openings of the same size. Cone-shaped flytraps are fitted into these openings. This board is placed in grooves so that either one of the two traps may be brought over the opening in the door by merely sliding the board.

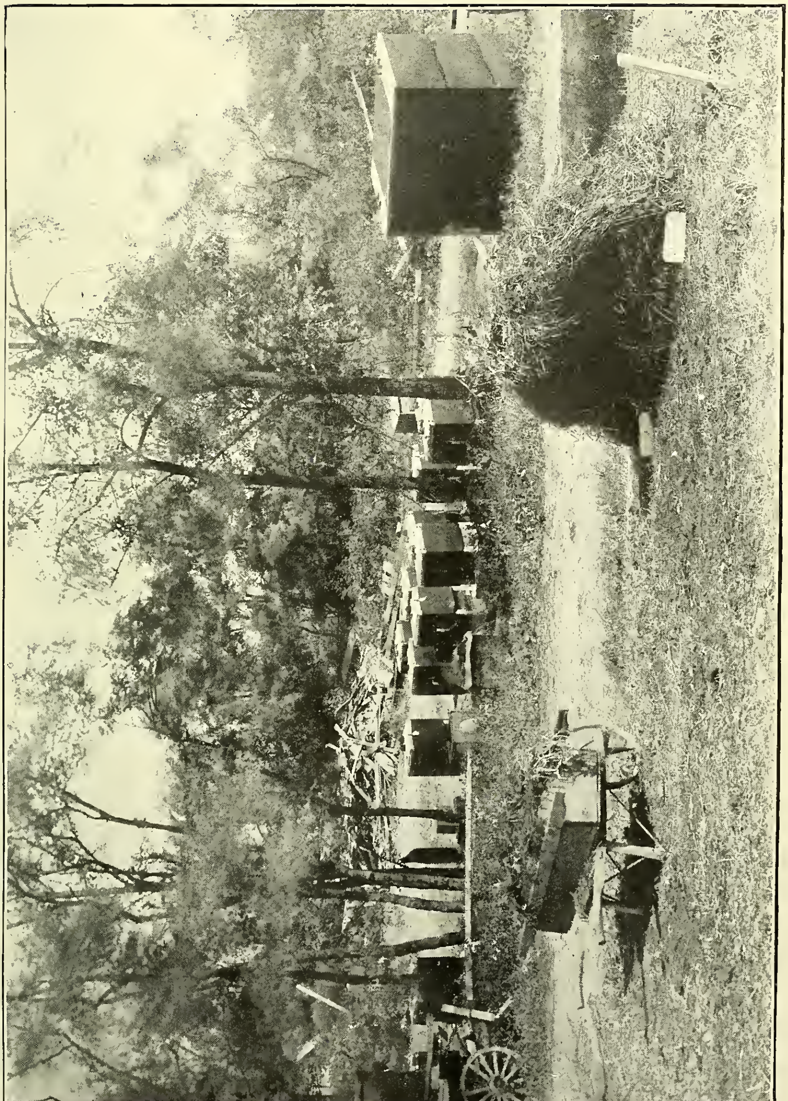
On one side of the cage is a small trapdoor 5 inches square through which samples of manure may be taken out for examination.

Each cage stands on legs 4 inches high and in a galvanized-iron pan 3 feet square with sides 4 inches high. This pan serves to collect drip water and escaping larvæ, and to isolate the cage from such predatory insects as ants.

Eight bushels of manure were used in each of the cage experiments. It was dumped in at the top and the chemical, in solution, was sprinkled on with a watering can. After two preliminary experiments it was found necessary, in order to insure thorough penetration, to use 10 gallons of the liquid per 8 bushels; that is, at the rate of 1 gallon to 1 cubic foot. Usually the sprinkling was done in three layers by putting 2 bushels of manure in the cage and applying $2\frac{1}{2}$ gallons of the solution. This was repeated in the second layer of 2 bushels. Finally, the remaining 4 bushels were added and the last 5 gallons of the solution applied. When a chemical was applied in dry condition it was scattered over the surface of the manure, which was treated in three layers as in the case of the solution; 10 gallons of water were afterwards added.

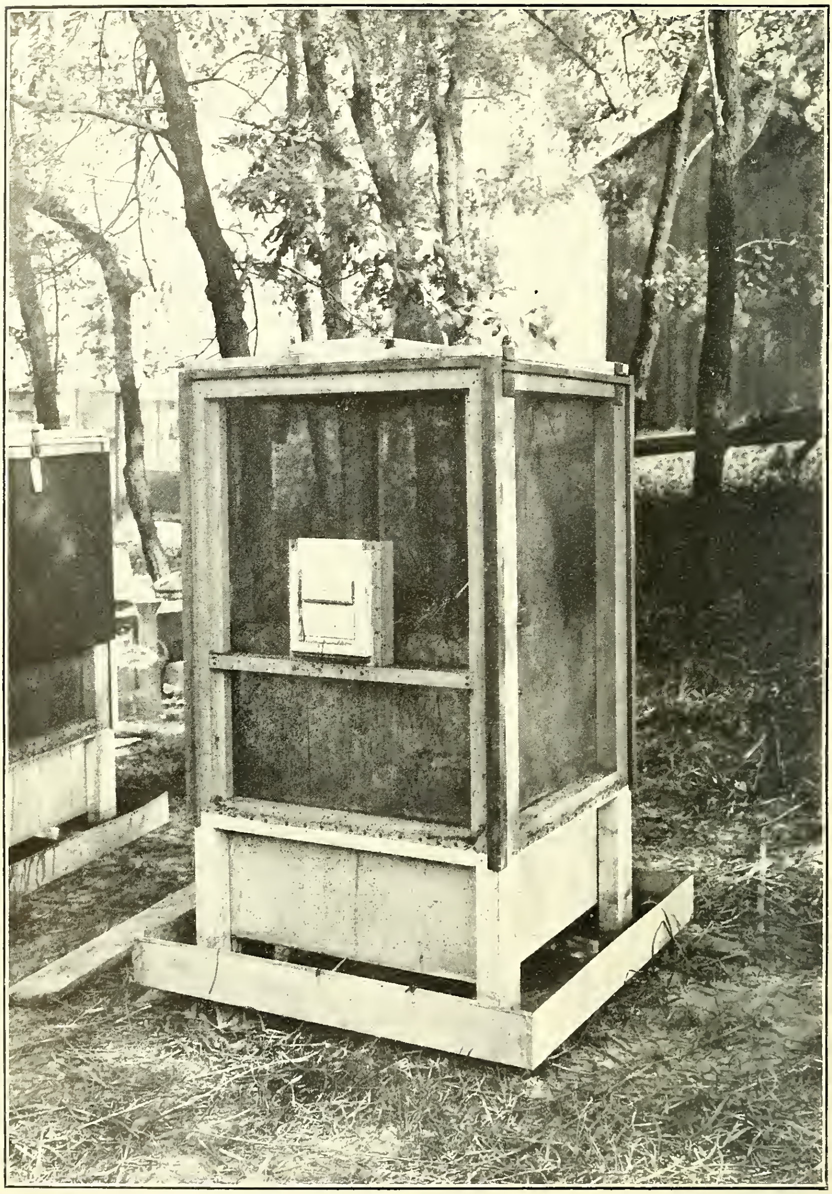
The manure in the control cages was sprinkled with water equal to the volume of the solutions of the chemicals used. In this way the moisture content of the manure was made as nearly as possible the same in all cages. It will be understood that 10 gallons of solution were applied to 8 bushels of manure in all the cage experiments mentioned below, unless some other explanation is given. After treatment in this way the doors of the cages were closed and the flytraps put in place. The cages were examined every day. The escape of any larvæ into the drip pan was noted, and the volume of the drip water measured and a sample analyzed. A quart sample of manure was removed through the small door at the side of the cage after a day or two and the percentage of living and dead maggots determined. The larval counts of quart samples were very unsatisfactory so far as indicating the comparative larvicidal value of the chemicals, but the results of some of these counts are given in the tables.

After five to seven days flies began to emerge, and then it was necessary to darken the cages with black cloth tacked on the sides, as seen



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

View of manure pile cut in half. The places where the fly pupæ are found, just above the ground and around the edges of the pile, are indicated by the two pieces of white cardboard. (Original.)



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

Cage used in the chemical treatment of manure, showing the flytraps at the top, the small door at the side through which samples of manure can be removed, the pan for collecting drip water, and other details of the structure. (Original.)

DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

A view of some open-pile experiments to show the size of the piles and the method of treatment. No. 1 has been treated with dry powdered borax, No. 2 with a solution of borax, and No. 3 is the control pile, which is sprinkled with water only. (Original.)

on the cage to the left in Plate II. In this way the only light came from the opening into the flytrap at the top, and flies very soon after emerging made their way up into the trap. The flies caught in the traps were chloroformed and counted daily. At the end of each experiment the total numbers of flies from each cage were compared. The difference between the total numbers of flies from a cage of treated manure and from the control cages is taken as an index of the effectiveness of the chemical. In any one set of experiments the manure used was all from the same source and, being in fresh condition, contained only eggs and larvæ. It was mixed before transferring to the cages, but it is evident that under the conditions we could not be sure of an equal infestation in all cages. Therefore the chemicals were not regarded as having any larvicidal power if the differences in the totals were small.

OPEN-PILE EXPERIMENTS.

In order to simulate natural conditions a parallel series of experiments was carried out by treating manure piles on the ground. Here again 8 bushels were used for each treatment, but repeated applications of both manure and chemicals were made. At the beginning of an experiment a quantity of fresh manure was divided into piles of 8 bushels each. Chemicals to be tested were tried at the rate of 10 gallons to 8 bushels except as otherwise noted. One pile was sprinkled with water only and was used as a control. On the following day another lot of fresh manure was similarly divided and piled on top of that of the previous day, and the treatment repeated. At the end of four days there was a pile of 32 bushels which had received four applications of chemicals. Plate III gives an idea of the size of the piles and shows that the experiments were carried out on a practical scale.

Eight to ten days after the fourth and last treatment the piles were opened and gone over carefully in search of pupæ. The pupæ were collected from the edges of the piles (compare Pl. I), spread on a large sheet of paper, counted, and the numbers compared. Chemical and bacteriological examinations were made of certain of these open piles.

METHODS OF SAMPLING.

Manure consists of urine and dung more or less intimately mixed with straw, wood shavings, sawdust, peat, or other absorbent. When first carried from the stable it is not uniform in composition, as the dung may predominate in one part of the mass and the straw or other absorbent in another part. Thorough mixing will help greatly in making it more uniform, but as the eggs and larvæ in the manure are readily shaken out, it can not be mixed as thoroughly as desired, and consequently there is no way under ordinary field conditions by which a small sample may be obtained that will be truly representative.

The errors due to sampling are necessarily large, and the differences in the results from the controls show the extent of this variation. This is unavoidable and must be recognized in all work on manure, and applies to the bacteriological results as well as to the chemical data, but is not so pronounced in the former cases, as the difference between the counts of the controls and treated samples is so much greater than for the chemical results.

In order to secure the most uniform samples under these conditions for bacteriological and chemical analyses, the following procedure for obtaining samples was adopted. Approximately an inch of material was first removed from the top and then half a pound of the underlying manure weighed on a spring balance; another half pound was then weighed from the center of the pile, and finally the same quantity was taken from the bottom. The three samples were all put in the same container for transportation to the laboratory, where the whole sample was spread out on a clean sheet of wrapping paper and then cut into small pieces and thoroughly mixed. When the material appeared quite uniform the sample was quartered. One quarter was then cut into half-centimeter lengths with clean shears. The straw or shavings were cut with the other material. When this was completed the sample was again thoroughly mixed. As the bacterial content of manure is very high, no attempt was made to work under absolutely sterile conditions because the contamination arising from ordinary handling of the material was of no importance when compared with the great number of organisms present. However, precautions were taken to prevent excessive contamination by using clean paper, shears, etc., for each sample. The carefully prepared quarter sample was put in a clean Mason jar.

BACTERIOLOGICAL EXAMINATION.

Two 10-gram samples of the manure, prepared as described above, were taken for each bacteriological determination. A sterile spatula was used to convey the sample from the jar to the tared watch glass on the balance pan. One of the 10-gram samples was dried at 100° C. for one hour to determine the percentage of solids. The other sample was brushed into a 2-liter flask containing 1 liter of sterile water. The cotton plug was thereupon replaced by a clean rubber stopper which had been lightly flamed. The flask was then vigorously shaken for five minutes and again, after a five-minute interval, for three minutes. A 1 c. c. sample was then withdrawn and run into 100 c. c.

of sterile water. Five dilutions were prepared, ranging from 1 part in 10,000 to 1 part in 100,000,000. A duplicate series of Petri dishes was then prepared from these dilutions and standard beef agar. After five days' incubation at 28–30° C. the plates were counted. The average counts of the duplicate plates were taken and converted into equivalents for 1 gram of dry manure by the use of the figures obtained from the duplicate 10-gram samples that had been dried at 100° C.

The results obtained by plating on the standard beef agar are comparative and serve to show the germicidal action of the chemicals on the majority of the bacteria present in the manure. The total bacterial counts on this medium include not only some of the bacteria that increase the value of the manure by their metabolic processes, but also many that may decrease its value in the same way by destroying nitrogen salts available for plant food. For this reason the total bacteriological counts on beef agar are not considered as entirely indicative of the fertilizing value of the manure. It is even possible that the germicidal effect of formaldehyde, calcium cyanamid, and potassium cyanid in the manure might prove highly beneficial, as Russell and Buddin's (1913) results with formaldehyde, toluene, cresol, phenol, etc., in the soil indicate.

CHEMICAL EXAMINATION.

The method of taking the samples was described above, but the samples for chemical examination were twice run through a sausage grinder after cutting with shears and were placed in screw-capped Mason jars provided with rubbers and analyzed as soon as possible. Samples for chemical examination were taken from the control cages immediately after the experiments were started, and from all 15 cages after 10 days. In this way it was thought an idea of the change which had taken place in the various samples could be obtained, the changes in the controls being taken as an index of the normal rate of decomposition of the manure.

The manure samples were analyzed for solids, ash, ammonia, and nitrogen, using the methods of the Association of Agricultural Chemists (Wiley, 1908). The total nitrogen determinations were made by the nitrogen laboratory of the Bureau of Chemistry. The results obtained by the magnesium oxid distillation method for ammonia, although much higher, showed the same general tendencies as the results obtained on the water extracts.

Water extracts of the manure were prepared from each sample by taking 25 grams of the finely divided manure and adding 500 c. c. of distilled water, allowing them to stand for one hour, with occasional shaking. The solutions were filtered through S. & S. folded filters No. 588, and the following determinations were made: Water-soluble nitrogen, ammonia, amino nitrogen, nitrites, nitrates, and reaction.

Ammonia was extracted by the Folin and Macallum (1912) aeration method and nesslerized. The amino nitrogen was determined by the Van Slyke method (Van Slyke, 1911), but as very little nitrogen in this form was present in the extracts, the figures are not given. Nitrites were determined with the sulphanilic acid reagent and nitrates by the reduction method with aluminum foil (American Public Health Association, Laboratory Section, 1912). Nitrites and nitrates were not usually found in the samples examined, because the manure had not stood sufficiently long. The reaction was determined by taking 20 c. c. of the water extract, diluting with 200 c. c. of carbon dioxid free water, and titrating with N/20 acid, using Alizarin red as indicator. Fehling's solution was not reduced by any of the 20 or more water extracts tested.

GENERAL ACCOUNT OF CHEMICALS USED.

In the course of the season 24 different chemicals were tried in various concentrations. Of these only seven have shown any effective larvicidal action in the strengths used. In the following paragraphs some of the chemicals which gave negative results are first noted, and later in the paper those which appeared to have the greatest value are described in more detail.

CHEMICALS WHICH GAVE LOW LARVICIDAL RESULTS.

KEROSENE EMULSION.

Kerosene emulsion, prepared according to the Riley-Hubbard standard formula, was used in strengths varying from 1 part emulsion in 5 parts water to 1 part emulsion in 50 parts water. In no case were results obtained which showed any appreciable larvicidal action. Even from the cage subjected to the strongest dosage 956 flies were taken, the average from the two control cages being 1,355 flies.

No chemical analyses of the manure were made. The bacterial count, where the strongest emulsion (1–5) was used, was 16,600 million per 1 gram of dry manure as compared with 6,130 million in the controls. These counts were made eight days after treatment with the chemical, but as the bacterial content of manure varies greatly and only one determination was made no conclusion can be drawn.

Kerosene emulsion was not used on any open-pile experiments. We have already called attention to the fact that Dr. Howard in his tests found that this reagent was ineffective when applied on a large scale.

KAINIT.

Kainit, which consists of potassium chlorid and magnesium sulphate, furnished us by Dr. F. Zerban, of New Orleans, was used in two cage experiments and in one open-pile test. In the cage experiments 4 pounds of kainit were used. The total number of flies obtained from the treated cages averaged 2,194, and from the two controls 3,104 flies. In the open-pile experiment three applications of 4 pounds per 8 bushels were made, and after 10 days about 12,000 pupæ were found. The corresponding control pile contained about 20,000 pupæ.

In the two cage experiments no chemical or bacteriological examinations were made. In the open-pile experiment the bacterial count was high, 17.5 million, as compared with 5.9 million in the control. One hundred c. c. of water extract, equivalent to 5 grams of the manure, from the treated pile contained a trace of nitrites and nitrates. No nitrites or nitrates were found in the kainit, nor did the control manure show any. The ammonia nitrogen in the kainit-treated manure was 12.3 per cent and in the control manure but 8.8 per cent of the total nitrogen. The high bacterial count and the increased amount of NH_3 obtained, as well as the fact that nitrates were found in the kainit-treated and not in the control manure, suggests that this compound may have a stimulating action on the bacteria, but no conclusions are justified from this one test. This chemical may be used to reenforce manure, but possesses little larvicidal power.

PYROLIGNEOUS ACID.

Pyroligneous acid was used in commercial form without dilution. Certain claims have been made in some districts of the South, especially in North Carolina, that pyroligneous acid is of value as a repellent, and in our experiments special attention was given to this point. Two piles of fresh manure of 8 bushels each were sprinkled with 10 gallons of pyroligneous acid. Before treatment no eggs were to be found anywhere on the surface of either pile. Two hours later fresh batches of eggs were found on both piles. The pupæ collected numbered about 6,000 and 8,000. Further observations showed that fly eggs were deposited on other piles of manure treated with the pyroligneous acid. Evidently the pyroligneous acid has little, if any, value as either a repellent or a larvicide. The bacterial counts showed a great increase, rising from 25 million in the control to 653 million in one of the pyroligneous acid piles.

ISTHMIAN CANAL COMMISSION'S LARVICIDE.

The Isthmian Canal Commission's larvicide, which has been successfully applied in the Canal Zone for the purpose of killing mosquito larvæ, is prepared according to the following formula: 150

gallons of carbolic acid are heated to 212° F. and to this 150 pounds of finely broken resin and 30 pounds of caustic soda are added and the mixture kept at 212° F. till a dark emulsion without sediment is formed. The resultant emulsion is a good larvicide, 1 part to 10,000 parts of water killing mosquito larvæ in less than half an hour. However, we did not find it effective against house-fly larvæ. The results of three cage experiments are given in Table I, Series A, Nos. 1, 2, and 3. Compared with the corresponding controls (Nos. 7, 8, and 9) it seems as if few, if any, fly larvæ were destroyed, but the fact that a considerable number of larvæ were found in the drip water from the control and only a few from the three treated cages should be considered.

The chemical analyses, given in Table I, show variation in the total nitrogen of the treated and control manures. This is true of many of the samples analyzed and shows the normal variations. The water extract of the treated manure showed more nitrogen and ammonia present than did the water extract of the control manure. The reactions of the water extracts varied considerably. No nitrites or nitrates were present either in the larvicide treated or in the control manure.

Unfavorable action on the bacteria is shown where the numbers are progressively decreased as the volume of the larvicide was increased. The highest count for the larvicide-treated samples is considerably lower than the lowest control count.

Several open-pile experiments were also carried out. One of these was started September 15 and the treatment repeated on four successive days. From the resulting pile of 32 bushels of manure about 10,000 pupæ were taken on September 26. The control pile contained about 7,000 pupæ. This was a typical experiment and is sufficient to show that even with repeated daily applications this reagent is of no value as a maggot destroyer.

IRON SULPHATE.

The results of three cage experiments with iron sulphate are given in Table I, Series A, Nos. 4, 5, and 6. The controls for these are Nos. 7, 8, and 9. The total number of flies caught from these cages shows that the manure was rather lightly infested. However, a comparison of the total number of flies that emerged and the number of larvæ found in the drip pan from treated and untreated cages indicates that this chemical may have had some larvicidal power. However, in three other cage experiments not shown in the table no larvicidal action was evidenced.

Iron sulphate was not used on open piles. The chemical and bacteriological findings in Table I show an injurious action on the manure. The number of bacteria was noticeably reduced, varying inversely with the strength of the solution used. The amounts of water-soluble nitrogen were materially lowered in the iron-sulphate-treated manure, depending on the amount of iron sulphate employed. The iron sulphate evidently acts as a precipitant for some of the water-soluble nitrogen compounds. The ammonia was fully doubled, due possibly to the reduction of alkaline reaction, two of these three samples showing a faint acidity. Iron sulphate blackened the manure and deodorized it, as noted by Forbes. On the whole, we find iron sulphate less effective as a larvicide than Forbes's experiments seem to indicate. It is important, however, to note that the amount of iron sulphate used by Forbes was much greater than that used in these tests.

TABLE I.—*Destruction of fly larvæ in horse manure—Results with ineffective larvicides—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever solution was applied.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.	Bacteria per 1 gram of manure, dried at 100° C.	Manure, total nitrogen.	Water extract.		
									In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams of manure).
		Alive.	Dead.						Nitrogen.	Ammonia nitrogen.	
Series A:				*Number.*	*Per cent.*	*Number.*	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
1	Canal larvicide, 1-75 (7½ gallons)	0	5	113	0	6	3,700	0.73	35.62	6.58	12.00
2	Canal larvicide, 1-75 (10 gallons)	0	6	110	0	1	2,600	.61	34.43	3.93	5.50
3	Canal larvicide, 1-75 (12½ gallons)	......	......	179	0	0	1,600	.53	32.08	3.96	5.75
4	Iron sulphate, 1½ pounds per gallon	2	0	73	32.4	0	700	1.05	10.48	5.05	1.50
5	Iron sulphate, 1 pound per gallon	6	1	171	0	0	970	.67	16.42	6.72	[1]0.62
6	Iron sulphate, ½ pound per gallon	1	0	81	25.0	0	2,800	.76	22.37	6.84	[1]1.25
7	Control (water only)	32	0	146	0	15	5,200	.84	26.19	2.62	10.50
8	do	22	0	102	0	127	6,000	.68	25.00	3.09	6.50
9	do	5	0	76	0	221	5,100	.65	18.46	2.46	5.00
Series B:											
1	Sodium chlorid, 2½ pounds per gallon	28	1	141	55.5	0	2,550	.51	32.94	7.65	4.40
2	Sodium chlorid, 1 pound per gallon	110	0	217	30.0	100	......	.45	28.67	3.78	7.50
3	Copper sulphate, 1 pound per gallon	5	2	101	67.4	0	648	.69	9.71	3.78	2.75
4	Copper sulphate, ¼ pound per gallon	4	0	132	57.4	Few.	4,070	.75	14.93	2.40	7.75
5	Control (water only)	48	0	322	0	100	3,060	.55	23.45	2.55	7.75
6	do	12	0	298	0	30	4,800	.72	21.11	2.08	7.50

[1] Acidity.

SODIUM CHLORID (TABLE SALT).

The results of two cage experiments with manure treated with sodium chlorid are given in Table I, Series B, Nos. 1 and 2. The corresponding control cages are numbered 5 and 6. The average number of flies from these two controls is 310. Presuming that the infestation of the manure at the start of the experiment was the same in all cages, it appears from the table that sodium chlorid used at the rate of 2½ pounds per gallon killed 55 per cent of the larvæ. The 1-pound per gallon application showed a 30 per cent destruction of the maggots. The chemical results of the salt-treated manure are not very different from those of the untreated manure except that there is an apparent increase in the nitrogen and ammonia in the water extract of the treated samples. Only one bacterial examination was made and this showed that the strongest salt solution reduced the number of bacteria somewhat.

COPPER SULPHATE.

Nos. 3 and 4 of Series B, Table I, give the results of two cage experiments with copper sulphate. When compared with the controls it would seem that the dosage of 1 pound per gallon killed 67 per cent of the maggots and the one-fourth pound strength 57 per cent.

The bactericidal power of copper sulphate is well known. When added at the rate of 1 pound per gallon sufficient copper sulphate remained in solution to kill 87 per cent of the bacteria. Their number was not affected by the smaller quantity of this chemical.

The chemical analyses show an injurious effect from the heavier application of copper sulphate, which reduced the amount of soluble nitrogen and the alkaline reaction of the water extract. With the weaker strength the only apparent effect is a slight reduction of water-soluble nitrogen. No open-pile experiments with copper sulphate were carried out.

LIME-SULPHUR MIXTURE.

Lime-sulphur was used in three cage experiments, but in no open piles. There is no evidence that the lime-sulphur possessed any larvicidal power, for more flies developed from the cage receiving a 1–5 treatment than from the control. The bacteria do not appear to be affected by this treatment. From two other experiments where lime-sulphur was used in strengths of 1–15 and 1–30 fewer flies emerged than in the control, but this was probably due to differences of infestation.

In addition to the chemicals mentioned, acid phosphate, a proprietary fertilizer, and several proprietary disinfectants were tested with negative larvicidal results.

PARTIALLY EFFECTIVE LARVICIDES.

In Table II, page 15, some results obtained with potassium cyanid, Paris green, and formaldehyde, which were found to possess some larvicidal action, are recorded. Each of these three substances in the heaviest application, and formaldehyde in all cases, reduced the number of bacteria.

POTASSIUM CYANID.

Potassium cyanid gave favorable results in three cage experiments. These results are given in Table II, Series C, Nos. 1, 2, and 3, the control being No. 4. Quart samples of manure two days after treatment showed a large percentage of dead larvæ for the two stronger applications. The total numbers of flies developing were very much reduced. It appears that the two higher concentrations killed 93 per cent of the larvæ. The chemical results of analyses of these three samples of manure show considerable variations, but there is no evidence that the manure had been injured by the application of the potassium cyanid. The increased alkalinity results of the control and of No. 2 may be explained by the large amount of water-soluble nitrogen in these two cases. No open piles were treated with potassium cyanid. This reagent, when used in proper concentrations, will undoubtedly be found a very effective maggot killer, but its extremely poisonous nature makes it objectionable and dangerous. The bacterial counts show that potassium cyanid in the manure had no very definite bactericidal effect. A stimulating action is rather indicated in the two higher dilutions, but as the difference in the number of bacteria between the three treated samples is no greater than that between some of the controls, no conclusions can be drawn from this experiment.

PARIS GREEN.

Paris green was used in three cage experiments, the results of which, together with those of the corresponding controls, are given in Table II, Series D. The Paris green was not all dissolved, but was applied in the form of a suspension. The suspended particles were deposited on the surface and only the part in solution filtered into the deeper parts of the manure. It appears from these experiments that Paris green killed from 70 to 90 per cent of the larvæ.

The bacteriological counts vary considerably and inversely with the strength of the solution used. The most concentrated solution was strongly bactericidal and reduced the number of organisms by about 50 per cent. The higher dilutions showed the general stimulating action of poisons in small quantities. The effect in general is the same as that of potassium cyanid, but is much more marked.

The water-soluble nitrogen varied with the amount of Paris green used, and was lowest where the strongest application of Paris green was made, due probably to the precipitating power of the copper, and about equal to the control where the two weaker applications were made.

FORMALDEHYDE.

Formaldehyde solution was used in six cage experiments, but on no open piles. Three concentrations were tried, by mixing 1 part of the commercial 40 per cent formalin with 3, 6, and 12 parts of water, respectively. The results of three of these tests are given in Table II, Series E, together with the corresponding controls. In three experiments not given in the table the infestation of the manure was so slight that it was not possible to form any judgment as to the larvicidal action of this chemical. Even in the experiments which are given in the table, the manure was lightly infested. However, all the concentrations show considerable larvicidal action. Taking the average total number of flies of the controls it is evident that from 75 to 85 per cent were killed. It is probable that if this treatment had been made in closed boxes or receptacles to retard the loss of formaldehyde by evaporation, the larvicidal action would have been still higher.

As might be expected, the formaldehyde in these dilutions caused a great reduction in the number of bacteria. The highest dilution (1–12) killed 99.6 per cent of the bacteria that would grow on beef agar. The chemical results show a decreased alkalinity of the water extract. The ammonia results average slightly higher than those obtained on the control samples, but in No. 2, where the dilution of formaldehyde used was 1–6, the bacterial count, the water-soluble nitrogen, the ammonia, and the alkalinity are higher than in either of the other two treated samples. The fact that formaldehyde produces an acid reaction, either by conversion to formic acid or by combining with amino acids, a reaction used by Sörensen (1907) for the quantitative estimation of the amino acids, may explain the reduced alkalinity of these extracts. Nitrites and nitrates were detected in all three cases of the manure treated with formaldehyde. It is interesting in this connection to note that Russell and Buddin (1913) carried out some experiments on the action of various volatile antiseptics in the soil, and found that formaldehyde increased the production of nitrates and ammonia. While formaldehyde is extremely disagreeable to work with on account of the irritating action which it has on the mucous membrane, nevertheless further work with this chemical will be undertaken.

TABLE II.—*Destruction of fly larvæ in horse manure—Results with partially effective larvicides—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever solution was applied.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.	Bacteria per 1 gram of manure, dried at 100° C.	Manure, total nitrogen.	Water extract. In per cent of total nitrogen.		Water extract. Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams of manure).
		Alive.	Dead.						Nitrogen.	Ammonia nitrogen.	
				Number.	*Per cent.*	*Number.*	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*C.c.*
Series C:											
1.......	Potassium cyanid, 0.1 per cent solution.	2	9	82	93.6	......	5,250	0.68	19.85	3.09	10.25
2.......	Potassium cyanid, 0.02 per cent solution.	11	21	86	93.3	100	7,260	1.00	23.60	2.90	14.50
3.......	Potassium cyanid, 0.004 per cent solution.	11	4	251	80.6	350	7,620	.63	20.48	Trace.	10.00
4.......	Control (water only).....	64	1	1,287	0	400	6,130	1.12	24.11	3.57	17.65
Series D:											
1.......	Paris green, 1–20..........	0	2	92	70.3	Few.	1,740	.70	13.43	2.71	9.00
2.......	Paris green, 1–40..........	......	......	35	88.7	Few.	7,300	.59	22.88	1.86	7.50
3.......	Paris green, 1–80..........	0	1	32	89.7	Few.	19,950	.56	25.00	4.64	6.00
4.......	Control (water only).....	48	0	322	0	100	3,060	.55	23.45	2.55	7.75
5.......	.....do....................	12	0	298	0	30	4,800	.72	21.11	2.08	7.50
Series E:											
1.......	Formaldehyde,[1] 1–3 solution.	0	7	20	81.5	1	14	.58	18.97	3.62	.75
2.......	Formaldehyde, 1–6 solution.	3	1	16	85.2	22	44	.46	21.74	4.57	2.00
3.......	Formaldehyde, 1–12 solution.	165	15	27	75	0	22	.60	18.33	2.83	.75
4.......	Control (water only).....	32	0	146	0	15	5,200	.84	26.19	2.62	10.50
5.......	.....do....................	22	0	102	0	127	6,000	.68	25.00	3.09	6.50
6.......	.....do....................	5	0	76	0	221	5,100	.65	18.46	2.46	5.00

[1] Nitrites and nitrates were found in Nos. 1, 2, and 3, Series E.

SODIUM FLUORID.

Sodium fluorid was used in two cage experiments. In one it was applied at the rate of 2 pounds per gallon, and 454 flies developed. In the other 1 pound per gallon was used, and 1,053 flies developed. From the two control cages the totals were 6,152 and 5,870. Thus the stronger concentration destroyed over 90 per cent of the maggots, and the weaker strength 84 per cent. No open piles were treated.

No bacteriological or chemical analyses were made of the manure treated with sodium fluorid. From the limited number of tests with this chemical, it is evident that it may possess some value as a larvicide, and further experiments will be conducted, using commercial sodium fluorid, although the cost (5 pounds, $1) may prohibit its general use.

AMMONIACAL GAS LIQUOR.

Ammoniacal gas liquor, which is a by-product of the manufacture of illuminating gas, evidenced some larvicidal effect when used in the strengths of 1–5 and 1–25. From the cage treated with the stronger dosage 206 flies were caught and 179 flies from the other. The control cages showed 1,508 and 1,287 flies. The gas liquor in the 1–5 strength was strongly bactericidal, reducing the number of bacteria as shown in the control from 6,130 million to 92.8 million. In view of the fact that the gas liquor showed a bactericidal action and that the transportation of a liquid in large amounts is expensive, it was not studied further, although it possesses certain advantages, as it contains a considerable amount of nitrogen, practically all of which is in the form of ammonia. This nitrogen is, however, all in soluble and volatile form and easily lost.

CALCIUM CYANAMID.

The treatment with calcium cyanamid was tried at the suggestion of Dr. Alsberg. It has been used in cage experiments at Arlington, Va., and the results obtained are recorded in Table III.

TABLE III.—*Destruction of fly larvæ in horse manure—Larvicidal results with calcium cyanamid—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of water.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.
		Alive.	Dead.			
Series F:				*Number.*	*Per cent.*	*Number.*
1	Calcium cyanamid, 20 pounds	1	2	7	99.5	0
2	Calcium cyanamid, 5 pounds	0	4	52	96.3	......
3	Control	22	0	1,508	0	12
4	do	64	1	1,287	0	400
Series G:						
1	Calcium cyanamid, 5 pounds	4	0	92	20.0	30
2	Calcium cyanamid, 4 pounds	4	1	761	......	20
3	Calcium cyanamid, 3 pounds	......	......	56	51.3	25
4	Control	82	0	25	0	50
5	do	22	0	204	0	10

The calcium cyanamid was scattered over the manure in powdered form and in all cases water was added. From the table it appears that the 20-pound application killed over 99 per cent of the larvæ. The 5-pound applications gave varying results, as seen in the table, and in one cage experiment not shown 58 per cent of the larvæ were destroyed. This gives an average larvicidal power of 58 per cent for this amount of the calcium cyanamid. In one cage test not shown where 4 pounds were applied, 40 per cent were killed, but in the cage experiment given in Table III no larvicidal action was apparent. Since calcium cyanamid is used to some extent as a fertilizer and is a means of adding nitrogen to the manure, and thus to the soil, it is highly desirable that a further study of this chemical be made, not only to determine more exactly its larvicidal action, but also to de-

DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

On tbe left larvæ are shown which have been killed by borax. They were in the process of changing to pupæ. On the right normal pupæ are seen. (Original.)

termine by field experiments whether the amount of nitrogen thus added compensates for the cost of treatment. The cost of the cyanamid in 100 or 200 pound lots is about 3½ cents per pound.

The results of two typical open-pile experiments with calcium cyanamid are given in Table IV. The 5-pound application killed 82 per cent of the larvæ and reduced the number of bacteria markedly. The 4-pound application killed 71 per cent of the larvæ and reduced the bacteria 50 per cent. In both cases the water-soluble nitrogen, ammonia, and alkalinity were considerably increased.

TABLE IV.—*Destruction of fly larvæ in horse manure—Results with calcium cyanamid—Open-pile experiments (three applications) at New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of water.	Total number of pupæ found after 8 to 10 days.	Larvæ killed.	Bacteria per 1 gram manure, dried at 100° C.	Manure.		Water extract.		
							In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams manure).
					Solids.	Total nitrogen.	Nitrogen.	Ammonia nitrogen.	
			Per cent.	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
Series H:									
1.......	Calcium cyanamid, 5 pounds...	3,500	81.6	43	31.30	0.72	44.44	8.89	7.35
2.......	Calcium cyanamid, 4 pounds...	5,500	71.0	75	30.47	.59	47.46	13.56	8.15
3.......	Control........................	19,000	0	158	27.14	.43	19.54	6.51	5.30

EFFECTIVE LARVICIDES (BORATES).

The most favorable results were obtained by the use of borax (sodium borate) and calcined colemanite (crude calcium borate). Both substances possessed a marked larvicidal action and appeared to exert no permanent injury on the bacteria. These two borates have been used in a large number of experiments and the results all uniformly show a very high larvicidal action, both in cages and open piles, and whether applied in dry form or in solution.

A comparison of the total number of flies or of pupæ from borax-treated manure with the totals from control manure shows a larvicidal power of over 99 per cent in nearly all trials. One of the reasons why borax is so effective in reducing the number of flies is due to its toxic effect on the eggs, which do not hatch after contact with this chemical. The piles in one experiment, started on September 13, 1913, were examined for pupæ on September 25. At this time large masses of eggs of the house fly, perhaps 600 to 800, were found in a borax-treated pile. They were not empty, collapsed shells, but had normal shape and evidently had not hatched. They were somewhat discolored, many having a bluish tinge. Some of these were taken to the laboratory and examined daily under a microscope. None of these hatched after a week at room temperature and favorable moisture conditions. On October 6, in going over a pile, last treated with borax solution on September 28, batches of a thousand eggs or more were found. They had a bluish tinge. A mass of these eggs with surrounding manure was kept in a jar in the laboratory for a week and examined daily. None had hatched at the end of this time. Similar observations were made on other borax-treated piles. No such masses of unhatched eggs were ever found on control piles, nor on piles treated with other chemicals after the first three or four days of exposure.

Calcined colemanite, being largely insoluble, did not show this effect on the eggs. Borax acts very effectively through its toxic action on the eggs, but its action is not confined to the egg stage, as larvæ are also killed. In nearly all cases examinations of open piles showed the presence of dead larvæ as well as pupæ. In Table V it will be noted that in some piles large numbers of pupæ were found, but these were black, shrunken, wrinkled, and were not normal in shape, having more nearly the form of the larvæ than of the pupæ. Pl. IV.) When kept in the laboratory for a long time 1 per cent or less hatched. The borax had evidently killed them just at the time of transformation from larvæ to pupæ. This may be explained in several ways. (1) It may be that the larvæ, in the younger stages, resisted the action of the borax they had ingested but became very sensitive to it at the time of the breakdown of larval tissues. (2) The action of the borax may be cumulative and so may not evidence its toxic action until toward the end of the larval stage. (3) It may be that the larvæ in their earlier stages were found some distance in from the surface where the borax had not penetrated, but that, when ready to pupate, they migrated to the outer lower edges of the manure pile where the concentration of the borax was greatest and were killed by it. The migration of the larvæ in the cages and open piles has already been referred to on pages 3 and 5, and is discussed more in detail by Mr. Hutchison (1914).

The fact that small quantities of borax are not detrimental to the normal fermentation of manure is further shown by some temperature determinations.

The manure piles were made with no attempt to pack the manure, because it was believed that the higher temperatures prevailing where aerobic fermentation was in progress would be an attraction to the flies. Three series of experiments were used for these tests. The temperatures were taken by inserting a thermometer about a foot deep in the top of the piles. As the piles were small the temperatures at this depth were very nearly the maximum. The three controls attained their highest temperature, 66° and 67° C. (150.8° and 152.6°

F.) in from five to seven days after the experiment was started. At the same time the borax-treated piles reached their maximum of 58° to 63° C. (136.4° to 145.4° F.). Even where one-eighth pound of borax was used the temperature was slightly suppressed, as it reached only 61° C. (141.8° F.). This effect, however, may have been due to the borax preventing the growth of organisms which produce firefanging. The effect of borax in entirely preventing this condition has been reserved for a future investigation. However, it was found that in three cases the control piles showed evidences of firefanging and the presence of a white powdery mold in the interior. This condition was never found in the borax-treated piles. After attaining a maximum, the temperature of all the piles declined rapidly. The treated ones continued lower than the controls.

One manure pile treated with 5 pounds of calcined colemanite showed a steady decline in temperature from the beginning of the experiment. The bactericidal effect of this large dose is further shown by a comparison of the bacterial count obtained from a sample of this pile and that of the control; a decrease of 64 per cent in the number of bacteria occurred.

The data of the borax-treated manure are recorded in Tables V and VI. The open-pile experiments, which are recorded in Table V, show marked variations in numbers of bacteria, but whether this is due to a variation in the penetration of the borax because of different natural factors, or because the samples were not representative of the pile, although taken in the usual manner (see page 5), can not be stated at this time. There is a reduction in the number of bacteria in Series J, Nos. 1 and 2, and Series L, Nos. 1 and 2, where colemanite was used. There are marked increases in Series I, Nos. 1 and 2, and Series K, Nos. 3 and 4. In Table VI, where the results are recorded for the manure experiments made in cages, an increase in the number of bacteria is seen in all the borax-treated samples.

The manure from the open-pile experiments, Table V, indicates an increase of water-soluble nitrogen and ammonia in the borate-treated samples. The reaction of the water extract is increased in all of these cases. Further, in four of the open-pile experiments nitrites and nitrates were both found. In no case did the control manure give a reaction for nitrites or nitrates. The presence of nitrites and nitrates in the borax-treated piles is very interesting and if it is obtained in all cases where the borax-treated manure has been allowed to stand for several weeks a strong argument will be presented for its use in addition to the effective larvicidal action which it is seen to possess. There are considerable variations in the water-soluble nitrogen and ammonia results for the open-pile experiments as well as for the bacterial counts as noted on page 6.

TABLE V.—*Destruction of fly larvæ in horse manure—Results with borates—Experiments on open piles, New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever liquid was added.	Number of applications.	Total number of pupæ found after 8–10 days.	Bacteria per gram manure, dried at 100° C.	Manure.		Water extract.		
							In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c., 5 grams manure.
					Solids.	Total nitrogen.	Nitrogen.	Ammonia nitrogen.	
				Millions.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
Series I:									
1	Na-borate,[1] 2½ pounds dry (no water added)	4	[2] 5,000	141	39.59	0.60	36.67	7.33	11.05
2	do.[1]	4	[2] 4,200	172	39.14	.55	29.09	8.18	10.60
3	Control (water)	4	10,000	105	34.54	.46	30.43	8.69	5.90
Series J:									
1	Na-borate, 2 pounds dry (no water)	4	30	.659	42.51	.67	44.78	12.54	10.20
2	do	4	39	.577	43.29	.68	39.71	11.03	10.90
3	Control (water)	4	2,500	316.	42.43	.63	30.16	8.89	6.50
Series K:									
1	Na-borate in solution, ⅙ pound per gallon	3	[2] 985	2	36.69	.52	25.00	8.27	12.45
2	do	3	[2] 575	5	43.08	.56	21.43	7.50	7.85
3	Na-borate [1] in solution, ⅛ pound per gallon	3	[3] 1,700	38	34.72	.47	34.04	11.91	8.55
4	do.[1]	3	[3] 1,900	36	43.01	.53	26.42	11.13	7.35
5	Control (water)	3	20,000	6	34.04	.49	24.49	8.78	6.10
Series L:									
1	Calcined colemanite, 3 pounds plus water	3	[4] 2,600	38	30.58	.49	30.61	16.33	7.05
2	do	3	[4] 3,200	26	30.77	.44	31.82	9.09	7.20
3	Control (water)	3	19,000	158	27.14	.43	19.54	6.51	5.30

[1] Nitrites and nitrates present.
[2] Approximate. Of pupæ from borax-treated piles about 1 per cent hatch.
[3] Of all these only 10 flies emerged after many days in the laboratory.
[4] Abnormal in shape and color. Only 1 fly developed in sample of 500 pupæ.

TABLE VI.—*Destruction of fly larvæ in horse manure—Results with borax—Cage experiments at New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of liquid.	Larval mortality, 1-quart sample manure 2 days after treatment.		Total number of flies emerged.	Larvæ in drip pan.	Bacteria per 1 gram manure, dried at 100° C.	Total nitrogen in manure.	Water extract.		
								In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4, per 100 c. c. (5 grams manure).
		Alive.	Dead.					Nitrogen.	Ammonia nitrogen.	
						Million.	*P. ct.*	*P. ct.*	*P. ct.*	*C. c.*
Series M:										
1	Borax, ½ pound per gallon	5	0	15	12	7,392	0.51	33.33	9.41	19.50
2	do	2	0	18	15	3,003	.55	18.18	10.18	16.50
3	Borax, ¼ pound per gallon	35	0	38	3	7,452	.58	27.59	11.55	13.00
4	do	5	4	22	6	5,800	.58	37.93	10.86	13.75
5	Control (water)	82	0	25	50	2,204	.74	16.22	4.46	8.30
6	do	22	0	204	10	3,484	.84	14.29	1.79	7.50

In the cage tests, Table VI, the water-soluble nitrogen, ammonia, and reaction were lower for the controls than for the borax-treated manure. The low water-soluble nitrogen and ammonia results of the controls may possibly be due to the unusual fermentation going on in these two samples, as indicated by the peculiar odor. The fact that, after grinding, the manure tended to cake or lump may have prevented the usual amount of material from going into solution. The bacterial counts in the cage experiments are higher than the controls, and also higher than those of the open piles. This is undoubtedly due to the artificial conditions of the cage experiments. The increase of water-soluble nitrogen, ammonia, and alkalinity has been found in all the borax-treated manure, both cage and open-pile tests, at Arlington and New Orleans.

In Table VII additional cage experiments showing the larvicidal action of borax, dry and in solution, and calcined colemanite with water, are recorded. Borax in small amounts, such as 1¼ pounds per 8 bushels of manure, destroyed 98 to 99 per cent of the maggots, and calcined colemanite, even when 2 pounds per 8 bushels of manure were used, showed the same percentage of larvicidal action.

TABLE VII.—*Cage experiments showing larvicidal action of borates on fly larvæ in horse manure.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever liquid was added.	Total number of flies emerged.
Series N:		
1	Na-borate, dry powder, 2½ pounds (no water added)	12
2	Na-borate in solution, ¼ pound per gallon	1
3	do	2
4	Control (water)	6,152
5	do	5,870
Series O:		
1	Na-borate in solution, ⅙ pound per gallon	5
2	do	13
3	do	68
4	Na-borate in solution, ⅛ pound per gallon	46
5	do	50
6	Caleined colemanite, 4 pounds plus water	55
7	Calcined colemanite, 3 pounds plus water	165
8	Calcined colemanite, 2 pounds plus water	29
9	Control (water)	3,069
10	do	3,140

RECENT EXPERIMENTS TO DETERMINE MINIMUM AMOUNTS OF BORAX AND CALCINED COLEMANITE WHICH ARE EFFECTIVE AS LARVICIDES.

Some recent tests at New Orleans to determine the minimum amounts of borax and calcined colemanite which are effective have shown that 0.62 pound of borax and 0.75 pound of calcined colemanite are effective as larvicides, but when smaller amounts of either are used their larvicidal value is reduced. It is therefore apparent that 0.62 pound of borax and 0.75 pound of calcined colemanite to 8 bushels of manure (10 cubic feet), with the addition of 2 to 3 gallons of water, are the minimum quantities of these borates that will destroy practically all the fly maggots in manure.

ADVANTAGES AND COST OF BORAX.

The great demand for borax, due to its uses in the arts and in the household, has made this substance available in all parts of the country. It has the further advantage of being comparatively nontoxic, noninflammable, and easily transported and handled, as it is a powder. Thus borax is superior to most of the substances that have been tested as larvicides. Several investigators (see Haselhoff, 1913) have shown that in small amounts borax has a stimulating effect on plant growth, while larger amounts are toxic.

Borax is prepared from colemanite (calcium borate), which is mined in California, and has the following composition: Boron trioxid, 50.9 per cent; calcium oxid, 27.2 per cent; water, 21.9 per cent. The crude colemanite was tested for its larvicidal action, but this was so slight, undoubtedly due to its insolubility, that it was discarded in favor of borax and calcined colemanite. Calcined colemanite is prepared from crude colemanite by simply subjecting it to high temperatures.

The crude colemanite is not sold as such, but a considerable amount of the calcined colemanite is used in various industries. The calcined colemanite is a gray powder and is largely, but not entirely, insoluble in water. It costs about 2 cents per pound in large shipments, and in smaller amounts sells at approximately 4 cents per pound. Borax ($Na_2B_4O_7 10H_2O$) is prepared from colemanite by treatment with soda ash. It retails at about 10 cents per pound, but can be obtained in 100-pound lots or more in Washington at 5 to 6 cents per pound. Borax is readily soluble in water.

EFFECTS OF BORAX-TREATED MANURE ON PLANTS.

The chemical analyses and bacterial counts to which references have been made throughout this bulletin do not indicate any permanent deleterious effects of the borax on manure. On the contrary, a beneficial effect is suggested. This was especially the case with the chemical results where an increase of ammonia was obtained in all cases and no apparent reduction in the total nitrogen was evident. Nitrites and nitrates were found in several of the open piles where borax had been applied. In order to be certain of the effect of borax-treated manure on plants, extensive experiments have been performed both in the greenhouse and in open plats. The field work was conducted at four points in the South, as well as on the Arlington farm, and the pot tests were conducted in the greenhouses of the department at Washington. The following plants were tested: Wheat, tomatoes, peas, beets, radishes, kohl-rabi, oats, corn, cucumber, lettuce, as well as apple seedlings and rosebushes. Such elaborate experiments seem to be necessary on account of the known toxic effects of large applications of boron upon the growth of plants, as shown by several investigators. In this connection it is important to note that investigations of Russell and Buddin (1913) in England have shown that the application of very small amounts of volatile and some nonvolatile disinfectants have eventually resulted in the stimulation of plant growth. This same effect is indicated in some of the experiments with borax.

In the field and pot experiments no deleterious effects were observed from the application of borax at the rate of 0.62 pound per 8 bushels (10 cubic feet) of manure, except possibly on wheat. Larger doses of borax produced a discoloration of the tips of some other plants. In our field experiments with winter wheat the plants when 4 inches high showed a decided yellowing of the tips where very heavy applications of borax were made, but at the start of the growing period in the spring the yellowing of the tips decreased and the wheat was nearly normal in appearance. These effects vary with the plants and the amount of moisture present in the soil. Where rainfall is heavy the effects disappear quickly. At Orlando, Fla., for instance, where the experiment was conducted during a drought and larger amounts of borax than 0.62 pound per 8 bushels were used, injurious effects were much more evident than in other localities. In all these cases, however, except at Orlando, recent observations have shown that the plants have practically recovered—so far as can be determined without estimating the actual yields, which can not be done at the present time. From these experiments it is believed that no injurious effects will follow the application of the minimum amount of borax found necessary to destroy the larvæ, namely, 0.62 pound per 8 bushels of manure, which may be applied to the field at the rate of 15 tons per acre. If more is necessary, untreated manure may be used. Some recent pot tests have indicated that the addition of slaked lime in amounts equal to half that of the borax present tends to offset the toxic action which results from heavy applications of borax. Some questions relating to the effects of borax on the growth of plants remain to be determined, notably its possible cumulative action, and these will be reported later. It is expected that interesting results will follow from the experiments now under way with calcined colemanite, which, though cheaper than borax, is effective in destroying fly larvæ when applied at the rate of 0.75 pound per 8 bushels.

SUMMARY.

CLASSIFICATION OF CHEMICALS TESTED.

The substances used in the experiments dealt with in this bulletin may be arranged in two classes, as indicated below. The term "satisfactory" is used to indicate destructive action on fly larvæ, noninjurious effect on manure, and lack of extremely poisonous properties. Among the unsatisfactory or partially satisfactory substances are included several which when used in large amounts may kill fly larvæ but are placed in this class because of the large amount required or because of their extremely poisonous properties.

Iron sulphate has been used as a larvicide and in considerable amounts is stated to be effective. However, no studies of the effects of iron sulphate on the fertilizing value of manure have been reported. Our experiments indicate injury to the manure even from small applications of iron sulphate (see p. 10). Paris green and potassium cyanid are effective as larvicides, but are objectionable on account of their extremely poisonous nature.

UNSATISFACTORY OR PARTIALLY SATISFACTORY SUBSTANCES.

Kerosene emulsion.	Pyroligneous acid.
Kainit.	Sodium chlorid (table salt).
Isthmian Canal Commission larvicide.	Copper sulphate.
Iron sulphate.	Lime-sulphur mixture.
Several proprietary disinfectants.	Paris green.
Potassium cyanid.	Sodium fluorid.
Formaldehyde.	Ammoniacal gas liquor.
Calcium cyanamid.	

SATISFACTORY SUBSTANCES.

Borax.	Calcined colemanite.

By far the most effective, economical, and practical of the substances is borax in the commercial form in which it is available throughout the country.

Borax increases the water-soluble nitrogen, ammonia, and alkalinity of manure and apparently does not permanently injure the bacterial flora. The application of manure treated with borax at the rate of 0.62 pound per 8 bushels (10 cubic feet) to soil does not injure the plants thus far tested, although its cumulative effect, if any, has not been determined.

DIRECTIONS FOR TREATING MANURE WITH BORAX TO KILL FLY EGGS AND MAGGOTS.

Apply 0.62 pound borax or 0.75 pound calcined colemanite to every 10 cubic feet (8 bushels) of manure immediately on its removal from the barn. Apply the borax particularly around the outer edges of the pile with a flour sifter or any fine sieve, and sprinkle 2 or 3 gallons of water over the borax-treated manure.

The reason for applying the borax to the fresh manure immediately after its removal from the stable is that the flies lay their eggs on the fresh manure, and borax, when it comes in contact with the eggs, prevents their hatching. As the maggots congregate at the outer edges of the pile, most of the borax should be applied there. The treatment should be repeated with each addition of fresh manure, but when the manure is kept in closed boxes less frequent applications will be sufficient. Where the calcined colemanite is available, it may be used at the rate of 0.75 pound per 10 cubic feet of manure, and is a cheaper means of killing the maggots. In addition to the application of borax to horse manure to kill fly larvæ, it may be applied in the same proportion to other manures, as well as to refuse and garbage. Borax may also be applied to floors and crevices in barns, stables, markets, etc., as well as to street sweepings, and water should be added as in the treatment of horse manure. After estimating the amount of material to be treated and weighing the necessary amount of borax a measure may be used which will hold the proper amount, thus avoiding subsequent weighings.

WARNING IN CONNECTION WITH THE USE OF BORAX-TREATED MANURE.

While it can be safely stated that no injurious action will follow the application of manure treated with borax at the rate of 0.62 pound for 8 bushels, or even larger amounts in the case of some plants, nevertheless borax-treated manure has not been studied in connection with the growth of all crops, nor has its cumulative effect been determined. It is therefore recommended that not more than 15 tons per acre of the borax-treated manure should be applied to the field. As truckmen use considerably more than this amount, it is suggested that all cars containing borax-treated manure be so marked, and that public-health officials stipulate in their directions for this treatment that not over 0.62 pound for 8 bushels of manure be used, as it has been shown that larger amounts of borax will injure most plants. It is also recommended that all public-health officials and others in recommending the borax treatment for killing fly eggs and maggots in manure warn the public against the injurious effects of large amounts of borax on the growth of plants.

COST OF BORAX TREATMENT.

The amount of manure from a horse varies with the straw or other bedding used, but 12 or 15 bushels per week represent the approximate amount obtained. As borax costs from 5 to 6 cents per pound in 100-pound lots in Washington, it will make the cost of the borax practically 1 cent per horse per day. And if calcined colemanite is purchased in large shipments the cost should be considerably less.

LITERATURE CITED.

AMERICAN PUBLIC HEALTH ASSOCIATION, LABORATORY SECTION.

1912. Standard Methods for the Examination of Water and Sewage. 2d ed. New York, Amer. Pub. Health Assoc., 144 p. (Cover title: Standard Methods of Water Analysis. A. P. H. A. 1912.)

FOLIN, OTTO, AND MACALLUM, A. B.

1912. On the determination of ammonia in urine. *In* Jour. Biol. Chem., v. 11, no. 5, p. 523–525, June. See p. 523.

HASELHOFF, E.

1913. Landwirtschaftlichen Versuchs. vols. 79 and 80, p. 399.

1913. Uber die Einwirkung von Borverbindungen auf das Pflanzenwachstum. *In* Landw. Vers-Stat., Bd. 79 u. 80, p. 399–429, pl. 4–7, 1913.

HERMS, W. B.

1910. How to control the common house fly. Cal. State Board of Health Bul., May 5, no. 2, p. 269–277.

HOWARD, L. O.

1911. The House Fly—Disease Carrier. New York, Frederick A. Stokes Co., 312 p., illus. See p. 196 and 197.

HUTCHISON, R. H.

1914. The migratory habit of house-fly larvæ as indicating a favorable remedial measure, An account of progress. U. S. Dept. Agr., Bul. 14. 11 p. Feb. 28.

RUSSELL, E. J., AND BUDDIN, WALTER.

1913. The action of antiseptics in increasing the growth of crops in soil. *In* Jour. Soc. Chem. Ind., v. 32, No. 24, p. 1136–1142, Dec. 31.

SMITH, R. I.

1912. The house fly (*Musca domestica*). No. Car. Agr. Expt. Sta., Col. Agr. & Mech. Arts, Ann. Rpt. 34, p. 62–69, figs. 13–14. See p. 64.

SÖRENSEN, S. P. L.

1907. Enzymstudien. *In* Biochem. Ztschr. Bd. 7, Hft. 1/2, p. 45–101, Dec. 6.

VAN SLYKE, D. D.

1911. A method for quantitative determination of aliphatic amino groups, Applications to the study of proteolysis and proteolytic products. *In* Jour. Biol. Chem., v. 9, No. 3/4, p. 185–207, May.

WILEY, HARVEY W., editor.

1908. Official and provisional methods of analysis, Association of Official Agricultural Chemists. U. S. Dept. Agr., Bur. Chem., Bul. 107 rev. 272 p.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 119

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
September 2, 1914.

(PROFESSIONAL PAPER.)

FIVE ORIENTAL SPECIES OF BEANS.

By C. V. Piper, *Agrostologist in Charge*, and W. J. Morse, *Scientific Assistant, Forage-Crop Investigations.*

INTRODUCTION.

Among the food plants of secondary importance in different parts of Asia are five annual species of beans that at various times have been introduced into the United States but concerning which very little definite information has been published. These five are the adsuki bean (*Phaseolus angularis*), the rice bean (*Phaseolus calcaratus*), the mung bean (*Phaseolus aureus*), the urd (*Phaseolus mungo*), and the moth bean (*Phaseolus aconitifolius*). Unfortunately, there has been considerable confusion in the literature, both botanical and agricultural, concerning these beans, especially between the first two and between the third and fourth. The adsuki bean has even been confused with the very different urd.

The illustrations in this paper well show the peculiarities of each of these five species. They may also be distinguished by the following key (compare Pl. VII):

Leaflets parted into 3 to 5 narrow lobes.......... *Moth.*
Leaflets entire or occasionally 2 or 3 lobed.
  Plants and pods very hairy; seeds mostly dull.
    Pods with short hairs; seeds globose or subglobose, green, rarely brown, blackish or yellow, the testa marked with fine crenulate lines; hilum not concave.......... *Mung.*
    Pods with long hairs; seeds oblong, blackish, the testa not crenulate striate; hilum concave.......... *Urd.*
  Plants smooth or little hairy; seeds smooth and shiny.
    Pods constricted between the seeds; hilum not concave.......... *Adsuki.*
    Pods not constricted between the seeds; hilum concave.......... *Rice.*

The five species of Phaseolus considered in this bulletin were, together with others, placed by De Candolle (1825, p. 394–395)[1]

[1] For complete bibliographic references, see the alphabetical list of literature cited at the end of this bulletin.

and by Bentham (1840, p. 139) in the subgenus Strophostyles. Strophostyles Elliott is based on the American plant called *Phaseolus umbellatus* by Muhlenberg. American botanists generally consider Strophostyles a valid genus, differing from Phaseolus in having the keel curved but not spiral. The two keel petals are inflated near the middle in the broadest part and each has a semicircular expansion on the dorsal edge. The stigma is terminal; that is, there is no appendage at the tip as in Phaseolus. The pods and seeds of Strophostyles are much like those of the mung and related species, and it was apparently on these characters that Bentham associated the two. The keel and stigma characters of Strophostyles, however, indicate that there is no such close relationship.

The five species possess the following characters in common: Plants annual; stipules with a basal appendage; flowers yellow; keel spirally coiled, bearing on one side a hornlike appendage; style hairy, prolonged into a narrow appendage beyond the stigma; stigma lateral, subterminal; pods linear, subterete, sometimes torulose; seeds globose to oblong; hilum narrow, linear. The style and stigma characters of the adsuki are like those of the kidney bean (*Phaseolus vulgaris*) in that the terminal appendage is flattened, while in the other four species it is terete. This difference is apparently not significant, except as showing that these species truly belong with Phaseolus. The other characters, however, seem sufficient to warrant the recognition of a subgenus for the mung and its allies, which may be called Ceratotropis, from the Greek words signifying *horn* and *keel*.

The mung bean is cultivated more or less extensively in all parts of Asia where it will mature and also in southeast Africa, where it was probably carried by Hindoo traders. The urd and the moth bean are cultivated only in India. The adsuki is confined to Japan, Manchuria, China, and Chosen (Korea), unless a similar bean in Nepal and Sikkim is identical. The rice bean is most frequently seen in China and India, but it is also cultivated in Japan and the Philippines.

Presumably the cultivation of all of these was relatively more important previous to the discovery of America, which led to the general dissemination of the kidney bean and the Lima bean, both of which are now largely cultivated in all the regions mentioned. Nevertheless, the five oriental species are still of considerable agricultural importance and doubtless will always be cultivated. All of them have been rather extensively tested from the standpoint of forage and of green-manure crops in the United States, especially during the past six years, but it seems doubtful whether any of them can compete in these respects with the cowpea and the soy bean. As producers of seed for both human food and animal food, however, there are possibilities in these crops well worthy of much further investigation. Their final position in American agriculture

FULL-GROWN PODS AND A BRANCH WITH LEAVES AND FLOWERS OF THE ADSUKI BEAN.

will perhaps depend more on their acceptability as human food than on their value for other purposes.

The adaptations of these five species of beans are very similar to those of the cowpea, all requiring hot summer weather for their satisfactory development. The varieties of the mung and the urd are fairly numerous; some early, others late. The moth has but few varieties and all are rather late, so they will not mature as far north as Virginia. The adsuki produces numerous early varieties and some of these will probably ripen wherever the common bean will mature. Generally speaking, the mung, urd, moth, and rice beans are to be compared to the cowpea, while the adsuki is to be contrasted with the common bean.

THE ADSUKI BEAN.

The adsuki bean (*Phaseolus angularis* (Willd.) W. F. Wight; Pl. I) is much cultivated for human food in Japan and Chosen and to a less extent in China and Manchuria, but is apparently unknown in India and elsewhere in Asia. No mention of its cultivation in Europe has been found in agricultural literature.

Next to the soy bean it seems to be the most important legume grown in Japan. In 1910 the respective acreage and production of these two crops in that country were given as follows:

Crop.	Area.	Production.	Yield per acre.
	Acres.	*English quarters.*	*Pounds.*
Adsuki bean	345,634	598,794	969
Soy bean	1,171,438	2,105,964	1,002

From these figures the average yield per acre of adsuki beans is shown to be but little inferior to that of soy beans.

BOTANY AND HISTORY.

The first knowledge of the adsuki, or atsuki, bean to Europeans is the brief description by Kaempfer (1712, fasc. 5, p. 837). Kaempfer's drawing of the plant was later published by Banks (Kaempfer, 1791, pl. 40). This illustration is excellent and unmistakable. On the basis of Kaempfer's description and illustration Willdenow (1801, p. 1051) named the plant *Dolichos angularis*. While the species is clearly and abundantly distinct, it has been confused with related species by most botanists.

No doubt the botanical confusion of the adsuki bean with the mung and the urd is responsible to some extent for the fact that it is so little known.

In most Japanese botanical works the adsuki bean is confused with the mung and therefore called *Phaseolus mungo* or *Phaseolus* *radiatus*, from both of which it differs greatly. The adsuki is probably native either in Japan or in Chosen, but the plant is not definitely known in a wild state.

DESCRIPTION.

The adsuki bean is a summer annual, requiring essentially the same conditions of climate as the common bean.

The plants are bushy in habit, growing from 1 to 2½ feet high, according to variety and soil. The earlier varieties are strictly bushy in habit and mostly erect, while the later ones are slightly viny at the tips of the stems and branches, and some of them are decumbent. As with other annual legumes, the later varieties are larger than the early ones. The whole herbage is somewhat hairy, and the leaves persist until the pods are fully mature. The flowers are bright yellow, 6 to 12 in a cluster.

The varieties are very numerous, at least 60 distinct sorts having been tested at Arlington farm, and among these as strays or, more likely, natural hybrids nearly as many others have been detected.

The varieties are distinguished mainly by the period of maturity and the color of the pods and seeds.

At Arlington farm the earliest varieties are fully mature in three months, while the latest require five months.

The pods are straw colored in most varieties, brown in a few, and blackish in a considerable number. In size the pods vary with the seeds, the largest pods being 5 inches long, the smallest 2.5 inches.

Each pod bears normally 8 to 10 seeds. The pods do not shatter readily, but as they are thin the beans may germinate in the pods in long-continued wet weather.

The seeds are subcylindric or but slightly compressed, subtruncate at the ends, and but slightly longer than broad. The following colors occur in the order of their frequency: Maroon, straw to nearly white, gray (really black speckled on a greenish yellow ground color), maroon and straw, black, brown, blue-black, and straw.

The embryo in all cases is nearly white and brittle in consistency.

The adsuki bean is self-fertile, pods setting perfectly where the flowers are bagged. It forms natural hybrids readily, more so apparently than any other related species. In a number of cases the seed of a single plant grown in a row produced diverse progeny. Thus 80 plants were grown from the seed of a plant of S. P. I. No. 19988, which had blackish pods and brown seeds. Of these 80 plants 16 had maroon seeds, 8 with straw-colored and 8 with blackish pods; 53 had brown seeds, 17 with straw-colored and 36 with blackish pods; and 11 had buff seeds, 4 with brown and 7 with blackish pods. It is probably due to this ease of hybridizing that the varieties of adsuki beans are so numerous, and where they are grown near together new sorts will constantly appear.

YIELDS.

No attempt has been made to secure hay from adsuki beans, as it has been evident that none of them could compete with either cowpeas or soy beans for that purpose.

As seed producers, however, they are not only prolific, but ripen evenly and do not shatter readily. Under Arlington farm conditions only the soy bean has given larger yields of seed. (See Table I.)

TABLE I.—*Yields of seed of adsuki beans at Arlington farm, Virginia.*

S. P. I. Serial No.	Calculated yield per acre (bushels).				
	1906	1908[1]	1909	1912[2]	1913[3]
16791	[4] 33.3	22.9	[2] 13.6	23.3	....
17323	[5] 22.2	21.1	[3] 10.9	....	....
17324	[3] 23.3	....	....	....	....
17324A	[4] 26.6	24.6	[3] 18.1	20.5	19.2
17847	[3] 32.2	26.4	[3] 20.3	28.1	25.3
17851	[3] 26.6	24.8	[3] 22.8	28.6	31.3
19185	....	....	....	22.8	25.0
21082	....	....	....	12.0	22.6
21083	....	....	....	13.1	19.0
25255	....	....	[3] 14.6	12.5	10.5
28052	....	....	....	19.1	24.6

[1] Plats of one-eleventh of an acre.
[2] Plats of one-tenth of an acre.
[3] Plats of one-twentieth of an acre.
[4] Rows 4 rods long.
[5] Plats of 0.17 of an acre.

At the North Carolina Agricultural Experiment Station in 1910 the yields per acre secured were as follows: No. 17851, 22.9 bushels; No. 16791, 20.2 bushels; No. 17847, 20.2 bushels.

USE IN JAPAN.

In Japan the adsuki commands a higher price than any other bean, the varieties with maroon-colored seeds being most largely used. In every Japanese city are shops where adsuki beans and adsuki-bean meal are sold, and among the most common cakes and confections are those made wholly or in part from adsuki-bean meal.

Adsuki-bean meal is sometimes prepared simply by grinding the dry beans and then removing the seed coats with sieves. More commonly, however, a wet process is employed. The wet process seems to vary somewhat in different parts of Japan, but consists essentially of four stages:

(1) Boiling the beans until soft, usually after a preliminary soaking.
(2) Crushing the cooked beans.
(3) Removing the skins by forcing the mass through sieves or by putting the bean paste in cold water, when the skins are easily separated.
(4) Drying the bean paste.

The fresh, undried bean paste is called *an* and the dried product *sarashi-an*.

A modification of the above process is to remove the seed coats from the soaked and parboiled beans before they are crushed. In boiling, the red color of the seed coats dissolves, and on this account the water is sometimes changed once or twice. The final product is somewhat reddish, however. The bean meal in whatever way prepared is eaten in soups and gruels of various kinds, often sweetened. It is also used for making various kinds of cakes and confections.

Other kinds of beans which are cheaper are also used to make *an*, but usually to mix with the more expensive adsuki.

Adsuki beans are also eaten popped like corn, as a coffee substitute, and candied by boiling in sugar, the last product being called *amanatto*. The flour is also used for shampoos and to make facial cream.

The use of beans to make sweetmeats seems to be purely a Japanese invention, as there are no similar foods used by Europeans or Americans. There seems no good reason why food so rich in protein and lacking any objectionable "beany" flavor might not become popular in the United States. No other bean lends itself so well to grinding into meal or flour, as the seeds are hard and brittle.

COMPARISON WITH OTHER SIMILAR LEGUMES.

The most valuable feature of the adsuki bean lies in its large yield of seed, which under Arlington farm conditions is excelled only by the soy bean. These beans are exceedingly popular as food among the Japanese and Koreans. Owing to their texture they are easily ground into meal or flour and for such purposes are far superior to any other bean. The flavor, too, is very delicate, lacking any objectionable taste. The green pods quickly become fibrous, and therefore they are not desirable as snap beans.

As forage plants the adsuki beans can not compete with the cowpea and the soy bean, as their initial growth is slow and their total yield of herbage inferior. In the South they are subject both to wilt (*Fusarium* sp.) and to root-knot caused by the nematode *Heterodera radicicola*. Neither of these diseases has, however, caused any serious destruction of the plants.

PREVIOUS INTRODUCTIONS.

Among the seeds brought back from Japan by the Perry expedition in 1854 was a "red-seeded bean." (Browne, 1855, p. XV.) The identity of this bean has never been definitely determined, but it was doubtless the most common form of adsuki bean.

Two varieties of the adsuki bean were tested at the Kansas Agricultural Experiment Station in 1891 by Prof. C. C. Georgeson (1891, p. 237). Both of these had red seeds, one having the pods "white," the other "black." The white-podded variety yielded 16.3 bushels per acre; the black-podded, 8.7 bushels. In thrashing, the beans were found to crack easily, and so they were flailed. The beans were tested only as human food. "These beans have been submitted to several housekeepers for trial, who all, with two exceptions, give them most favorable recommendations." The professor of household economy, in a letter to Prof. Georgeson, praised the beans highly both for use in soups and baked.

Two varieties of the adsuki bean were grown at the Rhode Island Agricultural Experiment Station in 1893 and 1894, and yields both of forage and seed based on row tests were recorded. These two varieties were later obtained from the Rhode Island station and given S. P. I. numbers 17315 and 17317.

The North Carolina Agricultural Experiment Station (McCarthy and Emery, 1894, p. 143) gives a very brief report on two varieties of Japanese beans which are unquestionably the adsuki bean. No recommendations are made beyond stating that the beans are for table use only and not for forage.

The following notes on adsuki beans imported by the Office of Foreign Seed and Plant Introduction or obtained from other sources have been assembled for convenient reference. The S. P. I. number is shown in every case.

S. P. I. No.

226. A maroon-seeded variety from North China, March, 1898, under the name "wei-tou (vay-do)." No cultural notes.

494. From Amur Province, Siberia, March, 1898, imported there from China and called "wei-tou (vay-do)." No cultural notes.

5072. From Wahiawa, Oahu, May, 1900, where introduced from China. A maroon-seeded variety. No cultural notes.

6318. From Tokyo, Japan, April, 1901, under the name "muroran." Stocks of seed grown from this were also numbered 8488 and 17316, and it has been sold by seedsmen under the name "Japanese muroran bean." Plants erect, 20 to 24 inches high, maturing at Arlington farm in about 100 days; pods straw colored; seeds maroon.

6417. See No. 17323.

6418. See No. 17324.

8487. Progeny of No. 6417. See No. 17323.

8488. Progeny of No. 6318.

9419. Grown from No. 6417. See No. 17323.

10523. See No. 17315.

13384. Found mixed with soy beans No. 6558 from Hankow, China, May, 1901. Plants erect, 2 to 3 feet high, late, only half the pods maturing at Arlington farm in 140 days; pods $3\frac{1}{2}$ to 4 inches long, straw colored; seeds orange yellow.

13385. From the same source as No. 13384. In habit and maturity like No. 13384; pods straw colored; seeds pale greenish.

13386. From the same source as No. 13384. Plants erect, 16 to 24 inches high; late, about half the pods maturing at Arlington farm in 130 days; pods straw colored; seeds straw colored.

13387. From the same source as No. 13384. Plants erect, 30 inches high, the rows 24 inches broad; only about 30 per cent were mature on October 29, 1912, at Arlington farm, 151 days after planting; pods straw colored, 4 inches long; seeds straw colored.

13388. From the same source as No. 13384. This seems identical in every respect with No. 13386.

S. P. I. No.

13389. From the same source as No. 13384. Late, vigorous, not as large as No. 13386, only a few pods ripening at Arlington farm in favorable seasons; seeds greenish yellow.

13390. From the same source as No. 13384. Seeds greenish yellow. Much like No. 13386.

13391. From the Rhode Island Agricultural Experiment Station, 1903. Plants erect, 20 to 24 inches high, maturing in about 100 days at Arlington farm; pods straw colored; seeds maroon.

13392. See No. 17318.

13393. See No. 17317.

13405. Mixed with No. 6564 from Ichang, China, 1901. Plants erect, 30 inches high; very late, only a few pods maturing at Arlington farm in 140 days; pods straw colored, 3 to 3$\frac{3}{4}$ inches long; seeds straw colored. Apparently but little different from No. 13386.

16791. From Hangchow, China, December, 1905, under the name "tzŭ-tou." Plants erect, 16 to 24 inches high, maturing at Arlington farm in about 120 days; pods blackish, 2$\frac{1}{2}$ to 3$\frac{1}{2}$ inches long; seeds buff speckled and saddled with black.

17287. Grown from a single stray plant found at Arlington farm in 1905. It proves to be identical in all respects with No. 17317.

17315. Progeny of No. 10523, received from the Rhode Island Agricultural Experiment Station, March, 1904. Plants erect, 12 to 18 inches high, maturing at Arlington farm in about 110 days; pods straw colored, 3$\frac{3}{4}$ inches long; seeds maroon.

17316. Progeny of No. 6318.

17317. Progeny of No. 13393, secured from the Rhode Island Agricultural Experiment Station in 1903. Plants erect, 12 to 16 inches high, all maturing at Arlington farm in about 130 days; pods straw colored, 3 to 3$\frac{3}{4}$ inches long; seeds buff, coarsely sprinkled with black.

17317A. A black-seeded variety found mixed with No. 17317 in 1909 and identical with No. 20007A. The pods are brownish or sometimes dark purple, 3$\frac{3}{4}$ inches long. It is later than No. 17317.

17318. Progeny of No. 13392. Identical with No. 17317.

17319. Progeny of No. 13391, from the Rhode Island Agricultural Experiment Station. This proved to be identical with No. 17315.

17320. Progeny of No. 13405.

17321. Progeny of No. 13386.

17322. Progeny of No. 13384.

17323. Progeny of No. 6417, from Pyeng Yang, Chosen (Korea), May, 1901. Various lots of seed grown from No. 6417 were numbered 8487, 9419, and 17325, but all are identical. Plants erect, 14 to 16 inches high, maturing at Arlington farm in about 140 days; pods straw colored, 3 to 4 inches long; seeds straw colored. This variety is very similar to No. 20402.

17324. Progeny of No. 6418 from Pyeng Yang, Chosen (Korea), May, 1901. Plants erect, prolific, 15 to 22 inches high, maturing at Arlington farm in 140 days; pods straw colored, 4 inches long; seeds buff, speckled with black.

17324A. Selected from a single plant found with No. 17324 in 1905 and has bred perfectly true. Plants somewhat sprawling, 20 to 24 inches high, maturing at Arlington farm in about 130 days; pods straw colored, 3$\frac{1}{2}$ to 4$\frac{1}{2}$ inches long; seeds buff, blotched with black over half or more of the surface.

17325. Progeny of No. 8487. See No. 17323.

17847. From Changli, China, October, 1905. Plants erect, 16 to 22 inches high, maturing at Arlington farm in about 130 days; pods straw colored, 3$\frac{1}{4}$ to 3$\frac{1}{2}$ inches long; seeds straw colored. This is one of the very best varieties in habit and seed yield.

S. P. I. No.

17851. From Tientsin, China, November, 1905. "This variety is used as general food and to make confectionery. The beans are boiled, made into a pulp, and with sugar are baked in small cakes." (Meyer.) Plants erect, 16 to 24 inches high, maturing at Arlington farm in about 130 days; pods straw colored; seeds maroon. One of the very best varieties.

18618. From Shanghai, China, February, 1906. Plants erect, 16 to 18 inches high, about half the pods maturing at Arlington farm in 150 days; pods 3½ inches long; seeds brick red.

19185. From Newchwang, Manchuria, August, 1906. Plants erect, 12 to 24 inches high, maturing at Arlington farm in 120 days; pods straw colored on most plants, brown on about one-fifth, 3 to 4 inches long; seeds straw colored.

19468. From Hoijo (near Kobe), Japan, November, 1906. Plants erect, 16 to 20 inches high, maturing at Arlington farm in about 120 days; pods blackish; seeds maroon.

19988. From Yokohama, Japan, March, 1907. Identical in all respects with No. 19468.

19989. From Yokohama, Japan, March, 1907. Identical in all respects with No. 19468.

20007. From Shi-wa-nanan, Chosen (Korea), July, 1906. "Grows at high altitudes on very poor soils. Used for food, being boiled together with rice and millet." (Meyer.) Plants erect, 18 to 20 inches high, maturing at Arlington farm in about 140 days; pods straw colored, 3¾ inches long; seeds buff, half or more of the surface saddled and blotched with black.

20008. From near Musan, Chosen (Korea), September, 1906. Plants erect, 24 to 26 inches high, maturing at Arlington farm in about 130 days. Two slightly different varieties mixed, one having the pods straw colored, the other brownish; seeds maroon.

20009. From the same source as No. 20008. Plants suberect, 18 to 20 inches high, maturing at Arlington farm in about 140 days; pods brownish, 3 to 4 inches long; seeds buff.

20010. From the same source as No. 20007. In habit and life period almost identical with No. 20009; pods brownish; seeds buff, thickly speckled with black.

20402. From Khabarovsk, Siberia, November, 1906. Plants erect, 16 to 24 inches high, maturing at Arlington farm in about 130 days; pods straw colored, 3 to 3½ inches long; seeds straw colored.

20403. From the same source as No. 20402. Habit and life period quite the same as No. 20402; holds leaves well; pods brownish, 3 to 3½ inches long; seeds buff, thickly speckled with black.

20404. From the same source as No. 20402. Plants erect, about 16 inches high, maturing at Arlington farm in about 130 days; pods straw colored, 3 inches long; seeds maroon. In 1909 this lot seemed to be practically identical with Nos. 20008 and 21083.

20703. From southern Usuri, Siberia, March, 1907, where it is called "wei-tou (wei-do)." Grown only in 1907, maturing at Arlington farm in about 130 days; pods dark colored; seeds buff, thickly speckled with black.

20894. From Kobe, Japan, March, 1907. Plants erect, 18 to 20 inches high, maturing at Arlington farm in about 120 days; apparently a mixture of three kinds, one with dark brownish pods; all maroon seeds.

21081. From Tiehling, Manchuria, January, 1907. Chinese name "pei-hsiao-tou (pei-sha-toa)." This seems indistinguishable from No. 20402 in habit, life period, and seed characters.

21082. From the same source as No. 21081. Plants erect, 18 inches high, and broad, maturing at Arlington farm in 100 days in 1912; pods straw colored, 3 inches long; seeds maroon. In 1909 this variety appeared quite identical with No. 20402.

S. P. I. No.

21083. From the same source as No. 21081. Chinese name "hong-hsiao-tou (hong-sha-tou)." Plants erect, 16 inches high, maturing at Arlington farm in about 100 days; pods straw colored, 3 to 4 inches long; seeds maroon.

21084. From same source as No. 21081. Chinese name "hua-hsiao-tou (gwa-sho-toa)." Plants erect, 14 to 16 inches high, maturing at Arlington farm in about 120 days; pods straw colored, 3½ to 4½ inches long; seeds buff, half or more of the surface saddled and blotched with maroon.

21084A. Mixed with No. 21084. Plants erect, 20 to 22 inches high, maturing at Arlington farm in about 130 days; pods straw colored; seeds brown.

21824. From Hokushu (Hokkaido), Japan, January, 1908. This variety proved to be very similar to No. 19468 in all respects.

22310. From Shanghai, China, March, 1908. A very late variety which failed to mature any seeds at Arlington farm in 1908; pods straw colored, 4 inches long; seeds maroon.

22383. From Canton, China, March, 1908. Plants erect, the row 24 inches high, 30 inches broad, very late, only a few pods maturing at Arlington farm in 1908 and 1912 in 150 days; pods straw colored; seeds maroon.

22410. From Hongkong, China, March, 1908. Plants erect, 24 to 26 inches high, maturing at Arlington farm in about 125 days; pods straw colored; seeds maroon.

22508. From Yokohama, Japan, March, 1908. This proved to be identical with No. 21824.

22509. From Yokohama, Japan, March, 1908. In 1909, the only year grown, this could not be distinguished from No. 20402.

23210. From Tangsi, China, July, 1908. Plants erect, 24 to 30 inches high, a very few pods maturing at Arlington farm in 1909 in 150 days; pods straw colored; seeds maroon.

23210A. Seeds buff, speckled with black. Plants from seeds mixed with No. 23210 resembled that variety very closely; but none of them matured seed in 1909 at Arlington farm.

23210B. Seeds maroon, marbled with black. Plants from seeds mixed with No. 23210, resembled that variety very closely; but none of them matured seed in 1909 at Arlington farm.

23210C. Seeds straw colored. Plants from seeds mixed with No. 23210 resembled that variety very closely; but none of them matured seed in 1909 at Arlington farm.

23301. From Hupehko, Chihli, China, December, 1907. "Used as a vegetable when sprouted; also pounded up with sugar and used in small cakes as a stuffing. Chinese name 'hei-hsiao-tou' (chao-shau-doh). Is able to grow on rather sandy and on alkaline land." (Meyer.) No field notes.

23304. From Peking, Chihli, China, February, 1908. Plants erect, 24 inches high, maturing at Arlington farm in about 130 days; pods straw colored, 3 inches long; seeds maroon. Very similar to Nos. 17851 and 22410.

25139. From Soochow, China, March, 1909. Plants erect, 12 to 14 inches high, half of the pods maturing at Arlington farm in 150 days; pods blackish, 4 to 5 inches long; seeds maroon.

25140. From the same source as No. 25139. Plants erect, 12 to 14 inches high, only a few pods maturing at Arlington farm in 1909 in 150 days; pods straw colored; seeds straw colored.

25141. From the same source as No. 25139. Plants erect, 24 to 30 inches high, a few pods maturing at Arlington farm in 1909 in 150 days; pods straw colored, 3½ to 4½ inches long; seeds buff, thickly speckled with black.

S. P. I. No.

25255. From the Botanical Gardens, Tokyo, Japan, 1907. Plants erect, 24 inches high, maturing at Arlington farm in about 130 days; pods straw colored; seeds nearly white. This variety has paler seeds than any other. It is of excellent habit and one of the most prolific varieties.

25916. From Hangchow, China, August, 1909. Plants suberect, spreading, the row making a mass 30 inches high and broad, only a few pods maturing at Arlington farm in 150 days; pods blackish; seeds maroon.

28052. From Mukden, Manchuria, June, 1910. "Chinese name 'hung-chiang-tou.' Commonly grown in central Manchuria for human food. The beans are sometimes cooked green, but more commonly dried and boiled with millet or kaoliang." (Parker.) Plants erect, 20 to 22 inches high, maturing at Arlington farm in about 110 days; pods straw colored; seeds maroon.

34416. From Cabanas, Cuba, October, 1912. Plants erect, 16 inches high, maturing in about 112 days; pods brown, 3½ inches long; seeds buff, marbled and speckled with black.

34643. From Kyoto, Japan, November, 1912. Plants erect, 26 inches high, maturing in about 143 days; pods straw colored, 5 inches long; seeds maroon.

34644. From Kyoto, Japan, November, 1912. Plants erect, 16 inches high, maturing in about 109 days; pods straw colored, 5 inches long; seeds straw colored.

34700. From Shantung Province, China, December, 1912. Plants slender, erect, somewhat viny at tips, 18 inches high, maturing in about 143 days; pods straw colored, 3 inches long; seeds maroon.

34701. From Shantung Province, China, December, 1912. Plants slender, erect, somewhat viny at tips, 20 inches high, maturing in about 143 days; pods straw colored, 3½ inches long; seeds buff, marbled and speckled with black.

34812. From Tokyo, Japan, January, 1913. Plants erect, 20 inches high, maturing in about 102 days; pods dark, 3¾ inches long; seeds maroon.

34813. From Tokyo, Japan, January, 1913. Plants erect, 30 inches high, the first pods maturing in about 135 days; pods dark, 3½ to 4½ inches long; seeds greenish buff.

34814. From Tokyo, Japan, January, 1913. Plants erect, 20 inches high, maturing in about 109 days; pods straw colored, 4 inches long; seeds maroon.

34815. From Tokyo, Japan, 1913. Plants erect, 28 inches high, the first pods maturing in about 143 days; pods straw colored; seeds maroon.

34816. From Tokyo, Japan, January, 1913. Plants erect, 26 inches high, the first pods maturing in about 135 days; pods dark colored, 4 to 4½ inches long; seeds maroon, marbled and speckled with black.

34948. From Sapporo, Japan, March, 1913. Plants slender, erect, somewhat viny at tips, 18 inches high, maturing in about 102 days; pods dark, 4 inches long; seeds maroon.

34949. From Sapporo, Japan, March, 1913. Plants erect, 18 inches high, maturing in about 102 days; pods dark, 3¾ inches long; seeds maroon; leaflets narrow, strongly 3 lobed at base.

34950. From Sapporo, Japan, March, 1913. Plants erect, 12 inches high, maturing in about 102 days; pods brown, 3½ inches long; seeds maroon.

34951. From Sapporo, Japan, March, 1913. Plants erect, 20 inches high, maturing in about 102 days; pods dark, 4 inches long; seeds maroon.

34952. From Sapporo, Japan, March, 1913. Plants erect, 18 inches high, maturing in about 102 days; pods straw colored, 4 inches long; seeds maroon.

34953. From Sapporo, Japan, March, 1913. Plants erect, 12 inches high, maturing in about 102 days; pods straw colored, 3½ inches long; seeds straw colored.

S. P. I. No.

34954. From Sapporo, Japan, March, 1913. Plants erect, 18 inches high, maturing in about 112 days; pods straw colored, 3½ inches long; seeds buff.

34955. From Sapporo, Japan, March, 1913. Plants erect, 18 inches high, maturing in about 105 days; pods straw colored, 3¾ inches long; seeds buff.

34956. From Sapporo, Japan, March, 1913. Plants erect, 20 inches high, maturing in about 105 days; pods dark, 4 inches long; seeds buff.

34957. From Sapporo, Japan, March, 1913. Plants erect, 24 inches high, maturing in about 112 days; pods dark, 3¾ inches long; seeds greenish.

34958. From Sapporo, Japan, March, 1913. Plants erect, 22 inches high, maturing in about 112 days; pods straw colored, 4 inches long; seeds maroon, marbled and speckled with black.

34959. From Sapporo, Japan, March, 1913. Plants erect, 20 inches high, maturing in about 105 days; pods straw colored, 3½ inches long; seeds maroon, marbled and speckled with black.

34960. From Sapporo, Japan, March, 1913. Plants erect, 12 inches high, maturing in about 100 days; pods brown, 3½ inches long; seeds black.

34961. From Sapporo, Japan, March, 1913. Plants erect, 14 inches high, maturing in about 100 days; pods brown, 3½ inches long; seeds black.

34962. From Sapporo, Japan, March, 1913. Plants erect, 20 inches high, maturing in about 112 days; pods straw colored, 3½ inches long; seeds buff, marbled and speckled with black.

34963. From Sapporo, Japan, March, 1913. Plants erect, 10 inches high, maturing in about 105 days; pods straw colored, 2½ inches long; seeds buff, half or more of the surface saddled and blotched with maroon.

34964. From Sapporo, Japan, March, 1913. Plants erect, 14 inches high, maturing in about 102 days; pods brown, 3½ inches long; seeds buff, marbled and speckled with black.

34965. From Sapporo, Japan, March, 1913. Plants erect, 16 inches high, maturing in about 116 days; pods brown, 3½ inches long; seeds buff.

34966. From Sapporo, Japan, March, 1913. Plants erect, 18 inches high, maturing in about 100 days; pods dark, 4 inches long; seeds straw colored, saddled and spotted with maroon.

34967. From Sapporo, Japan, March, 1913. Plants erect, 16 inches high, maturing in about 102 days; pods straw colored, 3½ inches long; seeds maroon.

34968. From Sapporo, Japan, March, 1913. Plants erect, 14 inches high, maturing in about 102 days; pods dark, 2½ inches long; seeds maroon.

34969. From Sapporo, Japan, March, 1913. Plants erect, 16 inches high, maturing in about 112 days; pods brown, 3½ inches long; seeds maroon.

35216. From Morioka, Japan, March, 1913. Plants erect, 22 inches high, maturing in about 116 days; pods brown, 4 inches long; seeds maroon.

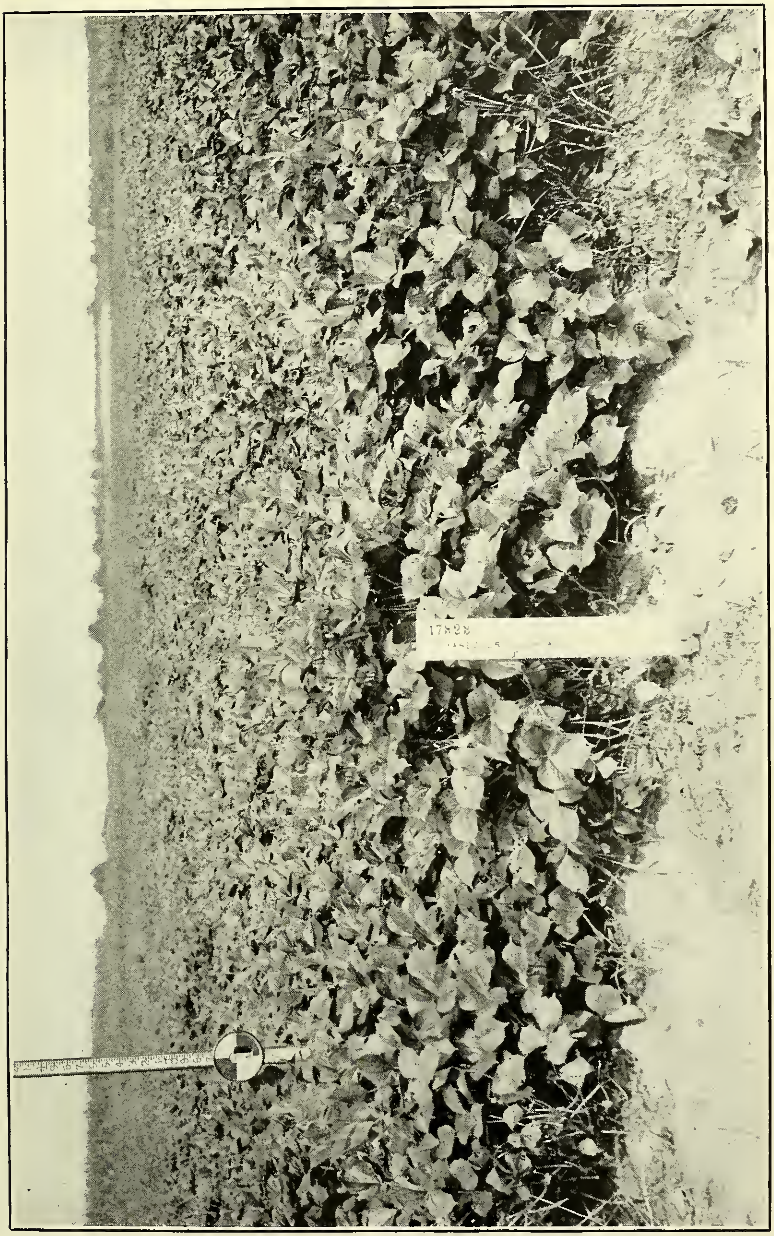
35217. From Morioka, Japan, March, 1913. Plants erect, 12 inches high, maturing in about 143 days; pods brown, 4 inches long; seeds maroon.

35218. From Morioka, Japan, March, 1913. Plants erect, 24 inches high, maturing in about 116 days; pods straw colored, 3½ inches long; seeds buff, marbled and speckled with black.

35219. From Morioka, Japan, March, 1913. Plants erect, 14 inches high, maturing in about 100 days; pods brown, 3½ inches long; seeds black.

35220. From Morioka, Japan, March, 1913. Plants erect, 24 inches high, maturing in about 112 days; pods dark, 3½ inches long; seeds maroon, marbled and speckled with black.

35221. From Morioka, Japan, March, 1913. Plants erect, 22 inches high, maturing in about 116 days; pods brown, 4 inches long; seeds buff.



FIELD OF RICE BEANS IN 36-INCH ROWS AT ARLINGTON FARM, VIRGINIA.

BRANCH WITH FLOWERS OF THE RICE BEAN AND ANOTHER BRANCH SHOWING FULL-GROWN PODS AND LEAF.

THE RICE BEAN.

The rice bean (*Phaseolus calcaratus* Roxb.; Pls. II and III) is cultivated to a limited extent in Japan, China, India, Mauritius, Java, and the Philippines. What is supposed to be the wild original occurs in India. Twenty lots, consisting of nearly as many varieties, have been introduced during the past 11 years. At least one sort was introduced previously and has become sparingly naturalized in Alabama. (See No. 13380.)

The plant is strictly an annual and half twining in habit. Planted in rows the different varieties grow 12 to 30 inches high and produce vining branches 3 to 6 feet long. The leaves closely resemble those of the common bean, but not infrequently are 3 lobed. The flowers are bright yellow, produced in racemes of 10 to 20. The pods are smooth, slender, falcate, straw colored, brownish, or blackish, 3 to 4 inches long, and burst open readily at maturity. Though very productive of seed, the vining habit of the plant, as well as the shattering, makes it difficult to harvest. The flowers are self-fertile, as when bagged at Arlington farm they set pods perfectly.

Like other annual legumes, the later varieties are much larger in growth than the early ones. The late ones are very vigorous in growth and make a thick, dense mass of foliage. Such sorts may prove valuable as cover crops in the South, but unfortunately they are all subject to root-knot. This, together with the shattering of the seed, will always militate against their extensive use.

The varieties differ mainly in their periods of maturity and in the color of the seeds. The latter includes straw colored, brown, maroon, black, and gray marbled.

During the past six years all of the varieties have been grown at Arlington farm, and several have been tested at Chillicothe and San Antonio, Tex.; New Orleans, La.; Agricultural College, Miss.; Auburn, Ala.; Monetta, S. C.; and elsewhere. In the light of present knowledge it is not likely that the rice bean will be used in this country either as a forage crop or as a cover crop, as other plants fill the need better. Nor is it probable that it will be grown for human food, notwithstanding its prolific seeding, as the habit of the plant and the shattering of the seed make it difficult to harvest.

The plant is well adapted to practically the same area as the cowpea and will doubtless attract attention from time to time. Under present conditions it is very doubtful whether this bean can be economically utilized in this country.

In different parts of India various vernacular names are given to this bean, among them Sutri, Sita-mas, Pau maia, Gurush, and Gurounsh.

In Japan it is called Tsuru-adsuki; in China, Mu-tsa (Shanghai), Crab-eye or Lazy-man pea (Soochow), and climbing mountain bean (Yachow); in Cuba, where introduced, Little Devil or mambi bean.

BOTANY.

Phaseolus calcaratus was first described by Roxburgh (1832, p. 289) from plants grown in the Botanic Gardens near Calcutta. The seeds were obtained from cultivated plants in Mysore and are described as "dark brownish black," a description which agrees with No. 32640.

Four botanical varieties have been described by Prain (1897, pp. 424–425). *Phaseolus calcaratus major* Prain, from the hills of northern India and Burma, is distinguished by its larger flowers; *P. calcaratus glaber* Prain (*P. glaber* Roxburgh), originally from Mauritius but occurring also in northern India, lacks the hairiness on the leaves and stems; *P. calcaratus rumbaiya* Prain is a variety with short erect or spreading stems, cultivated in the Khasi Hills of Burma under the name Rumbaiya. *P. torosus* Roxburgh, cultivated in Nepal, is said to be very similar and probably a mere form of Rumbaiya, differing only in having the pods torose. The seeds of *P. torosus* are described as short and subcylindric and of a pale cream color. *P. calcaratus gracilis* Prain is a wild form, with slender smooth stems and rather narrow leaflets.

The species is evidently more variable than the varieties introduced during the past 13 years would indicate.

INTRODUCTIONS.

Brief notes and descriptions of the varieties of the rice bean secured mainly by the Office of Foreign Seed and Plant Introduction are here given.

S. P. I. No.

6564. From Ichang, China, 1901. "Grows on the mountains between the Indian corn. Largely takes the place of rice; is also cooked with vegetables before fully dry." Received May, 1901.

This lot of seed contained three varieties as to seed color, which are described under Nos. 13381, 13382, and 13383.

13380. From the Alabama Agricultural Experiment Station, where it has been grown since about 1904. The original seed was secured from Anniston, Ala., where it was said to occur spontaneously. At the Alabama Agricultural Experiment Station it has been called "Alabama bean" and on the station farm volunteers year after year. This variety makes a solid mass 2 feet deep when planted in 3-foot rows. At Arlington farm only a few pods had matured when the plant was killed by frost in 140 days; seeds straw colored.

The same variety has been secured from Mr. Clarendon Davis, of Huntsville, Ala., who writes:

> I believe this will prove a valuable crop. It will take one year more to prove this. The mere fact of the seed remaining sound on ground all winter will prove very valuable for hog pasture, and they will reseed themselves. From what I know of this bean I think it equal to cowpeas for hay, and the fact of its reseeding itself or the seeds remaining on the ground sound until they are eaten would put us in a position to compete with any pea-fed hogs of the West. I now have about 40 or 50 pounds of this seed. My original start was a pod or two. I will plant some in February in wheat. I can not understand why this bean was imported, as it is very rare and only found on the tops of mountains. In fact, I have found only one mountaineer who has ever seen it.

S. P. I. No.

13381. A selection grown from No. 6564. Plants make a dense mass 18 to 24 inches deep, maturing at Arlington farm in about 140 days; seeds straw colored.

13382. A selection from No. 6564. This makes a mass of vine 18 to 24 inches deep. Seeds mature at Arlington farm in about 140 days. In habit, quite like No. 13381; seeds maroon.

13383. A selection grown from No. 6564. In habit and life period quite the same as No. 13380; seeds straw colored, marbled with fine black specks.

17310. Progeny of No. 6564.

17311. Progeny of No. 13380.

17312. Progeny of No. 13383.

17313. Progeny of No. 13381.

17314. Progeny of No. 13382.

17850. From Shanhaikwan, China, 1906. "Used for food, especially in soups." (Meyer.)

The earliest variety tested, maturing at Arlington farm in about 110 days. Vines 14 inches high, hardly covering the ground when in 3-foot rows; pod dark colored, 3 to 4 inches long; seeds straw colored.

18444. From Shanghai, China, 1906. Chinese name "mu-tsa." A vigorous variety, making a mass of vines 18 to 20 inches deep. Too late at Arlington farm, not maturing in 1907, 1908, or 1909, but heavily set with pods when killed by frost in October. A few seeds matured in 1907; seeds maroon.

21291. From Rangoon district, Burma, India, under the name "lobiya," 1907. A very vigorous late variety, the vines 2 to 3 feet high and making a solid mass when planted in rows 3 feet wide. At Arlington farm does not bloom when planted June 1; seeds straw colored. At Auburn, Ala., in 1908, and at Raleigh, N. C., in 1909, its behavior was very similar.

25142. From Soochow, Kiangsu, China, 1909. "From the shape of the seed these are called 'Crab-eye.' They are also the 'Lazy-man' peas, for the reason that they replant themselves. Growth rank; vine bunchy, not very long." Vines in rows make a mass 24 inches deep, 3 feet broad; pods dark colored, 3½ inches long; all mature in about 150 days at Arlington farm; seeds maroon.

25143. From the same source as No. 25142. Exactly like No. 25142 in habit, size, and life period; seeds straw colored.

25523. From the Botanic Gardens, Tokyo, Japan, 1906. Vines in rows make a mass 14 to 18 inches deep, 3 feet wide; pods dark colored, 3 inches long, all maturing at Arlington farm in about 120 days; seeds dark maroon.

30727. From Iloilo, Philippine Islands, April, 1911. Seeds black. No field notes.

30728. From Iloilo, Philippine Islands, April, 1911. Vines make a dense mass 2 feet deep, but not even. Was blooming at Arlington farm in 1912 when killed by frost; seeds straw colored.

30729. From the same source as No. 30728. Identical in growth and appearance to No. 30728; seeds straw colored.

30730. From the same source as No. 30728. At Arlington farm in 1912 this grew exactly like No. 30728; seeds straw colored.

31728. From the market, Canton, China, 1911. Said to be grown locally; seeds maroon; a very vigorous late variety, 2 feet high, blooming properly at Arlington farm, but no pods maturing in 135 days.

32640. From Buitenzorg, Java, November, 1911. Malay name "katjang kajoe aro." Vines making a solid mass 30 inches deep, but blooming at Arlington farm in 1912 when planted June 1; seeds black.

32641. From the same source as the preceding. In habit and behavior identical with No. 32640; seeds brownish.

32642. From the same source as No. 32640. In habit and behavior just like No. 32640; seeds brown, finely marbled with black specks.

S. P. I. No.

32643. From the same source as No. 32640. Growth and maturity just like No. 32640; seeds grayish green, finely marbled with black specks.

32644. From the same source as No. 32640. Indistinguishable in growth from No. 32640; seeds straw colored.

33098. From Cuba, 1912. "Little Devil or mambi bean. An indigenous legume, found growing wild in the woods of Oriente Province, especially in the valley of Guantanamo. A climbing vine of vigorous growth that covers and smothers the tree over which it grows; for this reason the native country people call it 'Little Devil.' It is also called 'mambi,' because it was discovered as edible by the Cuban soldiers during the war of 1868–1878." Very late, not even blooming at Arlington farm in 150 days in 1912 when killed by frost. Vines vigorous, making a solid mass 2 feet deep, but not quite so large as No. 21291; seeds maroon.

01555. From Mr. E. T. Shields, Yachow, China, March, 1911. "This bean is known as climbing mountain bean. It is fed to pigs and not much eaten by the natives." Vines in rows 16 inches high, 30 inches broad, in full bloom at Arlington farm in 120 days, a few pods maturing when killed by frost at the end of October.

THE MUNG BEAN, GREEN GRAM, OR GOLDEN GRAM.

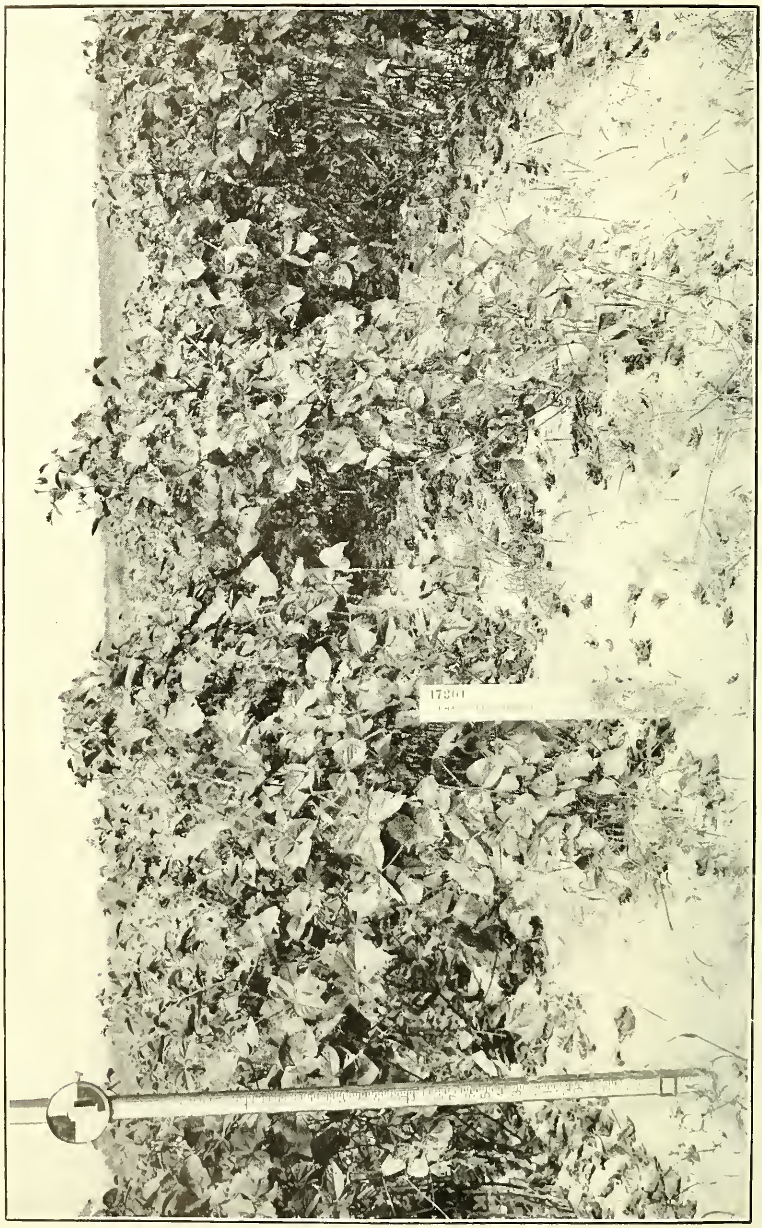
The mung bean (*Phaseolus aureus* Roxb.; Pls. IV and V) is cultivated throughout the southern half of Asia, in the adjacent Malayan Islands, and quite generally through the eastern portions of Africa. It has been introduced into Greece, but otherwise seems not to be cultivated in Europe. In India the plant is of very ancient cultivation, and numerous varieties are found in different parts. The plant is not definitely known in a wild state, but Prain (1897, p. 423) is inclined to think that it is a cultivated derivative of *Phaseolus radiatus* L. (*Phaseolus sublobatus* Roxb.), which grows wild in India. According to Mollison (1901, p. 87) this legume, or pulse, is sixth in importance in the Bombay Presidency, about 200,000 acres being grown each year, mostly mixed with other crops. The seeds are used almost exclusively as human food and the straw is fed to cattle. Duthie and Fuller (1882, p. 37) state that the average yield of seed per acre is 410 pounds. In the Northwestern Provinces and Oudh it is more important than the urd bean, the moth bean, or the cowpea.

In German East Africa it is called *chiroko*, and the same name is used in Portuguese East Africa. In Japan its name is *bundo* or *yayenari*. In Jamaica both the mung and the urd have been introduced by Hindoo laborers. The plant is there called Jerusalem pea and is being used largely as a green-manure crop (Harris, 1913, p. 192).

BOTANY.

There has been great confusion concerning the proper botanical name to apply to the mung. Most of the difficulties in the case have now been cleared up, thanks to the generous assistance accorded by Sir David Prain, director of the Royal Botanic Gardens at Kew. The

CLUSTER OF FULL-GROWN PODS AND LEAF OF THE MUNG BEAN.



FIELD OF MUNG BEANS IN 36-INCH ROWS AT ARLINGTON FARM, VIRGINIA.

mung bean was well known previous to Linnæus's time, having been described by various botanists and well figured by Dillenius (1732, p. 315). Strangely enough Linnæus never gave a binomial name to the mung, through having confused it with the urd and even with the soy bean.

Phaseolus max L. (Linné, 1753, p. 725), which by some botanists has been supposed to refer to the urd, is really the soy bean, as clearly shown by Linnæus's original specimen, which still exists. In naming this plant Linnæus evidently was under the impression that it was the *max* of Arabia described by Avicenna. *Max* is merely a modification of *mash*, under which name the mung is generally known in western Asia. While Linnæus, therefore, intended the name *Phaseolus max* to apply to the mung, the plant he actually described is the soy bean, and the name therefore belongs with the latter plant.

Phaseolus mungo L. (Linné, 1767, p. 101). There is no specimen in the Linnæan herbarium representing this name. Linnæus's description, however, is long and detailed, based on plants grown in the greenhouse at Upsala. From the specific name used, Linnæus evidently thought that his plant was the mung bean, but the description much more clearly accords with the tikari, a form of the urd, as Prain has previously pointed out (1897, p. 422).

Phaseolus radiatus L. (Linné, 1753, p. 725). The original specimen of this plant was grown in the greenhouse at Upsala from seeds obtained from Canton, China. This name has been supposed by nearly all botanists to stand for the mung bean. This is due to the fact that when Linnæus named the plant in 1753 he cited the illustration and description of Dillenius (1732, p. 315, pl. 235, fig. 304). He even took the name *radiatus* from Dillenius's description. Unfortunately, however, Dillenius's plant, which is the mung, is not the same as the plant which Linnæus grew in the garden at Upsala and which forms the type of his *Phaseolus radiatus*. This plant, in the opinion of the botanists at Kew, is the same as that later named *P. sublobatus* Roxburgh. It thus appears that there is no botanical name given by Linnæus that can properly be applied to the mung bean.

Roxburgh in 1832 described and named a number of the species and varieties of Phaseolus grown in India. He changed the application of Linnæus's names in several respects, applying the name *P. mungo* to the green-seeded mung, *P. max* to the black-seeded mung, and *P. radiatus* to the urd. These changed applications of Roxburgh can not be accepted. He also named the golden-seeded mung *P. aureus* (1832, p. 297). This last name is therefore the first published binomial which properly belongs with the mung and which must be accepted as its proper botanical designation, notwithstanding the fact that Roxburgh meant it to apply only to the variety with yellow seeds.

DESCRIPTION.

The mung is an erect or suberect, rather hairy, much-branched plant, growing to a height of 1 to 4 feet, depending on variety. Some sorts twine more or less at the tips of the stems and branches. In a general way the plants are intermediate in habit between the cowpea and the soy bean. The leaves are trifoliate, with rather large, ovate, entire or rarely trilobed leaflets. The flowers are pale yellow, crowded in clusters of 10 to 25. They are fully self-fertile, when bagged setting pods perfectly.

The adaptations of the plant are almost identical with those of the cowpea, and the methods of culture quite the same.

VARIETIES.

The varieties of the mung are numerous, about 20 having been introduced and tested during the past 10 years. They differ in habit, size, period of maturity, color of pods, and size and color of seeds. In habit most varieties are erect or suberect, but in some the tips of the branches are vining. Most kinds grow to a height of about 2 feet, but early sorts are only 1 foot high and very late kinds 3 to 5 feet. The earliest mature their first crop of pods at Arlington farm in about 80 days, while the latest barely ripen seed when killed by frost in 140 days. The pods are black or brownish and vary in length from 2.5 to 4 inches, each containing 10 to 14 seeds. The seeds are globose or oblong, green in most varieties, but in others marbled black and green, yellow, brown, and purple-brown. The weight of 100 seeds ranges from 1.5 to 4.2 grams. The seed coat is marked by innumerable fine wavy ridges, which are sometimes very faint, but apparently never entirely lacking. Sometimes nearly smooth seeds are found in the same pod with others strongly striate. The seeds of *Phaseolus sublobatus* are similarly striate, but those of the urd are smooth.

EARLY INTRODUCTION.

The mung bean was known in the United States previous to 1835, in which year the following article was published (Herbemont, 1835):

CHICKASAW PEA—PEA FODDER.

COLUMBIA, S. C., *May 11, 1835.*

To the Editor of the Farmers' Register:

I send you here enclosed a few of the peas mentioned in your last number [page 752, Vol. II], as a dark bottle green pea, the smallest of the tribe. I prefer it to all others for fodder. Not being a running vine, but rather a bush, it is much more manageable than the common cow pea. My horses prefer it to all other fodder, and when they have it, never leave a bit, eating it all to the oldest and dryest stalk. The best practice in curing pea vines here, is not to let them remain as long in the sun as your correspondent J. M. G. intimates is necessary; but they are cut one day and housed the next, taking care not to let them be packed too close, but kept open by poles or rails being put here and there between them, and kept so for three or four weeks, when the poles or rails are withdrawn, and the fodder may be then packed as close as convenient. Or a pen is made with rails, is filled up with a few sticks between, and the whole covered with a few boards. The pea herein sent, is called Chickasaw pea; by whom and why it was so called, I do not know; but I sent many years ago one or two gallons of them to the Editor of the American Farmer, in Baltimore, and having forgotten this circumstance, he sent me a few in a letter by the name of Chickasaw pea. I do not think it a native of this country, but have reason to believe it came from the East Indies. This is the plant that would make a most excellent and convenient green dressing for land, were it not as good as it is for fodder. The best way of planting it is in beds two or three feet apart, and ten to fifteen inches in the beds. I usually get one or two gatherings of the pods for seed, and cut them one day, and the next tie them in small bundles and house them as above * * *

N. HERBEMONT.

In 1853 the mung bean was known under the names of Chickasaw pea and Oregon pea, the latter name from a mistaken idea as to its origin. A. B. Rozell (1854), of La Vergne, Tenn., describes it as follows:

The Oregon pea was brought a few years ago from Oregon Territory. Whether it was found wild there, or was obtained from the Indians, I am not prepared to say. I obtained from the State of Mississippi, a year ago last spring, about a teaspoonful of seed, from the product of which I raised last season thirty bushels of peas. Had it not been for the cut-worm, the ravages of which were very great, I would have raised one hundred bushels.

The seed of this plant is very small—less in size than that of the "lady or sugar pea"—and of a pale green color, with a white "hilum," or eye. It grows on a bush from five to six feet high, with five or six large branches near the ground, and they, with the main stalk, put out other branches, until the stalks would make a bunch as large round as a tobacco hogshead, or near it. It grows more like cotton than anything else I know of, only it is much larger, with branches not so horizontal. After leaving the ground a little, all these branches, with those which put out at every joint, bear from four to ten pods in a bunch, with about fifteen peas in a pod, which, as an article of human food, are superior to anything of the kind I ever ate.

The stalks and leaves, which are very large and beautiful, make perhaps the finest hay in the world—stock preferring it to any other—and yield a greater abundance. The hay and pea together are a better and a far cheaper food than can be raised from anything else in the United States, for horses, mules, cattle, sheep, and hogs. I believe I can raise more and better feed for my stock, from one acre of land, than I can from five of anything else I know of. It will grow on land so poor that it would produce little or nothing else; and tolerably poor land is better for it, and will produce more than rich land. This may appear strange to some, but it is nevertheless true. Rich land will produce more stalks, but not so many peas; in this respect it is like cotton. As an improver of the soil, I consider it far superior to clover, or anything known in Tennessee, when fed off on the ground and then ploughed in.

If seed is the object one has in view in raising this plant, let it be sown in drills 4½ feet apart, one or two seeds in a place, one foot asunder along each drill. In the course of the summer, weed and cultivate with the plough or hoe, after the manner of raising bush-beans or Indian corn. For fodder or hay sow them broadcast, and lightly harrow them in, like wheat or other grain.

In short, taking this plant altogether, it is one of the finest and richest productions I ever saw; and I am satisfied in my own mind that it is the greatest acquisition to the farmers of the valley of the Mississippi, and the States adjacent, that has been introduced into this country—guano not excepted—for the last thirty years.

Numerous other articles concerning the Oregon pea occur in the agricultural literature of the period. Most of the reports referring to its cultivation in the Southern States are favorable as regards its value for forage, but there is much variance of opinion concerning the desirability of the beans as human food. The best account is by Ruffin, of Virginia, who in his article on the southern pea (1855, p. 355) includes a description of the plant as follows:

The small green or bush-pea—formerly called by Mr. Herbemont, of South Carolina, the Chickasaw. This kind only, of all enumerated and described here, seems to be a true pea, and therefore is not of the same species with all the other kinds, here termed varieties of the southern pea [cowpea]. Very recently, this pea has been brought before the public under the name of the Oregon pea, and as if a new as well as most wonderful plant. In this way, its real good qualities have been extravagantly exaggerated, and the trumpeters of the false praises have practiced on the public credulity so as to sell the seeds at from $60 to $80 the bushel. Though not reaching half the grade (at least in my culture), claimed for it by the interested eulogists, this pea has some peculiar and excellent qualities. It has been more than 20 years since I obtained the seed, and have cultivated it at several different times. The cessations were caused by neglect to save seed, and the difficulty of saving them, without unusual care.

The seeds are round, and when dry, of a uniform bright pea-green color. They are very small—scarcely as large as duck-shot—and not more than one-third of the size of seed of the early black, buff or other ordinary peas. Of course, fewer seed (by two-thirds or more) will serve for seeding. On the other hand, the young plants are proportionably small, feeble in growth at first, and therefore exposed to be over-powered by weeds, if broad-cast, or to be smothered by tillage, if among corn, or drilled. In later growth, the plant is large and vigorous. It is not a vine (like all kinds of the true southern pea) but an upright-growing shrub, or bush, with large and rough (vilose) leaves, of entirely different appearance from those of all other ordinary varieties. * * * But because of this peculiar manner of growth, this pea is much more easily turned under by the plough than any other kind. This is the great if not the only ground of superiority. The pods are black and short. If they could remain on the stems safely until frost, the gathering would be as easy as of any others, as the pods grow in clusters of from 3 to 6. But a great disadvantage is that if the ripe pods are not gathered before the first rain, they will burst open on drying, and waste their seeds. The ripening also is as late as of any known pea. The main value of this pea must be to plough under as a manure for wheat. Mr. Herbemont, of South Carolina, in a communication long ago published in the Farmers' Register, stated that this plant was valuable for hay. If it will make as good forage and hay as the other vine peas, (and none can be better,) this plant in its manner of growth, would have a peculiar advantage, in being easy to mow by the scythe.

This pea, different from all described as varieties of the great family of southern peas, is not of native origin. It has been supposed to have been derived from India, and more lately and falsely from Oregon. I believe it is from some warm coast of the Mediterranean Sea. The only certain information I have had was that some barrels of the peas were bought at Gosport Navy Yard, at a sale of the old and damaged stores of a frigate returned from a Mediterranean cruise.

[Footnote.] Since writing the above, I have inspected, at the United States Patent Office, some beans and peas, brought from remote countries. Among them was a pea brought from China, which seems to be the same with the kind above described. The Chinese seeds differ from our "Oregon" pea only in being something smaller, and not so plump and round, and being of a more pale and dull green color—as would be if gathered before being quite mature.

The Oregon or Chickasaw pea, as described by early writers, agrees very closely with a sort that has become naturalized in South Carolina in several localities and which was again brought into cultivation by Prof. C. C. Newman, of the South Carolina Agricultural College, in 1905, and hence has been called the "Newman bean." There can be but little doubt that the Newman bean is the same variety that was previously known as the Chickasaw or Oregon pea.

One variety, evidently rather early, as it is spoken of as maturing quickly, was tested in Louisiana (Dodson and Stubbs, 1898, p. 36) previous to 1898, the plant being considered nearly equal to the cowpea in value.

AGRICULTURAL VALUE.

Notwithstanding that the varieties of the mung bean exhibit a wide range of comparative excellence, it is doubtful whether the best will prove a permanent addition to American agriculture. As a field crop the mung is directly comparable to the cowpea and the soy bean, and it has nowhere proved superior to these. The mung is not as vigorous a plant as the cowpea and does not cope very successfully with weeds. As a seed producer it is far inferior to the soy bean, and the seeds are much subject to attack by weevils. The best seed yield that has been obtained was 22.8 bushels per acre, from No. 28053 in 1912 at Arlington farm. At Chillicothe, Tex., the seed yields ranged from 4.1 to 15.2 bushels per acre. The fact, too, that the mung bean did not find a permanent place in our agriculture 60 years ago when it was tested extensively is significant.

At Monetta, S. C., a trial of 20 varieties of mung showed that all were subject both to root-knot caused by the nematode *Heterodera radicicola* and to wilt (*Fusarium* sp.).

At Arlington farm the foliage is much affected each season by a white leaf-spot (*Amerosporium oeconomicum*) and to a greater degree by a red leaf-spot (*Cercospora cruenta*), both of which diseases also affect the cowpea. Some varieties were also considerably injured by a mildew (*Erysiphe polygoni*).

Among the disadvantages of the mung as compared to the cowpea are its slow initial growth, the rather stemmy character of the plant, the tendency of the herbage to turn black in curing, the susceptibility of the plant to root-knot and to wilt, the irregularity of its fruiting, and the shattering character of the pods.

The general conclusion reached from the extensive tests at Arlington farm, as well as at Monetta, S. C., and Biloxi, Miss., taken in connection with the results reached at several southern experiment stations and by various individual cooperators, is that under present economic conditions the mung bean is not to be recommended as a farm crop.

RECENT INTRODUCTIONS.

During the past 10 years the Department of Agriculture has introduced about 50 different lots of mung beans from various sources, which represent about 16 distinct varieties. These have been tested at Arlington farm, Virginia, for periods varying from two to seven years, and also in cooperation with various experiment stations. The following list gives the source of each of these lots, together with brief notes on their agricultural characteristics, based primarily on their behavior at Arlington farm:

S. P. I. No.

224. From North China, 1898, under the name of "lan-tou (lan-dow)." Seeds olive. No cultural notes.

486. From Amur Province, Siberia, where imported from China and called "lan-tou (lan-do)," 1898. Seeds olive. No cultural notes.

1100. From Turkestan, 1898, where it is called "naish" (probably error for "mash"). "The native Sarts use it for food, and the hay makes good winter fodder." (Hansen.) Seeds olive. No reports of trials.

1161. From Kulja, China, 1898. Grown at Arlington farm five seasons; also at Chillicothe and San Antonio, Tex. Stems suberect, 16 to 20 inches high. Eighty per cent of the pods mature in 100 days. Pods black, seeds olive. Apparently identical with this are Nos. 17290, 17303, 22409, 28053, 29445, and 30748.

1385. From Tashkend, Russian Turkestan, 1898. Grown at Arlington farm for six seasons. Plants 18 to 20 inches high, sprawling in habit. At the end of 120 days about 60 per cent of the seed is ripe, but many of the leaves become half dry from leaf-spot. This variety is a poor seeder and much inferior to others in habit. Seeds olive. The variety has also been grown at Chillicothe and Amarillo, Tex., where it grows similarly but not so large.

2873. From Wuchang, China, 1899. "It is often planted among the growing rice, etc." Grown at Arlington farm in 1900, when it proved to be very similar to No. 1385, but a little earlier.

3868. From China, 1899. Grown at Arlington farm for five seasons. Identical with No. 17283.

5071. From Wahiawa, Oahu, Hawaii, 1900. Grown at Arlington farm for six seasons. Identical with No. 6562.

5435. From Calcutta, India, 1900. Grown at Arlington farm, 1905. Planted on June 16 it was only in bud when killed by frost on October 12. Plants 18 to 24 inches high, decumbent, slender stemmed. Seeds yellow, small.

5436. From Calcutta, India, 1900. Seeds globose, small, green marbled with black, distinct from any other lot. No field notes.

5437. From Calcutta, India, 1900. Grown at Arlington farm for three seasons. Plants erect, 12 to 15 inches high, the pods about all ripe in 80 days. Seeds green. An early variety but much subject to leaf-spot.

5518. From Makassar, Celebes, 1900. Grown at Arlington farm one season, 1905. A very late variety, planted May 26 and beginning to bloom September 23, but no pods had matured when killed by frost on October 12. Plants 30 inches high, half erect. Seeds olive.

6224. From Negros, Philippine Islands, 1901, where it is called "mung (mongo)." Seeds yellow. No cultural notes.

6321. From Tokyo, Japan, 1901, under the name "yainari." Grown at Arlington farm for three seasons. Plants 18 to 20 inches high, the bulk of the pods ripening in 90 days. Seeds green. Foliage badly affected by leaf-spot.

6378. Progeny of No. 3868.

S. P. I. No.

6430. From Athens, Greece, 1901, under the name "*Phaseolus viridissimus.*" "Their culture in Greece is a restricted one, and the beans are considered a great delicacy." Grown at Arlington farm and elsewhere for five seasons. Plants erect, bushy, 18 to 24 inches high and 15 inches broad, the pods mostly ripe in 100 days. Seeds olive green. Indistinguishable from this are Nos. 5071, 6562, 8540, 8814, 9786, 13397, and 14960.

6562. From China, 1900. As grown for several seasons at Arlington farm this can not be distinguished from No. 6430.

8486. Progeny of No. 6321.

8540. From Poona, India, 1902, where it is called "mung (mug)." This lot is quite identical in growth and maturity to No. 6430.

8585. From Chinkiang, China, 1902. Seeds green. No records of any tests.

8814. From Basra, Arabia, 1902, where called "mash (maash)." "It is employed with rice or boiled and eaten alone." (Fairchild.) As grown for several seasons at Arlington farm this was quite identical with No. 6430.

9786. From Khojend, Russian Turkestan, 1903. Grown at Arlington farm and found not distinguishable from No. 6430.

9889. Progeny of No. 6430.

9890. Progeny of No. 6430.

10284. Progeny of No. 6430.

10329. Progeny of No. 6430.

10407. Progeny of No. 6430.

10527. From Patras, Greece, 1904. In cultural behavior this is exactly like No. 1385. It is not the same variety as No. 6430, also from Greece. Other numbers that are apparently identical with 10527 in all respects are 24813 and 28992.

10610. From Askabad, Turkestan, 1904, where called "mash (masch)." Arlington farm cultures prove this to be the same as No. 6430.

11098. From Abyssinia, 1904. Seeds olive. No cultural notes recorded.

12775. From Prof. C. C. Newman, Calhoun, S. C., 1905. This variety was found by Prof. Newman growing spontaneously near the South Carolina Agricultural Experiment Station and by him brought into cultivation, whence it has been called the Newman bean. As indicated on a previous page, there are excellent reasons to consider this identical with the Chickasaw or Oregon pea first introduced into the United States about 1835. Dr. Haven Metcalf states that he has seen the plant growing spontaneously at four different places in South Carolina. The Newman bean has been grown for seven seasons at Arlington farm and at various other places, besides being abundantly tested by practical farmers. It is a large, late variety, growing perfectly erect to a height of 3 to 3½ feet. At Arlington farm it matures only part of its pods in 130 to 140 days when planted about June 1. The stems are rather too coarse for good hay. Seeds olive green. This is the tallest of all the varieties tested, but becomes fully mature at Arlington only in occasional seasons. No. 30732, from Jolo, P. I., is not distinguishable.

13394. Progeny of No. 6562.

13395. Newman bean. Same source as No. 12775.

13396. From United Provinces, India, 1903. Grown at Arlington farm for three seasons. Plants 2 to 3 feet tall, bushy, late, the bulk of the pods maturing in about 125 days. Seeds olive. Very similar to No. 10527 and probably the same variety.

13397. From Nagpur, India, 1903, under the name "mung (mug)." Grown several seasons at Arlington farm and not to be distinguished from No. 6562.

13398. Found mixed in cowpea seed from Bombay, India, in 1903. The cultures of this show it to be the same as No. 6562.

S. P. I. No.

14960. From Shanghai, China, 1905. Identical with No. 6430.
15926. Progeny of No. 10527.
16210. Progeny of No. 6562.
16211. Progeny of No. 8540.
16323. From Kashgar, Chinese Turkestan, 1905. There called "mash" or "dal." Grown for three seasons at Arlington farm. Plants 18 to 20 inches high, bushy, producing but few pods, which mature in about 120 days. Seeds olive green.
16793. From Hangchow, China, 1905. Seeds olive green. Field notes insufficient.
17096. Progeny of No. 12775.
17283. Progeny of No. 1161.
17284. Progeny of No. 8814.
17285. Progeny of No. 9889 from No. 6430.
17286. Progeny of No. 6430.
17288. Progeny of No. 10407 from No. 6430.
17289. Progeny of No. 6562.
17290. Progeny of No. 13397.
17291. Progeny of No. 13398.
17292. Progeny of No. 13396.
17293. Progeny of No. 10610.
17294. Progeny of No. 9786.
17295. Progeny of No. 8540.
17296. Progeny of No. 6321.
17297. Progeny of No. 5071.
17298. Progeny of No. 5437.
17299. Progeny of No. 10527.
17300. Progeny of No. 12775.
17301. Progeny of No. 13395.
17302. Progeny of No. 6562.
17303. Progeny of No. 3868.
17304. Progeny of No. 1385.
17326. Progeny of No. 3868.
17512. Progeny of No. 10527.
17696. Progeny of No. 10527.
17722. Progeny of No. 10527.
17848. From Changli, China, 1905. Tested at Arlington farm in 1906 and 1907. Plants 18 to 20 inches high. Pods all mature in 130 days. Seeds olive. Probably identical with No. 8814.
20696. From Khokan, Russian Turkestan, 1906. Native name "mash (masch)." This as grown in 1907 was indistinguishable from No. 1385.
20698. From Usuri Province, Siberia, 1906. Chinese name "lango." Seed olive green. Failed to germinate.
21086. From Mukden, Manchuria, 1907. Chinese name "lü-tou (lu-toa)." "Used to make bean-vermicelli, etc." Grown at Arlington farm in 1907 and 1908. Plants bushy, 16 to 18 inches high. Pods begin to mature in 90 days and continue ripening till plant is killed by frost. Seeds olive.
21787. From Calcutta, India, 1908. A large, late variety grown for three seasons at Arlington farm. Plants 24 to 36 inches high, erect. Pods begin to mature in about 100 days, but only half are ripe in 120 days. This variety makes nearly as large a growth as the Newman bean. Seeds olive.
21788. From Calcutta, India, 1908. Grown for two seasons at Arlington farm. Plants sprawling and viny, 12 to 18 inches high, 2 feet broad. Very late. No pods ripe at the end of 120 days and but few in 140 days. Seeds yellow,

S. P. I. No.

22000. From Tientsin, Chihli, China, 1907. Chinese name "huang-lü-tou." In 1909 not distinguishable from No. 17283 in habit and time of maturing, but seeds yellow.

22409. From Hongkong, China, 1908. This proved to be identical with No. 17283, the progeny of No. 1161.

22510. From Yokohama, Japan, 1908, under the name "bundo-mame (runda-mame)."

24570. From Tashkend, Russian Turkestan, where called "mash (masch)," 1908. In 1909 this was found to be identical with Nos. 24813 and 10527.

24813. From Tashkend, near the northern limit of cotton culture in Turkestan, 1908. "It is largely grown in Turkestan under conditions similar to those obtaining in New Mexico and Arizona." (Hansen.) This proved to be identical with No. 10527.

25706. From Poona, India, 1907. Seeds olive. No cultural notes.

26361. From Malkapur, Berar, India, in 1909. This proved to be the same as No. 17283, the progeny of No. 1161.

28053. From Mukden, Manchuria, 1910. The Chinese name is "lü-tou." Grown at Arlington farm for two seasons. Plants 2 feet high, bushy, maturing nearly all their pods in 100 days, but not at all prolific. Seeds olive. Probably the same as No. 17283.

28992. From Kizil-Arvat, Russian Turkestan, 1910. This variety was not distinguishable in 1912 from No. 10527.

28993. From Old Bokhara, Turkestan, 1910. Grown at Arlington farm in 1912. Plants 15 inches high, bushy. Some pods mature in 100 days and about half in 120 days. Seeds yellow.

29445. From Manchuria, 1911, under the name "toza luida." As grown in 1912 at Arlington farm this was not distinguishable from No. 17283, progeny of No. 1161.

30731. From Moro Province, P. I., 1911. Grown at Arlington farm in 1913. Plants very similar to No. 30732. No pods were mature when killed by frost in 140 days. Seeds brownish red.

30732. From Jolo, P. I., 1911. Grown at Arlington farm in 1913. Plants erect, 36 inches high, 24 inches broad. No pods were ripe in 140 days when killed by frost. Seeds green. This variety is apparently identical with the old Chickasaw pea, that is, the Newman bean (No. 12775).

30733. From Iloilo, P. I., 1911. Plants very similar in all respects to No. 30732, but seeds golden. A few pods ripened at Arlington farm in 1913 in 132 days.

30748. From Wulukai, Manchuria, 1911. Chinese name "hsiao-lü-tou (hsiao-liu-tou)." As grown at Arlington farm in 1912 and 1913, not distinguishable from No. 17283.

32363. From Soochow, China, 1911. Grown at Arlington farm in 1913. Plants 3 feet high, 2 feet broad, the branches somewhat viny near the tips; pods few, maturing in 130 days; seeds bright green, nearly smooth. Some of the plants of this lot had the leaflets deeply trilobed.

32608. From Trichinopoly, India, 1911. Grown at Arlington farm in 1913. Plants weak, decumbent, 24 inches high and broad; about half the pods maturing in 140 days. Seeds dark brown.

34776. From Beira, Portuguese East Africa, 1913. On the Zambesi River called "soroko" and in the interior "zoombi." Grown at Arlington farm in 1913. Plants 24 inches high, 30 inches broad, rather sprawling in habit; not prolific; a few pods maturing in 132 days. Seeds olive.

The above 91 lots of seeds represent at least 16 distinct varieties. By the seed characters alone 11 varieties can be distinguished. While there is great difference in value between the varieties, even the best are not as desirable as the cowpea for forage or green manure, and all are inferior to the adsuki bean in seed production.

THE URD, OR BLACK GRAM.

The urd, or black gram (*Phaseolus mungo* L.; Pl. VI), is very similar to the mung and the botany of the two has become much confused. It is easily distinguishable from the mung, however, by the much shorter, stouter, very hairy pods and larger oblong seeds, which vary in color from blackish to olive. The flowers are fully self-fertile. It is cultivated only in India. According to Mollison (1901, p. 88) an area equal to about 250,000 acres is devoted to this crop in the Bombay Presidency, and Duthie and Fuller (1882, p. 39) say that the area in the Northwestern Provinces and Oudh is about 260,000 acres.

In botanical characters the urd is very similar to the mung, but in habit the plants are lower and spreading, the branches usually procumbent. The very hairy stems are never twining in any variety grown at Arlington farm, but a twining variety occurs in India and is distinguished as a crop under the name "tikari."

There is still room for slight doubt regarding the botanical name to be applied to the urd. There is no specimen labeled *Phaseolus mungo* in the Linnæan herbarium. Prain (1897, p. 423) points out, however, that Linnæus's description of *Phaseolus mungo* accords better with the tikari than with any related species, and his judgment, based on a wide knowledge of the Indian species, can hardly be controverted.

From the standpoint of a forage or cover crop the urd is inferior to the mung, as it makes much less herbage. The pods, however, do not shatter so readily, so little of the seed is thus lost. Owing to the low, spreading habit, however, it is necessary to pull the plants in harvesting. The best yield of seed at Arlington farm was 13.6 bushels per acre from No. 17308. The average yield in India was stated to be about 7 bushels per acre in 1912.

The urd is utilized as a green-manure crop in Trinidad under the name of "woolly pyrol," and wherever Hindoo laborers are numerous in the West Indies they cultivate this plant for food.

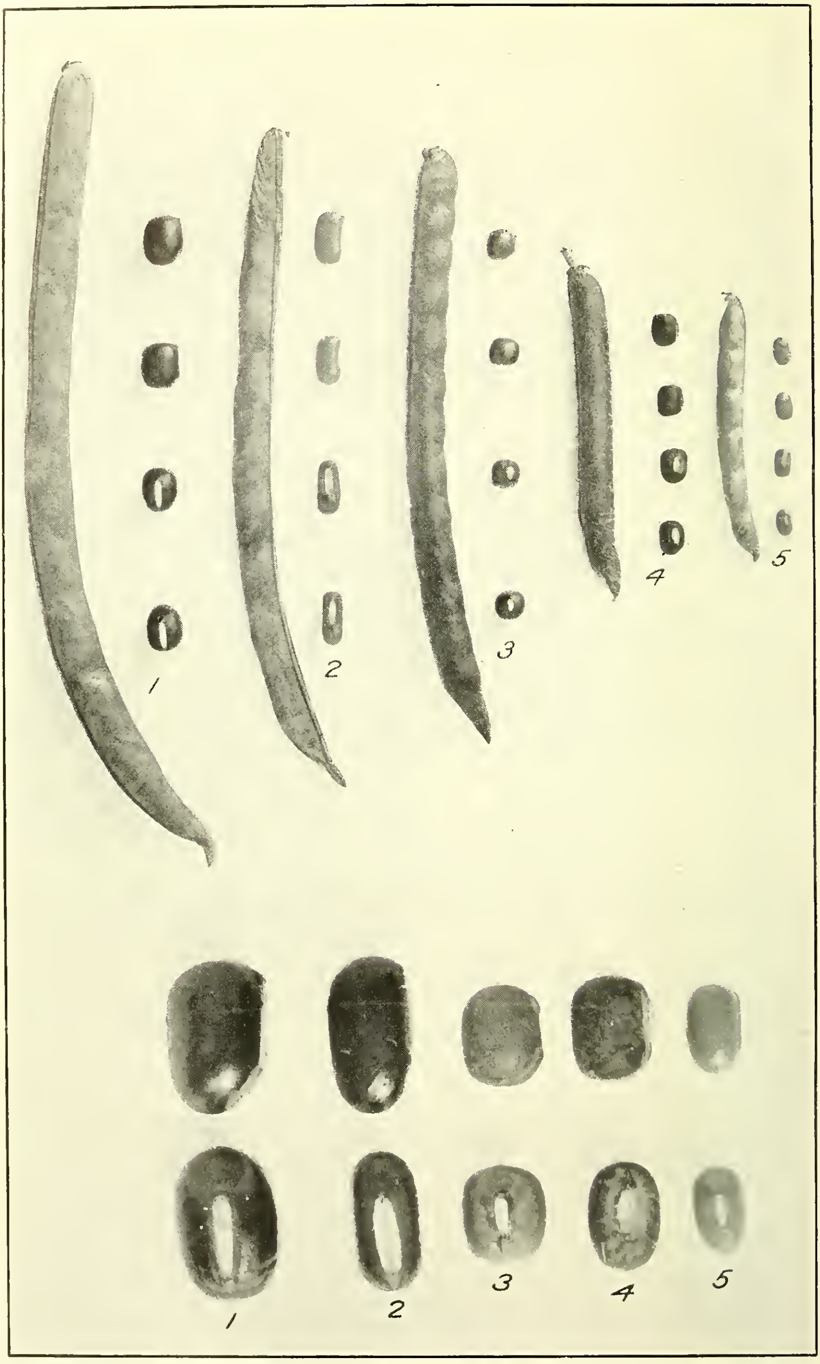
In warm, moist weather the urd is much subject to mildew (*Erysiphe polygoni*). It is also affected by both the leaf-spots that attack the mung and the cowpea.

The habit of the urd is such that it can not be as easily harvested for hay or seed as the mung. It is difficult to see wherein it can compete as a forage crop under American conditions with either the cowpea or the soy bean. As human food the seeds seem far less desirable than other species.

INTRODUCTION.

One variety of the urd, erroneously named *Dolichos cultratus*, was grown in Louisiana in 1898 (Dodson and Stubbs, 1898, p. 37). It was early enough to mature and shatter its seeds by September 1, so that when it was plowed under a good second crop was produced.

FULL-GROWN PODS AND A BRANCH WITH LEAVES AND FLOWERS OF THE URD.



PODS AND SEEDS OF THE (1) ADSUKI, (2) RICE, (3) MUNG, (4) URD, AND (5) MOTH BEANS.

In the lower figure the seeds are magnified 2½ diameters.

Except the trial in Louisiana, there has been found no record of the urd in the United States previous to 1900. Since that year more than 20 lots have been secured, mainly from India, by the Office of Foreign Seed and Plant Introduction. The source of these and their cultural behavior are stated in the following notes:

S. P. I. No.

5438. From the Botanic Gardens, Calcutta, India, in 1900, as "*Phaseolus pilosus.*" Grown but a single season at Arlington farm. A very late variety that did not bloom. Seeds black and gray marbled, very small. Killed by frost October 12. The row formed a mass of herbage 20 inches high and about 3 feet broad.

5439. From the Botanic Gardens, Calcutta, India, in 1900, as "*Phaseolus roxburghii.*" Seeds small, olive. No records of the testing of this variety are preserved.

8541. From Poona, India, 1902, under the native name "udid." Grown at Arlington farm for several seasons. In rows the plants grow to a height of 16 to 18 inches and spread to a width of 2 feet. The majority of the pods ripen in 120 days, but there is a constant tendency to form new pods, so that many are unripe when the plants are killed by frost. Seeds black and gray marbled, dull. At Chillicothe, Tex., this variety produced abundant seed, but too near the ground to harvest with machinery. The seed of this lot germinated 91 per cent in 1906.

13399. From the United Provinces of Agra and Oudh, India, 1903, under the name "katikha." Grown at Arlington farm for three seasons. Plants procumbent, 12 to 18 inches high, about 30 inches wide in the row. Late, only a few pods being mature when killed by frost in 135 days; seeds olive.

13400. From United Provinces of Agra and Oudh, India, 1903, under the name "bhadela." Grown at Arlington farm for five seasons. Plants decumbent, 12 to 20 inches high, not vigorous. Seeds begin to mature by September 1 and 80 per cent are ripe on October 1. Pods dark colored. Seeds olive green.

13401. From United Provinces of Agra and Oudh, India, 1903, under the name "jettira." Grown at Arlington farm in 1905. Not distinguishable from No. 13400.

13402. From Bombay Presidency, India, 1903, under the name "udid." Grown at Arlington farm in 1905. Plants 15 to 18 inches high and 2 to 2½ feet broad. First pods ripen in 100 days. Nearly all are mature in 134 days, when killed by frost. Seeds black, finely marbled with gray. Hardly distinguishable from No. 8541.

13403. From Nagpur, India, 1903, under the name "udid." At Arlington farm this was quite indistinguishable from No. 13402.

16129. From the Louisiana Sugar Experiment Station, Audubon Park, La., in 1905, under the name "*Dolichos formosus.*" Grown at Arlington farm for four seasons. Plants 15 to 20 inches high, about 2 feet broad. Pods mostly mature in 120 days. Seeds black and gray marbled. Hardly to be distinguished from No. 13400.

17134. Progeny of No. 8541.

17305. Progeny of No. 8541.

17306. Progeny of No. 13400.

17307. Progeny of No. 13401.

17308. Progeny of No. 13402.

17309. Progeny of No. 13403.

18310. From Barbados, 1906, where called "woolly pyrol" and much used as a green-manure crop. Grown for four seasons at Arlington farm. A very late, vigorous variety, growing 20 to 24 inches high and 4 feet wide, but not yet blooming when killed by frost after 130 to 150 days. Seeds black and gray marbled.

S. P. I. No.

21708. From Amraoti, India, in 1907, under the name "urid." A late, vigorous variety at Arlington farm growing 20 to 24 inches high and 3 feet broad. At the end of 141 days, when nipped by frost, just beginning to bloom. Seeds black and gray marbled. Apparently the same as No. 21790.

21789. From the Botanic Gardens, Calcutta, India, 1908. Grown at Arlington farm in 1908 and 1912. Plants 12 to 18 inches high, 2 feet broad; 40 per cent of the pods mature in 100 days, 80 per cent in 120 days; pods straw colored; seeds olive.

21790. From the Botanic Gardens, Calcutta, India, in 1908, as "*Phaseolus pilosus*." Grown at Arlington farm for several seasons. A very sprawling, late variety, the plants 20 to 30 inches high and 3 feet broad. Begins to bloom in about 140 days. At Gainesville, Fla., matured a few pods in 1909, but was badly affected both by wilt and root-knot. Seeds black and gray marbled. Probably the same as 5438.

25516. From Gobindapur, India, 1909. Seeds black and gray marbled. No field notes.

25705. From Poona, India, 1909. Plants 12 inches high, 3 feet broad, blooming in 100 days, but no pods maturing seeds. Seeds black and gray marbled.

26360. From Malkapur, India, 1909. Seeds black and gray marbled. No cultural notes.

28765. From Port of Spain, Trinidad, 1910. "Woolly pyrol." Grown at Arlington farm in 1912. Plants 16 inches high, sprawling, 3½ feet wide. No blossoms when killed by frost. Seeds gray and black marbled.

32607. From Darjiling, India, 1911. Late, not blooming in 1913. Plants large, 30 inches wide, 15 inches high. Seeds shining, black and olive marbled.

34363. Seeds rather small, gray and black marbled.

THE MOTH BEAN.

The moth bean (*Phaseolus aconitifolius* Jacq.; Pl. VII) is cultivated as a crop only in India. It is at once distinguished from any other cultivated bean by the leaflets being divided into narrow lobes. What is doubtless the wild original occurs both in India and Ceylon.

The moth is apparently more important in India than the mung or urd. According to Mollison (1901, p. 86) an area of 300,000 acres is grown in Bombay. Duthie and Fuller (1882, p. 41) give the area in the Northwestern Provinces and Oudh as 211,000 acres. This bean is nearly always planted mixed with other crops.

The plants produce numerous slender, decumbent branches from a short stem, a well-grown plant making a dense mass 18 to 24 inches in diameter and 12 to 15 inches high. In none of the varieties grown is there any tendency of the branches to twine. The seeds are linear, straw colored, nearly smooth; pods 1 to 1.3 inches long, 5 to 7 seeded.

In eight lots of seed secured from India the seeds were the same in all, buff colored, but occasional seeds were marbled with black. These last bred true as to seed color, but the plants were apparently identical with those bearing buff-colored seeds. Occasional plants have leaves with fewer lobes. These are the only variations that have been noted in this bean.

The moth bean has grown very satisfactorily at Arlington farm, Va., and also at Chillicothe, Tex. Owing to its numerous slender stems it produces a very fine quality of hay, but in unfavorable weather for curing the leaves drop off readily. The decumbent habit of the plant also makes it difficult to harvest with a mower. When planted in 3-foot rows at Chillicothe in 1907 for hay production, Nos. 21600 and 8539 averaged 2,680 pounds of hay to the acre, as compared with 3,204 pounds for Whippoorwill cowpeas and 2,380 pounds for Iron cowpeas. At Dalhart, Tex., the moth bean produced in 1909 a yield of 2,500 pounds of hay per acre.

Under the conditions where most fully tested, the moth bean has produced but little seed. During several seasons' trial at Arlington farm very few flowers have formed and but few pods have ripened. At Chillicothe, Tex., the results have been similar, except in 1908, when a small yield of seed was obtained from thin plantings. The reasons for this light seed production are obscure. In India the moth bean yields as much seed as the mung. Duthie and Fuller (1882, p. 41) give the average yield per acre as about 11 bushels.

Even were its seed production higher—and this might be secured by selection—the procumbent habit of the moth bean is such that it is not likely to be grown in preference to the cowpea. At Chillicothe it endured drought better than the cowpea, and this quality of resistance to drought is also noted by writers on Indian agriculture. The difference does not seem sufficient, however, to commend the plant to American agriculture under present conditions.

CHEMICAL ANALYSES.

The results of chemical analyses made by the Bureau of Chemistry of the hay of four of the five species of beans described in this bulletin and of the cowpea for comparison are shown in Table II.

TABLE II.—*Chemical analyses of the hay of the mung, urd, adsuki, and rice beans and of the cowpea.*

Plant.	Water.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.
Mung bean (No. 17283), cut when pods were three-fourths grown	7.18	8.40	1.47	10.69	20.57	51.69
Urd bean (No. 17308), cut when pods were half grown	7.66	10.92	1.31	12.72	22.33	45.06
Adsuki bean (No. 17324), cut when pods were three-fourths grown	7.68	9.87	2.03	17.66	23.04	39.72
Rice bean (No. 25523), cut when pods were half grown	6.41	10.15	1.51	11.16	32.88	37.89
Cowpea	10.5	8.9	2.6	14.2	21.2	42.6

Comparative analyses of the seeds of the five oriental species of beans described in this bulletin, with the same data for the kidney bean for comparison, are presented in Table III.

TABLE III.—*Chemical analyses of the seeds of various species of Phaseolus.*

Plant.	Analysis made by—	Water.	Ash.	Crude protein.	Crude fat.	Crude fiber.	Nitrogen-free extract.
Adsuki bean (No. 17847).	Bureau of Chemistry	10.06	3.40	19.22	0.40	4.55	62.37
Adsuki bean	Massachusetts Agricultural Experiment Station.[1]	14.82	3.74	20.23	.75	3.83	56.63
Mung bean	Church [2]	11.4	3.8	23.8	2.0	4.2	54.8
Urd bean	...do [2]	10.1	4.4	22.7	2.2	4.8	55.8
Moth bean	...do [2]	11.2	3.6	23.8	.6	4.2	56.6
Rice bean	...do [3]	10.5	3.9	21.7	.6	5.2	58.1
Kidney bean	Massachusetts Agricultural Experiment Station.[1]	13.0	3.56	19.75	1.22	62.27	

[1] Brooks, 1892. [2] Church, 1886, p. 151–152. [3] Church, 1901, p. 15.

LITERATURE CITED.

BENTHAM, GEORGE.

1840. De leguminosarum generibus commentationes. *In* Ann. Wiener Mus. Naturgesch., Bd. 2, p. 61–142.

BROOKS, W. P.

1892. Report on trial of miscellaneous crops.—Japanese varieties of beans. *In* Mass. Hatch Agr. Exp. Sta. Bul. 18, p. 100–104.

BROWNE, D. J.

1855. Report on the seeds and cuttings recently introduced into the United States. *In* U. S. Com. Patents, Rpt. Agr., 1854, p. X–XXXV.

CANDOLLE, A. P. DE.

1825. Prodromus Systematis Naturalis Regni Vegetabilis, pars. 2, 644 p. Parisiis.

CHURCH, A. H.

1886. Food-Grains of India, 180 p., 35 pl. London. With supplement, 23 p., 1901.

DILLENIUS, J. J.

1732. Hortus Elthamensis . . . t. 2, p. 207–438, pl. 168–324. Londini.

DODSON, W. R., and STUBBS, W. C.

1898. Grasses, clovers, forage and economic crops. La. Agr. Exp. Sta. Bul., s. 2, no. 53, 55 p., illus.

DUTHIE, J. F., and FULLER, J. B.

1882. Field and Garden Crops of the North-Western Provinces and Oudh . . . pt. 1, 87 p., 22 pl. Roorkee.

GEORGESON, C. C.

1891. Test of some Japanese beans. *In* Kans. Agr. Exp. Sta. Bul. 32, p. 233–238.

HARRIS, W.

1913. Notes on Jamaican vegetables. *In* Bul. Jamaica Dept. Agr., n. s., v. 2, no. 6, p. 180–202.

HERBEMONT, N.

1835. Chickasaw pea—Pea fodder. (Letter.) *In* Farmers' Register, v. 3, no. 2, p. 93–94.

KAEMPFER, ENGELBRECHT.

1712. Amoenitatum Exoticarum Politico-Physico-Medicarum, fasciculi V . . . 912, [32] p., illus., 16 pl. Lemgoviae.

———

1791. Icones Selectae Plantarum . . . 3 p. 59 pl. Londini.

LINNÉ, CARL VON.

1753. Species Plantarum . . . t. 2, p. 561–1200. Holmiae.

———

1767. Mantissa Plantarum, 144 p. Holmiae.

MCCARTHY, GERALD, and EMERY, F. E.

1894. Some leguminous crops and their economic value. N. C. Agr. Exp. Sta. Bul. 98, p. 135–170.

MOLLISON, J.

1901. Textbook on Indian Agriculture, v. 3, 283 p. Bombay.

PRAIN, DAVID.

1897. Noviciae indicae XV. Some additional Leguminosae. *In* Jour. Asiatic Soc. Bengal, v. 66, pt. 2, no. 2, p. 347–518.

ROXBURGH, WILLIAM.

1832. Flora Indica . . . v. 3, 875 p. Serampore.

ROZELL, A. B.

1854. The Oregon pea. *In* U. S. Com. Patents, Rpt. Agr., 1853, p. 223–224.

RUFFIN, EDMUND.

1855. Essays and Notes on Agriculture . . . 407 p. Richmond, Va.

WILLDENOW, K. L.

1801. Species plantarum . . . t. 3, pars. 2, p. 851–1474. Berolini.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
∇

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 120

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
September 3, 1914.

APPLE POWDERY MILDEW AND ITS CONTROL IN THE PAJARO VALLEY.[1]

By W. S. Ballard, *Pathologist, Fruit-Disease Investigations*, and W. H. Volck, *County Horticultural Commissioner of Santa Cruz County, Cal.*[2]

INTRODUCTION.

Apple powdery mildew is a fungous disease which attacks the foliage and young twig growth of the apple. Occasionally it occurs on pears, more particularly on nursery stock in damp or foggy localities, and at times it seriously injures quinces. The disease is quite widely distributed over the world and may be caused by either of two very similar fungi, namely, *Podosphaera leucotricha* (E. and E.) Salm., and *P. oxyacanthae* (DC) de Bary.[3]

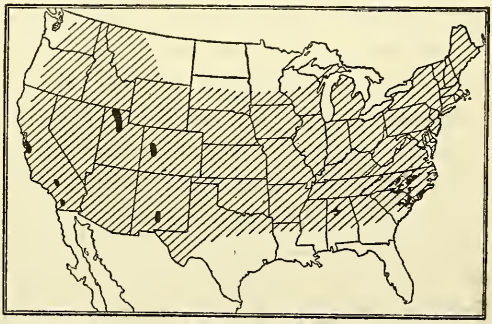


Fig. 1.—Map of the United States, the shaded area showing where apple powdery mildew occurs occasionally and the black spots where serious outbreaks are common.

Powdery mildew of the apple occurs at least occasionally in nearly all parts of the United States and is reported from some Provinces of Canada. It is widely distributed in Europe and occurs also in Australia, New Zealand, and Japan. In the central and eastern United States it has been known for many years as a more or less serious disease of nursery stock, but it is only during the last few years that it has been reported as doing any considerable damage in bearing orchards. In the western United States, however, from

[1] This bulletin is intended to assist apple growers in dealing with a fungous disease which is becoming a serious menace to their industry. It is suitable for distribution in the apple-growing sections west of the Rocky Mountains and in certain limited areas east of the Rocky Mountains, as shown on the map.

[2] These investigations were carried on cooperatively between the Office of Fruit-Disease Investigations of the Bureau of Plant Industry and the office of the county horticultural commissioner of Santa Cruz County, located at Watsonville, Cal.

[3] See also page 5.

46689°—Bull. 120—14——1

Utah and New Mexico westward, and more particularly along the Pacific coast, climatic conditions appear to favor its development into a serious menace to successful apple growing. Throughout this whole territory it is increasing in its distribution, and in those districts in which it is already established it is gradually becoming a serious orchard disease. It occurs more or less commonly throughout Washington and Oregon and in some districts has already acquired sufficient importance to be given regular attention in the annual schedule of spraying applications. At the present time the orchards of the Pajaro Valley in California suffer more from apple powdery mildew caused by *Podosphaera leucotricha* than do those of any other large apple-growing district in the United States. It is true that in one or two small coast sections in California the disease causes even greater damage to the trees, but its commercial importance in those districts is not comparable with that in the Pajaro Valley, where the annual output of apples is about 3,500 carloads of packed fruit. In that section more than 80 per cent of the apple acreage is in Yellow Newtowns and Yellow Bellflowers, both of which varieties are particularly susceptible to mildew attack.

Throughout the western United States, according to the writers' observations, apple powdery mildew attacks only the foliage and young twigs and produces no direct injury of the fruit; therefore, it is difficult to estimate the financial loss which the disease causes. However, a comparison between the general appearance of a tree badly attacked by mildew and one that has been kept relatively free from the disease by spraying should readily convince one that such unhealthy trees can not be expected to produce the kind of crops they should and that their annual growth and increase in bearing surface must be less than normal. Plate I, figures 1 and 2, and Plates II and III show such a comparison between sprayed and unsprayed Yellow Newtown apple trees in the same orchard. Badly diseased orchards that are allowed to remain untreated become more and more seriously infected each year. The cumulative effect of such a gradually increasing general infection results in a decided decline in the vigor and appearance of the orchard.

The commercial importance of controlling apple powdery mildew has long been recognized, and many investigators, both in America and abroad, have given attention to the problem. As early as 1889[1] the Department of Agriculture conducted investigations and issued spraying recommendations for the control of the disease on nursery stock, and since that time numerous formulas for spray mixtures and instructions for spraying have been published by various State experiment stations. Meantime, similar investigations have been in

[1] Galloway, B. T. Experiments in the treatment of pear leaf-blight and the apple powdery mildew. U. S. Dept. of Agr., Section of Vegetable Pathology, Cir. 8, 11 p., 1889.

progress in Europe and elsewhere. In 1907, when the work in the Pajaro Valley was started, it was naturally assumed that some of the spray mixtures recommended, either in this country or abroad, would prove successful in controlling the disease in that district. Such was not the case, however, and several seasons have been spent in developing a method that can be used satisfactorily.[1] One source of delay in arriving at a practical solution of the problem has been the peculiar climatic conditions of the Pajaro Valley, which distinguish it from any other large apple district in the United States. It will not be out of place to call attention to some of these peculiarities.

CLIMATIC CONDITIONS OF THE PAJARO VALLEY.

The Pajaro Valley lies along the northern shore of Monterey Bay and is situated about 75 miles south of San Francisco Bay. As is common to California in general, the year is divided into two seasons, the rainy and the dry. The rainy season extends from the latter part of October to the month of April, and during that time there is an average precipitation of about 25 inches. Throughout the remainder of the year showers are rare and of practically no importance. The winter weather is mild and comparatively little frost occurs.

In the summer and early fall the valley is subject to winds from the ocean. These winds are of low velocity and produce no appreciable wind damage. They commence about noon and continue to blow until evening. As a result the evenings and nights are cool or even chilly. Very frequently the winds bring in fogs, which begin to cover the valley about 4 o'clock in the afternoon and remain until 9 or 10 o'clock the following morning. These fogs, of course, obscure the sun. They are of two types, high and low. The main body of the high fogs is at an elevation of perhaps a thousand feet, and in consequence the foliage of the trees is not much dampened. On the other hand, the land fogs lie close to the ground and envelop the trees, drenching the foliage so that the leaves often drip profusely during the night and early morning. This foggy weather is not continuous, but is interspersed with clear periods of 2 to 10 days. During the foggy weather the daily fluctuation of the temperature is between 50° and 65° F., and in the clear periods the range is from 65° to 80° F. Temperatures above 90° F. are rarely experienced more than once or twice during the summer.

[1] During the time these investigations have been in progress near Watsonville, Cal., a considerable portion of the orchards of the C. H. Rodgers estate has been given over each year to experimental work, and in the past two years spraying and pruning experiments have also been conducted in the orchard of Mr. O. D. Stoesser. In addition, the hearty cooperation of many other growers in the valley has been of material assistance in determining from a commercial standpoint the feasibility of the control methods recommended.

BEARING OF CLIMATIC CONDITIONS ON THE SPRAYING PROBLEM.

It is very probable that this cool, foggy climate with its lesser amount of sunshine is the factor which produces apple foliage that has a lower resistance to injurious spray materials and a higher susceptibility to powdery mildew attack than that grown in districts where more intense sunshine and higher temperatures obtain. Also, the presence of fog and dew moisture on the foliage tends to dissolve and decompose some spray materials after they have been applied. In fact, the conditions surrounding the problem of spray injury in the Pajaro Valley are distinctly different from those in the eastern United States, for instance, where the foliage is frequently subjected to washing rains. In the latter case the injurious substances liberated by the decomposition of the spray materials on the foliage are, to a great extent, washed off as rapidly as they are formed. In the Pajaro Valley, on the other hand, no such washing occurs, and the injurious substances remain on the leaves, to be dissolved night after night by the fog and dew and absorbed directly through the leaf surface or through abrasions, thereby producing foliage injury. This susceptibility of the foliage to spray injury has been especially noticeable in the case of arsenicals. Paris green, even of the best grade, can not be used, on account of the severe foliage injury which it produces. The ordinary type of lead arsenate, known as the acid arsenate, that is used freely on apple foliage in most parts of the United States, is capable of causing serious burning and defoliation of the trees in the Pajaro Valley, and it was not until the much more stable so-called triplumbic, or neutral, lead arsenate was introduced that a safe arsenical was available. This tendency to decompose and cause burning is shown by other spray materials. However, injury from Bordeaux mixture, for instance, is not as severe in the Pajaro Valley as it is in the humid Eastern States. Possibly fog moisture is not as free a solvent of resistant copper compounds as is rain water. Nevertheless, Bordeaux mixture and other copper sprays are too injurious to permit of their repeated use in this valley. The same is true of lime-sulphur solution and other soluble sulphids which naturally suggest themselves as mildew sprays. Lime-sulphur solution of a strength commonly employed with success throughout the East for summer spraying can not possibly be used in the Pajaro Valley on account of the foliage injury which it produces.

Extensive field tests of spray materials have been carried out by the writers, and further examples might be cited illustrating the striking susceptibility of Pajaro Valley apple foliage to injury from sprays. Several years of investigations and observations have convinced the writers that the trees of that district are in a particularly sensitive physiologic condition and that almost any artificial treatment given them is liable to bring striking results, either beneficial or injurious. In fact, precipitated sulphur may be applied as a spray in such a manner as to produce two distinct physiologic effects, one markedly beneficial and the other decidedly injurious.

APPLE POWDERY MILDEW.

Apple powdery mildew, as has been stated, may be caused by either *Podosphaera oxyacanthae* or *P. leucotricha*, formerly called *Sphaerotheca mali* (Duby) Burr. *Oidium farinosum* Cooke, which is frequently reported as the cause of the disease, is probably, according to Salmon, the conidial form of *P. leucotricha.* It is also probable that in the absence of what is termed the perfect stage the fungus is often assumed to be *P. oxyacanthae* when *P. leucotricha* is the form actually present, though both species exist on the cultivated apple in the United States. The species occurring in the Pajaro Valley is *P. leucotricha.* The identity of the fungus has been determined by repeated examinations of the perfect stage, which occurs frequently in that locality on the twigs, though not on the leaves. However, the following description of *P. leucotricha* and its life history will apply very well to *P. oxyacanthae* except for certain technical differences, some of which will be mentioned.

As has been stated, the disease attacks the foliage and current year's twig growth. Infection of the young fruit is extremely rare, and only occasionally does one find a flower-cluster bud that has been attacked. In the latter case the entire individual flowers are usually involved, the floral organs are reduced in size and much deformed, and the stems are short and thick. (Pl. IV, fig. 2.)

Mildewed areas on the leaves occur most commonly on the under sides. They are white or grayish, and the term "powdery" very well describes their mealy appearance. The diseased spots may vary in size from a point invisible to the naked eye to patches three-fourths of an inch or more in diameter, and several of these may become established on a single leaf. In a large percentage of cases the entire upper and lower surfaces of the leaf become involved. Mildewed leaves are crinkled and stunted and often very much narrowed, owing to the fact that the growth and expansion of the leaf tissue are checked in the areas covered by the fungus. Plate V, figure 2, illustrates this crinkling and stunting, and Plate IV, figure 1, illustrates the narrowing. In the Pajaro Valley the disease makes such rapid progress during the spring and summer that by the end of the leaf-forming season it is difficult to find normal, healthy leaves in any unsprayed Yellow Newtown or Yellow Bellflower orchard.

When a virulent infection becomes established on a leaf, the mildew frequently extends down the petiole to the twig, where it may continue to grow until it covers practically the entire surface of the bark. In such cases the new leaves become badly infected as rapidly as they come out. Plate IV, figure 1, illustrates this condition. Mildewed shoots are stunted in their development, the internodes are very much shortened, and a year's growth may be compressed into an inch or two. Plate IV, figure 2, and Plate VI, figure 2, show a number of examples, and it will be seen that in many cases the affected portion of the twig is considerably thickened. The ends of many of these diseased twigs die back during the winter, and in the following spring a shoot is sent out from a lateral bud, as shown in Plate IV, figure 2, *a*. In the case of the largest twig shown in Plate IV, figure 2, this dying back of the terminals and their replacement by laterals has occurred twice, as shown at *a* and *a'*. Some idea of the abundance of these twig infections can be obtained from Plate I, figure 1, an unsprayed tree, in which it will be seen that practically all of the terminals have been attacked and the greater portion of their foliage has died and dropped off, the few remaining leaves being stunted and distorted. Plate I, figure 2, shows a sprayed tree in the same block as that shown in Plate I, figure 1. A close examination of the size and abundance of the leaves shown in Plate I, figure 1, as compared with those shown in Plate I, figure 2, will impress one with the necessity of controlling the mildew if the vigor and future crop prospects of the tree are to be given proper consideration. Similar comparisons may be made between Plates II and III, though the illustrations do not bring out the strong contrast which exists between the sprayed and unsprayed trees. In winter, when the foliage is off the trees, the grayish mildew covering remains on the twigs, and they glisten in the sunlight when viewed from the proper angle. One is astonished at their abundance, for unsprayed trees fairly bristle with them, and it is probable that in a third of the orchards of the valley more than 50 per cent of the terminals are diseased.

Under the microscope the fungus presents the appearance of a much-branched and loosely interwoven tangle of very fine threads lying on the surface of the leaf or shoot. Scattered all through this tangle and forming a powdery layer on its surface are enormous numbers of minute reproductive bodies called conidia, or summer spores. Collectively the fine fungous threads are termed the mycelium. The mycelial threads branch and rebranch as they grow over the surface of a leaf or shoot (fig. 2), and at intervals short, saclike processes, called haustoria, penetrate the outer, or epidermal, layer of the leaf or twig and by means of these haustoria the fungus absorbs its nourishment. Thus the mildew derives its food materials from that particular portion of the leaf or twig surface upon which it is growing.

The very characteristic powdery appearance of the mildew (Pl. VI, fig. 2) is due, as stated above, to enormous numbers of summer spores. These are produced in chains (fig. 2) from certain branches of the mycelium, and their function is to start new mildew infections during the summer. The chains readily break up into individual spores, which are very light and are easily carried about

FIG. 2.—Peach mildew growing on the surface of a peach leaf. Apple powdery mildew has much the same appearance. At *s* a summer spore is shown germinating. Highly magnified. (After Tulasne.)

by the wind. When a spore lodges in a suitable place, such as the under side of the young leaf, it quickly germinates, if the moisture conditions are suitable, and sends out a small, threadlike germ tube (fig. 2, *s*), which is the beginning of a new mycelium, and by this means a new infection is established. These new mildewed areas immediately begin to form and throw off conidia in large numbers. The individual leaves are susceptible to infection during their entire growing period and up to the time when they become fully matured.

Very early in the season there is a period when great numbers of what appear to be mild infections establish themselves and cause a characteristic crinkling of the foliage. These infections soon die out and the damage done is not particularly serious, though it is undoubtedly of some importance.

The climatic conditions of the Pajaro Valley offer excellent opportunity for the establishment and progress of the mildew. The fogs furnish excellent moisture conditions for the germination of the spores, and it is probable that the somewhat peculiar climatic conditions of the valley influence the character of the foliage in a way to make it more than normally susceptible to infection. The result is that unless proper protection by spraying is provided, 90 per cent of the foliage of Yellow Newtowns and Yellow Bellflowers may become diseased before the end of the growing season.

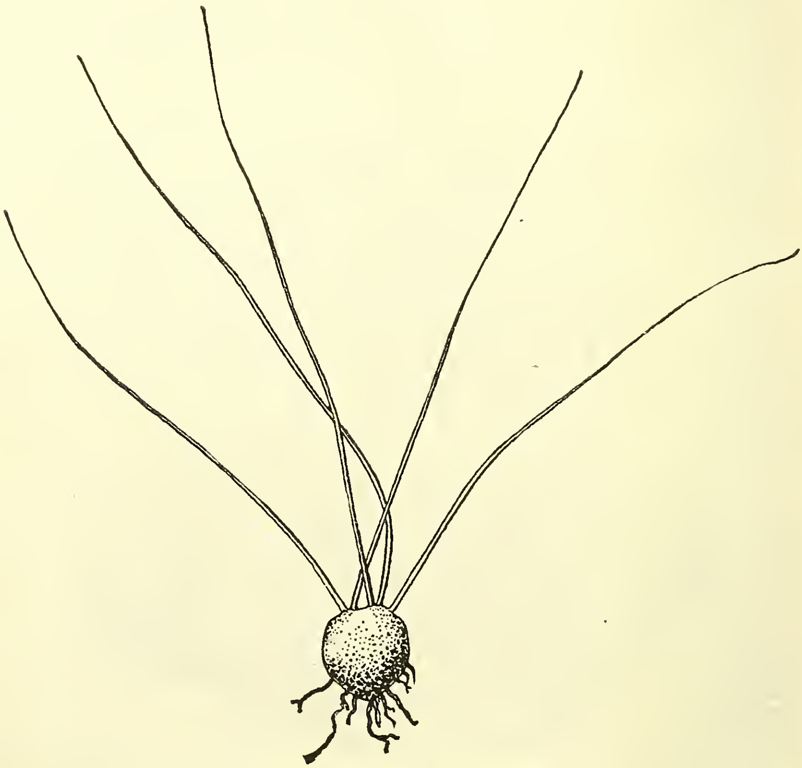


FIG. 3.—A perithecium of *Podosphaera leucotricha*, showing the two types of appendages. Magnified 90 times. (After Grout.)

The summer spores, or conidia, that have just been discussed serve only to spread the summer infections. They are not long lived, and therefore are not capable of carrying the mildew over from fall until the next spring. Furthermore, the mycelium on the twigs dies during the latter part of the summer and fall, and thus plays no part in starting the disease the following spring. The natural method by which the fungus is able to bridge over the winter period is by means of another kind of reproductive bodies frequently called winter spores. This stage of the life history of the fungus develops only occasionally in most localities, but is particularly abundant in the Pajaro Valley. If a careful examination of vigorous twig infections be made about the first of July or shortly thereafter, it will be seen that on many of them irregular, dark, smoky-looking patches have developed. (See *p*, in Pl. IV, figs. 1 and 2, and Pl. VI, fig. 2.) These patches contain great numbers of closely crowded, globose, dark-brown bodies, each having a cluster of 4 to 11 long, stiff, brown, hairlike appendages on the upper side and varying numbers of short, tortuous, irregular processes on the under side. (Figs. 3 and 4.) These bodies are called perithecia, and within each one there is developed a single saclike body (fig. 4, *a*), in which eight so-called ascospores, or winter spores, are produced.[1] These winter spores are long lived and remain dormant until the following spring, when they are liberated, fall on the young foliage, and give rise to the first mildew infections of the season.

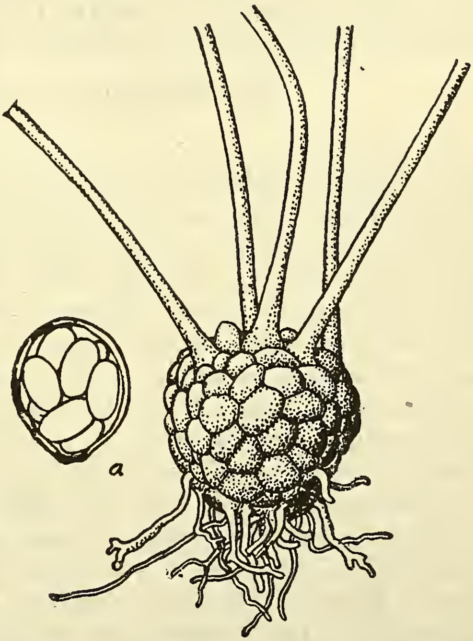


Fig. 4.—A perithecium of *Podosphaera leucotricha*, showing details of the perithecium wall and the basal appendages. At *a* is shown a single ascus which contains eight ascospores. Magnified 312 times. (After Grout.)

Careful observations have led the writers to the conclusion that in the Pajaro Valley this method of bridging over the winter season amounts to practically nothing in the matter of starting the first infections of the following year. It may be that relatively a very small percentage are established by this means, but the really important source is in what the writers have termed the dormant-bud infections. It can be easily seen that in such serious twig infections

[1] In *Podosphaera oxyacanthae* there is a tendency for the perithecia to be more scattered. The appendages, which are more or less equatorially placed, are of only one type. They are spreading and dichotomously branched at the tips.

as are shown in Plate IV, figures 1 and 2, and Plate VI, figure 2, the mildew growing over the surface of the shoots has an excellent opportunity to work its way in between the bud scales and penetrate both the lateral and terminal buds. This actually happens, and within these buds the mildew passes the winter in a dormant condition. The following spring, as the infected buds begin to open, the mildew commences to grow and keeps pace with the development of the new twigs.[1] Hence, infected shoots appear all over the trees as soon as they leaf out in the spring. The mildew growing on the young leaf and twig tissue is particularly virulent and produces summer spores in great abundance. It is not surprising, therefore, that a rapid infection of the healthy foliage soon takes place and that eventually practically all the leaves on the tree become diseased.

SUSCEPTIBILITY OF VARIETIES.

No varieties of apples grown in the Pajaro Valley are immune from powdery mildew, but some are more seriously affected than others. The relative susceptibility of different varieties will probably be found to vary in different apple-growing districts, depending, among other factors, upon the effect which the local climatic and other conditions have on the foliage vigor. In general, the varieties that produce strong, vigorous foliage are less susceptible than the more delicately growing ones. In this connection it is interesting to note that in the Pajaro Valley the Yellow Newtown, which is one of the most susceptible varieties, can apparently be made much less susceptible if the vigor of the foliage be increased by stimulation such as comes from spraying with very finely divided forms of sulphur. A list of the most susceptible varieties grown in the Pajaro Valley includes the Yellow Newtown, Yellow Bellflower, Smith (Smith's Cider), Missouri (Missouri Pippin), Esopus (Spitzenberg), and Gravenstein. The varieties that are less severely attacked are the White Pearmain (White Winter Pearmain), Winter Pearmain (Red Pearmain), Red Astrachan, Rhode Island Greening, and Langford.

SPRAYING EXPERIMENTS.

At the beginning of the writers' investigations it was assumed that the winter spores were the important source of the first infections in the spring, and the significance of what they have called the dormant-bud infections was not realized. It appeared, therefore, that there were two phases of the spraying scheme: (1) The winter spraying, directed toward killing the winter spores on the twigs, and (2) the

[1] Other investigators have reported a similar wintering over of the mycelium of apple and other mildews, but its occurrence in the Pajaro Valley is particularly noticeable because of its abundance and bearing on the problem of mildew control.

spring and summer spraying, intended to prevent foliage and twig infection and to kill out any mildew that had become established.

WINTER SPRAYING.

The experiments in dormant spraying were conducted through two winters. About 16 different materials were used, some of which were tested on several plats and in various strengths. Among the mixtures used were Bordeaux mixture, lime-sulphur solution, various soluble sulphids, copper sulphate, sulphuric acid (alone and in combination with copper sulphate and iron sulphate), and various soluble copper salts. The results showed that the plats which received the various dormant sprayings were just as badly attacked by mildew the following spring as those which were not sprayed.

FOLIAGE SPRAYING.

While the investigations in winter spraying were in progress, it became evident that the dormant or winter spores played a very unimportant part in establishing the first infections the following spring. It was seen that on each tree great numbers of mildewed twigs developed from dormant-bud infections, and that on these diseased twigs summer spores were produced in quantities and served to infect the healthy foliage as it came out.

The work of winter spraying for the direct control of the mildew was, therefore, dropped, though it was taken up again later from a different standpoint. Attention was given to finding a suitable fungicide for foliage spraying and a practical method of reducing to a minimum the number of dormant-bud infections.

About 125 different materials have been tested for foliage spraying, and many of them have been used in several different strengths. Experiments with the more promising ones have been repeated through several seasons, and the investigations have been in progress six years. For the purposes of this bulletin it will not be necessary to give a detailed account of the experimental work, but a brief statement of some of the results will not be out of place. It will be remembered that these remarks apply particularly to the Pajaro Valley, though for the most part they will probably hold true for other sections as well.

Copper compounds in general can not be used, on account of the leaf burning and fruit injury which they cause. Bordeaux mixture gives very poor control of apple powdery mildew. Copper acetate and copper oxychlorid give fair control of the mildew, but they can not be used repeatedly on account of their fruit and foliage injuring properties. Dilute lime-sulphur solution and solutions of the soluble sulphids in general, such as potassium and sodium sulphid, can not be used, on account of the severe foliage injury resulting when they are employed in sufficient concentration to be effective against the mildew.

At present sulphur in some very finely divided form is the most efficient fungicide against apple powdery mildew. However, ordinary ground sulphur, sulphur flour, and flowers of sulphur, or sublimed sulphur, are all far too coarse to give appreciable results. The extremely finely divided form known to the chemist as precipitated sulphur and the still finer form known as colloidal sulphur are both particularly effective against the mildew.

In 1909 one of the writers[1] published a method for preparing what has been called iron-sulphid spray.[2] It was made by precipitating a solution of iron sulphate (copperas) with the required amount of lime-sulphur solution. Twenty pounds of iron sulphate were used in preparing 200 gallons of the spray mixture. By stirring together the lime-sulphur solution and a solution of iron sulphate, a black, muddy precipitate is formed, which contains precipitated sulphur, iron sulphid, and calcium sulphate. This spray was found particularly effective against the apple powdery mildew. It also possessed the very desirable property of stimulating a vigorous foliage growth, but it was found that serious injury in the form of leaf shedding and fruit dropping might result unless great care was exercised in applying it. Subsequent investigations showed that of the three compounds contained in this iron-sulphid mixture the precipitated sulphur is the ingredient which gives the preparation its properties as a fungicide, and it is at the same time responsible for the physiologic effects seen in the fruit and foliage shedding and in the stimulation of a more vigorous foliage growth. Pure precipitated sulphur used in amounts equivalent to that contained in the iron-sulphid mixture produced effects similar in all respects to those obtained from the iron-sulphid spray, and the same was true of colloidal sulphur, which is sulphur in a much more finely divided form than precipitated sulphur. Similar results were obtained from still other mixtures containing very finely divided sulphur.

From these investigations, which extended over several seasons, it became evident that aside from their power to control mildew, precipitated and other very finely divided forms of sulphur were capable of producing what may be termed sulphur effects. These sulphur effects are of a physiologic nature, and their intensity is

---

[1] Volck, W. H. The apple powdery mildew in the Pajaro Valley. Office of County Entomologist for Monterey and Santa Cruz Counties, Cal. Special Bul. No. 1. 1909.

[2] The expression "iron-sulphid spray" or "iron-sulphid mixture" will be used in this publication to refer to the mixture prepared from iron sulphate and lime-sulphur solution. The compound sold by chemical dealers under the name of iron sulphid is an entirely different substance and is of no value as a spray material.

proportional to the sulphur content of the spray mixture employed. If the first spraying is delayed until the apples are an inch or more in diameter and a spray mixture containing a relatively large amount of sulphur is used, a heavy shedding of fruit and foliage may be expected to follow. The leaves that fall are turgid and green and look in all respects fresh and normal. In bad cases the foliage shedding may be so severe as to leave the trees bare. The fruit that drops is also normal in appearance and may amount to 50 per cent of the crop. The loss of foliage is usually more than replaced by the vigorous production of new, extra-large leaves. Spraying with very weak mixtures brings about an increased foliage growth without causing leaf dropping. It is therefore evident that this unusual foliage production is not a reaction to any leaf pruning caused by spraying.

It might seem that the increased foliage growth is only the normal production of new growth to be expected as a result of the mildew control. That this, however, is not the case and that sulphur spraying has an actual stimulating effect seems to be a clearly established fact. Plate V, figure 1, shows two twigs from a tree that was not sprayed until considerable growth had been made. The first leaves that came out in the spring, those at the bases of the twigs, were of fair size. Gradually, as the new leaves appeared, they became more and more infected with mildew, and when the twigs had grown to the length indicated by the letter *T* in the figures, the leaves were small, distorted, and badly diseased. Very little more growth could have been expected. At that time the tree was sprayed with a mixture made by dissolving sulphur in carbon disulphid and emulsifying this solution with ammonia soap. Such a spray leaves a very fine coating of sulphur all over the foliage. Almost immediately growth was resumed and conspicuously large leaves were sent out. The photograph reproduced as Plate V, figure 1, was taken some time after the spraying was done, and no spray had been applied meantime. In other words, the extra growth of leaves took place after the spray was applied and their large size was not due to killing any mildew that was on them or to preventing infection, because they were not out at the time the spraying was done, and therefore they received none of the application. Thus, it seems evident that the spraying itself stimulated a new growth of foliage.

One type of fruit injury that may result from sulphur spraying is shown in Plate VI, figure 1. A strong dosage of iron-sulphid mixture was applied after the fruit had become partly grown. Shortly after the application was made there were several days of very hot weather, and on the exposed sides of the fruit, where the hot sun had an opportunity to act on heavy sulphur deposits, the skin and outer layers of the flesh became brown and leathery. Mild cases of such injury have very much the appearance of ordinary sun scald, but when the damage becomes more serious the growth of the affected area is checked and the fruit cracks open. This type of injury has developed only occasionally, and then only when a strong dosage of sulphur or iron-sulphid mixture has been used. No such damage has ever been produced by the weak dosages of sulphur that are recommended in this bulletin for mildew control.

When it became evident that the tendency to cause fruit and foliage dropping was one of the general properties of these finely divided forms of sulphur, attention was turned to the investigation of a large number of other materials, in the hope that some substance might be found which would prove as effective as sulphur against the mildew and yet be free from the injurious property of causing fruit and foliage to drop. Among such substances tested, the most satisfactory results in mildew control were obtained from a number of dye materials. Fifty or more commercial dyes and laboratory stains were tested, and it was found that a number of them, when applied in water solutions, were capable of staining the mycelium and killing the mildew. Such sprays, however, are curative rather than preventive in their action, and while, with the exception of eosin, no injurious physiologic effects were encountered, their fungicidal properties were not entirely satisfactory.

Meantime, investigations with the iron-sulphid and other precipitated sulphur sprays were continued, and it has been found that by using weak mixtures, starting the spraying early, and repeating it frequently a very satisfactory mildew control can be obtained without danger of causing fruit to drop. Thus, after six years of investigations, in which 250 or 300 spraying experiments were conducted and over 100 different materials tested, sulphur in some very finely divided form still remains the most satisfactory fungicide for use against apple powdery mildew in the Pajaro Valley.

It may be repeated here that those forms of sulphur known commercially as sublimed sulphur, or flowers of sulphur, sulphur flour, and ground sulphur are far too coarse to be effective. Sulphur in its colloidal form gives excellent mildew control and possesses some distinct advantages of its own, especially in the matter of covering power. Certain difficulties involved in its preparation, however, prevent the grower from making his own supply. Precipitated sulphur may be made in a number of different ways, but what is here called the iron-sulphid mixture is the simplest and safest form in which the grower can prepare it.

FIG. 1.—YELLOW NEWTOWN APPLE TREE, UNSPRAYED AND UNPRUNED, SHOWING SCANTY FOLIAGE, SMALL LEAVES, AND BARE, MILDEWED TIPS.

Photographed in August, 1911.

FIG. 2.—YELLOW NEWTOWN APPLE TREE NEAR THE ONE SHOWN IN FIGURE 1, SHOWING THE RESULTS OF ONE SEASON'S SPRAYING WITH IRON-SULPHID MIXTURE. UNPRUNED.

Note the abundance of foliage, the size of the leaves, and the scarcity of mildewed tips. Photographed in August, 1911.

YELLOW NEWTOWN APPLE TREE, UNSPRAYED AND UNPRUNED, SHOWING SCANTY FOLIAGE, SMALL LEAVES, AND MILDEWED TIPS.

Photographed in August, 1911.

YELLOW NEWTOWN APPLE TREE NEAR THE ONE ILLUSTRATED IN PLATE II, SHOWING THE RESULTS FROM TWO YEARS' SPRAYING WITH IRON-SULPHID MIXTURE.

Note the abundance of foliage, the size of the leaves, and the scarcity of mildewed tips. Photographed in August, 1911.

FIG. 1.—YELLOW NEWTOWN APPLE TWIGS.

Practically the entire bark and leaf surface of most of the twigs is covered with mildew. The badly diseased leaves are long and narrow. Many have died and dropped off. Patches of perithecia are seen at *p*. Photographed in July, 1911.

FIG. 2.—YELLOW NEWTOWN FLOWERS AND TWIGS.

The cluster of flowers (A) is completely covered with mildew. Photographed April 15, 1913. The twigs (B), similar to those in figure 1, show stunted growth and enlarged diameter of the diseased portion. *a* and *a′* are diseased laterals sent out from infected buds after the ends, *e*, of the previous year's growth had died back. Photographed in July, 1911.

FIG. 1.—YELLOW NEWTOWN APPLE TWIGS.

The trees were unsprayed until the twigs were of the length indicated at T. The vigorous growth from that point on resulted from a single application of a carbon disulphid and sulphur emulsion. Photographed June 12, 1911.

FIG. 2.—YELLOW NEWTOWN APPLE TWIG.

Typical mildewed foliage, showing the stunting and crinkling. (After Volck.)

FIG. 1.—YELLOW NEWTOWN APPLES, SHOWING SULPHUR INJURY.

This injury resulted from the hot sun acting on the heavy deposit of iron-sulphid mixture. Photographed in August, 1911.

FIG. 2.—YELLOW NEWTOWN APPLE TWIGS.

Typical appearance of twigs developing from dormant-bud infections. A thick, powdery layer of summer spores is shown on the twig at the left. A patch of perithecia is shown at *p*. Photographed in July, 1911.

PREPARATION OF THE IRON-SULPHID MIXTURE.

The following directions are for the preparation of sufficient stock iron-sulphid mixture to make 500 gallons of spray: Fill a 50-gallon barrel about two-thirds full of water. Weigh out 10 pounds of iron sulphate (copperas), place in a sack, and suspend in the water. The iron sulphate will dissolve fairly rapidly, and when it is all in solution measure out carefully 2¼ gallons of commercial lime-sulphur solution testing 33° Baumé, or 2 gallons and 3 pints of a lime-sulphur solution testing 32° Baumé. Slowly pour all but 2 pints of the lime-sulphur solution into the iron-sulphate solution in the barrel, stirring the mixture vigorously with a hoe or shovel. The addition of the lime-sulphur solution will produce a bulky, black precipitate, and when all but 2 pints of the lime-sulphur solution has been added the mixture should be allowed to stand for a few minutes, when the black precipitate will begin to settle and a little of the clear liquid at the top can be carefully dipped out with a clean glass or cup. This clear liquid will probably show no yellow lime-sulphur color, which means that an excess of lime-sulphur solution has not yet been added. In other words, there is still some iron sulphate in solution, in which case the addition of a drop of lime-sulphur solution to the clear liquid in the glass will produce a black precipitate. This means that more lime-sulphur solution should be added to the stock in the barrel, and about half of the remaining 2 pints should now be poured in and the contents of the barrel stirred vigorously and allowed to stand. Some of the clear liquid should again be dipped off and tested as before, to determine whether an excess of lime-sulphur solution has been added. If necessary, the addition of small quantities of lime-sulphur solution should be continued until some of the clear liquid dipped from the top, after the contents of the barrel have been well stirred and allowed to settle, shows a pale yellowish lime-sulphur tint. The purpose of using a slight excess of the lime-sulphur solution is to insure all the iron sulphate being utilized. The voluminous black precipitate that is formed consists of iron sulphid, precipitated sulphur, and calcium sulphate. After a slight excess of lime-sulphur solution has been added, the barrel should be filled with water and the contents stirred thoroughly and allowed to stand for several hours. The black iron-sulphid mixture will settle into the lower half or third of the barrel, and the clear liquid should be poured off by carefully and gradually tipping the barrel, without allowing any of the black precipitate to run out. The barrel should again be filled with water, the contents thoroughly stirred and allowed to stand several hours, and the clear liquid poured off as before.

This operation of washing the precipitate should be repeated until the water poured off no longer shows the yellow lime-sulphur tinge. Probably three or more such washings will be required, depending upon how careful the operator has been in using only a slight excess of lime-sulphur solution.

It is evident that the preparation of this stock supply should be commenced two or three days before the spraying is to be done, but when once prepared it may be kept indefinitely. If care is used in weighing out each lot of iron sulphate and if the lime-sulphur solution used is accurately measured there will be no trouble in making up the stock supplies rapidly after the first two or three batches have been prepared, and it will be remembered that each batch is sufficient for making 500 gallons of spray mixture. In order to keep a supply of the stock mixture on hand, several batches should be prepared before the spraying commences, and as rapidly as a barrel is emptied the preparation of a new batch should be started. Iron sulphate is comparatively cheap, and the entire cost of materials for preparing 100 gallons of the mildew spray, when diluted according to the recommendations given in this bulletin, should not exceed 15 or 20 cents.

When the washing has been completed, the stock barrel should be filled with water to exactly 50 gallons. The material is now ready for use as directed under "General formula for the spray mixture," on page 17, but care should be taken to stir the contents of the barrel thoroughly each time before any of the mixture is taken out.

IMPORTANCE OF EARLY SPRAYING.

Attention has been called to the fact that the apple foliage is subject to mildew attack shortly after it begins to come out in the spring. The serious fruit dropping that may result from delaying the first application until after the fruit is an inch or more in diameter has been discussed, and attention has been called to the possibility of developing sulphur immunity or resistance to injurious sulphur effects by beginning the spraying early and repeating it at intervals of two to three weeks. Also, it has been stated that these sulphur sprays have a distinct stimulating effect on foliage growth and that the mildew is more readily controlled on vigorously growing trees. Thus there are a number of reasons for making the first spray application early in the season, namely, to protect the very early foliage from mildew, to develop immunity to sulphur injury and thus avoid serious fruit dropping later in the season, and to bring about sulphur stimulation, thus inducing a vigorous early growth of foliage. Furthermore, it has been found that precipitated sulphur acts as a restrainer of the arsenical foliage injury that in the Pajaro Valley frequently results from the use of acid arsenate of lead applied after the early foliage has developed.

SPRAYING FOR APPLE SCAB.

Considering the climatic conditions of the Pajaro Valley, one might expect apple scab to become a serious disease of the fruit, and for that reason its relative absence is the more striking. Occasionally scab does considerable damage in scattered orchards, but in those in which the writers have carried on investigations in its control it has never been sufficiently abundant to make the experiments satisfactory. It is therefore not of sufficient importance in this district to require regular attention in spraying. Apple scab, in the degree in which it is present, is the only fungous disease of the fruit occurring in the Pajaro Valley.

GENERAL FORMULA FOR THE SPRAY MIXTURE.

Stock iron-sulphid mixture [1]	20 gallons.
Arsenicals and nicotine solution to be added	as required.
Water, to make	200 gallons.

When arsenicals and a nicotine solution are to be used in conjunction with the iron-sulphid mixture, the combined spray may be prepared by first running about 150 or 160 gallons of water into the spray tank. The agitator is then started and the 20 gallons of stock iron-sulphid mixture is poured in, after which the nicotine solution and the arsenicals may be added in the usual way. Sufficient water should then be added to make 200 gallons.

This same strength of iron-sulphid mixture, namely, 20 gallons in 200 gallons of spray, is to be used in all of the mildew applications. It will be seen that the 20 gallons of stock mixture used in each 200 gallons of spray contains the product from 4 pounds of iron sulphate. If commercial iron-sulphid preparations or other commercial products containing sulphur in very finely divided form are employed, they should be used in such quantities as to give the same sulphur content as the above amount of iron-sulphid mixture, or, better, the optimum dosage for mildew control should first be determined by experiments, since the fineness of the product will influence its effectiveness and therefore the amount to be used.

SPRAYING SCHEDULE.

The following spraying schedule for the control of apple powdery mildew has been worked out for the Pajaro Valley in particular, but

[1] See page 15, "Preparation of the iron-sulphid mixture."

it can undoubtedly be modified when necessary to meet the local requirements of other districts in which the disease may demand treatment. No recommendations regarding the use of insecticides are given, but it will be understood that the arsenicals and nicotine solutions which can safely be employed should be added in the proper amounts required for insect control at the various times when the mildew applications are made. This statement applies equally well to other districts than the Pajaro Valley. Several years of experimental and commercial spraying have demonstrated that the various arsenicals commonly employed, and also nicotine solutions, can be combined with the iron-sulphid mixture without affecting the insecticidal or fungicidal value of any of the materials.

FIRST APPLICATION.

The first application should be made at the time of and in conjunction with the first spraying for the control of the codling moth, and the combined spray, containing iron-sulphid mixture and the necessary insecticides, should be prepared as directed under "General formula for the spray mixture," on page 17.

The object in making this first application of the iron-sulphid mixture so early in the season is to develop sulphur immunity, which will lessen the danger of fruit and foliage dropping that might result from the subsequent sprayings, and to keep the early foliage protected from the mildew.

SECOND APPLICATION.

The second application should be made in conjunction with the second spraying for the control of the codling moth, and the kinds and amounts of insecticides regularly employed in this second codling-moth spraying should be added, as directed under "General formula for the spray mixture," on page 17.

In some apple-growing districts it may be found that on account of the rapid growth of the early foliage large numbers of mildew infections will become established on the leaves during the interval between the first and second sprayings. In that case it will undoubtedly be advisable to make an application of iron-sulphid mixture, 20 gallons of the stock mixture diluted to 200 gallons of spray, about 10 days after the petals fall. The sulphur stimulation of foliage growth resulting from these early sprayings is a very important factor in insuring vigorous foliage conditions later in the season. The writers have had opportunity to observe the decided improvement in foliage vigor on blocks that received these early treatments as compared with other portions of the same orchard that were not given the first spraying with iron-sulphid mixture until relatively late in the spring.

THIRD APPLICATION.

The third application should be made three weeks after the second, and the insecticide regularly employed at that time should be added to the spray mixture, as directed under "General formula for the spray mixture," on page 17.

FOURTH APPLICATION.

The fourth application should be made three weeks after the third, and the insecticides commonly employed at that time should be added to the spray mixture, as directed under "General formula for the spray mixture," on page 17.

SPRAYING METHODS.

In the spraying schedule here recommended it will be noted that the intervals between the applications are never greater than three weeks. In order to avoid any risk of causing sulphur injury in the form of fruit dropping it is very important that strict attention be given to the timing of the application, and, if necessary, the intervals should be made less rather than greater than three weeks. Obviously the weak dosage of iron-sulphid mixture recommended will not bring as marked and rapid mildew control as a stronger one would; but if the spraying is consistently and regularly done good results will surely be obtained, and it has been a noticeable fact that when a portion of an orchard is given this treatment for one year that portion, as compared with the remainder of the orchard, has shown decided improvement when the trees leaf out the following spring. Such an effect is probably partly physiologic and partly the result of mildew control, and its bearing on the general condition of the trees is evident.

Too much can not be said regarding the value and importance of thoroughness in spraying. A very large proportion of the men who handle the spray rods have, to say the least, a very inadequate conception of a satisfactory job of spraying, and when it is remembered that every leaf is susceptible of mildew attack, the importance of taking time to do a thorough job should be apparent.

Equipment is an important factor in good work. While practically all the spraying in the Pajaro Valley is done with power outfits it is entirely out of the question to spray a hundred-acre orchard with a single machine and finish the work in anything like schedule time. Attention has been called to the great number of twig infections in the upper parts of the trees, which means that care should be taken to spray the tops thoroughly. Spray rigs having towers are not used in the Pajaro Valley, and it has been necessary to depend upon long spray rods for reaching the tops of old trees. This deficiency can be largely overcome by using angle nozzles of a type that throw a long, solid cone of driving spray. Such a type of nozzle is illustrated in figure 5. The writers wish to lay particular stress on using angle nozzles, which are so constructed as to throw the spray at an angle of 45° from the spray rod. Much more thorough work can be accomplished with such a nozzle, for by turning the rod it is possible to spray from below or above and from either side. Care should be taken to cover thoroughly the lower sides of the leaves, since that is where most of the mildew infections take place.

The spray deposit on the foliage protects the leaves from infection and kills out any patches of mildew that may be present. However, summer spraying is of comparatively little value in cleaning virulent twig infections, such as are shown in Plate IV, figures 1 and 2, and Plate VI, figure 2. This phase of the disease must be dealt with by another method, which will be discussed under "Pruning."

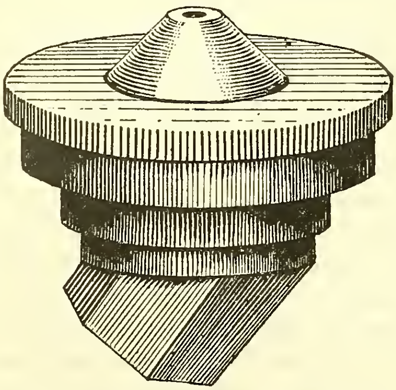


Fig. 5.—An excellent type of angle spray nozzle. The liquid enters the eddy chamber through an opening at the side and also through a hole in the center, directly under the orifice of the conical tip. By this construction a long, slender, solid cone of driving spray is produced.

WINTER SPRAYING FOR STIMULATION.

Two years of experimental work have demonstrated that winter spraying with fungicides is of no appreciable value in controlling apple powdery mildew. Attention has been called to the fact that the mildew attacks vigorous foliage much less severely than it does that which is puny and slow growing. In this connection the value of the foliage stimulation obtained from summer spraying has been pointed out, and it is evident that if a stimulation of vigorous spring growth can be brought about by a winter spray, just that much will be added to the success of the mildew treatment, as well as to the improvement of the general condition of the trees. As a matter of fact, it has been found that spraying during the dormant period with crude-oil emulsions, as commonly practiced in the Pajaro Valley for scale-insect control, will stimulate a vigorous early growth of foliage the following spring. Occasionally a few buds are injured by the oil, but material damage is very rarely noticeable.

PREPARATION OF CRUDE-OIL EMULSION.

Crude-oil emulsion, ready for applying, is prepared as follows:

Water	175 gallons.
Fish-oil soap	10 to 12 pounds.
Lye (caustic soda)	2 pounds.
California crude oil	25 gallons.

The materials are to be mixed in the spray tank in the order given and with the agitator in motion. The fish-oil soap should be dissolved in hot water before adding it to the 175 gallons of water in the tank, and for the first trial 10 pounds should be used. The required weight of lye may be added directly to the soap solution in the tank, allowing a few minutes for it to dissolve before pouring in the 25 gallons of crude oil. A light-brown emulsion should be formed as soon as the crude oil is added, and none of the oil should remain floating on the top of the mixture. Very little agitation is required to keep the oil emulsified, and the mixture is ready for immediate use. If the crude oil does not emulsify properly—that is, if some of the oil floats on the surface or if the mixture seems to contain small globules of oil—the preparation has not been successful. The trouble may be due to a lack of sufficient soap, in which case the remaining 2 pounds should be dissolved in hot water and poured into the tank. In some cases, when very hard water is used, a little extra lye may be required, and in rare cases it is necessary to use less than the 2 pounds. Occasionally a little difficulty is experienced in preparing the first tank of spray, but when the proportions of soap and lye are once determined there will be no trouble in making the emulsion.

It will be noted that the above formula gives a 12½ per cent crude-oil emulsion. Such a mixture must be used only when the trees are entirely dormant, preferably during January. The spraying should be very thoroughly done, so as to produce a uniform, shiny, dark-brown coating over the entire surface of the twigs and branches. It may be well to repeat the statement that this winter spraying with crude-oil emulsion is not for the direct purpose of controlling the mildew, but is intended as a stimulant which will induce the production of vigorous early foliage, and this latter is of decided importance in mildew control.

Investigations that are still in progress seem to indicate that under some conditions dormant spraying with solutions of nitrate of soda plus caustic soda will be more desirable than crude-oil spraying.[1]

---

[1] Ballard, W. S., and Volck, W. H. Winter spraying with solutions of nitrate of soda. Journal of Agricultural Research, v. 1, no. 5, p. 437–444, pl. 50–51. 1914.

PRUNING.

The subject of pruning demands consideration because of its bearing on the problem of mildew control.

Attention has been called to the abundance of mildewed tips that can be seen during the dormant period. From the infested buds on these tips large numbers of seriously diseased shoots develop the following spring, and the question of eliminating them is a very important one, because on them are produced the enormous numbers of spores which serve to infect the healthy foliage as soon as it appears. Pruning offers the only practical solution of this problem, because, as has been stated, summer spraying is not effective in cases in which the entire twig and its leaves have become badly mildewed. The reason is that it is impossible to wet the entire mildew covering thoroughly, the spray collecting in drops, even when the operator is successful in wetting all parts of the shoot and its leaves. Particular attention should therefore be given to cutting out the mildewed tips, and that work should be made a part of the regular dormant-pruning operations.

It has been stated that trees that are growing vigorously and producing large, thrifty leaves are less seriously affected by mildew than poorly growing ones, even though they are of the same variety. One of the commonly recognized effects of winter pruning fruit trees is the improvement in growth and foliage conditions that result the following year. The apple is not an exception in this respect, and the improvement in vigor that can thus be obtained by pruning should be taken advantage of in combating the mildew.

To obtain the full benefits of winter pruning in the Pajaro Valley greater attention should be given to thinning out the trees. This should not be done by cutting out large framework limbs, but by pruning out far more brush than is ordinarily removed. Interlacing branches should be removed, and the current year's growth should be cut back one-third to one-half, or even more in the case of very young trees or very vigorously growing shoots. There is a tendency to allow the lower branches to become so long that they droop almost to the ground. It is true, as usually claimed, that the best fruit is borne on these lower branches, but that condition has been brought about largely by the fact that the tops of the trees have become badly affected by mildew or have lost their vigor through other causes. For these reasons it is important that the tops of the trees should be cut back as well as thinned out, so as to increase their vigor. The long spindling branches in the lower parts of the trees should be gradually shortened and the vigorous young twigs should be cut back so as to induce fruiting.

It will be understood that at the same time that this general pruning is being done very careful attention should be given to removing all mildewed tips. In fact, the pruning for mildew can be most conveniently done during the dormant period, because the grayish mildewed tips can be most easily seen when the foliage is off the trees. To do it thoroughly requires patience and very careful searching for the diseased tips, many of which are not more than an inch long and may occur on short lateral spurs. Even after the most careful work it will be found the following spring that some mildewed tips have been left and are sending out diseased shoots. These, however, can be removed with very little extra labor at the time the fruit is thinned. Even when no attempt is made to keep the mildewed tips cut out, it has been found that far less of them develop in orchards that are well sprayed and cared for than in those that are poorly sprayed and improperly cared for, and from these facts it should be seen that by giving careful attention to both pruning and spraying the number of mildewed tips can be reduced to a minimum.

It has been stated that in thinning out the trees large limbs should not be removed. Of course, there will necessarily be some exception to this rule, but in general, especially in the cases of the Yellow Bellflower and Yellow Newtown varieties, when limbs more than an inch and a half in diameter are cut off there is great danger that a serious wood-and-bark disease locally known as "sappy bark" will develop. This trouble appears at the wound and travels down the limb, eventually reaching the trunk and killing the tree. It causes a characteristic puffing and sloughing off of the bark, and the wood underneath becomes mushy. Disinfecting and painting the wounds have been found ineffective in preventing the disease, and when once started, cutting below the diseased portion does not eradicate it. The cause is unknown. Limbs an inch and a half or less in diameter can be removed without much danger of the disease appearing, and in winter pruning the heavy cutting should be confined as far as possible to that size or smaller.

In practicing the pruning methods outlined here, it might appear that a considerable proportion of the crop will be sacrificed by cutting out bearing wood. It is necessary to thin the fruit thoroughly almost every year, however, and the pruning will serve, in a measure, as a thinning operation. Moreover, the fruit will be found to size up better, especially after the system has been in use for two or three years.

It is true that a considerable annual expense will be incurred in keeping up the pruning of a large orchard of 20-year-old trees according to the plan outlined here. However, that expense will be greatest by far during the first year, when an extra-large quantity of mildewed tips and superfluous branches must be cut out.

If necessary, the work may be started on a part of the orchard and additional portions or rows included each year. Meantime close attention must be given to spraying.

CONCLUSIONS.

The orchards of the Pajaro Valley in California suffer more from apple powdery mildew than do those of any other large apple-producing district in the United States. The disease attacks the foliage and also the bark of the young twigs, but does not directly injure the fruit. It is therefore impossible to estimate the amount of commercial damage done, but since as much as 90 per cent of the foliage on trees of susceptible varieties may become diseased it is evident that such trees must eventually have their capacity for production lowered, either as a result of the vitality of the trees being reduced, or, more directly, because the annual growth and consequent increase in bearing surface is less than normal. The importance of giving proper attention to control measures is still further emphasized by the fact that the disease recurs regularly year after year and gradually acquires a stronger foothold if its progress is not checked.

The climatic conditions of the Pajaro Valley are peculiarly different from those of other large apple-growing sections, and their bearing on the general problem of mildew control may be summarized as follows:

(1) They are responsible for a peculiarly sensitive physiologic condition of the trees, (*a*) which is manifest in the extreme sensitiveness of the foliage and fruit to spray injury of one form or another, and (*b*) which appears to be evidenced by the pronounced susceptibility of the foliage to mildew attack.

(2) They influence directly the prevalence of the disease and the damage done by it, in that they furnish favorable conditions for the spread and development of the fungus.

(3) They supply conditions favorable to the breaking down of many compounds that are employed in spray mixtures and at the same time furnish conditions for the solution and the absorption of those decomposition products by the foliage. Thus, indirectly, the weather furnishes extreme conditions for the development of certain types of spray injury.

The fungus *Podosphaera leucotricha*, which causes apple powdery mildew in the Pajaro Valley, winters in the lateral and terminal buds of badly mildewed twigs. The shoots that develop during the following spring from these infected dormant buds soon become more or less covered with mildew, and spores are produced in enormous numbers. These spores give rise to the first infections of the healthy foliage. Therefore, one of the most important steps in the control of apple powdery mildew is the elimination of these early twig infections which develop from the diseased dormant buds. Cutting out the mildewed twigs on which the infected buds are borne is the only successful method of dealing with this phase of the problem. Fortunately, this work can be done during the dormant season, for the grayish mildew covering remains on the diseased twigs, making them readily distinguishable from the healthy ones even after the leaves have fallen. The cutting out of the mildewed twigs should therefore be made an important part of the regular pruning operations.

Vigorous foliage is less susceptible to mildew attack than that which is puny and slow growing. One method of obtaining vigorous foliage is by winter pruning; hence, because of the value of vigorous foliage in the problem of mildew control, as well as for the betterment of the general condition of the trees, a more thorough system of pruning should be practiced in the Pajaro Valley. An increased vigor of foliage growth is also obtained by the spraying methods recommended in this bulletin.

Precipitated sulphur or sulphur in other extremely finely divided forms is the most satisfactory fungicide to use in foliage spraying for the control of apple powdery mildew.

In the Pajaro Valley several different effects may be obtained from spraying with such a finely divided form of sulphur, as follows:

(1) If the diseased areas are thoroughly covered with the spray mixture, the mildew will be killed out. A deposit of spray on the healthy foliage will prevent the establishment of new infections. As has been noted on a previous page, it is practically impossible, by spraying, to clean up satisfactorily those virulent cases of leaf and twig infection in which both the upper and lower surfaces of all the leaves, as well as the bark surface itself, become covered with mildew. The solution of this phase of the problem is in pruning out these mildewed twigs during the dormant season.

(2) Sulphur acts as a stimulant and induces the production of a vigorous growth of new foliage.

(3) Spraying with strong mixtures or allowing too long an interval to elapse between sprayings may, under Pajaro Valley conditions, result in serious foliage and fruit dropping, though in the East no such damage from sulphur spraying has thus far been reported.

(4) Spraying at frequent intervals with weak mixtures causes the tree to develop what the writers have termed an immunity to the damaging sulphur effects noted in the preceding paragraph.

(5) Finely divided sulphur in the spray mixture acts as a restrainer in reducing the tendency of zinc arsenite or acid arsenate of lead to produce the arsenical burning of foliage.

Winter spraying with crude-oil emulsion, as practiced in the Pajaro Valley at the present time, has been found effective in stimulating a vigorous growth of early foliage the following spring. Because of this stimulation, the use of crude-oil emulsion as a dormant spray offers valuable assistance in the general program of mildew control, for, as has been stated, vigorous foliage is less affected by the disease.

It is probable that investigations now in progress will show that in some cases dormant spraying with solutions of nitrate of soda plus caustic soda is more desirable than crude-oil spraying.

SUMMARY OF CONTROL METHODS.

By way of summarizing the above conclusions it may be stated that there are three distinct phases of the method of controlling apple powdery mildew as outlined in this bulletin:

(1) Foliage spraying with iron-sulphid mixture, precipitated sulphur, or sulphur in some other very finely divided form.

(2) Winter pruning of trees (*a*) for the purpose of obtaining the general stimulating effects that come from pruning at that time and (*b*) directed particularly toward the eradication of mildewed twigs.

(3) Winter spraying with some spray that has the effect of inducing a vigorous foliage growth in the spring.

The practice of careful and thorough summer spraying year after year will gradually bring about a much-improved condition of the trees, but for the best results the entire method, as outlined above, must be followed.

Finally, it will be remembered that the results, statements, and recommendations recorded in this bulletin are based chiefly on experiments and observations made in the Pajaro Valley, in California; and, because of the somewhat extreme conditions obtaining in that valley, it will probably be found desirable to vary the recommendations here given to suit the local conditions and requirements of other apple-growing districts in which the disease may become sufficiently prevalent to require attention. In some sections, for instance, summer spraying alone may provide a satisfactory control of the disease, and in certain districts it will probably be found possible to increase the amount of stock iron-sulphid mixture used to each 100 gallons of spray.

The various effects of sulphur which have been discussed, such as fruit and leaf dropping and stimulation of foliage growth, may not develop as strongly in other districts as they do in the Pajaro Valley, but before attempting to use very much stronger dosages of sulphur than those recommended in this bulletin careful consideration should be given to the possibility of causing sulphur burning on the fruit. In any case, it will probably be found necessary to repeat the mildew spraying at intervals of three weeks or less during the entire period in which the trees are putting out new foliage.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 121

Joint Contribution from the Bureau of Plant Industry, William A. Taylor, Chief; and the Office of Markets, Charles J. Brand, Chief.
June 24, 1914.

SPINNING TESTS OF UPLAND LONG-STAPLE COTTONS.[1]

By Fred Taylor, *Cotton Technologist;* and Wells A. Sherman, *Assistant in Market Surveys.*

INTRODUCTION.

Only three years ago the long-staple cotton situation as it then existed in the United States was considered acute by spinners. The Mississippi Delta and the lowlands of Louisiana, which for a generation had been the principal source of supply for cottons ranging from $1\frac{1}{8}$ to $1\frac{1}{2}$ inches in length, had been invaded by the boll weevil with disastrous results. So complete was the destruction that considerable areas in Louisiana entirely abandoned the production of cotton. Throughout southern Mississippi and the lower half of the Delta region, early maturing, short-staple varieties were being rapidly introduced because they were found to be more profitable under weevil conditions than were the long-staple varieties then in cultivation. The spinners besought the Department of Agriculture to assist in an effort to maintain the staple industry in the Mississippi Delta. They also raised funds to be expended under their direction in experimental work with the hope of developing new varieties of Delta staple cotton which could be produced profitably in the presence of the weevil.

Those engaged in the breeding work of the Department of Agriculture were already satisfied that excellent Upland cottons of $1\frac{1}{4}$-inch staple could be produced on the Atlantic slope, but the experiences

[1] The work discussed in this bulletin was carried on as a part of the work of the Office of Cotton Handling and Marketing Investigations conducted jointly by the Bureau of Plant Industry and the Office of Markets. The tests were conducted and supervised in detail by Mr. Fred Taylor, Cotton Technologist, Department of Agriculture, who received every possible courtesy and assistance from the faculty of the New Bedford Textile School. Managing Director W. E. Hatch and Principal William Smith, in charge of the carding and spinning department, rendered special assistance. The facilities of the school were generously placed at the disposal of the department for the purposes of these tests, and due acknowledgment is made of the material assistance thus rendered the investigational work.

Note.—This bulletin is a report of tests of Upland long-staple cotton as compared with Deltas of the 1912 crop. Of interest to spinners and growers of Upland cotton on the Atlantic slope.

of the spinners with so-called long-staple Carolina uplands had been unsatisfactory.

Subsequent investigation seems to indicate that this was because most of the so-called staple cottons produced in this territory had been grown from seed brought over from the Mississippi Delta, which was not acclimated. No adequate care had been taken to keep such importations pure by preventing cross-pollenization in the field or mixing of seed at the gin. Furthermore, few ginners in the Carolinas, outside the Sea Island belt, were familiar with staple cotton, and much of that which they handled was seriously injured in the ginning process.

There were, however, in the Carolinas a few careful breeders who had taken up systematic selection and breeding work with the best strains obtainable of the Columbia variety, which had been developed and introduced by the Department of Agriculture some years before. At the same time this department was developing the Durango cotton in the West. This variety is especially adapted to the irrigated regions of the extreme Southwest and has given excellent results on river bottoms in Texas and in other favorable locations having sufficient moisture. It has recently been grown with marked success as far north as Norfolk, Va.

With the sudden decrease in the staple production of the Delta, Carolina breeders found sale for their best qualities at very satisfactory prices, which stimulated greatly the planting of staple varieties in areas previously given over almost entirely to short cotton. A study of the quality of the staples produced for some years past in certain parts of the Carolinas and of the prices received seems to indicate that the few spinners who understood the true character and value of these cottons added largely to their profits by quietly absorbing the entire output at prices very much below those prevailing for corresponding qualities grown in the Delta. A very large number of spinners, however, still hold to the opinion that Upland staple cottons grown in the Carolinas and Georgia are wholly inferior to those grown in the Delta. They believe the Eastern staples to be more "wasty," that is to say, that they contain a larger proportion of short fibers which will be taken out as waste in the manufacture of combed yarns. The department's breeders have satisfied themselves, by examination in the field, that the best of the new Upland varieties are fully equal in uniformity of staple to the average "Deltas" or "Peelers" of the same length.

The results of the experiments here recorded show the character of the best Upland staples grown in the East to be sufficiently high to warrant spinners in being less conservative in buying them.

It must be remembered that these are the first tests in a new field of investigation. Too sweeping and far-reaching conclusions should not be drawn until corresponding tests can be made from the crops of other years and on samples of the same varieties grown under different conditions.

In order to determine how the best strains of the new varieties actually compared in spinning value with Delta cottons, arrangements were made in the fall of 1912 for conducting a series of spinning tests in cooperation with the New Bedford Textile School, New Bedford, Mass. Owing to the miscarriage of two bales in transit, the tests, which were made in May, 1913, included only five bales. These represented four different varieties or strains grown in three entirely distinct regions of production. Two of the bales are of similar origin and represent an early and a late picking, with different methods of handling the seed cotton. The tests showed these Upland cottons to be of such high quality that publication of the results was withheld with the intention of making similar tests on a much larger number of samples and varieties from the crop of 1913. Such tests should show whether the exceptional quality of some of the bales in the first experiments was due in any degree to seasonal conditions.

A very serious situation, however, now confronts the long-staple cotton growers in the Southeast, in view of the fact that the crop the Delta suffered comparatively little from weevil injury during the past season. The prejudice of the spinners still persists against Upland staple from the Southeast, the movement of the crop of 1913 has been exceedingly slow, and during the latter part of the picking season prices were very little above those of short cottons. There is a serious disposition to abandon the long-staple industry just as it is becoming well established on a thoroughly sound basis in the new territory. These conditions make it advisable that both spinners and growers be given all the information in the possession of the department concerning the value of the new Upland staples. The results of the spinning tests thus far made are accordingly presented herewith.

THE VARIETIES TESTED.

The five bales of cotton actually tested were: One bale of Durango, grown on the Brazos bottoms near Waco, Tex.; one bale of Columbia, grown by C. H. Carpenter, near Easley, S. C.; one bale of Lewis, grown by E. P. Lewis, of Gastonia, N. C.; two bales of Webber, grown by E. W. Evans, Bennettsville, S. C., from highly-bred seed produced by J. L. Coker & Co., Hartsville, S. C. Of these two bales, Webber No. 1 was from cotton ginned in November immediately after picking, and Webber No. 2 was from a pile of about 6,000 pounds of seed cotton picked about October 1 and stored six weeks before ginning.[1]

[1] For history of this storage experiment see: Brand, C. J., and Sherman, W. A., Behavior of seed cotton in farm storage. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 123–B. 1913.

The Durango is a variety developed by the Department of Agriculture from a selection made from cotton which came originally from the State of Durango in Mexico. The staple of the bale tested was $1\frac{3}{16}$ inches and the grade good middling.

The bale of Columbia from Easley, S. C., was from a selected strain of that variety carefully bred by Mr. Carpenter. It stapled $1\frac{3}{16}$ inches and graded strict good middling. The season had been adverse in this locality, and this cotton was not as long as is frequently produced by the same strain under more favorable conditions.

The bale of Lewis cotton was obtained from the originator of this variety, who is unable to give a detailed account of its origin beyond the fact that it was developed from a single plant which is believed to have been originally of Delta stock. The entire production of this variety has up to the present time been consumed by local mills. The bale tested stapled a full $1\frac{5}{16}$ inch and graded good middling.

The Webber variety has been developed by Mr. D. R. Coker, of Hartsville, S. C. The original plant was selected from the Columbia variety and was pointed out to Mr. Coker by Dr. H. J. Webber, then of the Bureau of Plant Industry, as closely approximating his ideal of what a Columbia cotton plant should be. By systematic selection Mr. Coker has decidedly improved the length of the staple and has named his strain "Webber" in honor of the originator of the Columbia variety.

It is fair to state that other strains of Columbia in the hands of skillful breeders have shown similar improvement over the original type. The two bales of Webber tested were grown under high fertilization and intensive cultivation by an excellent farmer and represent what may be expected of this variety under favorable cultural conditions. They graded middling and each stapled $1\frac{5}{16}$ inches.

After the bale of Durango cotton was purchased it was brought to the attention of the department that the grower had not been taking measures to maintain the purity or standard of the variety, but had grown it for a number of years in fields adjacent to short-staple varieties. This may account in some measure for the large percentage of short fiber found. It was, however, then too late in the season to secure a bale of better parentage.

SOIL TYPES REPRESENTED.

The Durango grew on Texas river-bottom land heretofore given over entirely to the production of short staples. The Lewis and Columbia were grown in the Piedmont section of North Carolina and South Carolina at elevations of 800 feet or more, while the Webber was produced in the level, Pee Dee River section of the

Carolina Coastal Plain, at an elevation of about 150 feet above sea level.

The tests included, therefore, not only four comparatively little-known varieties or strains, but also represented three distinct producing areas, none of which are generally believed by the cotton trade to be well suited to the production of staple cotton.

It was planned to compare the results obtained from these varieties of Upland long staple with a test on the same machines of Mississippi Delta cotton of similar grade and staple, but before this could be done the textile school closed for the summer vacation.

On February 16, 1914, a finisher picker lap was secured from one of the New Bedford mills, which was believed to represent an average blend of $1\frac{1}{4}$-inch Delta cotton. This lap was composed of a mixture of five different bales, one each from Black Bayou and Beulah, Miss., and Laconia, Henrico, and Archillion, Ark. These bales graded as follows: One bale strict low middling, two middling, and two good middling, and the staple was a full $1\frac{1}{4}$ inch. It was thought that such a composite sample of Delta cotton would more nearly represent an average commercial quality.

The same machines with the same adjustments and settings were used for the Delta test as for the other tests, so that the results should be comparable.

VARIATIONS IN GRADE AND STAPLE.

It will be noticed that three of the bales tested were $1\frac{5}{16}$-inch staple, while two were $1\frac{3}{16}$ inches. There were two middling, two good middling, and one strict good middling bales, while the Delta cotton was a mixture of three grades. Our purchases were made so late in the fall of 1912 that it was impossible to secure all the bales of the same grade, and the difference in grade will account for the great differences in the percentage of waste on the opener, breaker, intermediate, and finisher pickers and card as shown in Table I.

TABLE I.—*Percentage of waste removed at each machine in the picking and carding processes.*

	Variety.					
	Durango, grade G. M.	Columbia, grade S. G. M.	Lewis, grade G. M.	Webber No. 1, grade M.	Webber No. 2, grade M.	Delta blended.
Staple (inches)	$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$1\frac{1}{4}$ full.
Breaker picker	1.125	1.125	.875	2.75	2.50	[1]
Intermediate picker	1.48	.77	.90	1.57	1.57	[1]
Finisher picker	.50	.57	.63	1.26	1.43	[2] 3.70
Card	3.96	4.13	3.70	5.20	5.81	7.03
Total	7.065	6.595	6.105	10.78	11.31	10.73

[1] Not itemized.

[2] Inasmuch as a picker lap was purchased, it is impossible to show the invisible loss in the picker room or the itemized picker waste for the Delta sample. The total picker waste had, however, been ascertained by the mill.

DIFFERENCES IN LENGTH OF STAPLE.

These tests were designed to determine approximately the relative amounts of waste in the several varieties and the breaking strength of yarns made from them. The Delta was included so that comparison of results could be made not only with the ordinary commercial calculations for $1\frac{1}{4}$-inch cotton similarly handled, but also with actual tests of such cotton made on the same machines. Each of the five bales tested in this experiment was run on the same machines and with absolutely the same settings, so that the data were strictly comparable in every way throughout. Notwithstanding the fact that the staple of the different samples varied from $1\frac{3}{16}$ to $1\frac{5}{16}$ inches, they were all put through the machines with the settings used for $1\frac{1}{4}$-inch cotton, because each of the varieties tested is believed under favorable conditions to be in competition with $1\frac{1}{4}$-inch Delta staples. The Columbia and Durango were apparently at a disadvantage in this test, because with their shorter staple they would naturally give an increased percentage of waste. Table I shows, however, that the total picker and card waste was very nearly in proportion to grade, the Lewis apparently being slightly better than the others.

THE INVISIBLE LOSS.

The invisible loss, which is shown in Table II, is caused chiefly by loss of moisture and also to some extent by dust and short fibers which are lost in the air during the operation of stripping at the card. There is no appreciable invisible loss after the cotton has passed through the card, as all dust, short fly waste, and excessive moisture have been removed. The percentage of humidity maintained affects the amount of invisible loss, as the greater the humidity in the mill the more moisture will be retained in the cotton within certain definite limits. There being no humidifying apparatus in the picker, card, and comber rooms at the New Bedford Textile School, the humidity during these tests could not be regulated. It will be seen in Table II that the invisible loss is greater in the low grades, probably because they contain more dust and light trash.

TABLE II.—*Percentage of invisible loss at each machine in the picking and carding processes.*

	Variety.					
	Durango, grade G. M.	Columbia, grade S. G. M.	Lewis, grade G. M.	Webber No. 1, grade M.	Webber No. 2, grade M.	Delta blended.
Breaker picker	1.875	0.375	1.125	1.75	2.00	(1)
Intermediate picker	.58	.77	.38	.78	.52	....
Finisher picker	.071	.144	.49	.31	.57	....
Card	.503	1.31	.48	1.49	.72	0.62
Total	3.029	2.599	2.475	4.33	3.81	....

[1] No invisible loss is shown for the Delta cotton up to the card, as this sample was started at that machine. This blend contained one strict low middling, two middling, and two good middling bales.

CARD WASTE.

The function of the pickers is to remove from the cotton all the heavier impurities such as sand, hulls, stems, bunches of neppy fibers, broken seed, etc., while the card removes the smaller impurities such as neps, tangled fibers, minute particles of trash and leaf, and a small percentage of short fibers. The card waste is itemized in Table III.

Table III.—*Percentage of each type of card waste obtained from each variety.*

	Variety.					
	Durango, grade G. M.	Columbia, grade S. G. M.	Lewis, grade G. M.	Webber No. 1, grade M.	Webber No. 2, grade M.	Delta blended.
Stripping waste [1]	0.69	0.85	0.73	1.12	1.82	1.62
Flat stripping waste [2]	2.41	2.53	2.40	2.62	2.54	3.64
Licker in and screen waste [3]	.86	.75	.57	1.46	1.45	1.77
Total card waste	3.96	4.13	3.70	5.20	5.81	7.03

[1] Card stripping waste is composed of short fibers that slip down in the spaces between the wires of the card clothing. This waste is chiefly composed of fibers up to about ⅜ to ½ inch in length with some longer fibers.

[2] Flat stripping waste is composed of neps, tangled fibers, gin-cut or damaged fibers, motes, and all those fibers that do not readily disentangle and which adhere to the flats.

[3] Licker in and screen waste is composed of extremely short fibers and minute particles of seed, sand, leaf, stalks, etc., and those fibers that fly from the general mass and drop through the screens underneath the card.

RELATION OF GRADE TO WASTE.

When the cotton has passed the card almost all foreign matter has been removed. The greater part of those fibers below three-eighths to one-half inch in length have also been separated. A glance at Table I will show that the Webber bales contained from 4 to 5 per cent more foreign matter than the other three, but it must be noted that the grade of these two is middling, while the others are good middling and strict good middling. The mixture of Delta cotton, which averaged slightly better than middling, compares closely with Webber. Thus 4 to 5 per cent on a 500-pound bale amounts to 20 to 25 pounds of cotton waste. This at 20 cents per pound amounts to $4 to $5 per bale, a difference equal to 80 to 100 points in value.

It is now of interest to compare the waste percentages up to and including the card in the case of the two middling bales with that of the two good middling bales. The total waste itemized in Tables I, II, and III is obtained by adding the picker waste, card waste, and invisible loss. The two middling bales show an average of 15.11 per cent, and the good middling an average of 9.34 per cent, a difference of 5.77 per cent in favor of the good middling. However, it must be stated that this does not represent the true relation of values between grades, as there are a number of other factors which influence more or less the value of cotton to a spinner. If we compare a 500-pound bale of middling with a 500-pound bale of good middling on the basis of the above percentages, ignoring tare, we find that the middling bale produces 424.45 pounds of yarn or thread, while the good middling produces 453.30 pounds. These figures show a difference in the amount of finished product of 28.85 pounds, which represents an important item to the manufacturer, as this 28.85 pounds, if it had not been removed as waste, would have appeared as finished yarn and thus would be worth the value of the finished product. Again, the machines must be operated just as long, at the same or greater cost to the mill, to produce the 424.45 pounds from the middling bale as they are to produce the 453.30 pounds from the good middling bale.

Again, the machines can not run as fast or produce as much when running on low grades as when on the higher grades. Therefore it is apparent that increased labor charges per pound accrue on a decreased outturn of production. This is due to the increased percentage of waste and necessarily slower speeds, and it is necessary either to operate with a lower production or to overcome these factors by running double shifts of operators on some processes or by increasing the equipment for these processes, either of which is an expense to the manufacturer, and adds its influence to the relation of values between the grades.

Again, on account of the increased amount of foreign matter in the lower grades such machines as the picker and card require more frequent cleaning or "stripping." This necessitates more frequent stoppage of the machinery for this purpose, especially of the cards, which reduces production and increases cost. It should be remembered also that the low grades of staple cotton have only a very limited use in the regular or so-called white lines of goods. It is sometimes the custom to mix low grades of off-colored cottons in very small quantities with the better grades. If a great number of low-grade bales should be put through the mill simultaneously the color of the yarn or cloth would likely be of such character as to be considered by the trade as undesirable, or difficult to bleach, or to dye with such delicate shades as are sometimes used. This attitude of the trade accounts largely for the discrimination against the low-grade staples. It is a question how far this discrimination should be carried, as frequently these low grades, after being cleaned of their excessive trash, are almost as valuable to the spinner as the better grades.

Summarizing these statements it seems that every increase of waste or of labor necessary and every per cent by which production is decreased increases the final cost per pound to the mill. The important fact is that even with a reduced production all overhead or fixed expenses at the mill, such as heat, light, power, clerical force, fixed salaries, insurance, etc., continue on the basis of the larger production. Thus it will be seen that other factors than the percentage of waste in the different grades should and do influence the values of those grades to the spinner.

COMPARISONS AT THE COMBER.

Since all these samples were put through the same machinery under identical speeds, drafts, and weights per yard, it is assumed that they arrived at the comber with approximately similar waste contents. The percentages shown on the comber, therefore, should be strictly comparable. It must be borne in mind that the five tests were performed without the slightest mechanical alteration on the comber, which was so adjusted as to remove 13 to 15 per cent waste or short fiber from 1¼-inch cotton under ordinary mill conditions. The Delta sample was put through the same machine with the same settings about 10 months later.

TABLE IV.—*Actual comber waste with the 13 to 15 per cent setting.*

	Variety.					
	Durango, grade G. M.	Columbia, grade S. G. M.	Lewis, grade G. M.	Webber No. 1, grade M.	Webber No. 2, grade M.	Delta blended.
Comber waste, per cent	13.01	10.71	8.08	13.07	11.56	12.92

It will be seen that the greatest difference occurs between Webber No. 1 and the Lewis samples, viz, 4.99 per cent, or practically 25 pounds of cotton per bale. At 20 cents per pound this equals $5, and would justify a premium for the Lewis of nearly 1 cent per pound.

One of the most interesting results of this test is the wide variation shown by these varieties in the percentage of short fibers removed by the same machine. It was to be expected that the Delta cotton would compare favorably with Eastern long staple varieties, but it is seen that with a comber setting of 13 to 15 per cent this lot is among the three bales showing the largest percentage of waste. The highest percentage of waste removed from any one bale exceeded the waste removed from the Delta sample by only fifteen hundredths of 1 per cent, while the Delta loss exceeded that of the Columbia by 2.21 per cent and that of the Lewis by 4.84 per cent. The average loss of the two Webber bales was 12.32 per cent as compared with 12.92 per cent loss by the Delta, which was composed of 5 typical bales from as many Delta markets. It seems probable that had these 5 Delta bales been tested separately instead of in a mixture, some of them would have proved inferior to any of the Upland bales tested.

The Columbia and the Lewis varieties appear very much superior to the other bales tested in "body" or uniformity, and give results far better than the usual mill estimate for cottons of their lengths. The geographical comparison is interesting. The commercial calculation was for a loss of 13 to 15 per cent. The one Texas bale lost 13.01 per cent; the five Delta bales mixed, 12.92 per cent; the four Carolina bales averaged 10.105 per cent.

COMBER TESTS WITH WIDE SETTINGS.

After these tests were completed, the combing machine was adjusted so as to remove 23 to 25 per cent waste and another test of each bale was made with the following results:

TABLE V.—*Percentage of fiber removed as waste from each sample with comber at 23 to 25 per cent setting.*

	Variety.					
	Durango, grade G. M.	Columbia, grade S. G. M.	Lewis, grade G. M.	Webber No. 1, grade M.	Webber No. 2, grade M.	Delta blended.
Comber waste, per cent	20.43	16.15	12.15	21.81	18.10	16.15

The most remarkable thing about these tests is the great difference between varieties in the amount of comber waste and the very low waste content of Columbia and Lewis.

The widest range between bales occurs between Webber No. 1 and Lewis, viz, 21.81 and 12.15 per cent, a difference of 9.66 per cent in the amount of short fibers removed. These two bales were approximately the same in length of staple. This difference is equivalent to almost 50 pounds of cotton per bale. At 20 cents per pound this is equal to $10, or 2 cents per pound.

Samples of cotton from these two bales were shown to a large number of brokers and others, and the opinion generally expressed was that, by the method of "classing" or stapling ordinarily employed it was practically impossible to distinguish between them, in spite of the fact that the difference in waste would equal 50 pounds per bale.[1]

[1] Cook, O. F. The relation of cotton buying to cotton growing. U. S. Department of Agriculture, Bulletin 60. 1914.

It is noteworthy that the actual waste obtained was in every case decidedly below the usual mill estimate for this wider setting. The Lewis bale again showed the least waste, while the Columbia and the Delta lost identical percentages.

Averaging the two Webber bales we have the following showing for the five varieties as compared with the arbitrary commercial or standard expectation of 24 per cent of loss at this setting. The order of excellence then appears as follows: The Lewis showed an actual loss of 11.85 per cent less than the standard. Columbia and Delta each showed 8.85 per cent less. Webber showed 4.04 per cent and Durango 3.57 per cent less, respectively.

Compared geographically the Texas bale showed a total waste on the wide setting of 20.43 per cent; the Delta, five bales mixed, lost 16.15 per cent; the Carolina staples, four bales averaged, lost 17.05 per cent. Special attention is called to the fact that the bale of Columbia which exactly equaled the Delta in this test was one-sixteenth inch shorter cotton than any of the others, save Durango, and must have possessed superior uniformity, else it would have lost more than the longer staples.

The very slight superiority shown by the Delta over some of the Carolina staples at this wider setting does not offset the much greater superiority of the Carolinas over the Deltas at the 13 to 15 per cent setting, the latter being more frequently used in actual millwork.

NUMBER AND UNIFORMITY OF TESTS.

A study of the large number of percentage tests and weighings made on each variety, as shown in Table VI, ranging from 17 on Lewis to 36 on Webber No. 1, shows conclusively that at no time during the run on any bale was the variation sufficient to cause any uncertainty as to the amount of short fiber contained in the sample. The widest variation between any two weighings on the same variety is found in the Durango, namely, 1.48 per cent. In the Delta the widest variation was 1.43 per cent. Even under the most ideal conditions the machinery builders never claim for their combers less than about 2 per cent variation for different runs on the same cotton, even on the best Peelers and Egyptians. It appears, therefore, that each of the varieties tested was practically uniform throughout the entire run made upon it, such variation as occurred being within the limits of error of the machine. The weighings or tests were made at intervals of 10 to 20 minutes during a two to three day run on each bale.

TABLE VI.—*Actual percentages of waste on all comber tests with 13 to 15 per cent setting, with totals and averages.*

Durango.	Columbia.	Lewis.	Webber No. 1.	Webber No. 2.	Delta.
13.73	10.94	7.69	13.7	11.4	12.93
13.79	10.66	7.74	13.7	11.8	12.57
13.39	10.51	9.00	13.5	11.8	12.57
13.20	10.33	7.94	13.5	11.8	12.37
12.64	10.30	8.24	13.0	11.9	13.33
13.72	10.61	8.35	12.4	11.4	12.43
13.79	10.93	8.19	12.7	11.5	13.50
12.40	10.70	7.75	13.0	11.6	12.83
12.60	10.50	8.37	12.5	11.7	12.65
13.30	10.64	8.14	12.4	11.6	13.10
13.77	10.80	7.70	12.5	11.2	12.26
13.01	10.88	7.70	13.0	11.6	13.42
12.53	10.61	8.19	12.8	11.7	13.69
12.89	10.51	8.11	13.2	11.6	13.14
12.91	10.14	7.91	13.5	11.1	12.75
12.73	11.12	7.94	13.5	11.1	13.16
12.99	11.24	8.34	13.5	11.0	12.86
13.01	11.41		13.5	11.3	12.69
12.98	10.84		13.0	11.7	12.54
12.80	10.61		13.2	11.5	12.45
12.31			12.9	11.8	13.43
12.54			12.8	11.8	13.53
12.91			12.8	11.7	
12.36			12.8	11.9	
			13.0	11.6	
			13.1		
			13.3		
			13.0		
			13.3		
			13.0		
			13.0		
			12.9		
			13.0		
			13.2		
			13.2		
			13.1		
[1] 13.01	[1] 10.71	[1] 8.03	[1] 13.07	[1] 11.56	[1] 12.92

[1]Average.

DETAILS OF THE TESTS AT THE WIDE SETTING.

The machinery was run for approximately one full day on each bale at the 23 to 25 per cent setting, and test weighings were made at a little less than hourly intervals. The uniform quality of each bale is again shown, the variations being little greater than at the closer setting.

TABLE VII.—*Actual percentages of short fiber removed as waste with comber set to remove 23 to 25 per cent, by individual tests.*

Durango.	Columbia.	Lewis.	Webber No. 1.	Webber No. 2.	Delta.
19.32	15.45	12.01	21.21	17.97	15.55
19.58	15.03	11.92	21.27	17.16	15.70
20.50	16.29	12.19	21.34	18.75	15.73
20.84	15.91	11.73	21.14	18.63	15.62
20.60	16.00	12.27	22.64	18.38	16.18
20.96	15.43	12.64	22.18	18.18	16.74
20.69	16.64	12.79	22.81	17.94	16.63
20.39	16.82	11.66	21.87	17.81	16.54
21.08	16.79				16.84
	17.09				
[1] 20.43	[1] 16.15	[1] 12.15	[1] 21.81	[1] 18.10	[1] 16.15

[1] Average.

VALUE OF WASTE DIFFERENCES.

In order that the relative values may be shown, the difference in percentages has been converted into pounds on the basis of a 500-pound bale. In Table VIII the second column shows the waste that would have been removed if the comber had taken out the theoretical amount. The third column shows the pounds actually removed. The fourth column shows the difference between these two. The last column shows the actual value of this difference per bale of cotton, at 20 cents per pound, this being an average price when the cotton was bought.

Table VIII.—*The commercial calculation and actual comber waste removed per 500-pound bale at 13 to 15 per cent setting, with value of difference, in dollars, per bale.*

Variety.	Commercial calculation at 14 per cent.	Pounds actually removed.	Difference in pounds.	Difference in value at 20 cents per pound.
	Pounds.			
Durango	70	65.05	4.95	$0.99
Columbia	70	53.55	16.45	3.39
Lewis	70	40.40	29.60	5.92
Webber No. 1	70	65.35	4.65	.93
Webber No. 2	70	57.80	12.20	2.44
Delta	70	64.60	5.40	1.08

It must be remembered that the actual value per pound of the cotton after it has passed the comber is considerably more than 20 cents. There is at least 5 per cent tare on the bale. Table I shows an average loss of picker and card waste of 8.76 per cent. Table II shows an average invisible loss of 3.25 per cent, and Table IV shows an average comber waste of 11.56 per cent on the 13 to 15 per cent setting. Adding these losses, we get a total of 28.5 per cent tare and waste removed from the combed cotton, so that the actual value of the product from the comber with this setting is not 20 cents, but at least 25.71 cents per pound.

In addition to these losses in weight there has accrued a labor charge of at least 2 cents per pound and an overhead or fixed charge of like amount, so that the net cost to the mill of the combed cotton is about 30 cents per pound.

If the amounts for the last column of Table VIII are figured on a value to the mill of 30 cents per pound, the results show the additional worth of the Durango to be $1.38 per bale; of the Columbia, $4.93; of the Lewis, $8.88; of the Webber No. 1, $1.39; of the Webber No. 2, $3.66; and of the Delta, $1.62. These are based on the commercial calculation for the 13 to 15 per cent setting.

Only a part of this waste is an absolute loss to the spinner, as the card and comber wastes are sold to coarse-goods mills, waste factories, mattress factories, etc. Ordinarily the bagging and ties sell for about one-half to 1 cent per pound. Some of the picker waste brings one-half to 2½ cents per pound. Flat strips sell for 60 to 70 per cent of the value of middling Upland cotton. Card strippings are worth 70 to 80 per cent of the value of middling, and comber waste from the better grades usually sells at the price of middling Upland cotton.

The second column in Table IX shows the waste that would have been removed if the comber had taken out the theoretical amount with the 23 to 25 per cent setting. The third column shows the pounds actually removed. The fourth column shows the difference between these two, while the last column shows the actual value per bale of this difference at 20 cents per pound, the price actually paid for this 1¼-inch cotton.

TABLE IX.—*The commercial calculation and actual comber waste per 500-pound bale at 23 to 25 per cent setting, with value of difference in dollars per bale.*

Variety.	Commercial calculation, at 24 per cent.	Pounds actually removed.	Difference in pounds.	Difference in value at 20 cents per pound.
	Pounds.			
Durango	120	102.15	17.85	$3.59
Columbia	120	80.75	39.25	7.85
Lewis	120	60.75	59.25	11.85
Webber No. 1	120	109.05	10.95	2.19
Webber No. 2	120	90.50	29.50	5.90
Delta	120	80.75	39.25	7.85

Again, the figures shown in the last column are those for raw cotton at 20 cents per pound. However, in order to get the actual value of the difference at this point we must now take into account, as before, the tare, waste on pickers and cards, the invisible loss, and the average actual comber waste of 17.46 per cent on the 23 to 25 per cent setting. These various factors make a total of 34.47 per cent loss when the cotton has passed the comber, so that the actual value of the cotton from the comber is not 20 cents, but 26.90 cents per pound. Adding again the labor and overhead charges the cost to the mill of the cotton from the comber will be about 31 cents. Therefore, if the values as shown in the last column of Table IX are calculated on the basis of 31 cents per pound the Durango would be worth, per bale, $5.53; the Columbia, $12.26; the Lewis, $18.36; the Webber No. 1, $3.39; the Webber No. 2, $9.14; and the Delta, $12.26 more than the commercial calculation on the 23 to 25 per cent setting.

A comparison of the values given in the last column in Table VIII shows that all the Carolina cotton, if averaged on the 13 to 15 per cent setting is better than the commercial calculation by $3.17 per bale, while the Delta is $1.08 better. This shows a difference of $2.09 per bale in favor of the Carolina staple cottons as against the Delta, while on the 23 to 25 per cent setting the average of the Carolina cotton shown in the last column in Table IX is $6.95, and that of the Delta $7.85, a difference of 90 cents per bale, in favor of the Delta on the wider setting.

The grade of the samples being tested does not appreciably affect the quantity of the comber waste, as is shown by comparing Durango and Lewis, both of which are good middling, but which show a difference of 8.28 per cent in comber waste on the 23 to 25 per cent setting.

ACCURACY OF THE MACHINE WORK.

The following mathematical formulæ show that the variations in percentages between the 13 to 15 per cent and 23 to 25 per cent settings on the bales showing highest and lowest waste are consistent with the mechanical changes involved:

$25 \div 15 = 1.66$, the ratio between the two settings.

$21.81 \div 13.07 = 1.668$, the ratio between the two percentages actually obtained on the Webber No. 1.

$12.15 \div 8.08 = 1.504$, the ratio between the two percentages actually obtained on the Lewis cotton.

The mechanical construction of the comber is such that all fibers up to any desired length are taken out, so that these results represent fairly the inherent value of each bale tested, when used for fabrics which require combed yarns. If later tests substantiate the findings of this report, namely, that these bales are representative of inherent differences in the varieties represented, as there is every reason to assume, the great importance to the spinner of knowledge concerning the varieties of cotton purchased for his mills will be fully demonstrated. It is not safe to assume, however, that the same differences will be found between representative bales of these varieties when the latter are grown under radically different climatic conditions. In other words, uniformity may prove to be a much more constant characteristic of some varieties than of others.

FACTORS INFLUENCING WASTE.

There are a multitude of factors which influence the percentage of waste in such tests as those here discussed. If cotton is picked and ginned while damp, or is ginned at too high speed, even the best varieties may be so damaged as to show large percentages of card and comber waste. The mixing of long and short staple seed, at the gin or otherwise, results in the production of cotton lacking uniformity or "body."

After the cotton has reached the mill it is still possible to get varying results from the same bale by running the beaters too fast, thus breaking the fibers, by feeding too heavily, or by operating with improper adjustments of beater grids, or by allowing too strong an air current on the pickers.

On the card it is possible to get a wide variation in results, even when the machine is supposed to be adjusted accurately. The reason for this is that the most important settings or adjustments are made anywhere between five and fifteen one-thousandths of an inch. A difference of one or two thousandths will measurably affect the per cent of waste. It is therefore apparent that only the most painstaking care can obviate these possibilities of error. Again, if the speed of certain parts of the card is varied, or if a heavier lap is fed, or if the grinding of the steel wire clothing of the cylinder, doffer, or revolving flats is neglected, or if the stripping of these is too infrequent, a varying amount of waste will result.

At the comber a number of conditions may cause a variation in the amount of waste. Among these are differences in speed, in the angle of the top comb, in the distance between the nippers and the detaching rolls, in the weight of the lap, in the rate of feed, the timing of the parts, etc. If any of these factors are changed, even in a slight degree, a different result is obtained. The temperature and humidity also affect the results of such tests.

Items enough have been enumerated to show the possibility of error in tests of this nature. However, as all of these tests were made on the same machines, and all except the Delta, at the same time, and without the slightest mechanical change, the results obtained are strictly comparable as to five samples and very closely comparable as between these and the Delta.

TESTS OF BREAKING STRENGTH.

Table X shows the breaking strength in pounds per skein of the carded and combed yarns. All varieties were spun into 50s yarn, and the twist per inch was calculated as follows: The standard twist factor for filling yarns being 3.25, this factor, multiplied by the square root of the counts (50s) gives the twist per inch thus: $\sqrt{50}=7.07$; $7.07\times3.25=22.97$ turns per inch.

In preparing the yarn for these breaking strength tests it is the custom of the trade to reel off a skein containing 120 yards. The reel is 54 inches in circumference, and when the skein is attached to the testing machine it is an endless length of yarn. This skein is hung upon two hooks and when the tester is started these hooks begin to draw slowly apart. The strength of the skein is registered on a dial.

TABLE X.—*Breaking strength in pounds per skein of carded yarns and of combed yarns resulting from the 13 to 15 per cent comber settings.*

Variety.	Staple.	Carded yarn.	Combed yarn.	Difference.	
				Pounds.	Per cent.
Durango	$1\frac{3}{16}$	24.03	33.07	8.94	37.6
Columbia	$1\frac{3}{16}$	25.56	34.50	8.94	34.9
Lewis	$1\frac{5}{16}$	34.93	41.92	6.99	20
Webber No. 1	$1\frac{6}{16}$	25.88	32.12	6.24	24.1
Webber No. 2	$1\frac{5}{16}$	26.13	33.47	7.34	28.1
Delta	$1\frac{1}{4}$	32.98	42.05	9.07	27.5

The last column of this table shows that the combed yarn ranges from 20 to 37.6 per cent stronger than the carded. The increased breaking strength of the combed yarn is due to the fact that most of the short fibers have been removed by the comber. It is safe to assume that fabrics made of combed yarns possess better wearing qualities than similar fabrics made of carded yarns.

An analysis of Table X shows that there was but slight difference in strength between the yarns made from Durango, Columbia, and Webber. These varieties, whether spun from the carded or combed cotton, appear to be closely comparable in this respect. The Lewis and Delta varieties, however, here show a marked superiority over the others, their breaking strength being from 25 to 33 per cent greater in carded yarns and slightly more than 25 per cent greater in combed yarns. The carded yarn from Lewis had a breaking strength practically 2 pounds greater than that from Delta, while the combed yarn from Delta was thirteen one-hundredths of a pound stronger than that from Lewis. It is notable that the yarns made from the Delta types, which are usually small-bolled cottons, were stronger than those from the big-bolled types, and that the Lewis, which seems to be an acclimated strain of Mississippi cotton brought several years ago to the Piedmont section of North Carolina, is fully equal in strength to the native Delta cottons.

CULTURAL CHARACTERISTICS.

The purpose of this publication is to show the comparative spinning values of the varieties tested, but it must not be assumed that their relative value to the farmer is the same as to the spinner. The Columbia, Webber, and Durango have much larger bolls than the Lewis and are much more rapidly picked. In a number of test plots, where single rows of 16 varieties of staple cotton have been grown for comparison, the Lewis has been among the lowest in yield and in gross value per acre when calculated at the same price, while Durango and Columbia have stood high. The percentage of lint to seed in the Lewis has been lower than in the Durango and Columbia. The department therefore can not recommend the Lewis variety for general planting in the Southeast except in cases where the grower is reasonably assured of a substantial premium. He should have a premium not only over the price of short cotton, but over the price paid for other Upland $1\frac{1}{4}$-inch cottons. If he can get a premium for his length of staple only, he can probably grow the more productive varieties with greater profit.

COMPARISON OF EARLY AND LATE PICKED COTTON.

It is interesting to follow the two bales of Webber through these tests and to note the differences between them. Both bales were middling in grade and came from the same field. Webber No. 1 was picked and immediately ginned during the early part of November, while Webber No. 2 was picked about one month earlier and was stored six weeks before ginning. The early picked bale shows better quality in the comber tests with both the close and wide settings. Adding picker, card, and invisible waste, we get for Webber No. 1, 15.11 per cent and for Webber No. 2, 15.12 per cent. These figures show that the grade governs the waste to this point. However, on the 13 to 15 per cent comber setting, Webber No. 1 lost 13.07 per cent and Webber No. 2, 11.56 per cent, a difference of 1.51 per cent in favor of Webber No. 2, while with the 23 to 25 per cent setting Webber No. 1 shows 21.81 per cent and Webber No. 2 shows 18.10 per cent loss, a difference of 3.71 per cent in favor of the cotton picked early and stored before ginning.

The values shown in the last column of Tables VIII and IX are also in favor of the Webber No. 2, as these values correspond with the percentage of comber wastes.

The average breaking strength of the Webber No. 2 is measurably greater than that of Webber No. 1, as shown in Table X.

We might infer from this showing that in normal seasons the earlier cotton is more desirable than the late pickings from the same field, even though the latter are of the same grade and have sustained no visible damage. There is a widespread belief that the length and strength of cotton increases when it is allowed to lie in bulk for some time between picking and ginning. In this test no difference in length was discernible, and the difference in the amount of short fiber taken out by the comber could hardly be attributed to storage. Greater strength is the only remaining factor of superiority in the Webber No. 2, and it is wholly unsafe to assume that this was due to storage. It would be necessary, in order to determine this point, to test bales picked at the same time, one of which had been stored in the seed, while the other had been immediately ginned.

CONSUMPTION OF STAPLE COTTON IN THE UNITED STATES AND CANADA.

In the fall of 1912 a letter was addressed to each of the cotton mills in the United States and Canada, asking for a statement of their average annual consumption of cotton of each of the different commercial staple lengths. Detailed replies were received from practically all of the mills, and the result of this inquiry is shown by States in Table XI. Some of the mills reported their exact consumption for the last preceding year; others reported their average consumption for a period of three to five years.

These figures can not be absolutely accurate, because one mill may designate its cotton as $1\frac{3}{16}$ inches, while another mill, using exactly the same cotton, might call it $1\frac{1}{4}$ inches.

Table XI represents as nearly as possible only Upland staples of American cotton. A special effort was made to secure separate reports on all Sea Island and Egyptian, and also of all cotton of $\frac{1}{16}$-inch staple or less.

It will be seen that the average consumption of Upland staple cotton of $1\frac{1}{8}$ inches or more in length is considerably over 1,000,000 bales, or more than one-fifth of the entire American consumption of raw cotton, the total number of bales consumed for the entire United States and Canada being reported as 5,429,916.

TABLE XI.—*Number of bales of cotton of each length of staple consumed annually by the mills of the United States and Canada.*

State.	$1\frac{1}{8}$ inches.	$1\frac{3}{16}$ inches.	$1\frac{1}{4}$ inches.	$1\frac{5}{16}$ inches.	$1\frac{3}{8}$ inches.	Total.
Alabama	8,437	2,100	1,500	.....	.....	12,037
California	2,000	500	.....	.....	.....	2,500
Connecticut	26,427	9,340	5,718	500	4,500	46,485
Georgia	36,555	12,020	3,600	.....	.....	52,175
Indiana	33,055	.....	.....	.....	.....	33,055
Kentucky	.....	500	700	.....	.....	1,200
Louisiana	11,000	.....	.....	.....	.....	11,000
Maine	47,400	9,950	150	950	80	58,530
Maryland	4,264	.....	.....	.....	.....	4,264
Massachusetts	248,035	41,924	25,158	3,434	16,578	335,129
Mississippi	3,100	.....	.....	.....	.....	3,100
Missouri	.....	.....	.....	6,381	.....	6,381
New Hampshire	147,809	.....	4,146	500	1,500	153,955
New Jersey	8,714	.....	900	.....	2,942	12,556
New York	2,000	814	1,500	.....	.....	4,314
North Carolina	76,290	25,300	16,600	5,000	2,400	125,590
Oklahoma	800	600	.....	.....	.....	1,400
Pennsylvania	2,619	30	1,000	.....	2,025	5,674
Rhode Island	86,248	14,869	15,145	4,843	6,138	127,243
South Carolina	26,932	5,100	8,984	6,250	1,000	48,266
Tennessee	1,400	.....	.....	.....	.....	1,400
Texas	5,070	500	.....	.....	.....	5,570
Virginia	.....	900	.....	.....	.....	900
Vermont	3,300	.....	1,200	.....	.....	4,500
Canada	65,979	2,000	2,000	.....	.....	69,979
Total	847,434	126,447	88,311	27,858	37,163	1,127,213

CONCLUSIONS.

These tests show that careful breeders in the Carolinas are producing cotton fully equal in almost every respect to average Deltas of the same length. They also show that several strains now grown in commercial quantities in the Southeast are less wasty than average Deltas, although not so strong. These varieties are earlier, have larger bolls, and are usually more prolific than Delta types.

These uniform varieties are the result of intelligent breeding work. The importance to the spinner of such work can hardly be overestimated. It suggests the wisdom of more direct dealing between spinners and careful producers, that the latter may be guaranteed suitable premiums for their superior products.

It is possible that there was some peculiarity in the season of 1912, either in the Delta or in the Southeast, which caused these tests to give exceptional results. Material is now in hand for more comprehensive tests on bales of several varieties grown in 1913. If the results of later tests confirm those already made, the wisdom of basing mill purchases on variety as well as upon grade and apparent staple will be fully demonstrated.

The greatest care on the part of buyers in "stapling" cotton will not reveal the difference between two samples which contain 10 and 20 per cent of comber wastes, respectively. If two competing mills were continuously supplied with these two qualities, the difference might easily mean wealth to the one and bankruptcy for the other. The methods now employed by the best cotton breeders enable them by field inspection to judge the uniformity of the cotton more accurately than can any buyer or spinner by examination of samples from the bale.

We seem to be rapidly approaching the time when it may be possible to standardize our pure varieties. If the spinner is wisely to serve his own interests he must modify his buying system in such a way as to see that superior varieties are recognized as varieties, not merely as cottons of a certain length or coming from a certain territory. Such recognition will stimulate pure-seed work and better cultural methods.

The system now prevailing in the primary markets does not assure the grower sufficient recognition of an exceptional product. The indifference of spinners to the improvement of our marketing system is the chief obstacle to a rapid increase in the production of pure-bred staple cottons of superior uniformity.

O

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 122

Contribution from the Bureau of Soils, Milton Whitney, Chief.
August 24, 1914.

(PROFESSIONAL PAPER.)

THE INORGANIC COMPOSITION OF SOME IMPORTANT AMERICAN SOILS.

By W. O. Robinson, *Scientist in Soil Laboratory Investigations.*

INTRODUCTION.

There is now recorded an enormous number of analyses of extracts of soils. These extracts have been prepared by treating the soil with aqueous solutions of acids, salts, various organic substances, and mixtures. There are, however, very few analyses available of the soil itself—that is, showing the total constituents, or the total amount of any particular constituent—and more especially are wanting such analyses made by quantitative methods of approved validity.

The advancement of soil and biological chemistry requires a knowledge of the actual chemical composition of the soil, including not only the common but the rarer elements. Such data are necessary for the comparison of soils and subsoils, for tracing the genetic relations of soils and rock materials, processes of soil formation, and for studying certain relations of soils and plants. The absorption of mineral nutrients, whether necessary to the plant or merely incidental or accidental, the possible functions of so-called catalytic fertilizers, and many other problems of the soil and plant require a definite knowledge of the mineral composition of the soil. The work presented in the following pages is a systematic investigation of those types of American soils which, for agricultural reasons, are of relatively greater importance. So far as reliable methods have been available, quantitative results are given.

SELECTION OF SOIL TYPES.

The classification of soils which has proved the most practical for field investigations and which is employed in the Bureau of Soils is

NOTE.—This bulletin gives the results of chemical and mineralogical investigations of certain important soils. The inorganic part alone is considered, and special attention is given to the so-called rarer elements. It is technical and intended for the use of research workers in agricultural chemistry and teachers in the same field. It will also be found of secondary interest to practical agriculturists.

46688°—14——1

based primarily on texture and other obvious physical properties. These qualities serve to divide soils into types which are further grouped into series and provinces. The provinces east of the Mississippi are as follows: Piedmont Plateau, Appalachian Mountain and Plateau, Limestone Valley and Uplands, Glacial and Loessial, Atlantic and Gulf Coastal Plains, and River Flood Plains.[1]

In the selection of samples for analysis only important agricultural types were chosen. They were selected to represent various textures, provinces, and conditions of fertility. A comparatively small number of soils were examined. Owing to the time-consuming character of the analysis and the inability to secure samples from places where field parties were not working, the samples do not represent as wide a range as desired.

DISTRIBUTION OF THE RARER ELEMENTS.

It would seem that all elements present in the rocks from which a soil is formed would be present in the soil, for the soil has been shown to contain all the more common rock-forming minerals.[2] While there is great change in chemical composition as a rock weathers to a soil, and much of the more soluble constituents are washed away, it is hardly conceivable that any one element should completely disappear. Had the mineral which contained this one element completely disintegrated, the weathered products might contain the element in an insoluble form, other elements might combine with it to form an insoluble compound, or in case none of these things happened, the soil possesses such a marked capacity for physical absorption that it is doubtful if it would yield the last traces of the soluble element to the soil solution. Further, the soil is by no means stationary, but is continually being translocated by wind and water.[3] It is evident that such processes add to the chemical complexity of the soil.

Provided methods of analysis were sufficiently delicate, we would expect to find in the soil every element for which it is examined, and it would seem, judging from the extreme complexity of the soil, that failure to find an element in the soil shows the method of analysis of insufficient delicacy rather than the absence of the element.

The distribution of the elements in igneous rocks is given by Washington,[4] special attention being paid to the elements in smaller amounts. From this work and from that of Clarke[5] and Hillebrand,[6]

[1] Bul. 96, Bureau of Soils, U. S. Dept. Agriculture (1913), upon which descriptions of the types are based.

[2] See F. K. Cameron and J. M. Bell, Bul. 30, Bureau of Soils, U. S. Dept. Agriculture (1905).

[3] For a full discussion see E. E. Free, Bul. No. 68, Bureau of Soils, U. S. Dept. Agriculture.

[4] Trans. Am. Inst. Min. Eng., 39, 735 (1908).

[5] Data of Geochemistry, Bul. 491, U. S. Geol. Survey (1911).

[6] Analysis of Silicate and Carbonate Rocks, Bul. 422, U. S. Geol. Survey (1910).

the following memoranda are taken concerning the distribution of the rarer elements in igneous rocks. Only those elements reported in the present work are considered.

BARIUM.

This element is found in feldspathic rocks and appears to be associated in some quantitative way with potassium. The occurrence of barium in soils has been very thoroughly treated by Failyer.[1] It was found wherever sought in all soils of the Great Plains, in amounts from 0.02 to 0.11 per cent expressed as the oxide. It was further qualitatively shown to be present in many soils east of the Mississippi. Of all the soils examined only two, the Orangeburg fine sandy loam and Houston clay, from Texas and Alabama, respectively, failed to give the barium reaction in the samples tested.

CÆSIUM.

This is the rarest of the alkalies. It has been found in spring water and reported in the ash of the sugar beet by Von Lipman,[2] and Vernadski[3] has found spectroscopic traces in feldspars and micas, so that in very small quantities at least it may be expected in rocks and soils.

CHROMIUM.

This element occurs more especially in the ferromagnesian rocks, though in small amounts. It has been reported in soils and the ash of plants.

COPPER.

Copper appears to be widely distributed and to be more abundant in the basic rocks. However, Hillebrand points out that there is great danger of contamination during the process of analysis by copper from numerous copper utensils employed. It has been reported in a number of plants to which it must have come from the soil.

LITHIUM.

Washington states that lithium often occurs in rocks high in sodium. It is widely distributed but seldom occurs in more than spectroscopic traces, except in its characteristic minerals.

MANGANESE.

Manganese is hardly to be considered as a rare element, though it is present in rocks and soils in small amounts. It is widely distributed. The analytical results for manganese in soils hitherto reported are probably inaccurate.

---

[1] Bul. 72, Bureau of Soils, U. S. Dept. Agriculture (1910).
[2] Ber., 21, 3492 (1889).
[3] Bul. Acad. St. Petersburg, 821 (1909).

MOLYBDENUM.

Hillebrand has found molybdenum to be present in the very siliceous rocks, though in amounts too small to determine quantitatively. Demarcay[1] has detected it in the ash of the grapevine and various trees, so that its occurrence in soils is possibly quite common even if in very minute quantities.

NICKEL.

Nickel occurs associated with cobalt in certain ferromagnesian rocks and in some sulphides. The amount present is very small. Like copper, there may be contamination with nickel during the process of analysis. Tending to an error in the opposite direction, however, is the known solubility of certain of its precipitates in the reagents employed.

RUBIDIUM.

This alkali has been reported in springs and brines. Vernadski[2] found it in spectroscopic traces in various feldspars and micas, and Pfeiffer[3] has reported it present in sugar beets and tobacco.

THE RARE EARTHS.

This group of elements appears to be associated with rocks high in silica and possibly sodium.

VANADIUM.

Demarcay[1] and Von Lipman[4] report vanadium in the ash of the grapevine, sugar beet, and various trees. It is widely distributed, more especially in the basic rocks, though in small amounts.

ZIRCONIUM.

Zirconium occurs in largest amounts in rocks high in silica and sodium. It rarely amounts to 0.2 per cent and is usually less than 0.05 per cent. Zirconium is present in soils as the silicate. A careful microscopic examination of any soil generally shows the presence of zircons.

PREPARATION OF THE SAMPLE.

The samples were collected from one or two spots considered typical by men familiar with the soil type. One hundred pounds of the surface soil, after taking off the sod, were collected, and then the subsoil taken directly underneath to a depth of 3 feet when rock strata did not make it impossible. Care was taken to keep the sides of the hole perpendicular. Only iron tools were used in the sampling and the samples were shipped in clean grain sacks.

---

[1] Compt. Rend., 130, 91 (1900).

[2] Bul. Acad. St. Petersburg, 1909, 821.

[3] Arch. Pharm. [2] 150, 97–102.

[4] Loc. cit.

When received at the laboratories the sample was spread on brown wrapping paper and allowed to air-dry. It was then passed through an iron sieve of 6 meshes to the linear inch. The soil clods not passing were crushed with a wooden rolling-pin on brown paper and passed through the sieve. The stones, sticks, roots, etc., were rejected.

The soil passing through the sieve was well mixed and quartered down to a subsample of 7 to 10 pounds. This was crushed in an iron mortar to break up the larger soil particles, such as iron and manganese concretions and the like. It was then quartered down to a sample of 50 grams, which was ground till it passed entirely through a silk bolting cloth of 100 meshes to the linear inch.

In this work of subsampling and grinding great care was taken, for it was recognized that in some cases the rarer elements were segregated in comparatively large pieces of their mineral species. For instance, manganese is often found in large concretions and zircons occur in fairly large, hard crystals. If such samples were not carefully ground and mixed, that portion taken for analysis might contain an undue number of these crystals or concretions.

NOTES ON THE METHODS OF ANALYSIS.

For the determination of the major constituents the soil was first ignited to destroy organic matter, then fused with sodium carbonate, following the procedure outlined by Hillebrand.[1] Where there were choices of different methods or special difficulties encountered, variations were adopted. Notes explaining these points are given below.

IRON AND ALUMINUM.

Generally soils are higher in iron and aluminum than rocks and contain but little manganese and comparatively small quantities of calcium and magnesium. The precipitate of the iron and aluminum group, obtained by the use of sodium acetate, is difficult to handle when large, and has a tendency to run through the filter. Although this part was filtered off when the filtrate from the iron group was concentrated, the precipitate of the calcium oxalate contained much more iron and aluminum than when the iron group was precipitated with ammonia. Accordingly precipitation of this group was made with ammonia. Manganese may have been present in the iron group precipitate, but in small quantity only, for nearly all was recovered in the ammonium sulphide precipitate, as shown by a comparison of the amount obtained in this way with the total amount determined by the use of hydrofluoric acid on another sample of the soil.

---

[1] Bul. 422, U. S. Geol. Survey (1910).

MANGANESE.

Contrary to the experience of Gortner and Rost[1] the method for the determination of manganese outlined by Hillebrand[2] has given excellent results. If the soil was finely ground and ignited prior to the treatment with hydrofluoric and sulphuric acids, the insoluble residue[3] contained only the merest traces of manganese, and in many cases gave no color whatever. The residue was fused with sodium carbonate with a very little niter, and in case the color indicated manganese the melt was dissolved in acid and oxidized to permanganate. In all cases the manganese in the residue was below 0.01 milligram of manganous oxide, MnO.

FERROUS IRON.

Ferrous iron is undoubtedly present in soils, for ferrous minerals are common constituents, as shown by microscopic examination.[4] But since organic matter is invariably present, no attempt was made to estimate ferrous iron, for there is a certainty that some ferric iron would be reduced during the analytical operations, and, further, if titration with permanganate solution were attempted some permanganate might be reduced by persisting organic matter. The iron is therefore calculated as ferric oxide.

LOSS ON IGNITION.

The loss on ignition is a figure difficult to duplicate, especially in soils high in iron and aluminum. Although the crucibles were subjected to a comparatively low temperature and an oxidizing flame, there was probably some reduction by the organic matter. Since the sum of the constituents is in most cases well over 100, it is probable that errors due to this cause were greater than those due to the imperfect dehydration of hydrated minerals.

SULPHUR.

The ignitions with sodium carbonate and nitrate for the determination of sulphur were made in an electric furnace, thus avoiding any contamination by the sulphur of a gas flame.

RARE EARTHS.

The results obtained for the rare earths are to be taken as qualitative in nature, that is, as showing the presence of the rare earths rather than the absolute amounts. However, work by different analysts

[1] J. Ind. Eng. Chem., 4, 522 (1912).

[2] Bul. 422, U. S. Geol. Survey, p. 116.

[3] This residue contained zircons, fluorides of calcium and the rare earths, barium sulphate, and, strange as it may seem, fragments of quartz.

[4] McCaughey and Fry, Bul. 91, Bureau of Soils, U. S. Dept. Agr. (1913).

agreed fairly well and concordant results were obtained by both the preferred and alternative method outlined by Hillebrand.

NICKEL AND COBALT.

These elements were found in determinable amounts in the first soils analyzed. Later in the work only traces were found. The crucibles in which the fusions were made had been previously used in fusions of material which had been precipitated from an ammoniacal liquid coming into contact with nickel plate. It is not impossible that some of the nickel reported in the first eight anaylses might have come from that previously absorbed by the crucible, although they were scrupulously cleaned by fusion with potassium bisulphate and sodium carbonate prior to the first soil fusion. A blank fusion after the first six analyses showed no nickel. Noyes, Bray, and Spear [1] have shown that nickel sulphide is not completely insoluble in cold hydrochloric acid (1: 1 HCl), and since the method used calls for this separation, further work with this process was discontinued.

COPPER.

Copper was detected in the precipitate for nickel, cobalt, and copper. Since there is a possibility that there might have been contamination from the copper steam baths, by means of air currents carrying the oxidized copper, the presence of the element at this point in the analytical operations is not to be taken as indicating that it is present in the soil.

MOLYBDENUM.

The test used for molybdenum was that recommended by Hillebrand. It is very delicate.

LITHIUM, CÆSIUM, AND RUBIDIUM.

Lithium was invariably present, giving stronger tests in some instances than in others. For the identification of this element and also for cæsium and rubidium, a Hilger wave-length spectroscope was used. For lithium the line 6708.2 was used. The two doublets 4593.3–4555.4 and 4215.6–4201.9 served to identify cæsium and rubidium respectively. To determine the rare alkalies 10 grams of soil were fused with 10 grams of calcium chloride and 40 grams of calcium oxide for 4 hours. The chlorides of all the alkalies were obtained by the method of J. Lawrence Smith. To the solution of the chlorides about 0.05 gram of platinic chloride was added, the solution stirred, and evaporated to pastiness. The unchanged chlorides were rapidly dissolved in a minimum amount of hot water, the platinum salts washed onto a small carbon filter, dried and re-

[1] A System of Qualitative Analysis, p. 78.

duced with hydrogen. The chlorides of the rare alkalies, together with a comparatively large amount of potassium chloride, were washed through with hot water into a very small dish, evaporated to dryness, taken up, and filtered off with 3 portions of 4 drops each of strong hydrochloric acid. By this method 0.0001 gram of rubidium or cæsium mixed with 10 grams of soil could easily be separated and identified. The method of Gooch and Phinney [1] for the identification with the spectroscope was followed. On account of the large amount of potassium present, quantitative refinement was not attempted, though the results obtained are given in four magnitudes. These magnitudes were obtained by comparison with four known amounts of rubidium treated in exactly the same manner as the soils tested.

PHOSPHORIC ACID.

Considerable difficulty was experienced in getting concordant results with this determination. The phosphoric acid solution was obtained in two ways—by fusion with sodium carbonate and solution in nitric acid and by decomposition with hydrofluoric and nitric acids. Both methods yield results which agree well. The main difficulty seems to be in preventing the separation of a flocculent precipitate, either from the solution or from the glass which may be attacked by the ammoniacal solution. This flocculent precipitate increases on standing. Woy's [2] method of weighing the gently ignited molybdate precipitate gives results slightly lower than the magnesia method, though it may be as near the truth when the amount of vanadium in the soil is small.

OTHER ELEMENTS.

The results for barium, manganese, strontium, zirconium, and chromium were sharp and clear cut and are believed to be reliable. The vanadium determinations, however, were somewhat uncertain as to absolute amount, though confirmatory tests with hydrogen peroxide and nitric acid showed the element to be present in all cases and showed a depth of color proportional to the amount found by titration.

Throughout the work double precipitations were performed, except in special instances, and blanks were made in all cases. The corrections for calcium and magnesium in the reagents and that derived from the solubility of the glass were quite large, considering the amounts present in the soil. Evaporation, precipitations at the boiling point, etc., were made in platinum, but filtrates were caught in glass, and funnels and stirring rods made of glass were used.

The silica not precipitated in the first and second evaporation was separated from the iron group and suitable corrections made. Calcium was invariably present in the magnesium precipitate and re-

[1] Am. J. Sci., 44, 392 (1892).

[2] Tredwell, 2, 348, New York (1906).

markably uniform in amount. This represents the solubility of calcium oxalate in aqueous ammoniacal solutions of sodium and ammonium chlorides, together with that dissolving during washing. It appears to be independent of the amounts of calcium and magnesium present. In this work the amount of calcium oxide separated from the precipitated magnesium was almost uniformly 0.7 milligram for the first 18 soils. This correction was applied in the last 8 analyses, instead of making the separations.

The amount of manganese in the magnesium precipitate was so small that no correction was made for this impurity.

All calculations except water (H_2O) at 110° are based on the weight of the soil dried at 110° C.

DESCRIPTION OF THE SAMPLES.

(1) Norfolk sandy loam, 3 miles southwest of Laurinburg, N. C. Depth 0 to 14 inches. This type is formed from the outwash of the more resistant soil particles of the higher formations farther inland. It is a light yellowish sandy loam of the Coastal Plain province, and generally considered productive. This particular sample was taken from virgin soil covered with longleaf pine, white oak, hickory, and occasional dogwood trees. No stones larger than ⅛ inch were found.

(2) Norfolk sandy loam, subsoil of No. 1, depth 14 to 36 inches. No stones larger than ⅛ inch in diameter were found.

(3) Decatur clay loam, 1 mile east of Hollywood, Ala. Depth 0 to 4 inches. This soil is derived from the decomposition of limestone and Knox dolomite. It belongs to the Limestone Valley and Uplands province. It is of a dull-red color and considered fertile. The sample was taken from an uncultivated spot forested with shortleaf pine, hickory, white and red oak, persimmon, and shrubs of different species and native grasses. No stones larger than ⅛ inch were found.

(4) Decatur clay loam, subsoil of No. 3, depth 4 to 15 inches. No stones larger than ⅛ inch in diameter were found.

(5) Hagerstown loam, 1 mile northwest of Conshohocken, Pa. Depth 0 to 8 inches. This type is derived from the weathering of limestone and belongs to the Limestone Valley and Upland province. The sands are rich in mineral species. It is one of the best general farming types in the eastern States. The sample was taken from a potato field. The texture was that of a mellow brown silty loam. This sample contained 1.8 per cent stones. Of this amount 92.4 per cent was quartz, 5.6 per cent limonite, and 1.8 per cent mica schist.

(6) Hagerstown loam, subsoil of No. 5, depth 8 to 24 inches. This sample contained 5.1 per cent of stones. Of this 90.0 per cent was quartz and 9.1 per cent mica schist.

(7) Volusia silt loam, $3\frac{1}{2}$ miles southwest of Naples, N. Y. Depth 0 to 8 inches. This soil is of the Glacial and Loessial province and is formed from sandstone and shale, with a small portion of material from other sources, mixed in by glacial action. This sample was taken from a "slashing," from which the virgin forest of pine, chestnut, and oak had been removed 40 years ago. In color and texture it is a yellow silt loam. A cultivated field of the same soil type near by has produced very poor crops, and this sample would therefore be considered relatively infertile. The soil contains 7.5 per cent stones. This coarse rock material was 82 per cent shale, 9.5 per cent crystalline, 5 per cent sandstone, and 3 per cent flint.

(8) Volusia silt loam, subsoil of No. 7, depth 8 to 36 inches. This sample contained 32 per cent of stone. Of these 87.5 per cent was shales, 10 per cent sandstones, 2 per cent flint, and 0.5 per cent crystalline.

(9) Marshall silt loam, T. 34 N., R. 54 W., 1 mile north of Edgerton, Mo. Depth 0 to 15 inches. This type is of the Glacial and Loessial province, and is derived from loessial deposits. It is nearly black in color. The Marshall silt loam is the most important corn soil in the United States and supports other crops well. In productiveness it would be graded generally as good to excellent. This sample contained no stones.

(10) Marshall silt loam, subsoil of No. 9, depth 15 to 36 inches. This sample contained no stones.

(11) Gloucester stony loam, 3 miles east of Marlboro, N. H. Depth 0 to 8 inches. This soil is of the Glacial and Loessial province and is derived from materials mainly from granite, mica schist, and other crystalline rocks, ground up and mixed by glacial action. It is grayish yellow in color and full of small stones. The sample was taken in a field that had been in grass for eight years. No fertilizer had been added during that time. The crop was light, though adjoining fields, which were well cultivated, produced good crops. As a type its fertility is considered low to fair. This sample was fairly productive. This soil contained 6.5 per cent of stone. Of this amount 16 per cent was amphibolite, 40 per cent mica schist, 31 per cent granite, and 13 per cent quartz.

(12) Gloucester stony loam, subsoil of No. 11, depth 8 to 36 inches. This sample contained 3 per cent of stone. Of this amount 56 per cent was mica schist, 32 per cent granite, and 12 per cent quartz.

(13) Carrington loam, Sec. 24, T. 11 N., R. 10 E., Lowville Township, Columbia County, Wis. Depth 0 to 11 inches. This is a brownish black mellow loam formed from glacial till. It belongs to the Glacial and Loessial province. As a type it is of excellent fer-

tility. The sample was taken from a potato field. The kind and amount of fertilization given is not known. This sample contained 2.2 per cent of stone. Of this amount 77 per cent was decomposed granite, 15 per cent quartz, and 8 per cent diabase.

(14) Fox fine sand, T. 11 N., R. 11 E., Otsego Township, Columbia County, Wis. Through an error the subsoil of this type was analyzed rather than that of the Carrington loam. Fox fine sand is of the Glacial Lake and River Terrace province and is derived from glacial outwash or valley fill. The sample was taken from an old outwash field. It is of low fertility and subject to eolian erosion and deposition. This sample contained no stones.

(15) Cecil clay, 2½ miles northwest of Charlotte, N. C. Depth 0 to 6 inches. It is of Piedmont Plateau province and is derived from granite, gneiss, and other crystalline rocks. The Cecil clay is a reddish clay loam to clay underlain by a stiff tenacious red clay. Both soil and subsoil contain considerable sand which is characterized by a large proportion of minerals other than quartz. It is one of the strongest soils of the Piedmont Plateau and is used for general farming. This soil would be considered productive. It contained no stones.

(16) Cecil clay, subsoil of No. 15, depth 6 to 36 inches. This sample contained no stones.

(17) Cecil sandy loam, 3½ miles southwest of Charlotte, N. C. Depth 0 to 8 inches. This soil is derived from granite, gneiss, and to a less extent from other crystalline rocks. It is a gray to yellowish sandy loam, underlain by a red brittle clay. It belongs to the Piedmont Plateau province and can be successfully used for cotton, corn, and forage crops. This particular sample was poor and had not been fertilized in recent years. This soil differs from its subsoil more than any other in the series in texture, color, and chemical composition. There were no stones in this sample.

(18) Cecil sandy loam, subsoil of No. 17, depth 8 to 36 inches. This sample contained no stones.

(19) Durham sandy loam, 1¾ miles northeast of Archer, Johnson County, N. C. Depth 0 to 10 inches. This sandy loam is formed mainly from light-colored, medium-grained granite. It is a light-yellow sandy loam of the Piedmont Plateau, lying along the border of the Coastal Plain province. The field from which this sample was taken had been cultivated for some years and produced poor yields. Little, if any, fertilizer had been applied in recent years. The sand of this soil contained a large percentage of potash feldspar, derived from a light-colored granite. There were no stones in this soil.

(20) Durham sandy loam, subsoil of No. 19, depth 10 to 36 inches. This sample contained no stones.

TABLE I.—*Showing the chemical composition of important*

[Analyses by W. O. Robinson.]

Constituents.	Coastal Plains province.		Limestone Valley and Uplands province.				Glacial and Loessial province.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SiO_2	94.50	85.30	79.35	74.81	70.99	66.49	75.12	74.64	73.61	71.43	65.68	73.80
TiO_2	.71	.91	1.15	1.28	1.01	1.01	.68	.70	.71	.77	.79	.71
Al_2O_3	2.07	8.82	8.89	12.80	11.39	14.80	10.49	12.26	9.67	13.44	14.15	13.24
Fe_2O_3	.83	1.91	4.44	5.28	4.23	5.99	4.13	5.01	3.54	4.28	5.67	4.37
MnO	.007	.004	.070	.053	.180	.100	.022	.036	.120	.104	.068	.072
Cr_2O_3	.004	.007	.018	.008	.004	.005	.009	.010	.006	.013	Trace.	.009
V_2O_5	.01	.01	.02	.02	.08	.06	.02	.05	.06	.04	.08	.05
Rare earths	.02	.03	.01	.02	.08	.03	.02	.02	N. T.	N. T.	N. T.	N. T.
ZrO_2	.02	.05	.01	.05	.08	.07	.03	.05	.06	.04	.04	.02
MoO_2	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.
NiO+CoO	Doubt.	Doubt.	N. T.	N. T.	N. T.	N. T.	.04	.06	N. T.	N. T.	N. T.	N. T.
CuO	N. T.	N. T.	N. T.	N. T.	N. T.	N. T.	P.	P.	N. T.	N. T.	N. T.	N. T.
CaO	.39	.38	.63	.40	.93	.35	.49	.37	1.08	1.40	1.36	1.19
BaO	.004	.004	.021	.027	.060	.063	.042	.041	.084	.084	.53	.051
SrO	.02	.03	.04	.04	.11	.11	.04	.05	.03	.01	.05	.03
MgO	.09	.19	.39	.33	1.08	1.93	.48	.90	.77	1.28	.83	.39
K_2O	.10	.12	.67	.75	2.71	3.58	1.40	1.99	2.28	2.03	2.16	2.22
Na_2O	.11	.07	.24	.16	.82	.66	.90	.99	1.03	.63	1.39	1.75
Li	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.
Rb	.001	.001	.001	.001	.002	.002	.002	.002	.002	002	.002	.002
Cs	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.
P_2O_5	.06	.04	.18	.15	.19	.16	.18	.15	.22	.16	.15	.11
SO_3	.07	.13	.13	.19	.39	.14	.09	.10	.17	.14	.17	.03
Ignition loss	1.74	3.22	4.80	4.63	6.08	5.06	4.44	3.59	7.44	5.56	9.52	3.13
Water at 110°	.48	1.48	1.99	2.38	1.61	1.40	2.03	1.28	2.94	4.12	3.39	1.18
Organic matter (1)	1.13	.29	1.96	.93	2.87	.82	2.43	.60	4.29	2.72	7.07	1.39
CO_2 from carbonates	N. F.	N. F.	N. F.	N. F.	.33	.56	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.

N. T. Not tested. N. F. Not found. P. Present. (1) Determinations by W. B. Page, of this bureau.

(21) York silt loam, Bethany, S. C., ¾ mile east of Kings Mountain battleground. Depth 0 to 10 inches. This soil is derived from imperfectly crystalline rocks, consisting mostly of talcose and micaceous schists. It belongs to the Piedmont Plateau province. In appearance it is an almost white silty loam full of small spangles of mica. The spot from which this sample was taken supports a virgin growth of shortleaf pine and red oak. Nearby fields were in poor condition and the type is markedly infertile. This sample contained 7.6 per cent stones. Of this amount 59 per cent was quartz and 41 per cent was mica schist.

(22) York silt loam, subsoil of No. 21, depth 10 to 22 inches. This sample contained 8 per cent of stones. Sixty per cent was quartz and 40 per cent mica schist. The mica schist particles had largely disintegrated and fell to pieces when washed with water.

(23) Louisa loam, 1¼ miles southeast of Trevilians, Va. Depth 0 to 12 inches. This type belongs to the Piedmont, and is formed from talcose and micaceous schists and imperfectly crystalline slates. It is a friable pale-yellow loam. The sample was taken from a woodland, principally of Spanish and red oak. Nearby fields supported scant crops, and the fertility would be considered low. This sample

types of American soils—Fusion analysis for total constituents.

[Analyses by W. O. Robinson.]

Glacial and Loessial province—Con.		Piedmont Plateau province.											
No. 13.	No. 14.	No. 15.	No. 16.	No. 17.	No. 18.	No. 19.	No. 20.	No. 21.	No. 22.	No. 23.	No. 24.	No. 25.	No. 26.
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.*
73.50	76.86	66.49	44.15	88.57	55.69	80.79	69.35	76.71	74 .38	84.58	74.99	74.33	71.76
.59	.60	1.02	1.14	.55	.91	.55	.60	.41	.40	1.51	1.59	1.04	1.06
9.10	9.49	17.11	27.58	5.76	24.42	10.55	18.04	12.85	16.31	5.54	10.90	11.00	14.36
4.30	3.79	7.43	16.23	1.55	8.83	1.61	3.42	2.81	2.56	3.30	6.75	4.64	5.82
.113	.062	.51	.033	.044	.022	.017	.014	.005	.005	.045	.039	.136	.109
.010	.010	.013	.025	.002	.006	.004	.002	.007	.004	.013	.014	.006	.007
.03	.03	.05	.06	.01	.04	.02	.02	.04	.03	.03	.03	.03	.05
N. T.	N. T.	.02	.02	.03	.04	.03	.01	.02	.02	.04	N. T.	N. T.	N. T.
.05	.04	.003	.01	.04	.01	.08	.06	.04	.01	.08	.02	.05	.04
N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	P.	N. F.	P.	N. F.	N. F.	N. F.	N. F.	N. F.
N. T.	N. T.	.04	.04	.03	Doubt.	.04	.03	N. T.	N. T.	N. T.	N. T.	N. T.	N. T.
N. T.	N. T.	P.	P.	P.	P.	P.	P.	N. T.	N. T.	N. T.	N. T.	N. T.	N. T.
.94	.93	.36	.44	.39	.40	.89	.72	.08	.21	.21	.26	1.13	1.73
.063	.048	.063	.027	.039	.042	.112	.098	.287	.360	.037	.030	.053	.053
.05	.05	.04	.03	.01	.01	.05	.04	.05	.03	.04	.03	.04	.03
.71	.58	.31	.09	.21	.29	.19	.29	.29	.38	.25	.32	.69	1.06
2.03	1.04	.62	.61	.82	1.06	3.96	3.34	3.26	4.07	.74	.97	1.57	1.50
1.67	1.22	.16	.15	.16	.14	.87	.89	.39	.30	.14	.28	1.53	1.54
P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.	P.
.001	.001	Trace.	Trace.	.001	.001	.01	.01	.001	.001	.001	.001	.002	.002
N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.
.24	.20	.17	.15	.08	.07	.12	.12	.05	.05	.12	.15	.16	.10
.13	.18	.07	.07	.04	.09	.06	.06	.12	.14	.15	.16	.15	.10
7.70	4.76	8.06	11.83	2.93	8.94	1.41	4.54	3.16	2.80	3.89	4.72	4.51	2.83
2.75	2.03	2.47	2.90	.53	2.00	.48	1.53	.47	.22	.92	1.43	1.72	2.06
4.94	2.62	1.26	.27	1.46	.09	.40	.33	1.78	.41	2.40	1.04	1.99	1.21
N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.	N. F.

contained 11.2 per cent stones; of this amount 53 per cent was ferruginous quartz, 43 per cent quartz, 3 per cent clay nodules, and 1 per cent mica schist.

(24) Louisa loam, subsoil of No. 23, depth 12 to 30 inches. This sample contained 20 per cent of stones. Seventy-seven per cent was quartz, 15 per cent ferruginous quartz, and 8 per cent clay nodules.

(25) Penn silt loam, ½ mile west of Penn Square, Morristown, Pa. Depth 0 to 9 inches. This soil belongs to the Piedmont Plateau province and is derived from sandstones of Triassic age. It is a light Indian-red mellow silt loam with a darker silty clay subsoil. The sample was taken from a field supporting a good stand of grass, having been cleared 13 years ago and since then used for corn, wheat, and grass in regular rotation. No commercial fertilizer has been added, but an application of about 5 tons of barnyard manure to the acre was made every three years. In general this soil is used for general farm crops and is considered a productive type. No stones were present in this sample.

(26) Penn silt loam, subsoil of No. 25, depth 9 to 24 inches. This sample contained no stones.

DISCUSSION OF THE RESULTS.

The most important generalization to be drawn from Table I is that most of the rarer elements tested for were found in all the soils. They seem to be rather evenly distributed among the various soil types and provinces. The barium of the York silt loam soil and subsoil is remarkably high. There appears to be some quantitative relation between barium and potassium. Strontium does not appear to be associated with barium, nor do these elements appear to be combined with sulphur. Molybdenum was proved to be present in two cases only.

Rubidium was detected in all soils examined. In addition to the soils given in Table I it has been found in Colorado sand from Colorado, Knox silt loam from Missouri, Oswego silt loam from Kansas, and Greenville sandy loam from Georgia. Cæsium was proved to be present in only one soil, Colorado sand, from Greeley, Colo. Since Vernadski[1] has found cæsium to be widely distributed in feldspars and micas it would seem that there must be small amounts present in all soils, since all soils contain large quantities of either feldspars or micas.

The amounts of the rare earths precipitates were too small to separate into simpler groups or elements. The precipitate probably contained cerium for the most part, with a smaller amount of thorium. Thorium has been reported in an Italian soil to the amount of 1 part of thorium oxide to 60,000 parts of soil by Blanc,[2] and Joly[3] has found it in sedimentary rocks in amounts averaging about 1.2×10^{-5} grams per gram of rock, or 1 part in 70,000.

Nickel and cobalt are probably generally present in soils; the figures given do not have quantitative significance, however, and are subject to the doubts referred to in the paragraph on methods. Further work is needed to establish the amounts of these elements present in soils and also to prove definitely the presence of copper in anything but the merest traces.

Since the number of soils in the Coastal Plain and Limestone Valley and Upland provinces analyzed was small, the partial analyses of such soils reported by Failyer, Smith, and Wade[4] are given in Table II for the purpose of comparison.

Soils of the Glacial and Loessial province are higher in calcium, magnesium, sodium, and organic matter than those of the Piedmont Plateau or Coastal Plains. Whereas most of the soils of the Piedmont Plateau are low in potash, the large amount in numbers 19, 20, 21, and 22 brings the average up to that of the glaciated areas.

---

[1] Bul. Acad. St. Petersburg (1909), 821.

[2] Atti. Accad. Lincei., 17, I, 101.

[3] Phil. Mag., 20, 353.

[4] Bul. 54, Bureau of Soils, U. S. Dept. Agriculture (1908).

TABLE II.—*Partial composition of soils analyzed by Failyer, Smith, and Wade.*

COASTAL PLAIN SERIES.

Soil type and location.	CaO.	MgO.	K_2O.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Collington sandy loam, New Jersey	0.12	0.13	0.79	0.03
Norfolk sand, Maryland	.13	.19	.60	.06
Norfolk loam, Maryland	.24	.10	.79	.07
Leonardtown loam, Maryland	.07	.29	1.11	.03
Orangeburg sandy loam, Alabama	.08	.05	.28	.06
Crowley silt loam, Louisiana	.19	.29	.92	.14
Orangeburg fine sandy loam, Texas	.14	.10	.42	.11
SOILS DERIVED FROM LIMESTONES AND SHALES.				
Oswego silt loam, Kansas	0.40	0.36	1.24	0.12
Hagerstown loam, Tennessee	.40	.56	.77	.12
Hagerstown clay, Kentucky	3.12	1.54	4.30	.40
Houston clay, Alabama	28.02	1.21	1.01	.59

Soils formed from limestone may be low in lime, as is shown by the Oswego silt loam and the Hagerstown loam in Table II and by Nos. 3 and 4 in Table I.

During the process of formation and changes in the soil, manganese, with one exception, appears to be concentrated in the surface layers. This seems to be due to a difference in the solubility of the salts of lower and higher states of oxidation. Solutions of reduced manganese could move unchanged in the subsoil, but on coming near the surface, where oxidizing conditions prevail, the manganese would be precipitated as the nearly insoluble higher oxide. Plants might accumulate certain elements selectively absorbed as food in the surface soil, provided such elements were not soluble in atmospheric conditions. Phosphorus has undergone a similar concentration, and it would seem that in this case the larger part of the concentration was effected by the selective absorption of this element by plants, the plants yielding their phosphoric acid to the soil by decomposition and this element being held in the surface soil in difficultly soluble combinations with the ever present bases.

The most striking differences in composition between the surface soil and the subsoil is shown by the silica content. This difference is greater in soils profoundly weathered and subject to erosion and less in the glaciated soils. Complementary to this silica variation is the variation in iron, aluminum, and, generally, titanium. It seems that at the surface erosion has carried away the finer particles containing large amounts of iron and aluminum and has left the larger sand grains, consisting mostly of quartz, in the surface soil. Some of the finer particles might have been driven into the subsoil by rain, or by the movements incident to alternate wetting and drying, but it would seem that by far the larger part of the concentration was effected by surface wash.

Gloucester stony loam, Nos. 11 and 12, shows a greater amount of silica in the subsoil and the iron and aluminum does not follow the general rule of being greater in amount in the subsoil. It would seem that the samples used in analysis might have been transposed, but the analysis of a second sample showed the same relation. This type is an exception to the rule, though the difference in the composition of the surface soil and the subsoil is not great.

Potash and magnesia are noticeably higher in the subsoil. In the Durham sandy loam, Nos. 19 and 20, the sands, or larger soil particles, are mostly potash feldspars. This fact accounts for the greater amount of potash in the surface soil. Barium and lime do not seem to have been concentrated in either layer of the soil. Zirconium appears in the surface soil in larger amounts. The particles of mineral containing this element are comparatively coarse and resist surface wash.

The average amount of sulphur trioxide present in these soils is 0.13 per cent, whereas phosphorus pentoxide averages 0.14 per cent. In one case there is one-fourth as much sulphur trioxide as phosphorus pentoxide. These facts support the evidence brought out by Hart and Peterson [1] and further by Shedd [2] that the sulphur content of soils is lower than that of phosphorus. The average of 16 Wisconsin soils was 0.08 per cent SO_3 and 131 Kentucky soils averaged 0.06 per cent SO_3. Hart and Peterson point out that average crops of cereals remove in the grain and straw two-thirds as much sulphur as phosphorus, grasses about the same, alfalfa somewhat more, and cabbage and turnips 2 to 3 times as much. They advise that sulphur be considered in fertilizer practices.

MINERALOGICAL COMPOSITION.

The micro-petrographical determinations were made by W. J. McCaughey, now of the University of Ohio, and William H. Fry, of this bureau. The examinations were made on separates made by mechanical analysis.

Quartz was universally present in all the soils examined and its presence is not noted in the individual reports.

(1) NORFOLK SANDY LOAM, SOIL.

No. 4 sand.—Practically pure quartz sand with apatite and rutile inclusions.

No. 5 sand.—Nearly pure quartz sand, with a few subangular, though mostly clear, well-rounded grains. Minerals other than quartz, 3.5 per cent. Rutile, zircon, ilmenite, and tourmaline present.

---

[1] Wis. Agr. Expt. Sta., Research Bul. No. 14.

[2] Ky. Agr. Expt. Sta. Bul. No. 174.

Silt.—Minerals other than quartz, 40 per cent; potash feldspars, 7 per cent; muscovite, 0.5 per cent. Epidote is present in fairly large quantities. Hornblende, rutile, zircon, chlorite, magnetite, and sponge spicules are also present.

(2) NORFOLK SANDY LOAM, SUBSOIL.

No. 4 sand.—No potash feldspars. Practically pure quartz with rutile and apatite inclusions. Andesite present.

No. 5 sand.—Minerals other than quartz, 4.7 per cent. Quartz grains very clear and bright, mostly well rounded, with a few subangular and angular grains. Tourmaline, rutile, zircon, chlorite, magnetite, cyanite, hypersthene, weathered feldspars, and apatite inclusions in quartz are present.

Silt.—Minerals other than quartz, 60 per cent. Potash feldspars (orthoclase), 1 per cent, characterized by a large amount of highly kaolinized feldspars and the presence of sponge spicules. Epidote, chlorite, rutile, orthoclase, and zircons are also present.

(3) DECATUR CLAY LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 4 per cent. Potash feldspars, negligible. No muscovite. Magnetite, hematite, rutile inclosed in quartz, orthoclase, and epidote are present.

No. 5 sand.—Minerals other than quartz, 4.2 per cent. Potash feldspars (orthoclase), less than 0.5 per cent. No muscovite. The feldspars are much altered and few in number. Rutile, zircon, tourmaline, magnetite, and epidote are also present. Characterized by quartz crystals inclosing iron oxide.

Silt.—Minerals other than quartz, 39 per cent. Potash feldspars, 6 per cent. The feldspars are much altered. Epidote and chlorite are the predominating minerals. Tourmaline, rutile, and zircon are also present.

(4) DECATUR CLAY LOAM, SUBSOIL.

No. 4 sand.—No potash feldspars or muscovite found. The quartz is very impure. Magnetite, hematite, and rutile inclosed in quartz are present.

No. 5 sand.—Minerals other than quartz, 4 per cent. Potash feldspars less than 0.5 per cent. The quartz grains are well rounded and subangular. Tourmaline, zircon, rutile, magnetite, and calcite inclosed in quartz are also present. Characterized by quartz crystals.

Silt.—Minerals other than quartz, 37.5 per cent. Potash feldspars, 9 per cent. Zircon, epidote, tourmaline, magnetite, muscovite, chlorite, and sponge spicules are also present.

(5) HAGERSTOWN LOAM, SOIL.

No. 5 sand.—Minerals other than quartz, 40 per cent. Potash feldspars (microcline), 8 per cent. Dolomite, rutile, augite, biotite, plagioclase, tourmaline, and quartz crystals are also present. Characterized by many rhombohedral fragments of dolomite and also by a large amount of microcline, biotite, and rutile, which is generally twinned in knee-shaped forms.

Silt.—Minerals other than quartz, 49 per cent. Potash feldspars (microcline), 11 per cent. Muscovite, 2 per cent. Epidote, dolomite, microcline, rutile, biotite, chlorite, tourmaline, augite, and sponge spicules are also present. This silt is characterized by the absence of altered minerals.

(6) HAGERSTOWN LOAM, SUBSOIL.

No. 5 sand.—Minerals other than quartz, 18 per cent. Potash feldspars (microcline and orthoclase), 11.5 per cent. Quartz crystals, biotite, dolomite, augite, tourmaline, rutile, and zircon are also present. Characterized by a predominance of potash feldspars and biotite.

Silt.—Minerals other than quartz, 67 per cent. Potash feldspars (orthoclase), 18 per cent; muscovite, 2 per cent. Epidote, twinned rutile, biotite, chlorite, tourmaline, and augite are present.

(7) VOLUSIA SILT LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 6 per cent. Potash feldspars (microcline and orthoclase), 4 per cent. Magnetite, rutile inclosed in quartz, garnet, augite, and plagioclases are also present.

No. 5 sand.—Minerals other than quartz, 8 per cent. Potash feldspars (microcline and orthoclase), 4.4 per cent. Predominant minerals are microcline, orthoclase, garnet, hornblende, and augite. Epidote, tourmaline, zircon, rutile, magnetite, hypersthene, zoisite, and plagioclase are also present.

Silt.—Minerals other than quartz, 38 per cent. Potash feldspars (orthoclase), 8.9 per cent. Biotite, hornblende, muscovite, rutile, epidote, tourmaline, garnet, and augite are also present.

(8) VOLUSIA SILT LOAM, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 7 per cent. Potash feldspars (microcline and orthoclase), 4 per cent. Magnetite, albite, rutile inclosed in quartz, zircon, and hornblende are also present.

No. 5 sand.—Minerals other than quartz, 10.8 per cent. Potash feldspars (orthoclase), 5.7 per cent. Microcline, hornblende, and garnet predominate. Zircon, diallage, magnetite, tourmaline, and hypersthene are also present.

Silt.—Minerals other than quartz, 48 per cent. Potash feldspars (orthoclase), 5 per cent. Chlorite, biotite, muscovite, epidote, hornblende, tourmaline, rutile, and magnetite are also present.

(9) MARSHALL SILT LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 4 per cent. Potash feldspars (orthoclase), 2 per cent. Muscovite, 1 per cent. Glass, biotite, and muscovite are also present.

No. 5 sand.—Minerals other than quartz, 20 per cent. Potash feldspars (orthoclase), 10 per cent. Muscovite, 2 per cent. Biotite, magnetite, epidote, albite, labradorite, oligoclase, tourmaline, zircon, garnet, and augite are also present.

Silt.—Minerals other than quartz, 34 per cent. Potash feldspars (orthoclase), 4 per cent. Muscovite, 4 per cent. Biotite, magnetite, epidote, albite, labradorite, oligoclase, tourmaline, rutile, glaucophane, hornblende, and augite are also present.

(10) MARSHALL SILT LOAM, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 7 per cent. Potash feldspars (orthoclase), 3 per cent. Muscovite and phlogopite, 2 per cent. Biotite is also present.

No. 5 sand.—Minerals other than quartz, 16 per cent. Potash feldspars (orthoclase and microcline), 5 per cent. Muscovite, 5 per cent. Biotite, magnetite, hornblende, epidote, oligoclase, albite, tourmaline, and garnet are also present.

Silt.—Minerals other than quartz, approximately 50 per cent. Potash feldspars (orthoclase and microcline), 8 per cent. Muscovite, 7 per cent. Biotite, hornblende, magnetite, axinite, epidote, augite, zircon, apatite, tourmaline, labradorite, and albite are also present.

(11) GLOUCESTER STONY LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 10 per cent. Potash feldspars (orthoclase and microcline), 2 per cent. Muscovite, 5 per cent. Biotite, magnetite, hematite, phlogopite, hornblende, andesite, hypersthene, garnet, diopside, tourmaline, and oligoclase are also present.

No. 5 sand.—Minerals other than quartz, 15 per cent. Potash feldspars (orthoclase and microcline), 2 per cent. Muscovite, 5 per cent. Biotite, phlogopite, magnetite, hornblende, apatite, rutile, tourmaline, augite, garnet, epidote, and albite are also present.

Silt.—Minerals other than quartz, 60 per cent. Potash feldspars (orthoclase), 2 per cent. Muscovite, 30 per cent. Biotite, phlogopite, garnet, epidote, sillimanite, hornblende, zircon, labradorite, and rutile are also present.

(12) GLOUCESTER STONY LOAM, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 25 per cent. Potash feldspars (orthoclase and microcline), 6 per cent. Muscovite, 10 per cent. Biotite, phlogopite, oligoclase, garnet, labradorite, hornblende, and piedmontite are also present.

No. 5 sand.—Minerals other than quartz, 30 per cent. Potash feldspars (orthoclase), 5 per cent. Muscovite, 8 per cent. Phlogopite, hornblende, biotite, epidote, rutile, garnet, tourmaline, labradorite, andesite, andalusite, and enstatite are also present.

Silt.—Minerals other than quartz, 65 per cent. Potash feldspars (orthoclase), 2 per cent. Muscovite, 35 per cent. Phlogopite, biotite, garnet, hornblende, epidote, rutile, zircon, plagioclases, and augite are also present.

(13) CARRINGTON LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 6 per cent. Potash feldspars (orthoclase and microcline), 5 per cent. No muscovite. Magnetite and rutile inclosed in quartz are also present.

No. 5 sand.—Minerals other than quartz, 15 per cent. Potash feldspars (microcline and orthoclase), 10 per cent. No muscovite. Magnetite, hornblende, oligoclase, labradorite, albite, zircon, and corundum are also present.

Silt.—Minerals other than quartz, 30 per cent. Potash feldspars (orthoclase and muscovite), 12 per cent. Muscovite, 1 per cent. There are also present magnetite, hornblende, oligoclase, labradorite, rutile, epidote, and an isotropic mineral with an index of refraction below 1.50, making it impossible to accurately determine with available oils.

(14) FOX FINE SAND, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 6 per cent. Potash feldspars (orthoclase), 4 per cent. No muscovite. Magnetite, apatite inclosed in quartz, labradorite, oligoclase, and hornblende are also present.

No. 5 sand.—Minerals other than quartz, 14 per cent. Potash feldspars (orthoclase and microcline), 8 per cent. No muscovite. Magnetite, labradorite, oligoclase, hornblende, rutile, and epidote are also present.

Silt.—Minerals other than quartz, 26 per cent. Potash feldspars (orthoclase and microcline), 10 per cent. Muscovite negligible. Magnetite, hornblende, epidote, plagioclases, rutile, biotite, and the same indetermined isotropic mineral as noted in No. 13 are also present.

(15) CECIL CLAY, SOIL.

No. 4 sand.—Minerals other than quartz, 4 per cent. Potash feldspars (orthoclase), 1.5 per cent. No muscovite. Magnetite, epidote, rutile inclosed in quartz, zircon, and augite are also present.

No. 5 sand.—Minerals other than quartz, 4.5 per cent. Potash feldspars (orthoclase), 1 per cent. Muscovite, 2 per cent. Epidote and augite are the predominant minerals. Chlorite, zircon, sillimanite, biotite, hypersthene, magnetite, augite, plagioclases, and hornblende are also present. The angular quartz grains are nearly transparent, but the subangular and rounded grains inclose iron oxide.

Silt.—Minerals other than quartz, 43 per cent. Potash feldspars (orthoclase), 2 per cent. Muscovite, 5 per cent. Chlorite very abundant. Biotite, sillimanite, zircon, epidote, hornblende, and feldspar residues are also present.

(16) CECIL CLAY, SOIL.

No. 4 sand.—Minerals other than quartz, 2 per cent. No potash feldspars. Muscovite, 1 per cent. Magnetite and biotite are also present.

No. 5 sand.—Minerals other than quartz, 4 per cent. Potash feldspars (orthoclase), 1 per cent. Muscovite, 1 per cent. Magnetite, biotite, hornblende, and feldspar residues are also present.

Silt.—Minerals other than quartz, 60 per cent. Potash feldspar (orthoclase), 3 per cent. Muscovite, 2 per cent. Feldspar residues and chlorite abundant. Epidote, zircon, magnetite, hematite, biotite, and plagioclases are present.

(17) CECIL SANDY LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 7 per cent. Potash feldspars (orthoclase), 1.5 per cent. No muscovite. Magnetite, rutile, inclosed in quartz, indeterminable plagioclase, and hornblende are also present.

No. 5 sand.—Minerals other than quartz, 8.3 per cent. Potash feldspars (microcline and orthoclase), 3.6 per cent. Microcline, orthoclase, and zircon are most abundant. Hornblende, muscovite, magnetite, chlorite, and apatite inclusions in quartz are present. Quartz grains are mostly clear, transparent, and angular to subangular.

Silt.—Minerals other than quartz, 30 per cent. Potash feldspars, 2 per cent. Muscovite, 2 per cent. Epidote, feldspar residues, zircon, chlorite, and magnetite are present.

(18) CECIL SANDY LOAM, SUBSOIL.

No. 5 sand.—Minerals other than quartz, 12 per cent. Potash feldspars (microcline and orthoclase), 3.6 per cent. Microcline, orthoclase, and zircon predominate. Hornblende, magnetite, chlorite, muscovite, biotite, epidote, plagioclase, and apatite inclusions in quartz are also present. The quartz consists of an equal number of clear transparent grains and those carrying inclusions or coatings of iron oxide.

Silt.—Minerals other than quartz, approximately 60 per cent. Potash feldspars not determinable. Muscovite, 4 per cent. Feldspar residues are abundant. Epidote, zircon, hornblende, chlorite, and magnetite are also present.

(19) DURHAM SANDY LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 25 per cent. Potash feldspars (orthoclase and microcline), 20 per cent. No muscovite. Magnetite, biotite, and zircon are also present.

No. 5 sand.—Minerals other than quartz, 30 per cent. Potash feldspars (microcline and orthoclase), 24 per cent. Muscovite, 1 per cent. Unaltered feldspars. Microcline and orthoclase predominate; zircon, rutile, magnetite, epidote, sillimanite, biotite, and quartz inclosing both zircon and apatite are also present. The quartz grains are beautifully clear and transparent and show no signs of chemical weathering.

Silt.—Minerals other than quartz, 55 per cent. Potash feldspars, 26 per cent. Muscovite, 2 per cent. Potash feldspars predominate; biotite, zircon, and epidote are fairly abundant. Tourmaline, magnetite, and chlorite are also present. The minerals do not show signs of alteration.

(20) DURHAM SANDY LOAM, SUBSOIL.

No. 5 sand.—Minerals other than quartz, 31 per cent. Potash feldspars (microcline and orthoclase), 25 per cent. Microcline, orthoclase, and epidote predominate; biotite, muscovite, chlorite, zircon, magnetite, and ilmenite are also present. There is little indication of chemical weathering.

Silt.—Minerals other than quartz, 60 per cent. Potash feldspars (orthoclase and microcline), 21 per cent. Muscovite, 2.5 per cent. Orthoclase, microcline, muscovite, and chlorite predominate; hornblende and rutile are also present.

(21) YORK SILT LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 4 per cent. No potash feldspars. Muscovite, 0.5 per cent. Magnetite, tourmaline, chlorite, and hornblende are also present.

No. 5 sand.—Minerals other than quartz, 6 per cent. No potash feldspars. Muscovite, 1 per cent. Chlorite, magnetite, epidote, and feldspar residues are also present.

Silt.—Minerals other than quartz, 80 per cent. No potash feldspars. Muscovite, 49 per cent. Characterized by the large amount of muscovite and feldspar residues. The latter are short and long needles having positive elongations and the refractive index and birefringence of pyrophyllite. They are not to be confused with the fibrous variety of epidote which has a much higher refractive index and results from the alteration of plagioclase feldspars; chlorite and magnetite are also present.

(22) YORK SILT LOAM, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 10 per cent. No potash feldspars. Muscovite, 2 per cent. Magnetite, biotite, and tourmaline present.

No. 5 sand.—Minerals other than quartz, 12.7 per cent. No potash feldspars. Muscovite, 1 per cent. Pyrophyllite present in large quantities. Magnetite, chlorite, tourmaline, and epidote also present.

Silt.—Minerals other than quartz, 85 per cent. Characterized by a high muscovite and pyrophyllite content. Rutile present.

(23) LOUISA LOAM, SOIL.

No. 5 sand.—Minerals other than quartz, 7.7 per cent. Magnetite, zircon, chlorite, muscovite, and apatite inclosed in quartz are present.

Silt.—Minerals other than quartz, 51 per cent. Potash feldspars, 3 per cent. Muscovite, 2.3 per cent. Magnetite, biotite, epidote, and chlorite predominate; tourmaline, zircon, and rutile are also present.

(24) LOUISA LOAM, SUBSOIL.

No. 5 sand.—Minerals other than quartz, 10 per cent. Magnetite, zircon, hematite, and apatite inclusions in quartz are present.

Silt.—Minerals other than quartz, 60 per cent. Potash feldspars (orthoclase), 2.5 per cent. Muscovite, 1.7 per cent. Biotite, chlorite, orthoclase, and muscovite predominate; epidote, zircon, magnetite, diallage, and rutile are also present.

(25) PENN SILT LOAM, SOIL.

No. 4 sand.—Minerals other than quartz, 10 per cent. Potash feldspars (orthoclase), 1 per cent. Muscovite, 6 per cent. Labradorite, zircon, apatite inclosed in quartz, hornblende, rutile, magnetite, and hematite are also present.

No. 5 sand.—Minerals other than quartz, 15 per cent. Potash feldspars (orthoclase), 6 per cent. Muscovite, 4 per cent. Magnetite, hematite, labradorite, tourmaline, hornblende, andalusite, zircon, and albite-oligoclase are also present.

Silt.—Minerals other than quartz, 18 per cent. Potash feldspars (orthoclase), 5 per cent. Muscovite, 9 per cent. Tourmaline, biotite, epidote, hornblende, albite, apatite, and augite are also present.

(26) PENN SILT LOAM, SUBSOIL.

No. 4 sand.—Minerals other than quartz, 14 per cent. Potash feldspars (orthoclase), 5 per cent. Muscovite, 7 per cent. Magnetite-biotite, rutile inclosed in quartz, apatite inclosed in quartz, and albite-oligoclase are also present.

No. 5 sand.—Minerals other than quartz, 15 per cent. Potash feldspars (orthoclase), 4 per cent. Muscovite, 6 per cent. Magnetite, biotite, tourmaline, oligoclase, zircon, epidote, hypersthene, labradorite, and hornblende are also present.

Silt.—Minerals other than quartz, 40 per cent. Potash feldspars (orthoclase), 4 per cent. Muscovite, 15 per cent. Tourmaline, biotite, epidote, hornblende, albite, and augite are also present.

DISCUSSION OF THE MINERALOGICAL DATA.

The general results of the mineralogical examinations support the conclusions already given by McCaughey and Fry.[1] The soils of the Limestone Valley and Upland province are unique in containing quartz crystals with inclusions of calcite and iron oxide. In general soils of the glaciated areas are higher in minerals other than quartz than soils of the other areas.

Apatite is reported in 11 out of the 26 samples. The average of the phosphoric-acid content of the soils is 0.11 P_2O_5, whereas the average of those in which apatite was not recognized is 0.15 per cent. This indicates either that the phosphoric acid (P_2O_5) of soils occurs in other minerals either as a characteristic part or accidentally, or that a large part of the apatite is in the clay group, and thus escapes detection.

Types in which the titanium was larger or of about the same amount in the surface as compared to the subsoil contained rutile or rutile inclusions in quartz. The percentage of minerals other than quartz is higher in the finer separates, and particularly is this true in soils of the Piedmont Plateau province. The amount of minerals other than quartz is greater in the subsoil than in the surface soil, for the respective separates.

Tourmaline is present in the particles coarser than clay in 18 samples. This mineral is particularly interesting for it carries boron as an essential constituent. In some cases tourmaline occurs in relatively large amounts, indicating the presence of boron in more than mere traces. The micas, generally muscovite, occur in 24 samples. Phlogopite, of which fluorine is an essential constituent, occurs in soils Nos. 10, 11, and 12. Fluorine occurs in all micas in amounts varying from traces to several per cent, and therefore we would expect these soils to contain fluorine

The amounts of potash feldspars and micas in various soils have been determined by McCaughey and Fry, and is given in Tables III and IV.

[1] Bull. 91, Bureau of Soils, U. S. Dept. Agriculture (1913).

TABLE III.—*Percentage of potash feldspars and muscovite and the percentage of separates in the soil.*

No.	Feldspar.			Muscovite.			Mechanical analysis [1] separate in the soil.		
	In No. 4 sands.	In No. 5 sands.	In silt.	In No. 4 sands.	In No. 5 sands.	In silt.	No. 4 sand.	No. 5 sand.	Silt.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	N. F.	N. F.	7.0	N. D.	N. D.	0.5	23.9	17.3	18.5
2	N. F.	0.5	1.0	N. D.	N. D.	.5	19.5	14.1	15.2
3	N. D.	.5	6.0	N. F.	N. F.	N. F.	10.4	9.6	47.9
4	N. D.	.5	9.0	N. D.	P.	P.	6.2	6.9	45.2
5	N. D.	8.0	11.0	N. D.	N. D.	2.0	4.8	7.6	63.9
6	N. D.	11.5	18.0	N. D.	N. D.	2.0	7.4	8.6	52.9
7	4.0	4.4	8.0	N. D.	N. D.	P.	4.3	13.0	58.1
8	4.0	5.7	5.0	N. D.	N. D.	1.0	6.3	11.5	52.6
9	2.0	10.0	12.0	1.0	2.0	4.0	.4	6.0	72.6
10	3.0	5.0	8.0	2.0	5.0	7.0	1.3	4.4	68.2
11	2.0	4.0	2.0	5.0	7.0	30.0	21.9	15.0	20.9
12	6.0	5.0	2.0	10.0	8.0	35.0	31.9	18.7	17.9
13	5.0	10.0	12.0	N. F.	N. F.	1.0	23.6	11.3	32.3
14	4.0	8.0	10.0	N. F.	N. F.	1.0	27.5	12.3	28.4
15	1.5	1.0	2.0	N. F.	2.0	5.0	7.4	6.8	38.1
16	N. F.	1.0	3.0	1.0	1.0	2.0	1.0	3.0	47.6
17	1.5	3.6	2.0	N. D.	N. D.	2.0	13.8	11.6	26.2
18	N. D.	3.6	N. D.	N. D.	N. D.	4.0	4.2	5.0	27.6
19	20.0	24.0	26.0	N. D.	1.0	2.0	24.1	14.4	20.3
20	*20	25.0	21.0	N. D.	N. D.	2.5	17.7	9.6	18.0
21	N. F.	N. F.	N. F.	0.5	1.0	49.0	1.9	29.4	60.9
22	N. F.	N. F.	N. F.	2.0	1.0	54.0	2.5	28.9	63.5
23	N. D.	N. F.	3.0	N. D.	N. F.	2.3	17.1	20.4	39.1
24	N. D.	N. F.	2.5	N. D.	N. F.	1.7	12.6	16.7	32.2
25	1.0	6.0	5.0	6.0	4.0	9.0	3.7	16.1	60.2
26	5.0	4.0	4.0	7.0	6.0	15.0	3.1	14.5	59.0

[1] Mechanical analysis by L. A. Kolbe.

N. F. Not found. N. D. Not determined. P. Present. *Extrapolated.

TABLE IV.—*Showing the amount of potash feldspars and muscovite in some types of American soil.*

Number of sample.	Depth.	Feldspars.				Muscovite.				Quantity per acre to the depth indicated.		Quantity per acre to a depth of 3 feet.	
		Per cent in No. 4 sand.	Per cent in No. 5 sand.	Per cent in silt.	Per cent, total.	Per cent in No. 4 sand.	Per cent in No. 5 sand.	Per cent in silt.	Per cent, total.	Feldspars.	Muscovite.	Feldspars.	Mica.
	Inches.									*Tons.*	*Tons.*	*Tons.*	*Tons.*
1	0–14	N. F.	N. F.	1.30	1.3	N. D.	N. D.	0.09	0.1	30	2	.....	.....
2	14–36	N. F.	0.07	.15	.2	N. D.	N. D.	.08	.1	7	4	37	6
3	0–4	N. D.	.05	2.87	2.9	N. F.	N. F.	N. F.	N. F.	19	N. F.	.....	.....
4	4–36	N. D.	.03	4.07	4.1	N. D.	P.	P.	P.	218	Neg.	237	Neg.
5	0–8	N. D.	.61	7.07	7.6	N. D.	N. D.	1.28	1.3	102	17	.....	.....
6	8–36	N. D.	.99	9.52	10.5	N. D.	N. D.	1.06	1.1	489	51	591	68
7	0–8	.17	.57	5.17	5.9	N. D.	N. D.	P.	P.	78	Neg.	.....	.....
8	8–36	.25	.66	2.63	3.5	N. D.	N. D.	.39	.4	163	19	241	19
9	0–15	.01	.60	2.90	3.5	Neg.	.12	2.90	3.0	88	75	.....	.....
10	15–36	.04	.20	5.46	5.7	.03	.22	4.77	5.0	200	175	288	250
11	0–8	.44	.60	.42	1.5	1.10	1.05	6.27	8.4	20	112	.....	.....
12	8–36	1.91	.94	.36	3.2	3.19	1.50	6.26	11.0	149	513	169	625
13	0–11	1.18	1.13	3.88	6.2	N. F.	N. F.	.32	.3	114	6	.....	.....
14	11–36	1.10	.98	2.84	4.9	N. F.	N. F.	.28	.3	206	12	320	18
15	0–6	.11	.07	.76	.9	N. F.	.14	1.91	2.1	9	21	.....	.....
16	6–36	N. F.	.003	1.43	1.4	Neg.	Neg.	.95	1.0	70	50	79	71
17	0–8	.21	.42	.52	1.2	N. D.	N. D.	.52	.5	16	7	.....	.....
18	8–36	N. D.	.18	N. D.	.2	N. D.	N. D.	1.10	1.1	9	51	25	58
19	0–10	4.82	3.46	5.28	13.6	N. D.	.14	.41	.6	227	10	.....	.....
20	10–36	*3.54	2.40	2.78	9.7	N. D.	N. D.	.45	.5	431	22	648	32
21	0–10	N. F.	N. F.	N. F.	N. F.	.01	.29	29.8	30.1	N. F.	501	.....	.....
22	10–36	N. F.	N. F.	N. F.	N. F.	.05	.29	34.3	34.6	N. F.	1,500	N. F.	2,000
23	0–12	N. D.	N. F.	1.17	1.2	N. D.	N. F.	.90	.9	24	18	.....	.....
24	12–36	N. D.	N. F.	.80	.8	N. D.	N. F.	.55	.6	32	24	56	42
25	0–9	.04	.97	3.01	4.0	.22	.64	5.42	6.3	60	95	.....	.....
26	9–36	.16	.58	2.36	3.1	.22	.87	8.85	9.9	140	446	200	541

N. F.—Not found. N. D.—Not determined. P.—Present. Neg.—Negligible. * Extrapolated.

The method applied by them is as follows: Ten grams of the sample were separated into sands of five different grades and into silts and clays. The determinations were made on subsamples of very fine sand (1–0.05 mm. diameter) and on the coarser silts (0.05–0.005 mm. diameter). Six or eight counts were made on each sample, and from the number of potash feldspars and micas and the total number of particles present the percentages of the forenamed minerals have been determined.[1]

From this data and from the amount of each separate in the soil the minimum percentages of potash feldspars and muscovite have been determined. The minerals in question in the coarser sands and clays are not included, for these separates are difficult to examine. The percentage of potash-bearing minerals in the clay is very often higher than in any other separate, as shown by Failyer, Smith, and Wade.[2]

Table V shows the relation between the total amount of potash in the soil as shown by fusion analysis and that estimated from the amount of potash minerals determined in the sands and coarse silts. The theoretical[3] percentage of potash in orthoclase was taken as the basis for calculation and 8 per cent was used for muscovite.

TABLE V.—*Relation between the actual amount of potash present and the amount of potash in the minerals estimated.*

Number of soil sample.	Potash.	
	Actual.	From mineralogical data.
	Per cent.	*Per cent.*
1	0.10	0.22
16	.61	.32
19	3.96	2.33
22	4.07	2.77

Excepting sample No. 1, where the actual amount is small—and for this reason the exception is not important—there is much more potash present than is accounted for mineralogically. These figures simply show that the estimates based on an examination of the minerals are certainly not too high.

In all the soil types examined there were present either potash feldspars or potash mica in large amounts. In one case only is potash feldspar lacking and, likewise, muscovite was not found in one

[1] In this calculation it is assumed that in each mechanical subdivision the average weight of the particles of each mineral in question is equal to the average weight of the particles of any other mineral. While this is not strictly true, it is sufficiently accurate for the purpose. The error is probably greatest in the mica determinations.

[2] Bul. 54, Bureau of Soils, U. S. Dept. Agriculture.

[3] Orthoclase as ordinarily found does not contain the calculated amount of potash.

case. But in both these cases the other potash mineral, i. e., feldspar or mica, was present, and in large amounts. Therefore the potash in any of these soils was not only that held by physical or indefinite chemical absorption, but that contained in original minerals which will slowly yield their potash to the soil solution by decomposition extending through a long period of time.

It is interesting to note that zeolites and rare earth minerals were not recognized.

CONCLUSIONS.

(1) The rarer elements, chromium, vanadium, rare earths, zirconium, barium, strontium, lithium, and rubidium, were present in all soils examined. Chromium ranged from a trace to 0.025 per cent; vanadium, from 0.01 per cent to 0.08 per cent; rare earths, from 0.01 per cent to 0.08 per cent; zirconium, from 0.003 per cent to 0.08 per cent; barium, from 0.004 per cent to 0.360 per cent; strontium, from 0.01 per cent to 0.11 per cent. Lithium was found in spectroscopic traces only. Boron is indicated in 18 soils by the presence of tourmaline and fluorine in 24 soils by the presence of micas.

(2) Molybdenum was found in only two samples, the surface soils of the Durham sandy loam and the York silt loam.

(3) Cæsium was found in only one soil.

(4) While it seems likely that copper, nickel, and cobalt are present in soils, neither the amounts nor even the presence of these elements has been established with certainty.

(5) Silica is higher in the surface soil than in the subsoil, and aluminum, iron, and, generally, titanium, are higher in the subsoil. Potash and magnesium are higher in the subsoil. Manganese and phosphorous concentrate in the surface soil.

(6) The sulphur content is low, ranging from 0.03 per cent SO_3 to 0.39 per cent SO_3 with an average of 0.13 per cent.

(7) The evidence that soils contain the more important rock-forming minerals is strengthened by the mineralogical examinations described.

(8) There is an abundance of potash minerals in the soil. Samples Nos. 2 and 3, Decatur clay loam, do not contain potash mica in determinable amounts, though there are large quantities of potash feldspars present. Samples Nos. 21 and 22, York silt loam, do not contain determinable amounts of potash feldspars, but to offset this there are large quantities of potash mica. Taken to a depth of 3 feet the potash mineral content of the soil varied from 43 to 2,000 tons to the acre.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 123

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER March 22, 1916

EXTENSION COURSE IN VEGETABLE FOODS

FOR SELF-INSTRUCTED CLASSES IN MOVABLE SCHOOLS OF AGRICULTURE

By

ANNA BARROWS, Director, School of Domestic Science, Chautauqua, N. Y., and Instructor, School of Household Arts, Columbia University

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 123

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. ▼ March 22, 1916

EXTENSION COURSE IN VEGETABLE FOODS.

FOR SELF-INSTRUCTED CLASSES IN MOVABLE SCHOOLS OF AGRICULTURE.

By Anna Barrows,

Director, School of Domestic Science, Chautauqua, N. Y., and Instructor, School of Household Arts, Columbia University.

CONTENTS.

GENERAL SUGGESTIONS TO LEADERS.

Although the leader of this course does not need any more training than the other members, her special work will be easier if she reads at least a lesson ahead of the class work, or, better still, goes more or less rapidly through the whole bulletin in advance. In this way it will be easier for her to make wise suggestions regarding the materials to be used for the practical work in connection with each

Note.—This course is a revision of that published as U. S. Department of Agriculture, Office of Experiment Stations Bulletin 245. In its preparation the author cooperated with J. M. Stedman, Farmers' Institute Specialist, and with the Office of Home Economics, of the States Relations Service. The course is designed to aid agricultural colleges in their extension work. It is intended for the use of small groups of farm women assembled as a class to study the subject in a systematic manner with one of their number as a leader. It is adapted for such use in any part of the United States. The agricultural college is to loan the class the reference library listed in the Appendix and also a set of the apparatus designated therein. The class meets as often as convenient in a suitable room where tables for exercise work are available. The forenoon is devoted to the text and reference work and the afternoon to the exercise work, an entire day being thus consumed for each lesson. At the completion of the course and as often as desired the college conducts examinations through the leader and corrects and returns the papers.

16889°—Bull. 123—16——1

lesson and possibly regarding the order of some of the lessons. It is not essential that they be given in the precise order in which they are here presented and it may be desirable to change the order to meet local conditions. Some of the practice work, especially exercises which require several days to complete, may be done by the members of the class in their homes and the results discussed at the next meeting.

The leader should have at hand for use in every lesson these bulletins of the United States Department of Agriculture: Office of Experiment Stations Bulletin 28, revised edition, The Chemical Composition of American Food Materials, by W. O. Atwater; Farmers' Bulletin 142, Principles of Nutrition, by W. O. Atwater; Farmers' Bulletin 256, Preparation of Vegetables for the Table, by Maria Parloa; and Farmers' Bulletin 375, The Care of Food in the Home, by Mary Hinman Abel. One or two standard cookbooks are also desirable to provide variety in recipes, and more detail than can be given in these pages. The members of the group should be encouraged to consult any books in their homes bearing on the subject and to form the habit of using the dictionary and encyclopedias.

The queries at the end of each exercise are intended to aid in fixing the leading points in the students' minds. The majority of them have to do with facts brought out in the lessons, but some of them refer to matters which the student is expected to gather from experience and thought.

Plan the practical work carefully. For example, the fire must be ready and water heating while the vegetables are being prepared. Insist on careful weighing and measuring. Waste nothing.

By-products should be carefully used, or at least their possibilities noted, for conservation and efficiency should be watchwords in the kitchen quite as much as in business or national affairs.

LESSON I. CLASSIFICATION OF PLANTS.

A great variety of food plants are included under the term "vegetable," and there are many matters connected with their growth, selection, and preparation as human foods that are important in a study of their value and uses. The study of them may be conducted along a variety of lines, depending upon the use to which the information sought is to be put. For example, they may be studied with reference to—

(1) Their discovery and improvement by man.

(2) The parts which are desirable for food and their food value.

(3) The ways in which they are or should be handled and marketed.

(4) The cooking or other kinds of preparation necessary before they can be properly used as human food.

This course of study is more particularly along the line of the last item in this list—the culinary processes through which vegetables must pass before they can be properly utilized by the human body as food.

Few of the vegetables which are now man's main dependence were attractive in their original form, but most have been developed through centuries of cultivation and experiment. Cookery, as well as agriculture, has served to increase the number of plants available for food. "The number of inhabitants that can be supported in a country depends as much upon the art of cookery as upon that of agriculture; both arts belong to civilization," said Count Rumford, a pioneer in scientific food study. Primitive man gave little thought to agriculture, but took seeds, fruits, roots, leaves, and stalks, or fish and game, as nature provided them, thus satisfying his hunger and getting such variety as he could. In the division of labor between the sexes in early times the men were usually the hunters, and the women gathered, transported, and stored the simple forms of vegetable foods, including fruits and nuts, roots and seeds. The total number of kinds grown is very small compared to the total number of known plants; large markets offer hardly 50 varieties of vegetables, and most families use less than half this number.

CLASSIFICATION OF PLANTS.

To trace the common vegetables back to their sources would be interesting. Some have been known so long that it can only be guessed what land they came from or from what wild plant they were developed. More is known about others.

In order to describe and classify plants accurately botanists have adopted a system of Latin names for the principal forms and groups, and some familiarity with these is very helpful in studying this subject or even for reference to the dictionaries and encyclopedias.

There are many ways of classifying the plants which are useful to man. A simple plan is to divide them according to their uses into—

(1) Those that yield food for man, or for those animals which in turn are useful to man;

(2) Those which furnish materials for clothing and shelter; and

(3) Those which supply no material need, but add beauty to human surroundings.

The plants that are used for human food might be classified in several ways. One would be from the dietetic standpoint and would include, first, those used primarily for the sake of nutrients contained, and second, those used primarily for the sake of flavor or variety. Another classification would be according to the part of the plant used. This is a little difficult because in some cases several parts are eaten, but it is nevertheless worth considering. One of the important groups under such a classification would be that which includes the roots or similar underground parts. To the botanist, there are important differences between such forms as true roots like sweet potatoes or parsnips, tubers like white potatoes and Jerusalem artichokes, root stalks or rhizomes like ginger, bulbs like onions, etc., but from the point of view of human food they may all be roughly classed together as root crops. They represent the store of nutritive material which the plant collects underground to draw on during its growth. Asparagus represents the use of stems as food. Sago, which is made from the pith of a species of palm, is an example of the use of a part of a tree trunk. In celery and rhubarb the leaf-stalks are the edible portion. Many kinds of leaves are used, both dried and fresh. Among the fresh ones may be mentioned lettuce, endives, spinach, and greens of various kinds. Dried leaves appear in tea and such flavoring matters as sage, thyme, bay, etc. Fewer flowers are used than most other plant forms. Cauliflower and globe or French artichokes, however, represent the undeveloped flower heads, while capers are pickled flower buds and cloves are dried ones. There is a great variety in the fruits and seeds used. Sometimes the preparations of cereal grains, such as hulled corn or hominy, rice, or macaroni and other pastes made of wheat flour, are served with meat like potatoes. Another important group consists of various members of the pulse family. Most important of these are peas and beans, some of which are eaten half ripe in their pods, some ripe and fresh, and some dried. Tomatoes, eggplants, and various members of the gourd family, such as squash, pumpkins, cucumbers, etc., are still other fruit forms used as vegetables. The seeds of mustard, celery, nutmeg, allspice, cassia, and various peppers are dried and used for flavoring.

THE COMPOSITION OF PLANTS.

Every plant may be considered a factory into which are carried substances from the air and the earth to be manufactured into other and very different products. In general, the processes which go on within the plants are those of upbuilding, the substances which enter being simple and those which are produced complex.

Some plants may be considered factories for the manufacture of food, others for textile fibers, and still others for fuel or building materials. Some serve several or all of these purposes. But whatever the use to which the plants are put, they all have certain common characteristics which may be learned from any work on botany.

Most foods include more or less refuse as well as the edible portion. Modern commercial enterprise separates much of the refuse before delivering foods to the consumer. In each lesson notice the small portion of the plant studied which is actually used as food.

The edible portion consists of water and four types of nutrients. (Figs. 1 and 2.)

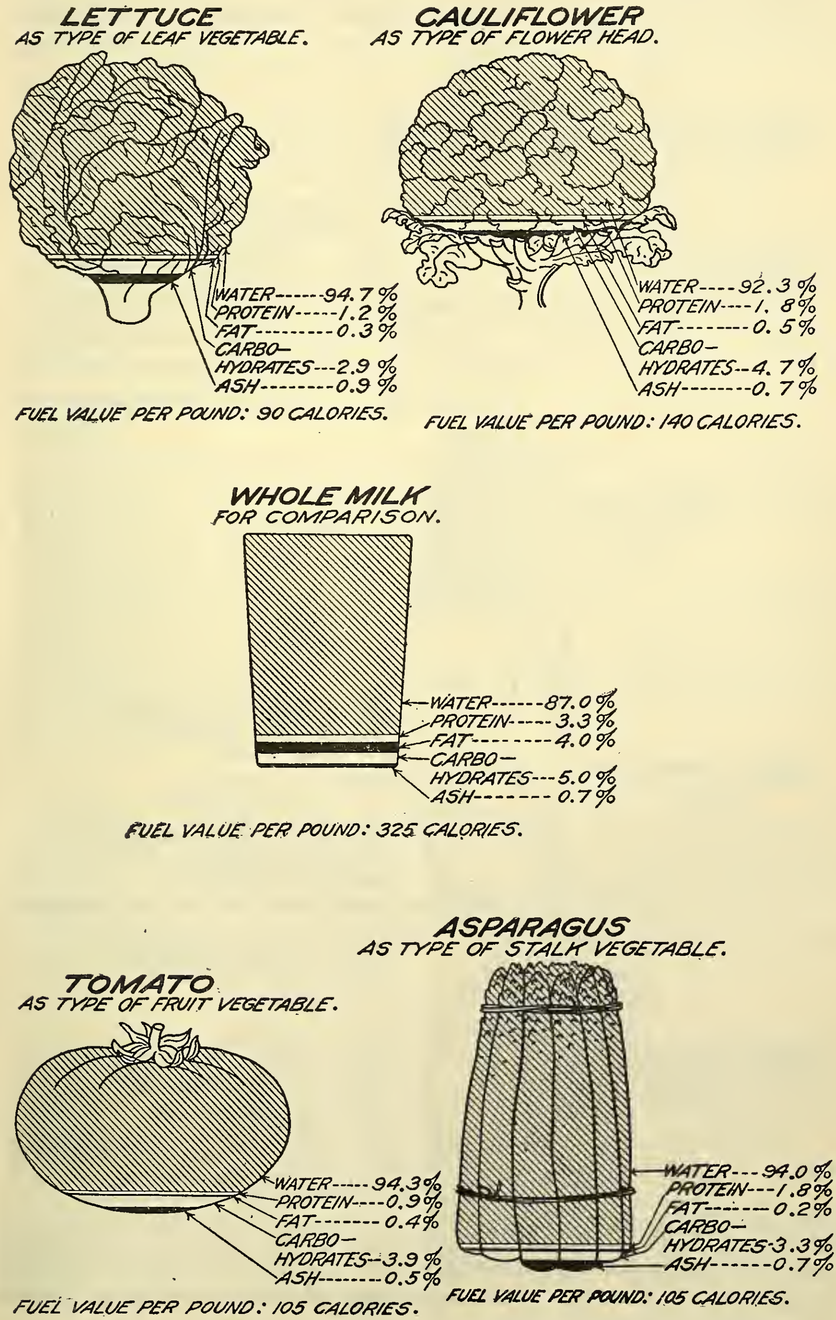


Fig. 1.—Composition of some succulent vegetables as compared with milk.

Water.—This substance, essential to life, forming over 60 per cent of the average human body, is present in almost all foods but in varying proportions. Even the dry cereals and other seeds contain

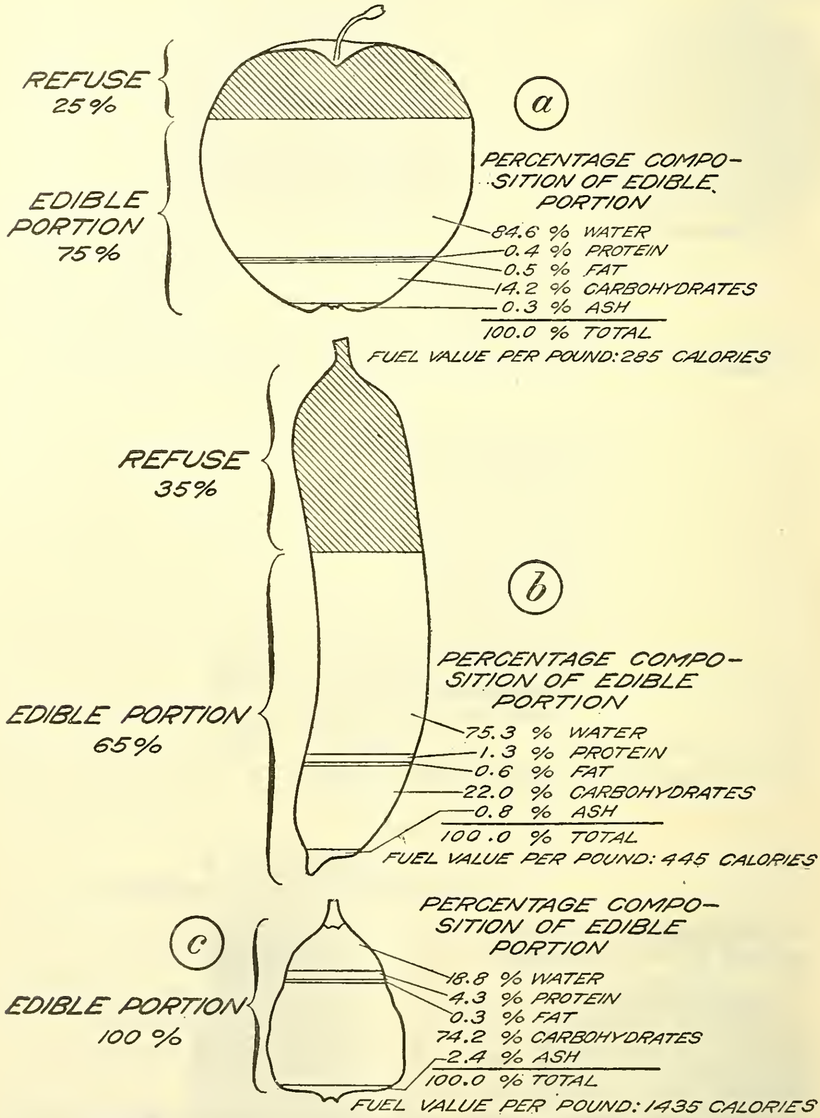


FIG. 2.—Composition of apple (*a*), banana (*b*), and dried fig (*c*).

10 per cent or more. In the fresh and the succulent vegetables watery juice is often apparent to the sight or touch or will be yielded by pressure. Most dry seeds must be soaked and cooked in water before they are ready to eat.

Mineral matter (*ash*).—In most vegetables the percentage of ash is higher than in grains. When one notes the small bit of ash remaining after food is burned and considers that it contains calcium, iron, potassium, sulphur, etc., one realizes how small an amount of each must be present. Still, these minute quantities, often barely 1 per cent of the total weight of the food, are essential to health. Mineral matters obtained from such foods are considered much more useful to the body than when taken in the form of "spring medicines."

Fat.—Comparatively few common vegetables contain enough fat to show readily. Nuts, such as pecans and coconuts, and seeds, such as cottonseed, peanuts (a beanlike seed commonly called a nut), and corn, and such fruits as the olive and avocado, or alligator pear, may yield a considerable amount. The lack of fats in most vegetables justifies the common habit of using cream, butter, or table oil with them, or of eating them with meat which usually contains considerable fat.

Protein.—Except for the legumes, vegetables contain too little protein to be detected by simple experiments. From the point of view of dietetics this is not significant, for vegetables are commonly eaten with meat and milk products which supply protein.

Carbohydrates.—As a class vegetables are rich in carbohydrates. Starch, cellulose (the woody fiber which forms the basis of all plant structures), and sugar are usually all present. Though the amount of sugar is usually small, its presence is shown by the sweet taste of squash, young peas, and green corn.

EXERCISES, LESSON I.

Materials needed.—Test tubes, paper, cheesecloth, wire strainer, filter paper, alcohol lamp or Bunsen burner; a few each of large seeds, such as corn, squash, beans, peas, nuts; ripe olives; onions and other bulbs; potatoes, beets, carrots, and piece of squash; small quantities of iodin, ether, nitric acid.

If possible, show the general structure of plants, by pictures or lantern slides or under the microscope.

COMPOSITION OF FOODS.

Water and mineral matter.—Weigh a small portion of a vegetable, slice thin or grate, spread on a shallow dish, and set to dry in the oven with the door open, on the back of the stove, in the uncovered part of a double boiler, or in the sunlight in a current of air. Weigh after 1 hour, again after 24 hours.

Soak dried fruit or vegetables, measure and weigh before and after soaking and reckon the percentage of water absorbed.

Burn any vegetable substance on a clean surface which can be made very hot; the ash left after all charcoal disappears is the mineral matter. In the laboratory small dishes called crucibles are used for this purpose, but small tin covers make convenient substitutes.

Weigh a potato; bake it, and weigh again after baking; put in the oven and allow it to turn to charcoal, and weigh again; then burn the charcoal, weigh the ash, and compare the result with the original weight of the potato.

Fat.—Crush nuts, ripe olives, or mustard seeds on blotting paper.

Put some peanut butter in a piece of cheesecloth and leave in the oven or in a water bottle until the oil separates.

If an equal volume of ether is added to ground flaxseed or peanuts and allowed to stand 10 minutes or more the fat will be dissolved in the ether. The liquid may then be filtered and left in a draft of air until the ether evaporates and the fat remains. The ether must be very carefully used as it is very volatile and inflammable. Do not use it near a fire or lighted lamp.

Protein.—Soak split peas for 24 hours or more, then heat in the same water. Skim the white froth and test that and some of the water with dilute nitric acid. The protein present becomes yellow when the nitric acid is added and the whole is heated. Treat egg white or milk in the same way for comparison.

A still simpler though less certain test for protein is the unpleasant smell given off when materials containing it are burned. Burned milk or eggs have a well-known odor, protein-rich seeds, such as beans or peas, burn with much the same smell.

Starch.—Grind peas or beans in a mortar or grate a potato or two, spread the ground material on a fine wire strainer or on a piece of coarse cloth, and pour water through a number of times. This will wash the starch through the strainer or cloth and it will settle in the water. Note that very little starch dissolves in cold water and that most of it settles. A drop of dilute iodin on raw starch gives a blue color. After starch is thoroughly cooked the blue color will not appear when iodin is added. (See also experiments under Lesson V, p. 30.)

Sugar.—Boil down the water in which carrots, beets, or squash have been boiled until it is a thick sirup; then test by tasting.

Evaporate further until it burns and compare the odor with that from burning sugar.

GERMINATION TESTS WITH SEEDS AND ROOTS.

Have some squash seeds soaked for 24 hours or longer. Split some open and find the seed leaves or embryo plant. Plant others and examine one or more each succeeding lesson, noting the differences as the embryo develops.

Try similar experiments with other large seeds, like peas, or kidney or Lima beans.

In the same manner experiment with sprouting potatoes or onions. After these have each been weighed and the weight recorded they may be put in earth or in a glass of water, or even wrapped in moist cloth or paper. Keep some away from the light and others in bright sunshine. Notice the changes from day to day and the gradual shrinking of the tuber or bulb as the sprouts develop; estimate loss of substance by appearance and by weighing the bulb or tuber (first cutting off the top or the sprouts) and comparing this with the original weight.

Cut the green top from a carrot; put the cut surface down in a glass of water, and place in the sunlight; in a few days small leaves will appear.

Chop raw spinach fine, press in a cloth, then heat the juice extracted. Dip or strain the extract from the water and combine with sugar to preserve it. The green coloring matter thus obtained may be reserved for tinting candies and ice cream. If cooked too long it loses its vivid green.

REVIEW QUESTIONS, LESSON I.

1. Give different methods of classifying plants.
2. Mention five of the principal plants most used in your home.
3. Describe the structure of some typical plant.
4. What is cellulose? What of its food value?
5. What proportion of some common plants is utilized for food? Give examples.
6. Report your personal observation in the germination of plants.
7. Describe the principal nutritive substances derived from plants.
8. How may the presence of each one of these substances be recognized?
9. Tell something of the changes produced by cultivation of plant foods.
10. What part have women had in the development of such foods?

LESSON II. LEAVES AND STALKS.

SALAD PLANTS.

There are many plants or parts of plants that may be eaten raw, the most important being the fresh green vegetables, such as lettuce, water cress, and celery. Such vegetables are generally relished and form a part of the diet wherever they can be obtained.

For the present purpose such vegetables may be called salad plants; but it is difficult to make an exact classification because so many of these plants are used in other ways than as salads, and because salads are often made of cooked vegetables, meats, etc. Lettuce, for example, a vegetable which in this country is most always eaten raw, in Europe is often cooked, and thus it becomes a potherb as well as a salad plant. Water cress, though often used as a salad, is sometimes used simply as a condiment or garnish. Peas, beans, potatoes, and vegetables such as spinach, which are most commonly served as "vegetables" are often put into salads. Some roots, as radish, and fruits, as cucumber, are also very commonly used raw as salads.

The whole matter will seem less confusing if what is meant by salad is exactly defined. Originally the word referred to a green plant rather than to a dish prepared from the plant, and its derivation indicates that it meant one which was to be eaten with salt. Now it is applied to a dish served cold with a dressing which always contains vinegar or other acid and usually some kind of oil or fat, and salt, pepper, or other seasonings. The basis of the salad may be vegetables, either raw or cooked, fruit, nuts, eggs, meat, or fish—in fact, almost any material or combination of materials of suitable flavor and consistency, and the dressing may be simple or elaborate.

This definition shows what a variety of salads it is possible to make. Many housekeepers in their search for novelties build up strange and ornate combinations, while others go to the other extreme and imagine all salads are foolish "new-fangled" things which it is a waste of time to prepare. The former do not realize that the most satisfactory salads are usually the simplest; and the latter forget that fresh cucumbers served with oil and vinegar, or the "greens" left over from dinner and served cold with vinegar at supper, are just as truly salads as elaborate combinations of all sorts of fruit and nuts and mayonnaise dressing. Moreover, the fact that small quantities of different materials can be easily combined to make an attractive salad, shows that it is often an economical and sensible dish.

Returning to the vegetables which can be used raw in salads, that is, the salad plants, they are valuable because their freshness and attractive appearance arouse an appetite for the more substantial materials served with them. Moreover, in this shape the body gets all the iron, calcium, and other mineral constituents present, and also vitamins, as certain substances are termed which are needed in at least small amounts for normal growth and health, and which may be partly lost or perhaps rendered less useful by cooking. Hence the desire for such foods should be considered to represent a real need, and raw salad plants and fruits should be supplied freely. "Spring bitters," which the housewives of earlier days thought necessary, are more palatable when obtained from salads than from medicine bottles. Aside from any question of medicinal value, such plants help to make the diet attractive and give a relish to food, particularly in the spring, when one is weary of the limited variety of the winter table.

The distinctive salad plants are very succulent; that is, they consist very largely of water. This is the chief reason why they are especially refreshing in warm weather and give a pleasant contrast to the heavier dishes of a heavy meal. They also serve to prevent too great concentration of food, and thus aid in the digestive process.

It is a very common custom to combine fat with salad plants, fresh or cooked. Fat is a compact food and, weight for weight, is about two and a quarter times as valuable as protein or carbohydrate for fuel in the human body. A tablespoonful of oil would go farther toward supplying energy for keeping the human machinery running than a large head of lettuce. The world over people have instinctively added a condensed dressing consisting mainly of fat (oil, bacon fat, or cream) to the salad plants bulky with cellular tissue and water, and have eaten such salads with meat and bread which supply protein and carbohydrates.

The use of salad plants and salads as decorations on the dining table deserves consideration.

Green salad plants grow near the earth and so are likely to be soiled with dirt which may often be accompanied by bacteria and other living things, which cause disease. They should always be made clean before use. Water cleanses to some extent, but only through intense or long-continued heat is it possible to check entirely the development of the microscopic forms of life—bacteria, yeasts, molds, etc.,—some of which make food decay and some of which cause human disease. Salad plants which can not be regarded as above suspicion would better be cooked than used raw. Many mysterious cases of disease doubtless arise from eating imperfectly cleaned green foods. Therefore unusual care is needed in the selection and preparation of foods which are not to be subjected to heat. Cress, lettuce, and other salad plants, carelessly cultivated or handled in the market and half cleaned in the kitchen, may transmit disease, as may milk, raw oysters, and other foods. Before washing, green vegetables should always be looked over carefully to make sure that any inferior portions, insects, or other undesirable things are removed.

The fashion of cutting down through a head of lettuce or celery, and serving it in lengthwise sections may give each person his fair share of the choice, tender portions, but can not be recommended, because it is practically impossible to cleanse the grooves of the leaves where they join the stem. Such plants should rather be separated into their natural divisions and washed in several waters, special attention being given to hollows in stalks and leaves. Sand, though unpleasant, may be less harmful than other things that may be left behind after washing; but its presence justifies the suspicion that the washing was not thorough or carefully done. Vegetables, such as spinach, which are difficult to free from grit, should be washed in many waters, and lifted out of the pan each time in loose handfuls before the water has been drained off. If the water is poured from the pan while the vegetables are in it, part of the sand falls back on the washed leaves. Salt in the water will aid in drawing out insects if they happen to be present. There is an advantage in washing all salad plants in running water, especially for the removal of insects. After washing several times and removing imperfections, salad plants may be kept in a cool place like a cellar or refrigerator for some hours or even a day before using. After draining off the last water, wrap the leaves or stalks in a cloth or put into a clean paper bag; that is more effective than keeping them in water.

The quality of vegetables may be greatly injured by insect pests and plant diseases. If the plant suffers severely from such enemies, it can not make normal growth, and so all or parts of it may be inferior. For instance, green peas or string beans from vines badly attacked by insects or by some fungus disease do not attain full perfection, and obviously, leaves used as greens are of inferior quality if worm-eaten. Insect pests and plant diseases are often controlled by the use of insecticides and in similar ways; if such things are used, there is all the more reason for washing vegetables thoroughly before preparing them for the table, to remove any hellebore, copper salts, or other poison which may still adhere to them.

During the cleaning process it is advisable to sort out the coarsest portions to add to soup materials; the next best may not be attractive to serve by themselves, but can be cut or shredded for combination with other materials, while the best of all—the heart of the cabbage, celery, or lettuce—should be served in the least elaborate way with salt or a simple dressing.

No plan for serving salads should be encouraged which leads to a waste of food material. For example, if the outer portion of a cabbage is to be used for a salad bowl, dig out the center after cutting a layer from the top. Chop this fine, mix with dressing, and pack in the case of larger leaves which were left in place; later, any dressing adhering to these larger leaves may be washed off and they may be used for a scallop or soup. Many materials may be combined with the cabbage, celery, and lettuce in salad making; for instance, raw apples, pears, or radishes, or canned fruit, such as pears cut in slices or cubes.

Lettuce is the principal salad plant in this country both for use alone and in combination with other foods. There are many varieties, adapted to different conditions, but all may be classed under two general heads—the cabbage lettuce, where the heads are solid and compact, and the cos lettuce, where the leaves are long, loose, and sometimes less delicate. Romaine is an example of cos lettuce. There are also varieties with blanched centers and others with curly, dark-tinged leaves.

Other good salad plants are chicory and its near relative, endive, both of which are improved by being blanched for a few days before they are picked; corn salad or lamb's lettuce, a small plant often found in city markets; sorrel, wild and cultivated; some young and tender seaweeds; and many mild-flavored plants or weeds. Others are better for partial cooking, even if served cold as salads.

Celery in its wild state is an unpromising if not harmful vegetable; but by cultivation, and especially by blanching its leafstalks, it has been made into an excellent salad plant, sometimes said to have certain medicinal virtues. The fibrous outer stalks and larger white leaves of a bunch of celery should be reserved for soup making. Some of the larger stalks, too stringy to serve whole, may be cut up and used in salads, or if too tough for that, may be cut, cooked, and added to soups or served with white sauce, perhaps on toast. The tender inner stalks should be served plain to eat with salt. Sometimes the groove in the stalk is filled with prepared cheese. The center of the root is a delicate morsel. Leaves and root may be dried to flavor future soups. Celery exposed to contamination in unclean cars, markets, and wagons, must be carefully washed before it is safe to eat. If wilted, the stalks should be separated and placed in cold water for an hour. They should then be washed and rinsed, wrapped in a cloth, and kept in a cool place. Do not scrape or trim them until just before serving.

EXERCISES, LESSON II.

Materials needed.—Any available salad plants, such as lettuce, dandelion, chicory, celery, chives, endive, escarole, cabbage, mustard, parsley, peppergrass, radish, romaine, water cress—as many types as possible. If only lettuce or celery can be secured, have one root for each student or group of students. Apples, cucumbers, etc., may also be used. For salad dressings provide olive, cottonseed, or peanut oil, sour cream, peanut butter, eggs, bacon fat, lemon juice, vinegar, and other seasoning materials, according to the recipes to be chosen from those at the end of this section.

Excursion.—If feasible, visit markets, farms, or gardens, or gather wild plants. Learn to recognize different salad plants and test their merits as raw foods, alone or with various dressings.

LETTUCE.

Weigh head of lettuce with the roots. Remove inedible portions and sort the leaves according to quality; weigh and estimate the percentage of refuse and relative values of each portion. Pull apart and wash each leaf thoroughly, dry on a cloth without bruising, then arrange in a salad bowl with the larger perfect leaves outside and the tender ones in the center. Torn but otherwise good leaves may be rolled or folded and cut in shreds or ribbons for other salads.

CELERY.

In the same way clean, weigh, and estimate values of all parts of celery, including the root. Reserve tough stalks, portions of the root, and coarser white leaves for use in soup stock in some succeeding lesson (V or XI). The tough outer fiber sometimes may be pulled or scraped off. Sort celery like lettuce, reserving tenderest portions to serve in simplest form. If there are enough of the green and the tender white leaves, cook them for greens. Lettuce leaves may be combined with them, if desired. The larger green leaves have too strong flavor for this purpose. Cut the larger, coarser stalks into lengthwise strips and then into quarter-inch slices. Let these stand in a French dressing for an hour or more, then combine with lettuce, nuts, apples cut into dice, or other material, or serve in a hollowed apple or tomato. Section of cabbage or cucumber may be used in this way when celery is not available.

CABBAGE.

Cut a portion of the stem from a cabbage, put the cabbage into a dish of water, and cover with a cloth. In 24 hours it will be much crisper, having absorbed water like any withered plant. Take a small, light-weight cabbage, turn back the leaves, and compare with a head of lettuce and with a cabbage of similar size, but weighing twice as much. Cut a cabbage into quarters, take out the inner third of each section and serve as a salad. Sometimes the inner cabbage leaves are tender enough to serve whole like lettuce, but usually they should be shaved with a knife or vegetable cutter or chopped. The coarser outer leaves may be reserved for soup or scalloped cabbage. (See Lessons III and XI.)

SALADS AND SALAD DRESSINGS.

Various salad dressings may be made in this lesson, and some reserved in glass jars for future lessons. The cooked dressings may be taken up later. In this lesson prepare the simplest types, like the following:

French dressing: To each tablespoonful of oil add a few grains of pepper and a little salt, blend thoroughly, and then add slowly one teaspoonful of lemon juice or vinegar.

Nut dressing: Dilute peanut or other nut butter with lemon juice and vinegar and a little water. Season with salt and pepper.

Cream dressing: Beat thick cream, sweet or sour, with an egg beater until stiff. Season with salt, pepper, and lemon juice or vinegar. Continue the beating while gradually adding the acid.

REVIEW QUESTIONS, LESSON II.

1. Mention five plants commonly eaten raw.
2. What of the possible medicinal value of raw foods of this kind?
3. What food materials are most abundant in salad plants? What do they lack?
4. Mention special characteristics and describe the preparation of three of the most common salad plants.
5. Explain importance of cleaning such food materials.
6. How may these leaves and stalks be kept in good condition for the table from one day to another?
7. Why are oils or other fats usually combined with such plant foods?
8. Give directions for dressing a salad with olive or other oil.
9. What are the usual ingredients in a cooked salad dressing? Give reason for the use of each.
10. What are the decorative possibilities of a salad?

LESSON III. LEAVES AND STALKS—Continued.

GREENS OR POTHERBS.

Closely associated with the plants that are eaten raw are a host of leaves and stalks commonly cooked and served under the general name "potherbs" or "greens." The latter suggests the instinctive desire which the dwellers in the temperate climates have to utilize the first green tips which appear in the spring and which were especially welcome after the monotony of the old-fashioned winter diet. Notwithstanding the low fuel value of such foods, the discerning housewife recognizes the necessity of supplying her family bountifully with this type of food, particularly because, as was stated in the lesson on salads, these green foods supply valuable mineral matter (iron, potash, lime, etc.), and vitamins as well as some protein and energy in the early spring, and these are valuable ingredients even when they must be purchased at the city market prices. A wide variety of plants both wild and cultivable are usable in this way.

WILD PLANTS USED AS POTHERBS.

A double purpose may be accomplished in the country home by the use of such wild greens, namely, freeing the grounds from some common weeds and providing food. Some of the wild plants which may be used in this way are here described.

The top of the common dandelion is used for greens before the flower bud has expanded. When it is desired to root out the plant from a lawn, the entire root must be dug up; if simply the top is cut off, the dandelion grows again and in a larger head. The slightly bitter flavor of the young tops is not disagreeable. The roots furnish a bitter extract often used medicinally, particularly in the domestic medicine of early times. When cultivated the dandelion is milder and more tender and may be used as salad, as may the very young wild plant. Cultivated dandelions may be blanched by covering them for a few days. A special bed may be set apart for this plant in the garden, but seeds should not be allowed to ripen and scatter.

The milkweed, cut when less than 6 inches high and before its leaves have fairly unfolded from the stalk, is considered almost as good as asparagus, and may be used to extend a scanty supply of the latter. The young milkweed stalks and leaves are also good when cooked like spinach.

The sour sorrels, so abundant on poor soil, may be added to soups or salads, and the larger leaves of the cultivated varieties make excellent greens. The garden sorrel is easily grown.

Chicory, which is a common weed in many places, furnishes excellent greens, much like the dandelion, only rather more bitter.

The cowslip or marsh marigold is sufficiently abundant in some regions to serve as a food plant, and is prepared like spinach or other greens.

Poke sprouts are a favorite potherb in some regions of the Southern States and are on sale in the spring in many southern cities. The young shoots are cooked and served like asparagus.

Purslane or "pusley" is one of the most common weeds now, yet 200 years ago it appears to have been cultivated as a potherb and to have been brought from the East to Europe as a salad plant. It is best when well developed, but just before it blossoms the roots should not be used. But little time is required for cooking its juicy, red, branching stems, which are not unlike beet greens in flavor.

Pigweed or lamb's-quarters, shepherd's-purse, plantain, and similar weeds are used in this fashion. Horse-radish tops are very fine greens, alone or mixed with other sorts.

Experiments with wild plants should never be tried unless one is sure that the plant is not poisonous, as there are some green plants like skunk cabbage, hellebore, and may-apple tops which are very dangerous.

CULTIVATED POTHERBS OR GREENS.

Among the plants cultivated especially for greens, asparagus is a general favorite. This is a member of the lily family akin to the lily of the valley, and like this plant, will live on and on after it is once established. Many an asparagus bed does good service until the second or third generation of owners, and it is strange that any farm should lack this long-lived, easily cultivated delicacy.

Asparagus should be cut just below the surface of the earth before the bud begins to unfold and when the stalk is 6 to 8 inches above the ground. Wash well and scrape the lower end. Cook in boiling salted water until tender; fresh asparagus should not require 30 minutes. Overcooking injures the flavor and color as it does with all green vegetables. Season with melted butter or arrange on toast and season with butter and salt. A cream sauce is often served with asparagus and a cream soup may be made from the water in which the stalks are boiled.

Spinach is a favorite kind of greens and is seen in city markets most of the year. A French proverb calls it the "broom of the stomach," and it is richer in iron than most common foods. The tenderest leaves may be served raw as a salad. Excellent canned and evaporated spinach may be found in the larger grocery stores.

Beets are sometimes grown especially for greens, but more often surplus plants or surplus leaves are used for this purpose. The beet plants are often eaten when very small. The tops of the early bunch beets should always be used for greens and are palatable even when the stalk and leaf are 6 or 8 inches long. Swiss chard is a variety of the beet plant with thick leaf stems which is raised especially for greens. Turnip tops, cabbage sprouts, kale, collards, alfalfa tops, and pumpkin tops are sometimes used in this way. Carrots are also occasionally used as a potherb and, like parsley, are perfectly wholesome, but it should be remembered that some of the same family of plants (the parsley family) are poisonous.

Hop sprouts are seen in the foreign markets in March and April and are commonly canned. Care is taken to cut the sprouts so as not to interfere with the later growth of the vines.

The Japanese use young shoots of burdock as a potherb. They are better if blanched with earth for a few days before cutting. They should be parboiled, drained, and cooked again until tender, and served warm or cold with a salad dressing. Udo is another Japanese salad plant which is being tried in this country.

Onion tops: The bulbs and tops of young onions and the stalks and leaves of leeks are good greens, the onion tops being more commonly cooked with other greens than alone.

Fennel is used as a culinary vegetable in Europe and occasionally in American gardens. The leafstalk is thick and swollen toward the root, and thus becomes united almost like a bulb. It is cooked and served much like onions, and also eaten raw as a salad or a relish. The finely divided leaves may be cooked like spinach, while the stalks may be cooked and served with white sauce like celery.

American housewives seldom realize that lettuce makes excellent "greens." This, as mentioned before, suggests a good way to use the tougher or outer leaves of the lettuce bought for salad and the surplus crop of the home garden. As is the case with all potherbs, lettuce should not be overcooked. The use of celery tops as greens, alone or mixed with lettuce, was introduced in the lesson on salad plants.

The cabbage tribe supplies many vegetables and is said to contain no harmful members. They have long been used to prevent scurvy. This group of plants now includes the white, red or purple, and Savoy cabbages, coleworts, Brussels sprouts, borecole or Scotch kale, cauliflower, broccoli, and others. To them the kohl-rabi is closely akin. The swollen stem which looks like a turnip growing aboveground is the part commonly eaten, though the leaves make excellent greens. The cauliflower is usually considered the most delicate of the cabbage tribe (see also Lesson VII); broccoli is similar in form but hardly equal in quality.

Collards or coleworts are similar to cabbage, but their leaves grow long and loose, instead of in a compact head. They grow where the climate is too warm for cabbages to head well.

Kale consists of curly, open leaves not forming a compact head. The dwarf green curled kale is thought by many to be the best for the table. It is cooked like cabbage. A very little soda (not more than a small saltspoonful) for each quart of kale added to the water in which it is cooked will preserve the green color and not injure the flavor. The blanched shoots of sea kale are prepared like asparagus and the flower heads are also used. The sprouts from cabbage stalks left in the ground over winter may be used in the same way. Like all green vegetables, kale, cabbage, etc., must not be overcooked, if they are to be delicate, wholesome, and at their best.

When cabbage and related vegetables are cooked an unpleasant odor and flavor is developed. This is prevented in large measure by cooking uncovered and in an abundance of water. It is also important that such vegetables shall not be cooked too long. Once it was considered necessary to cook cabbage several hours, but a young cabbage may be made perfectly tender in 20 minutes and an older one will not take twice as long. There is good reason to believe that overcooked cabbage is a cause of digestive disturbance, while rightly cooked it is not. If the white portion of cabbage or cauliflower begins to grow darker in color in cooking, it is a sign that it has been cooked too long.

16889°—Bull. 123—16——2

Some of the cabbage tribe may be used raw as salads when young and tender.

Rhubarb is another plant in which the leafstalks are the useful portion, and may be described here, though it may from its use be classed as a fruit rather than as a vegetable. Because of its markedly acid flavor it is acceptable in the early spring, when it is at its best. Later in the season, when the stalks are tough and fibrous, the juice may be extracted for jelly making. Because it contains some oxalic acid the use of rhubarb is frequently forbidden to persons of gouty tendencies.

SEAWEEDS.

Several varieties of seaweeds are used as foods in different parts of the world, sometimes for flavor or supposed medicinal value and sometimes in place of gelatin. The commonest of these is Irish moss, much used in making blanc mange.

EXERCISES, LESSON III.

Materials needed.—Different greens according to season, such as spinach, cabbage, cauliflower, Brussels sprouts, asparagus, either fresh or canned; also butter, eggs, and salad dressing. A quart of Brussels sprouts and a peck of spinach are convenient amounts.

Utensils.—Saucepans for boiling vegetables, pans for washing, knives, colander, chopping bowl, and chopping knife.

The first step in the preparation of all these plants is thorough cleansing; sand is particularly obnoxious in greens; and though the boiling process might render most of the invisible dirt harmless, it is safer to wash them carefully. (See Lesson II.)

PREPARATION AND COOKING OF POTHERBS AND SIMILAR VEGETABLES.

Exercise 1.—Let each member weigh, trim, and wash several roots of spinach; weigh refuse, estimate the percentage of loss. Cook in slightly salted water till tender, or approximately 30 minutes. Drain, measure the leaves, and compare with original bulk.

Let each pupil prepare one of the following, and all results be compared:

(1) Cook spinach in its own juice, in covered saucepan.

(2) Cook in considerable water uncovered.

Serve 1 and 2 plain and compare their flavor.

(3) Cook; then drain, chop, rub through sieve, reheat, and serve with a little cream or white sauce made of 1 tablespoon butter, 1 tablespoon flour, and one-half cup milk. Melt butter in saucepan, add flour, salt, and other seasoning to taste, blend, stir until bubbling, but not brown. Gradually add milk, cold or warm. Cook until it bubbles and thickens, stirring constantly.

(4) Cook, drain, and chop; mold in cups, garnish with egg rubbed through strainer.

(5) Cream of spinach soup: Prepare spinach as in 3, then dilute to desired consistency with milk.

Exercise 2.—If possible, let each member prepare a different dish, one using Brussels sprouts, one cauliflower, one cabbage to be boiled plain, one cabbage with white sauce, etc.; in this way small quantities will serve for the class and all varieties may be cooked at the same time.

Prepare and serve boiled cabbage in the following ways:

(1) Plain with butter.

(2) With oil and vinegar.

(3) With white sauce.

(4) With white sauce and crumbs. Mix cabbage with half its measure of white sauce. Sprinkle with buttered crumbs, and bake until crumbs are brown.

(5) With white sauce, crumbs, and cheese.

(6) With sausage. Cook sausage thoroughly. Leave a little fat in the pan, put in chopped cabbage, and cook 5 to 10 minutes. Serve with the sausage.

(7) With potatoes (kolcannon).

(8) German cabbage. Stew chopped red cabbage in its own juices with an ounce of butter or other fat to each quart of the cabbage. Keep covered. This may be seasoned with onions, nutmeg, salt, pepper, vinegar.

Exercise 3.—Supply each member of the class with a different "green" if possible.

The preliminary preparation should be similar to that for the raw salad plants. Even if all is to be cooked it is desirable to sort out the tougher parts and give them a "blanching" or parboiling before combining with the tenderer portions.

Let each vegetable cook in sufficient boiling, salted water to prevent any danger of burning. The dish should be uncovered except when the vegetable is to be cooked in its own juices, in which case the dish must be covered.

Adopt a small standard portion suitable for one serving per person—2 ounces or one-fourth cup is a fair average—estimate cost, including original cost, labor, and cost of additions. Compare with cost of canned vegetables.

Observe the constant tendency to add to such plants the protein, fat, etc., which they lack by combining with them milk, butter, eggs, and salad dressings.

When few fresh greens are available, use canned asparagus. Remove from can, taste of liquid, and reserve it if the flavor is good. The stalks may be reheated and served on toast. Or tips may be served for salad with French dressing, and the stalks used for cream of asparagus soup. To make the latter, split open stalks, add liquid from can if suitable, heat, rub through coarse strainer, add milk, thicken, and flavor.

In each case work out the cost of material in city and in country, and add the labor of preparation. Note the advantage in the country in the use of such by-products or weeds as thinned-out beet greens or purslane.

Irish moss blanc mange may fitly form a part of this lesson. The whole moss is preferable to the sea-moss farina.

Stewed pieplant or rhubarb will also illustrate use of leafstalks as food.

This lesson may be carried out in the preparation of a luncheon or simple dinner with either of these menus:[1]

No. 1.	No. 2.
Cream of asparagus soup.	Cream of celery soup.
Spinach and eggs.	Asparagus on toast.
Creamed cabbage with cheese.	Kolcannon (potato and cabbage).
Stewed rhubarb.	Blanc mange.

REVIEW QUESTIONS, LESSON III.

1. Explain the terms "greens," "potherbs."

2. How should you divide plants that part may be used for salads, part as greens, or in other ways?

[1] Recipes may be found in standard cookbooks.

3. Give general directions for choosing, cleaning, and cooking dandelion greens.
4. Give a list of wild plants in your vicinity suitable for this purpose. How many have you tried?
5. Explain the shrinkage common with such foods.
6. Why is fat meat often cooked with plants of this type?
7. Give general directions for cooking cabbage or cauliflower.
8. How many asparagus beds in your neighborhood? Can you give method of preparing canned asparagus?
9. What reasons for use of white sauce with cooked cabbage, celery, etc.?
10. Give directions for making white sauce.

LESSON IV. BULBS.

THE ONION TRIBE.

Next to leaves and stalks, bulbs may be studied; they may be considered as a form half way between stems and roots.

A bulb is a kind of bud, spheroidal in shape, and from the botanist's standpoint consists of a cluster of leaves, modified in form and tightly folded together, one over the other. Usually they form above or just below the top of the ground. In some cases the young bulblets appear in the axils of the leaves (tiger lily) or at the blossom, as in top onions. Bulbs are characteristic of the lily family, which includes some of the most ornamental plants of the flower garden—hyacinths, lilies, narcissus, and tulips, for example. The American Indians used certain wild bulbs, including wild onions, as food, and those of some garden lilies are eaten in Japan and China and are also sold in Chinese shops in American cities. From the culinary viewpoint, however, the most important of the bulbous plants are the onion and some of its relatives.

The derivation of the word "onion" is significant, indicating the oneness of the bulb or the close union of the leaves and stems underground. The onion appears to have been a native of Asia and to have been used by the human race from the most ancient times and is mentioned in the Bible and in old Egyptian writings.

Onions owe their flavor to a volatile, oil-like compound containing sulphur, which has been carefully studied by chemists. It is a matter of common experience that onions act as a laxative. To this and the sulphur-yielding material they contain are no doubt due the medicinal properties commonly assigned to them. They are very succulent, but nevertheless supply some nutritive material, chiefly carbohydrates and sulphur and other mineral matter.

There is a large number of varieties of onions and each is useful in its place. Many kinds are grown by American farmers and gardeners, and the native crop supplies the bulk of the onions found in the markets. The tiny pearl and button onions are convenient for salads or pickles where only a hint of flavor is wanted. From the

Bermudas and the South in the early spring come flat, crisp onions of a purplish tint which are appetizing either raw or cooked, and more agreeable in texture than the coarser varieties commonly raised for the winter market. The large Spanish onions are mild and tender, suitable for salad or cooking purposes. The white-skinned Egyptian onions are usually a satisfactory variety. Most of these types are now grown in this country. There are many onions in the market which are strong in flavor and tough, which are not suitable for cooking though they may be used for flavoring purposes if better kinds are not available. In general, the greenish yellow and red types of onion, owing to their texture and flavor, are less satisfactory for cooking as a vegetable than those of lighter hue.

Garlic is of interest in the study of bulbs, even to those who may not like its strong flavor. Each bulbous root or stalk is a compound made up of several smaller bulblets, each of which is known as a clove of garlic, clove signifying the cleavage or splitting of the larger group. This plant, like other members of the onion race, has been used in cookery from the earliest times. Its use is now especially common among the Latin races in southern Europe, where the climate is said to produce a more delicate flavor in the bulbs. Carefully used in small quantities garlic is a desirable seasoning. Merely rubbing the side of the salad bowl with the cut surface of a clove of garlic gives sufficient flavor to the salad. A little garlic very finely chopped and sprinkled on the top of meat before roasting gives a flavor which many consider extremely good.

The leek is another useful plant of the same race; the bulbous portion is much elongated and the leaves are long and flat and sheathed over each other. In cultivation several inches of the lower end of the leafy part of the leek are blanched like celery. Its use as a potherb has already been noted. (See Lesson III.)

To cook leeks remove the fine roots and the green ends of the leaves and cut the white portion in 3-inch lengths. Wash and cook in boiling water until tender; that is, for 20 minutes or more. Serve on buttered toast like asparagus or with white sauce. If the leeks are too thick, they may be split and flattened after cooking. The water in which leeks are cooked may be used in soups. Closely related species called wild leek or wild garlic grow in some parts of this country and are likely to flavor the milk and butter of cows that eat them in the pasture. Wild leek is sometimes used as a seasoning.

The shallot is a cultivated plant similar to the leek, but with a tubular leaf. Chive is another member of the family, the leaves of which have a delicate, appetizing flavor frequently relished by those who object to the stronger onion flavors. Chives are sometimes used as a border plant in flower gardens, having an attractive purplish blue blossom. A clump of these tiny bulbs will grow for weeks in the house; if they are planted in a dish of mixed ferns the peculiar shade of green in their leaves will make an attractive combination with the other plants, and the fine stalks may be cut as needed to flavor salads and soups. The essential oil is so abundant that a very small quantity of the leaf suffices.

Ordinary young onions are often sold under the name of "scullion" or "scallion," which properly belongs to any thick-necked or undeveloped bulb of the onion tribe which has not grown round, but more nearly resembles the leek in shape. In onion beds these are pulled out and marketed when young, or they may be grown from the bulbs of the previous year.

Onion tops, like the stalks of wild leeks and chives, can also be used for flavoring, especially the sprouts that start when the bulbs have been kept in a warm room. The young spring onions are sometimes eaten like radishes as a relish, or cooked and served like asparagus, and are a favorite dish. (See Lesson III.)

EXERCISES, LESSON IV.

Materials needed.—Butter or drippings, salt and pepper, milk, egg; one or two onions for each student, different varieties preferred; specimens of leek, etc., if possible.

PREPARATION OF ONIONS.

To prepare onions, peel under water, so that the volatile bodies which affect the eyes may remain in the water and be kept from scattering. If the onions are especially strong, after peeling place them in boiling water, to each quart of which one-fourth teaspoon of bicarbonate of soda has been added. After letting them stand in this water half an hour, drain and boil in plenty of salted water for 30 minutes to 2 hours, according to the toughness, changing the water if desirable. The water may be saved to flavor soups.

Often it is wise to take off one or two of the coarser layers next the outside skin and reserve them for flavoring soups, while a part of the tender, succulent center may be reserved for a salad. This plan of selection corresponds to that already suggested for cabbage, celery, lettuce, etc.

METHODS OF COOKING.

Any strong variety of onion is much improved for the table, in spite of loss of nutritive value, if the water is changed several times during the cooking process. Milk may be used for the final cooking.

If onions are cooked uncovered, the odor apparent in the house is less strong, and like cabbage and beans, they are commonly said to be more digestible when thus cooked.

There is a culinary tradition that parsley eaten with onions not only sweetens the breath but counteracts a tendency toward flatulence.

SECURING ONION FLAVOR.

The simplest way to extract onion flavor for seasoning salads, etc., is to cut a slice from the root end of the bulb and press the cut surface firmly against a grater, turning gently until some drops of juice fall. Cut off another slice and press the fresh surface if more flavor is required. Sometimes with a fresh onion the grater is unnecessary, as sufficient juice will follow gashes made with a knife. When the onion is old there is little juice; the soft pulp which passes through the holes of the grater may be used instead.

Another way to secure onion flavor is to cook the chopped bulb in water, milk, or soup stock. Slices from which some of the juice has been extracted will again yield flavor if cooked in this way.

A third method is to extract the juice in fat; and for this purpose sliced onion is cooked in the fat until light golden brown, or sometimes until very brown, thus securing a combination of caramel from the browned sugar and the peculiar flavoring bodies of the onion, a flavor quite different from those obtained by the other methods. The scraps of onion may be strained out and the flavored fat added to sauce or soup, or they may all be used together.

Force meat or stuffing may be flavored with onion in any one of these ways, or chopped onion may be blanched or scalded in soda water and then added directly to the forcemeat.

A little chopped or finely cut onion may be prepared without soiling the fingers by holding the onion on a fork, cutting off the outer skin, making a few gashes in one end, and then slicing across the gashes.

Let each student boil two varieties of onions or an onion and a leek and note the time required and other points of difference between them. Save the water, note color, compare flavor.

Further exercises follow.

SPANISH ONION.

Cut an onion in two, reserve small portions of center for salad; parboil remainder 10 minutes; save water. Cut onion small, put in saucepan with a tablespoon of butter or dripping, a little salt and pepper, cover and cook slowly until tender.

Another method for preparing is as follows: Cut, reserve center, cook in water until tender, drain, and add milk or white sauce.

Make a cream soup from Spanish onion: Cook as before in a little water, when soft rub onion with water through strainer, add milk, thicken slightly, and season. Try with further addition of (a) egg, (b) cheese.

ONION AND APPLE SALAD.

Slice centers of Spanish onion very thin. Pile up slices and cut across to divide still finer. Combine with twice as much sliced apple. Leave red skins on apple as garnish. Add French dressing and chopped parsley or sweet pepper. Mayonnaise or cooked dressing may also be used.

ONION SOUP WITHOUT MEAT.

This favorite French soup is easily and quickly made and very palatable. Peel a good-sized onion, cut into small pieces, and cook slowly and carefully until tender in a heaping tablespoonful of fat or of butter. Then move the saucepan to a hotter part of the stove and cook the onion until well browned, stirring all the time to prevent burning. Add a pint and a half of boiling water, or milk and water, half and half. Season with salt and pepper, bring to a boil, and serve poured over a piece of toasted bread, or serve small cubes of bread fried in butter. If no milk is used it is a common custom to serve some grated, mild-flavored cheese, such as Swiss cheese, with the soup. A garnish of fried onion is often added to this soup.

FRIED ONIONS.

Fried onions may be prepared in either of two ways: (1) Sauté (that is, fry in a small amount of fat, not enough to cover) sliced onion in olive oil, butter, or other fat until golden brown and tender; or (2) fry a few pieces at a time in deep fat, let them remain in the hot fat until they are crisp, like Saratoga potatoes, but do not let them become too brown. If after the onions are sliced all the rings are separated, they fry more quickly and make a more attractive dish. Use to garnish meats or to add to soups, or combine with potatoes, stewed beans, or other vegetables.

STUFFED ONIONS.

Parboil large onions, remove centers without breaking the outer layers, and stuff with seasoned crumbs or meat, and bake until tender.

ONION CUSTARD.

Cook onions until tender; drain thoroughly. Pour over them a custard mixture made of one egg, one-half cup milk, salt and pepper to taste, for each half pint of onions. Bake gently and serve as a vegetable. In southern Europe this dish is popular, cooked with a crust, like small custard pies.

ONION SOUFFLÉ.

Chop cooked onion fine or rub through a coarse strainer. Combine with equal quantity of soft bread crumbs or half as many dry ones. Season with butter, salt, and pepper. For each half pint of the mixture beat in one egg yolk and fold in one stiffly beaten white. Put in small dishes or in onion cases (see stuffed onions) and bake gently until firm.

REVIEW QUESTIONS, LESSON IV.

1. Describe a bulb. Give examples.
2. Tell something of the history of the onion.
3. Mention and tell characteristics of other members of the same family of plants.
4. Give general directions for their preparation for the table.
5. When the flavor is objectionable, how may it be reduced?
6. What portion of an onion would be most acceptable in a salad?
7. Describe several ways of extracting flavor from the onion for soups, salads, etc.
8. Suggest some method of warming over boiled onions left from one day's dinner, so that they may appear in different form.
9. Is the onion a desirable food?
10. Tell how to make an onion soup.

LESSON V. TUBERS AND ROOTS.

During the growing season many plants store material for future growth in enlarged roots or underground stems either in solution in the very abundant plant juice (as sugar in beet juice) or in insoluble form (as starch in a potato tuber). The tubers and roots which are characterized by starch may be roughly grouped as starch-bearing ones; those which are characterized by reserve material in solution, on account of their more or less juicy character, as succulent roots. Such distinctions, though inaccurate, will aid in understanding the nature and food value of the tubers and roots referred to in the following lesson.

WHITE OR IRISH POTATOES.

The potato is the most important vegetable of the group in the United States. Two distinct vegetables are commonly used in the United States under the name potato, i. e., the white or Irish potato and the sweet potato or yam of the Southern States. The prominence of the white potato in the daily diet of most Americans justifies special attention to it in these lessons. Though a native of America, it became so generally adopted in Ireland that it is now often termed the Irish potato.

One reason why the potato has become such a favorite vegetable is doubtless its lack of pronounced flavor. It harmonizes with foods having a more positive taste, and one does not tire of it as one would of the continuous use of turnip or squash. It is easily grown, gives an abundant yield, and may be stored for winter use. Mankind almost universally uses starchy food, and potatoes abundantly supply this in palatable form.

Potatoes should weigh 60 pounds to the bushel, or 15 pounds to the peck. As three or four average potatoes will together weigh 1 pound, a peck should number from 45 to 60.

The oftener potatoes are handled in their transit from producer to consumer the poorer their quality and the greater the percentage of refuse. When received from the market it is desirable to sort them carefully, that those of the same size may be cooked together—smooth, medium ones to be baked, large ones to be steamed in their skins, and imperfect and inferior ones to be pared before boiling. Any dark-colored or green portions should be removed, as they may impart a bad flavor to the rest. Sprouts should be broken from potatoes before cooking.

Langworthy (ref. No. 2)[1] states that cases of poisoning from potatoes are not unknown, which were attributed to the use of sprouted or very old potatoes or those which have turned green on exposure to the light. The poisoning which has been noted not infrequently after eating potato dishes of different sorts is now generally conceded to be due, like much other similar illness, to the accidental presence of bacteria of specific sorts and shows contamination with filth, even if the amount is too small to be recognized by ordinary means.

[1] The references in the text relate to the reference library specified in the Appendix which is to be supplied by the extension departments of the agricultural colleges.

Old and wrinkled potatoes are much improved by cutting off the ends or by partially or wholly paring and soaking in cold water for several hours. In fact, inferior potatoes of any age are much improved by paring and soaking. Where potatoes are inexpensive or the parings can be fed to animals, it is often a profitable custom to pare before cooking, since thus imperfections and strong-flavored portions are disposed of, leaving a nearly pure starch, comparable to arrowroot or tapioca and ready for the table as soon as cooked; this is true notwithstanding that careful investigations have proved that such cooking causes considerable loss of the nutrients in the potato.

The way in which foods are cooked has some effect on their food value. In the case of potatoes it has been found that when boiled with the skins removed there is a very considerable loss not only of organic nutrients but also of mineral salts. (Fig. 3.) When boiled with the skins on, the loss of nutrients is very slight. In the case of potatoes baked in the jackets, little if any nutritive material is lost. It is self-evident that, if it is desired to cook potatoes with as little loss as possible, they should be either boiled or baked with the skins on. When potatoes are the only vegetable obtainable it may be especially important to cook them without paring, so that their mineral salts may be retained, but people who use plants and other vegetables freely may be justified in considering chiefly convenience and palatability in the preparation of these tubers.

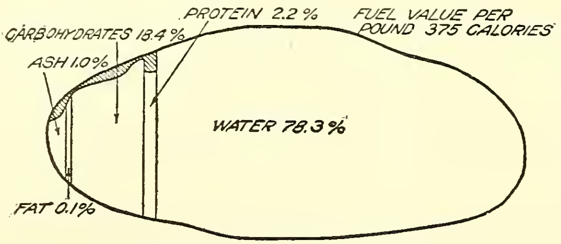


FIG. 3.—Composition of the potato. The shaded portion represents the average loss of nutrients when boiled with the skin on.

Often it is a convenience for the housekeeper who has several dishes to prepare at once just before dinner to have the potatoes pared earlier in the day. If so, they should be put in water with a little salt added, so that they will not turn dark.

Most good cooks believe that it is wiser to discard the water in which potatoes are boiled, as it is likely to be strong in flavor, rather than to save it for soup making or for some similar use as is recommended for the water in which celery, etc., is cooked. (See Lesson II.)

Potato flour may be found in large groceries and is used in cakes and for thickening purposes.

SWEET POTATOES.

Sweet potatoes are not strictly tubers, but tuberous roots. There are many varieties, with different shape and color. Northern markets prefer a dry, smooth, yellow type, while in the South the moist varieties showing more sugar when baked are the favorites. They may be kept in a dry place at a temperature of 50° to 65° F., and are sometimes canned and often dried like fruits for family use. A flour is also made from the sweet potato.

Because their sweetness is to some extent lost in water they are better steamed than boiled, and baking is the favorite method.

After cooking they may be pressed through a sieve and used in puddings or pies like squash or added to breads. (See Lesson VII.)

In southern homes it has always been customary to cook sliced sweet potato (often first parboiled) with sugar, butter, and other seasoning. Such dishes, under a variety of names, are now general favorites.

When the tubers are baked the process should not be too rapid, but should continue for an hour, until the skin separates from the pulp, and in the case of the varieties moist when cooked, until the sirup condenses and the pulp grows moist. The negroes in the Southern States bake them in the ashes in the fireplace and as soon as one meal is over put in those needed for the next.

JERUSALEM ARTICHOKE, YAM, CASSAVA, AND OTHER STARCH-BEARING TUBERS AND ROOTS.

The Jerusalem artichoke is a kind of sunflower which has a thickened rootstalk valuable for food. The carbohydrate material in the tuber is like gum rather than starch, which gives a peculiar texture after cooking. The tubers were more popular before potatoes came into general use. They are crisp in the spring before they begin to grow and may be cooked like creamed potatoes, served raw as a salad like radishes, or pickled. They are common in many rural regions, are found in city markets, and are not expensive.

Yam is a name carelessly applied to some types of sweet potato. The true yams belong to another variety of plants and include many species abundant in the Tropics, some of which may also be grown in temperate regions. Many are grown in the West Indies and Florida. They are rich in starch, though lacking the sugar of sweet potatoes, and the flavor is pleasant when they are boiled or cooked in other ways.

Many of these tubers are most satisfactory when baked, but, like the potato, they may be prepared in other ways.

A new tuber which has attracted much attention is the dasheen from tropical countries. The dasheens may be served like potatoes, boiled, fried, creamed, etc., but to many are, like potatoes, most acceptable when baked. They have a rough outer coating, which may be partially removed before cooking. If entirely pared there is a tendency to discolor, as with potatoes.

Cassava, or manihot, a semitropical plant used for food in the West Indies, Central and South America, is now cultivated in Florida. The roots are rich in starch. There are two principal types of the plant, the bitter and the sweet. The first is commonly grown in the Tropics and requires a longer season than the other, but produces a greater yield. The bitter cassava grown in Brazil contains more of the volatile poison found in this family of plants, but this is dissipated by heat and the washing of the grated roots. The sweet manihot is cultivated in some of the Southern States, but mainly for starch to be used for finishing in textiles and in other industries. From both varieties tapioca of various forms is made, as is also the cassava bread which is so common in tropical countries, and which is found in many city shops under the name of cassava cakes.

Arrowroot is the fine starch obtained from various tropical roots, and owes its name to the fact that the pounded roots were applied to swellings for poisoned arrows. The best arrowroot comes from Bermuda and the West Indies. In Europe it is popularly supposed to be the most digestible form of starch, and is much used for infants and invalids, as well as in fine puddings and similar dishes. In the United States cornstarch, the "corn flour" of English cooks, is more generally used.

Sago may be properly studied in connection with tapioca, arrowroot, and similar starches, as its use is very similar, but it is the product, not of a root or tuber, but the pith of a palm tree. The trees are cut and split; then the starch is washed, dried, and granulated. Fifteen years are required to grow a palm yielding 500 pounds of sago. The tree must be cut before blossoming. If time permitted, it would be interesting to study other palms which yield food products, especially the "cabbage palm" and those producing coconuts.

The principal food substance derived from all these underground stems is the starch which has been thus stored up for the next generation of the plant's life. Starches from different plants or plant parts differ in the form of the starch grain and can be identified by the aid of the microscope, but from the culinary standpoint they are practically interchangeable, and one form of starch may be substituted for another in nearly every case. The yam or a dish of rice may be substituted for the potato as a vegetable, or starch from the potato, or corn, or wheat, or rice may be used for thickening gravies or making puddings, slight changes being made in proportions, according to the expansive powers of each kind.

Starch cookery is a very important subject. That starch may be cooked it is essential that every starch grain be brought into contact with water of at least 140° to 178° F. A careful study of starch cookery shows that potato, arrowroot, and probably tapioca and sago starch pastes are not made more easily digestible by long-continued cooking. However, in the case of starch still inclosed in cellulose cells, as in many starchy foods, the long-continued cooking may be necessary. (Fig. 4.)

The selection of potato starch instead of corn or wheat starch for thickening sauces in accordance with the custom of French cooks is rational, since it does not require such long boiling for improvement in flavor as is the case with cornstarch.

EXERCISES. LESSON V.

Materials needed.—A potato for each student; any other tubers available; rice, tapioca, cornstarch, rice flour, fruit juice or jelly, milk, butter, salad dressing; fancy cutters, slicer, and scoops; different styles of potato mashers and ricers. The latter are for trial; a fork may be used to mash a small quantity.

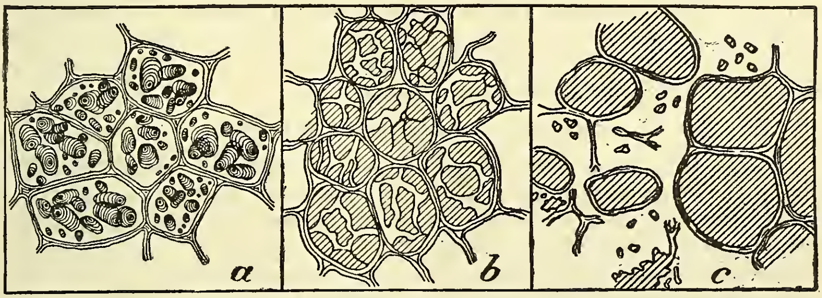


FIG. 4.—Changes of starch cells in cooking: *a*, cells of a raw potato with starch grains in natural condition; *b*, cells of a partially cooked potato; *c*, cells of a thoroughly boiled potato.

Exercises.—Let each student prepare a potato, each in slightly different fashion according to the directions given below; weigh before and after cooking, weigh refuse, estimate percentage of loss and the time and fuel required for cooking one potato. Are these factors proportionately increased for a larger quantity? Compare time required to pare potatoes before cooking and after. What advantages for either method?

POTATOES.

While the potatoes are cooking grate one raw potato, press out the water through a cloth or wire strainer into a glass measuring cup. Estimate percentage of water in the potato, then wash out the starch in the strainer, add to that settled from the juice, and cook it. Observe the nature of the material remaining in the strainer.

Among the methods of cooking potatoes which may be tried in this lesson are these:

Baked (1): Serve one at the right moment, leave another until the moisture condenses and the potato becomes soggy, with unpleasant odor and flavor.

Baked (2): Cut in two lengthwise, remove contents, mash, season, and return to skin. Add beaten egg white to one half, bake and notice difference. How is this difference caused?

Baked (3): Bake in dish, skin having been removed first; glaze occasionally with butter or meat fat.

Boiled: Cook one in skin, another without skin.

Steamed: Cook one in skin, another without skin.

Mashed: Boil one potato, mash, season with butter, salt, etc., add hot milk, measured, and note how much the potato will absorb.

Cut and boiled: Cut a potato in slices or cubes, add milk and seasoning as in previous recipe, and compare results. Add grated cheese to part.

Soup: Make soup from mashed potato in same fashion as with onion in previous lesson. Note lack of flavor—some addition of onion or celery indicated. Also note slight thickening needed in potato soup compared with onion soup.

Salad: Make salad with cooked potato and onion like apple and onion salad in Lesson IV.

Look up composition of potato. Does this suggest what other materials should be added?

For other dishes in which potatoes are an important ingredient, refer to standard cookbooks.

Comparison of rice and potato: Weigh out one-half pound rice, wash and cook in 2 quarts of rapidly boiling salted water until tender, and drain. The water may be reserved for soup in next lesson. Cook an equal money value of potatoes. Compare value of results, including cost of fuel and labor expended and considering refuse in potatoes, etc.

EXPERIMENTS WITH STARCHY MATERIALS.

Let each student or each two take a different form of starchy substance, tapioca (flaked, pearl, or granulated), cornstarch, rice flour, sago, starch from potato, etc.; cook with water until fairly transparent, salt slightly, and taste of each to learn to recognize characteristic flavor. Take equal amounts of each of them, add to each the same amount of fruit juice and sugar, and taste again to see how the flavor of the fruit affects or disguises the characteristics of each kind of starch. Note possibility of substitutions in recipes. Samples of these starches may be treated with dilute iodin before and after cooking. Dilute iodin turns starch a blue color. (See Lesson I, p. 8.)

REVIEW QUESTIONS, LESSON V.

1. Show differences between bulbs and roots; roots and tubers.
2. What are the principal food substances derived from roots?
3. Where did the potato originate and when was it introduced into Europe?
4. What differences in the nature of the new and old potato? How do these influence methods of cooking each?
5. What is the weight of an average potato?
6. How many pounds of potatoes are probably consumed in your household in a week or month?
7. How may you find that the potato contains starch?
8. How should potatoes as ordinarily purchased be selected for baking, steaming, croquettes, etc.?
9. Describe general preparation and use of the sweet potato.
10. What other roots and tubers furnish valuable starch?

LESSON VI. SUCCULENT ROOTS.

In the majority of these root vegetables the main or taproot has become thick and fleshy. If cross sections of such roots are carefully examined, with or without a microscope, it will aid one to understand the effect of heat and moisture upon such foods. In older vegetables of this type large amounts of woody fibers or cellulose will be found, which does not soften readily when cooked.

Plants of this class have long been cultivated by mankind and are used in great quantities, though less dependence is placed on them in winter than was the case before improved transportation made a greater variety possible.

BEETS.

The beet gives a good illustration of the difference between the young and old plant. When young, the whole plant, leaves, leafstalk, and root, may be cooked for greens (see Lesson III), but by the time the beet is as large as an egg, the leafstalk is too fibrous to use and the leaves are becoming tough; later only the root can be used. The bunches of beets from warmer climates found in northern markets in the spring usually have leaves that may be cooked and served for greens with the sliced roots, and heat and moisture (cooking) will make them tender in half an hour. Large winter beets which have been out of the ground for months have lost moisture and become woody and may require four hours or more to make them eatable. Pickling in vinegar must often be resorted to before such beets are really tender.

Beets contain a larger proportion of sugar than most vegetables, and to retain as much of this as possible, should be baked or steamed. At all events, they should be cooked in the skins, and the tip of the root and a portion of the leaf stems should be left on until after cooking. Even so, some color and sweetness are lost in the water in which they are cooked. Canned beets are generally preferable to fresh ones when the latter are large or withered.

TURNIPS.

Many varieties of turnips are cultivated, but those used for human food fall into two main classes, mainly white-fleshed sorts and those with yellowish color and called rutabagas or "Swedish" turnips. The first are used more commonly in summer and the yellow in winter since they keep better. The pungent flavor of turnips, like that of cabbage and radish of the same group of plants, is due to sulphur compounds. Turnips may be boiled whole and mashed, or be cut into cubes before cooking. In the latter way they lose more of their flavor.

KOHL-RABI.

The kohl-rabi, which belongs to the same family as the turnip and the cabbage and combines characteristics of both, has been described on page 17. This is cooked and served like turnip.

RADISHES.

Radishes, red or white, when a little too old to be eaten raw may be cooked like turnips and served with a white sauce.

CARROTS.

The plant family (parsley family, or Umbelliferæ) to which the carrot belongs furnishes many of the root vegetables. A characteristic is the much divided leaf, so noticeable in the carrot, celery, parsley, chervil (one of the less-known seasoning herbs), and parsnip.

The carrot may have been a native of England, or, if not, was known there at an early period. It is believed that originally the root was hard and fibrous and that the fleshy outside has been developed by cultivation. As with other vegetables, there are many varieties, some so coarse in texture that those who know no other type might consider the carrot unfit for table use. Small or young carrots properly prepared are deservedly popular. Raw carrots are often eaten by children, and are advocated by those who believe in the use of raw foods. When grated or put through a food chopper, raw carrots may be used in soups without further cooking, or added to salads. The carrot contains so much sugar that its use for sugar making, in the same way as the beet, has been seriously considered.

PARSNIPS.

The parsnip is said to have been cultivated even before the Christian era. The roots can be left in the ground until the frost comes, or even through the winter, for freezing does not injure them, but seems to soften the woody fiber. Like other such roots, they keep well stored in sand in a cool place. In any case the roots must be used before they begin to grow again or they lose their sweetness and get "rusty." Large parsnips are likely to be woody and not very sweet. Small parsnips just from the ground in the spring will cook in less than a half hour. If steamed without paring, they lose less sweetness than when boiled. They should be peeled after cooking, and served plain with butter or with white sauce, sautéd in butter, or mashed and made into fritters. They are also good made into a stew with potatoes, onions, and milk.

CELERIAC.

This is a variety of celery, edible rooted (see p. 12), which deserves to be better known. It is sometimes called German or "knob" celery or "turnip-rooted" celery, and resembles the turnip in shape and texture, and may be cooked in similar ways. If steamed, more flavor is retained than if boiled. If pared before cooking, the water should be saved to flavor soups, etc. Where time must be saved, celeriac, like carrots, may be cut into cubes before cooking, which means still more loss of flavor. Celeriac can be served plain with butter. It is an excellent addition to soups and stews, or as a basis for a cream soup. It may be creamed like potatoes, or may be used like them for making salads.

SALSIFY.

This vegetable, sometimes called oyster plant on account of its flavor, is available during the late fall and winter. Like the parsnip, it may be left in the ground over winter and is then particularly good for early spring use. The resemblance in flavor to the oyster is especially noticeable when the boiled vegetable is sautéd in butter or made into fritters. The root turns dark quickly if the skin is removed before cooking, and so if pared should be dropped at once into vinegar and water to prevent discoloration. After boiling for about 30 minutes, the salsify may be served with butter or white sauce, or mashed and made into fritters. It is also used made into a soup with milk.

CONDIMENTAL ROOTS.

Ginger and horse-radish are other valuable roots, but are used not so much for food as for the flavor or relish they give to other things. Horse-radish gravy is very good to serve with boiled meat. It can be made by adding to some thickened broth as much grated horse-radish as is liked. (See Lessons X and XIV.)

EXERCISES, LESSON VI.

Materials needed.—Old and new root vegetables, such as beets, carrots, parsnips, celeriac, or salsify; graters, cheesecloth, test tubes, saucepans, measuring cup, tablespoon, teaspoon, and knife; cup of milk, butter, flour, salt, and pepper.

Exercises.—Grate portions of each root available and note the proportion of water and the nature of the woody fiber. Compare results with those from the potato in the previous lesson. How about the proportion of starch? Taste the extracted water. Evaporate it and taste again.

PARSNIP, SALSIFY, BEET, AND CELERIAC.

(1) Cook parsnips, separating outer layer beforehand, and notice which part cooks sooner.

(2) Pare some before cooking, and cook others in the skin in separate kettles. Taste the water from each. Which has lost most sugar, presumably?

(3) Steam some parsnips of same size as those that were boiled. Compare time required for each process. Prepare salsify in same way. Use each for fritters or to sauté.

(4) Cook beets whole, in skins, and in smaller sections, and note loss of juice and color.

(5) Try celeriac in the same ways.

(6) Combine potatoes with some of these vegetables. Is the dish palatable? If so, does it not suggest a good way to make a small amount of such vegetables "go farther"?

CARROTS, TURNIPS.

(1) Cook one large old carrot whole in the skin.

(2) Cook one large old carrot whole with skin scraped off.

(3) Cook one large old carrot in slices.

(4) Cook one large old carrot cut into cubes.

If necessary, these may all be boiled in one kettle, and thus variation in time of cooking shown; but the difference in loss of substance can be shown only by cooking each form by itself. Compare, if possible, with young carrots as to time of cooking, texture, and sweetness.

The carrots cooked as above may be served: (1) Plain with butter, (2) with cream or white sauce, (3) buttered and combined with half as many green peas, or (4) buttered and blended with a little chopped parsley or chives.

Prepare turnips in the same way.

For further experiments grated carrots may be made into marmalade with sugar and lemon juice or added to a suet pudding. Grated carrot or that which has been put through the meat chopper makes an effective garnish for salad and may be used without cooking. It may be added to soups with little more cooking than is needed to heat it through.

WHITE SAUCE FOR VEGETABLES.

If white sauce (see Lesson III, p. 18) has been studied in a previous lesson, it should be reviewed. If not, it should be taken up now. Let each student also make a sauce in the same way, using in place of half the milk the recipe calls for water in which carrot, celeriac, etc., were boiled.

REVIEW QUESTIONS, LESSON VI.

1. Describe the structure of roots.
2. Tell of the methods of growth and preparation for the table of five common root vegetables.
3. Define succulence.
4. What are the principal food substances obtained from roots?
5. Suggest combinations of vegetables of this type with others of a different nature.
6. To increase the food value of this class of plants, what additions are desirable?
7. Mention some of the most helpful utensils for the preparation of these vegetables.
8. What are the advantages and disadvantages of paring before and after cooking?
9. Are there any vegetables of this class with which you are not familiar or have not learned to eat?
10. What substances extracted from roots have commercial value?

LESSON VII. FLOWERS AND FRUITS.

FLOWERS AND PRODUCTS MADE FROM THEM.

Most flowers are too delicate in structure to be of much value as foods, yet some are cooked occasionally, for instance, dandelion or marsh marigold buds in "greens." Cloves furnish another example. They are buds of a tropical tree and are picked before expansion and dried.

The buds, like the seeds of nasturtium, are occasionally pickled. Orange flowers are well-known ingredients of cakes, creams, and confectionery, being added for the flavor which they impart. Saffron and marigold petals once were considered important adjuncts in cookery, chiefly for the yellow color they imparted, and are often mentioned in old recipes for soups, etc. In southern Europe squash blossoms and the tiny squash to which the blossom is attached are dipped in batter and fried, and elder flowers and acacia blossoms also are used for fritters. Cooked squash flowers may be folded in an omelet.

Sometimes rose petals, violets, and mint leaves are candied, but are used more for garnishing than for food purposes. Rose petals in the Orient are used for making a very sweet preserve. Many other blossoms serve as food, chiefly in the Tropics, but need not be mentioned further.

Flowers are attractive ornaments for the table, but are not in good taste as garnishes for food. The fashion of serving salads in roses, molding blossoms in jellies, or adding nasturtium flowers to salads can not be commended.

CAPERS.

Capers are unexpanded flower buds of a tropical plant preserved in vinegar. They are imported, but are fairly common in shops and are most often used in a gravy to give relish to boiled mutton or to garnish salads.

CAULIFLOWER.

As noted elsewhere (see p. 4), the portion of the cauliflower eaten is the flower head; the leaf and stalks are usually discarded, though these may be used as "greens." In some countries the leaves which inclose the flower head are cooked and eaten with it.

GLOBE ARTICHOKE.

The French or globe artichoke is, next to the cauliflower, the most important example of the use as food of the flower portion of a plant. It thrives in southern Europe and the southern and central United States, but is not hardy enough for cold climates. The base of the flower head (known as the "bottom" or "button") and the thick bare scales of the leaves which inclose it have a delicate flavor if used before the bud is fully opened. The simplest method of preparing artichokes is the best. Remove the stalk and under leaves and cut off tips of scales. The flower heads may be eaten raw when very young, but commonly are soaked and parboiled in salted water until tender even when used as a salad. When done the leaves will separate readily. The "choke" is the fibrous center which should be scraped out with a spoon after cooking, but is not troublesome if left in the young heads. The individual "leaves" are pulled off and eaten with a sauce or dressing. The bottoms may be dipped in batter and fried in deep fat or covered with force meat and then baked like stuffed tomatoes. Artichokes are interesting garden plants worth knowing. The canned French artichokes are fairly common in shops which cater to Italian trade.

The cardoon is allied to the globe artichoke, but is little used in the United States.

HONEY.

Honey may be properly classed among the food products derived from flowers. In ancient times, before cane sugar was manufactured, it was the principal sweet, and to-day it is still much prized. A study of its history and folklore is interesting.

The varying qualities of honey derived from different flowers are worthy of note. That obtained from white clover fields is of fine flavor and light color; raspberry plantations furnish a good quality, while buckwheat gives a dark color and a flavor which some do not relish; and certain wild plants, such as mountain laurel, may impart poisonous qualities to the honey made from them. Recipes which have been handed down for generations are still used for honey cakes and cookies. Strained or extracted honey may be substituted for molasses or other sirups or for sugar in many common recipes. (Ref. No. 8.)

COLORS AND FLAVORING EXTRACTS.

Flowers find a considerable use in cookery for coloring and flavoring purposes. Dried saffron flowers, as already mentioned, are employed for coloring foods yellow. Violets are used in a similar way for imparting a purple color, while a number of other colors are made from blossoms or leaves. Some highly prized flavoring extracts are made from flowers; for instance, rose extract, orange-flower water, and sirup of violets. Nasturtium flowers are used, like tarragon, for flavoring vinegar, and other similar uses might be cited.

FRUITS USED AS VEGETABLES.

The fruit of a plant, botanically, is that portion in which the seed is perfected. In popular language, the distinction between a fruit and a vegetable is not easily made, and on the border line are several important food plants which have been called "vegetable fruits." Such are tomato, eggplant, peppers, and many members of the gourd family (melons, cucumbers, squash, pumpkin, vegetable marrow, etc.).

Some varieties of the gourd family were known in Egypt and Persia from the earliest times, and squashes or pumpkins, the "pompions" mentioned by some of the early writers in this country, were raised by the American Indians before the white men came.

PUMPKIN AND SQUASH.

There is great variety in texture and flavor of individual specimens of the same kind of either squashes or pumpkins. The best for table use are heavy in proportion to their size, having thick rather than thin flesh. Careful cooking is a great help. If the fibers are coarse, long cooking and straining will reduce them, and excess of water may be evaporated. Where the shells are hard, bake or steam and then scrape out and mash the flesh.

The cooked, strained pulp of squash or pumpkin is sometimes combined with milk or stock for soups or with custard for pies, or is added to doughs like those of corn bread or muffins, or may be cooked with sugar and spices for marmalades.

The summer squash is not always fully appreciated because too often it is allowed to grow too large before it is used. Both crookneck and turban varieties, or "cymling," should be so tender that the seeds and skin are edible when cooked. Cut in pieces, put in a kettle of salted boiling water, and cook 20 to 30 minutes till tender. Drain in a fine wire strainer, pressing out all the water possible. Then put the squash carefully on the back of the stove or in the oven with the door open so that more water will evaporate; then season with butter, salt, and pepper. Summer squash are also much liked cut in slices and fried. When fully grown they may be used like winter squash, skin and seeds being removed.

CUCUMBERS AND MELONS.

These fruits have long been popular. Not only are they liked as food, but since they contain so much water (90 per cent or more) are commonly used for quenching thirst in some eastern countries where good water is not easily obtained. Stale, wilted, or overgrown cucumbers may interfere with digestion, but a fresh, young specimen, thoroughly peeled and left in cold water (sometimes salted) before serving, seldom causes distress, and is a very popular relish.

The cucumber may be served as a salad by itself or to accompany fish or meats, or may be grated to add to meat or fish sauces, and is a favorite material both green and ripe for pickles. It may be cut into strips, cooked, and served on toast like asparagus, and in other ways. The skin and seeds may be removed and the firm flesh used as a case for salads or, like pepper and tomato, it may be filled with force meat and baked. Though not commonly so used in American families, cooked cucumbers are palatable and well worth using for the variety they give.

Melons rank with fruits. The common varieties are almost never cooked but are eaten as they come from the garden. The use of melon rinds and melons in their unripe state will be considered under pickles. (See Lesson XIV.)

GREEN PEPPERS.

The fleshy seed vessels of many varieties of garden peppers are used not only for their condimental value, but particularly the "sweet" varieties are prepared for the table in many ways. Green peppers, which lack the "hot" taste of the garden varieties which were formerly the more common, may be found in the city markets most of the year at reasonable prices and are used increasingly either stuffed and baked or fried like onions as an accompaniment to meat or as an ingredient of omelets, soups, and salads.

The stem and seeds of the green pepper should be removed together by cutting around the stem, and the end and the "core" may be used for flavoring soups. The seeds themselves are likely to be hot and need not be used.

If the peppers are small and fresh, they may be chopped or sliced thin and used raw in salads or as a garnish. Often they are better for parboiling. If put into a hot oven or on top of the stove for a few moments, the outside skin may be easily removed.

Garden peppers have long been popular for use in making pickles and relishes of different sorts.

The canned sweet Spanish red peppers (pimientoes) may be used in similar fashion and may be obtained from any large grocery store at moderate prices. Sweet peppers, like other varieties, will grow well as a garden vegetable, and they are being grown and canned by the members of the girls' canning clubs in the Southern States. These peppers are valuable because they make tasteless foods savory and attractive. Paprika is prepared from peppers of this mild type (see Lesson X); red or cayenne pepper, from "sharp" or "hot" varieties, which are also much used for making pepper sauce.

OKRA.

This plant succeeds best in warm climates, though it may be grown as far north as New England. Fresh okra stands shipment well and the pods are common in localities where the plant is not raised. Dried and canned okra is obtainable in most markets. Young pods cooked in boiling salted water will become tender in 20 minutes. They are then drained, seasoned with butter, cream, salt, and pepper, and served like any vegetable.

The pods and seeds are used together and usually are sliced crosswise. It may be used alone seasoned with butter, salt, and pepper, but is more often added to thin soups, as its mucilaginous nature serves as thickening, or with onions, carrots, etc., in making vegetable soups and in stews.

EGGPLANT.

This plant has long been known and succeeds well as a garden vegetable in many localities. It ships well and so is often found in market. It belongs to the same family as the potato and tomato—the nightshade family. As is the case with all succulent vegetables, its nutritive value is not high, but it is palatable and much liked by many, and should be better known than it is in some localities. It may be cut in two, stuffed and baked, or sliced, crumbed, and broiled or fried. To extract some of the moisture before frying, the sliced eggplant often is sprinkled with salt and a weight put on top of the pile of slices to press out the juice.

TOMATO.

The tomato is a native of America, but though known in Europe since the sixteenth century, was slow in coming into favor, no doubt because of supposed poisonous qualities. It did not become common as a vegetable in the United States until about the middle of the nineteenth century, though grown before that as an ornamental garden plant. It is now used very generally and has grown in popularity here and in Europe very rapidly.

To this vegetable fruit we owe much in cookery. Though its food value is not high it is very palatable and refreshing and very useful as a seasoning for a great variety of dishes. Alone and in combination it provides soups, sauces, and salads, and many relishes which make many mild-flavored materials appetizing. Tomatoes are preserved, made into pickles, and used in many similar ways, as well as raw and cooked as a vegetable. The tomato owes its flavor to special substances including citric acid.

Except in the case of special varieties with tender skin (and these should always be washed), tomatoes when served raw should always have the skin removed. This is easily done if the tomatoes are plunged into boiling water for less than a minute, then drained, and chilled. They may be peeled when needed. Perfectly ripe tomatoes may be scraped with the back of a knife to loosen the skin, which then will peel easily, but this is less rapid than the scalding process. If cooked, tomatoes are to be strained. It is unnecessary to peel tomatoes for stewing, as they can be strained before use and the skin will remain in the strainer with the seeds. The very small red tomatoes which grow in clusters, known as cherry tomatoes, are often found in large markets and are very attractive for salads, and the yellow plum tomatoes are perhaps always eaten without peeling, and hence should be carefully washed.

BANANAS.

The banana is very commonly used as a vegetable, especially when underripe. It may be baked or fried like the potato or yam and served with meats. A satisfactory and simple way to cook bananas is to remove the skin, scrape off the rough outside, cut large ones in two, dip in egg and crumbs, and fry brown in deep fat. Bananas are also used very commonly for making fritters to serve with meat.

EXERCISES, LESSON VII.

Materials needed.—Three cans of tomato or fresh tomatoes; onion, squash, green pepper, any other vegetable fruits in season; can opener or sardine scissors, strainer, masher, bread crumbs, butter, flour, seasoning.

Exercises.—The water in these fleshy seed receptacles may be shown by slicing and sprinkling with salt and leaving over night. Then drain, weigh, and compare the result with original weight. Have canned tomato of two grades with marked difference in price. Weigh each can; weigh contents again after emptying.

Cook each grade separately 15 minutes and strain through medium wire strainer, weigh refuse from each lot, and compare results. Estimate relative values based on cost, quality, and quantity.

Open another can of tomato and drain in strainer without pressing through. Reserve liquid for soup, use solid portion for escalloped tomatoes.

Use the strained tomatoes in any of the following ways:

(1) Tomato toast.

(2) Tomato jelly salad.

(3) Tomato soup. Several types of tomato soup may be made: (*a*) One part tomato, one part water with flavor of herbs, and slight thickening with cornstarch; (*b*) one part tomato, two parts water, and a little beef extract; (*c*) one part tomato, two parts milk, and seasoning.

(4) Tomato sauce.

(5) Spanish sauce.

The following processes are also suitable for this lesson if the materials are obtainable:

Stuffed eggplant; summer squash sauté (fried); winter squash, hard shell, steamed or baked; pumpkin or squash pie; stewed cucumbers on toast; cucumber and tomato salad; eggs poached in tomato sauce; stuffed peppers or tomatoes.

REVIEW QUESTIONS, LESSON VII.

1. What have you to say regarding the association of flowers with food?
2. Have you ever seen flowers used in a way that seemed unsuitable?
3. Tell something of the source and preparation of capers and cloves.
4. What product from flowers does the human race obtain through insects?
5. Describe a fruit.
6. Mention five so-called vegetables that are strictly fruits.
7. Mention several members of the gourd family that have been used from ancient times.
8. Tell something about the tomato plant, its family and characteristics.
9. Give a list of dishes where the tomato is useful.
10. Mention any other flowers and fruits used chiefly for condimental purposes.

LESSON VIII. SEEDS.

Seeds contain the embryo from which the new plant develops and almost always a store of nutritive material for the growth of the plant for a time after the seed has sprouted. The stored material varies in different plants; thus in such nuts as the walnut oil is very abundant, while in the cereal grains it is chiefly starch. Seeds are usually protected by a hard outer covering like the bran layers and skin of wheat kernels or the shell of a nut. Frequently there is additional protection, as the husks on an ear of corn or the pod in which beans or peanuts grow.

Seeds constitute one of the most important food groups, as is evident when it is considered that numbered among them are the cereal grains, beans, peas, and other legumes, as well as nuts and the oil-bearing seeds such as cottonseed and sesame seed.

Many seeds besides those used as food stuffs are important; for instance, those prized for their aromatic flavors, such as allspice, cardamom, and caraway.

The cereal grains have been considered at length in an earlier bulletin of this series, and aromatic seeds will be discussed in the lesson which deals with spices. (See Lesson X.)

The pulse family, which includes a number of the most important vegetables, is chosen for the subject of this lesson. Its seeds are often called legumes; the unripe seeds and pods are very popular vegetables, while in their dried form they are an important group of food materials.

The bean, lentil, and pea have been recognized in all ages and in all lands as substitutes for both bread and meat, and for the human race come next to the grains in general use.

The flavor of this class of foods does not appeal at all, and sometimes they are found to be a cause of digestive disturbance.

So far as the natural flavor is concerned, it is often wise to remove a portion of it, even if this means also loss of substance, by soaking before cooking and by occasionally changing the water in which the dried beans are soaked and in which they are cooked. The taste might be modified more commonly than is the case by the use of added flavors. Mint, parsley, onion, etc., often are cooked with green peas and beans, and their use would seem more needed with the dry ones. Other herbs and sweet peppers or pimientoes, either green or red, and tomatoes may also be used to give variety. Much can be learned from the Mexicans in their use of beans in combination with meat.

BEANS, PEAS, COWPEAS, AND LENTILS.

Such beans as the navy bean, Lima bean, cowpea, peas, and lentils contain relatively little fat. They do not grow rancid like grain products, but the older they are the harder it is to make them palatable and soft, and the longer the processes of soaking and cooking.

The long soaking of these dried seeds is an important factor in their cookery. It took a long time for the seeds to ripen and dry in the pod on the vine and they lose rather than gain water in the store and house. Therefore it is reasonable that considerable time should be required to fill out the cells of such a dense substance with water. Except when the weather is warm and there is danger of fermentation, beans, lentils, etc., may be profitably soaked for even 48 hours. Pick over, wash well, and add 1 quart of water for 1 cup of beans, and set in the refrigerator or other cold place. Soaking helps to remove any rank flavor.

After this complete filling of the tissues with water the time required for cooking will not be much longer than for shelled beans fresh from the garden. True, there has been some loss of substance, but a corresponding gain in palatability. If the soaking is not so thorough, the cooking must be continued longer. The use of bicarbonate of soda in the preparation of legumes is often decried, and it certainly should be employed with moderation, nevertheless it serves a useful purpose in making the skins more tender, and probably also forms new combinations with or neutralizes substances which tend to produce indigestion or flatulence.

Soft water is far better than hard for both soaking and cooking dried legumes. By "hard" water is meant water impregnated with various salts, as lime and magnesia salts which it may have gained from the rocks and soil over which it passed before it reached the place from which it was drawn or piped. These salts unite with the legumin (a form of protein) contained in the seeds to form insoluble compounds; and consequently portions of the vegetable remain hard, no matter how long they are cooked.

The question then arises, What is to be done when the only water obtainable for cooking is hard water? In most books on cookery it is advised to add to the water in which peas and beans are cooked a small quantity of baking soda, a teaspoonful to the gallon. If the hardness is due to calcium carbonate, the soda will remedy it for cooking purposes. Just why it is not easy to say. Peas and beans cooked in this water are indeed easily softened, but experiment shows that the flavor may be injured. If soda is added, it is better to boil the water before using. But since the cook has generally no means of knowing the degree of hardness of the water and thus the exact proportion of soda to be added, it is perhaps better simply to boil the water before using and pour it from the sediment. When the hardness is due to the presence of the sulphate of lime or magnesia, neither boiling nor the addition of soda will avail to make the water desirable for cooking legumes. It is often possible to use rain water for both soaking and cooking legumes, and this naturally distilled water is the very best for the purpose.

Since the proper preparation of legumes is a long process, it is well to cook enough to serve in two or more fashions. Thus the baked beans are often reheated or served cold and the final remainder used in soup. So, too, the dry Limas or red kidney or any variety may first appear as plain buttered beans, a further portion, prepared at the same time, be reserved for salad or croquettes, and any still remaining be utilized in making a soup.

The addition of potato or onion to the pot of beans before baking is doubtless an instinctive attempt to supply flavor lacking in the bean.

Lentils are not as generally used in this country as they deserve to be. They may be found in the markets of foreign sections of large cities and in the larger groceries. The price is about the same as that of dry beans and peas. There are many colors, as with beans, and Esau's pottage is supposed to have been made from red lentils. Sometimes they are served like peas or with a seasoning of fried onion. Sometimes soup or purée is made from them.

Cowpeas are cooked much like navy beans. Dried peas are most commonly used for making soup or for purées or pea porridge.

The Mexican frijole is another type of bean the use of which might well be extended. It is boiled, often highly seasoned with Chile pepper, and cooked in other ways.

Chick-peas are used extensively in southern Europe and may be found in the foreign markets in the large cities of this country. These are cooked in different ways, much as navy beans are.

The people of the Far East have cultivated many varieties of legumes that are not so well known elsewhere as food for man, though much use is made of them in the United States, particularly as forage crops. The soy bean from China and Japan differs from other common varieties in containing considerable fat; it is used in making special types of so-called bean cheese or bean curd and for sauces of agreeable flavor. Ground into flour, soy beans can be used for making muffins and for similar purposes. The adsuki bean from the same countries is very prolific, and may be grown in this country. Its seeds are smaller even than the pea bean, but when prepared in the same fashion seem not unlike other legumes. These beans are often combined with rice by the Japanese.

Flour made from beans and peas may be used in making soups, but the results are not always as palatable as soups properly made from the seeds themselves.

BEANS AND OTHER LEGUMES USED GREEN.

The use of fresh young peas, beans, and cowpeas is very common, the seeds being sometimes served alone, and often with the succulent pod containing them. The pods of peas are ordinarily discarded; but sometimes they are cooked for a while, and then the water in which they were boiled is used for cooking the peas themselves. There are also edible podded peas which are used in the same way as string beans.

"String" or "snap" beans, if young and tender, may be cooked quickly. Like all green vegetables, they should be cooked only until tender. Too long cooking spoils both color and flavor. If old and well grown, they need longer cooking. If overgrown, they will be improved by parboiling for a few minutes in water to which soda has been added, about one-fourth level teaspoon of soda for 2 quarts of water. They should then be drained and cooked in fresh water. A combination of string and shell beans is a pleasing change from either alone. String beans appear to be more wholesome if cooked uncovered.

The large, green pods of the red or cranberry beans remain tender until the seeds are nearly full grown, making them among the best snap beans. Canned fresh string beans and green peas are important commercial products, as are also canned baked beans and some similar goods.

In the Southern States cowpeas or field peas have been grown for many years as a food for animals and man and for green manuring. These have a distinctive, pleasant flavor; are used dry, green, and as "snap beans," and are cooked like other peas or beans.

PEANUTS.

Peanuts, though commonly classed with nuts, are in reality a legume and closely related to beans, peas, etc. After blossoming the stem bends over, and the seed pushes into the surface of the ground and ripens in the earth.

Peanuts assumed little commercial importance until after 1865. About this time their use became general all over the United States, where they are now used in great quantities for eating out of hand, in making many foods and confectionery, and for peanut butter, the demand for which increases.

Raw peanuts are sometimes eaten, and are relished by many if well ripened and cured. They are often said to be difficult of digestion, though this statement rests on belief rather than on experimental evidence. More commonly they are roasted. Some households find it wise to buy raw peanuts and roast them as needed. Overroasted peanuts are undesirable both as to flavor and digestibility.

Peanut butter may be made at home as wanted by putting the roasted and shelled nuts through the meat chopper. The name peanut butter is justified not only by its appearances and uses, but also by the large amount of fat which the peanut contains, and which differentiates it from other legumes.

COTTON SEED.

Cottonseed meal is being experimented upon for human food. It has long been used for animals. The meal or flour remains after the oil has been extracted. Cottonseed oil is used in many ways like olive oil and similar oils, and in the manufacture of culinary fats.

WHEAT, OATS, AND RICE.

The seeds of the common cereals are often used in preparing dishes served as vegetables, such as boiled rice, macaroni dishes, oatmeal fritters, farina cake, etc.

Cereals do not possess very distinctive flavors, so it is a common practice when using cereal products in this way to season the dishes highly with cheese, with tomato, or with onion, or else to cook them in ways which will give flavor as, for instance, by browning in fat. Rice cooked with tomatoes, macaroni with cheese, and noodles seasoned with fried onions are familiar examples of well-seasoned cereal dishes made tasty by the use of seasoning, while rice croquettes, mock oysters (made of sweet corn), and farina fritters are examples of foods made savory by browning in deep fat.

CORN.

Corn is a native of the New World and has been cultivated for centuries before America was discovered. Originally a tropical plant, it had been developed and changed by selection and culture until it would mature a crop as far north as Montreal, a remarkable achievement for an uncivilized people like the Indians.

Corn is commonly regarded as a distinctively American foodstuff, but it was long ago introduced into other countries and is now extensively used in the Mediterranean regions of Europe, in Africa, in Australia, and in China. In the United States it is—as it has been since colonial times—a staple and very important foodstuff.

Corn is a very important breadstuff and is served in more forms as a vegetable than perhaps any other grain. The Mexicans use the corn husk to wrap the combination of corn, meat, and seasoning known as tamales. The hulled corn or lye hominy is used not only as a breakfast cereal but also as a vegetable, and so is the cracked corn or hominy.

But the sweet or green corn is most used and is one of the most highly esteemed of American fresh vegetables. Enormous quantities are eaten fresh, and its canning is a great industry. The ears are roasted or boiled and served on the cobs; or the raw or boiled corn is cut from the cob and stewed or fried alone or in combination with beans, tomatoes, potatoes, etc., or served in soups or salads. Corn cut from the cob is sometimes used in making pickles or relishes. The very young cobs are also pickled. A full discussion of the food value of corn and corn products and of corn meal cookery will be found in earlier bulletins of the Department of Agriculture. (Ref. No. 3.)

BUCKWHEAT.

Another seed of importance is buckwheat, which in reality is not a wheat at all, but is a near relative of sorrel, dock, and bindweed. It has been used for centuries in many countries of the Old World where grains are cultivated. Buckwheat pancakes or griddle cakes are a characteristic American dish. A sort of biscuit or shortcake or shortbread is also made, though less commonly than in earlier times.

EXERCISES, LESSON VIII.

Materials needed.—Dry beans and peas of as many varieties as are obtainable, such as white pea, yellow eye, red kidney, black, Lima, green flageolet beans, whole, split yellow, split green peas, lentils, approximately one-half pound each; flour of beans, peas, and lentils; peanut butter; cans of green corn, peas, and of Lima or red kidney beans, or both; butter or other fat, milk, seasoning.

COMPARISON OF FRESH AND DRIED LEGUMES.

When possible secure green peas or beans in the pod, measure and weigh (1) as purchased, (2) after preparation for cooking, (3) after cooking, and estimate percentage of loss and actual cost per person. Keep a record of the time required to string the beans or shell the peas.

Compare all results regarding cost with those from canned peas and beans, using care in separating the liquid from the latter.

Taste the water in which fresh green peas are boiled and note its sweetness; allow it to evaporate until just enough remains to serve with the peas. Taste the water from canned peas; if agreeable in flavor, do not throw it away. Note the difference in the water from string beans.

LIMA BEANS.

Weigh and measure the dried beans, wash, soak, and leave 24 hours; weigh again; if feasible, leave 12 to 24 hours longer and again weigh, to see how much they swell after the first weighing; measure and compare with original bulk. Compare also with bulk of Lima beans. It is a good plan to count the number of beans in the can and compare with the cost of the same number of dry ones.

If Lima beans are not available, try the same experiment with any kind of beans available.

Dry Lima beans may be cooked until the skins are tender. The beans are so large that it does not take so long to slip off the skins by hand after parboiling as it would to rub the cooked beans through a colander, and most of the skin would go through also. The skinned beans may then be cooked and served much like mashed potato, with addition of fat, salt, and pepper, or may be used for croquettes or soup. Or some of the beans which retain their shape may be rinsed and served with lettuce and dressing for a salad.

In connection with this use of Lima beans it is interesting to note another use of legumes in salad dressing. Peanut butter reduced with lemon juice or water and vinegar and seasoned makes an excellent salad dressing. Cottonseed oil, peanut oil, and a number of other seed oils, when rightly made and refined and fresh, may be palatably used in salads in the same way as olive oil.

BAKED BEANS.

Baked beans are not easily managed in short experimental periods; but their study may be accomplished in lessons on successive days, or if this is not convenient, the leader or other member of the class should see that the beans are made ready for cooking or partly cooked the day before the lesson. Soak the beans 12 to 24 hours, then parboil, and then bake. If preferred, let them be well started in the baking process and then transfer to a fireless cooker, where they may remain till the next day. At the beginning of the next lesson put them in a hot oven and bake two or three hours more. By this plan a fairly good result will be obtained.

Recipe.—For 1 quart beans, soaked, parboiled in water with one-fourth teaspoon of soda and then drained and rinsed, use one-fourth to one-half pound of salt pork. Place the beans in a deep earthen bean pot and bury the pork in them. Mix one-half teaspoon dry mustard and one teaspoon salt, one-fourth cup molasses or brown sugar, with water to cover the beans. The bean pot must not be too full, and should be covered. As the water cooks away, add more. At the last bring the pork to the top and leave the bean pot uncovered to brown the surface. Beans should bake slowly 10 to 12 hours.

COWPEAS.

The cowpea, or field pea, as it is sometimes called, is commonly grown in the Southern States. Cowpeas may be used in place of other legumes in practice work, if more convenient, or may be used in addition to them.

The cowpea requires a longer season to mature than the kidney beans and so is seldom found in northern markets, though it might well be generally introduced on account of its distinctive and agreeable flavor. The tender cowpea pods can be cooked like string beans, the underripe peas shelled and cooked like green peas or green beans, while the dry peas may be used in various ways for making soups, croquettes, fritters, and other dishes.

Baked cowpeas may be prepared according to the directions given above for baked beans, or the dry cowpeas may be covered with lukewarm water and parboiled slowly for several hours until a little soft, at one lesson; and then at the next period transferred to the bean pot, seasoned with salt pork, and other seasoning if desired, and baked slowly for about six hours.

To accompany this lesson one of these menus might be prepared.[1]

1.	2.	3.
Green split-pea soup.	Peanut soup.	Cream of corn soup.
Baked beans.	Spanish beans.	Succotash, or
Apple and onion salad with peanut-butter dressing.	Green pea timbales.	Corn fritters, or
	String-bean salad.	Hominy croquettes.
	Peanut cookies.	Baked Indian pudding, or
		Cornstarch blanc mange.

[1] Recipes for these dishes may be found in many cookbooks; for instance, see reference numbers 10 and 11.

REVIEW QUESTIONS, LESSON VIII.

1. Describe seeds of different types.
2. Why do seeds contain more concentrated nutritive material than other parts of plants.
3. What groups of seeds are most important for human food?
4. Describe two principal types of leguminous plants.
5. What is the main difference in composition between dry beans and fresh shelled beans?
6. Explain the addition of fat meat in baking beans.
7. What uses have been found for cotton seeds?
8. What can you say of buckwheat, its characteristics, growth, and uses?
9. Mention points in favor of and against grinding peas, beans, etc., into a flour before using them for soups.
10. Compare canned and dry beans as to cost, labor of preparation, and quality.

LESSON IX. FUNGI.

There are many plants quite unlike those already referred to, in that they contain no green coloring matter and are flowerless. Mushrooms and puffballs are well-known members of this class of plants which is called by the Latin name *fungus*, and includes many curious specimens of varied sizes, forms, and colors.

A characteristic of this type of plant life is that it draws its subsistence not directly from the earth, but from other organic matter. There are thousands of species thriving either on the living tissues of their hosts or on the cast-off cellular matter of the latter. Some, like the molds, are very minute, while puffballs and toadstools are often very large.

Many of the larger kinds of fungi are popularly grouped together as mushrooms. Some of these are extremely poisonous; others are harmless, but of no particular culinary value, while there are many edible varieties much esteemed for their delicate and peculiar flavor.

Many of the edible mushrooms prove irritating to the digestive tract, if used when past their prime, and are then very commonly infested with insect life. None of the common tests of silver spoon, etc., for poisonous varieties are safeguards.

Mushrooms should be gathered without the adhering earth, the stems broken rather than pulled, for once sand is scattered through the gills it is hard to remove. First wash by floating in water, gills down. Young or button mushrooms need not be peeled, but old ones should have the skin removed, pulling it from the circumference to the center.

The common market mushroom (*Agaricus campestris*), which is often found growing in old pastures, is the only kind commercially cultivated in this country. It grows 2 to 3 inches high, has a cap about as wide when fully expanded, which is a brownish white above and sometimes tinged with pink below. The color deepens as the mushroom grows older, but even when it is fully expanded and quite dark the flavor is good. It may be purchased canned, but is much better fresh, and may be grown for home use. Dried mushrooms of various kinds may be bought in some large markets and in the small stores in the foreign quarters of large cities, or may be dried at home.

Many recipes for cooking mushrooms call for the removal of the stems, but they may be used if not too woody. It is a good plan to slice them crosswise and cook for a few minutes previous to adding the caps, or the stems may be reserved for flavoring soups or sauces.

The food value of the mushroom, which is really much the same as that of common green vegetables, has often been rated higher than it deserves, partly because the analyses of fresh and dry have been confused.

MILDEW, MOLDS, AND FERMENTS.

These are also classed under fungi. Some of them are looked upon as enemies, yet many of the characteristic and delicious flavors in butter, cheese, fruit cakes, and pickles are due to the development of such fungi. (Ref. No. 59, pp. 51–57.)

H. W. Conn (ref. No. 13) says: "A few of our food products are, however, benefited by the development of molds. * * * The peculiar flavor of certain cheeses is due to the growth of molds, Roquefort, Stilton, etc."

YEAST.

Yeast is a microscopic plant of the fungus type. It will grow without light, but like any plant it must be kept moist and warm. It will grow in a wide range of temperatures from just above the freezing point to over 120° F. Though formerly commonly prepared at home, yeast for bread making and similar purposes is now very commonly purchased ready prepared.

EXERCISES, LESSON IX.

Materials needed.—The materials needed include mushrooms, fresh, dried, or canned, pieces of rotten or moldy apple or other fruit, and either yeast cake or liquid yeast.

MUSHROOMS.

Prepare fresh, dried, or canned mushrooms with white sauce or use in soups.

MOLD AND DECAY.

(1) Cut through the skin of some vegetable or fruit with a knife dipped into mold or decay from another fruit. Watch day by day for changes.

(2) Put a whole fruit or vegetable and a piece of bread in a sterile jar, cover, and set away.

(3) Scatter spores of mold in a jar and then put in the jar a bruised fruit or vegetable and a piece of bread like that used in the previous experiment. Cover and leave for several days beside the other jar.

16889°—Bull. 123—16——4

YEASTS AND FERMENTATION.

(1) Experiment on the effect of temperature. Blend one yeast cake thoroughly in a pint of water to which has been added one tablespoon of sugar.

(*a*) Freeze a portion of the mixture, then allow to thaw at room temperature.

(*b*) Boil another portion and cool to room temperature.

(*c*) Take a third portion at room temperature.

(*d*) Chill a fourth portion.

Fill bottles from each of the above and invert them on plates. Keep (*a*), (*b*), and (*c*) at 32° to 37° F. and (*d*) packed in ice during the remainder of the lesson period. Explain results observed.

Yeast muffins, etc., may be made in the usual way and also with the addition of strained pulp of fruit or vegetables, such as white or sweet potato, apples, squash, or pumpkin, and mashed parsnips. These may be used interchangeably.

If there is time in connection with the lesson, breads should be made wholly or in part with flours made from bananas, chestnuts, potatoes, soy beans, or such other substances of like vegetable origin as can be secured.

Some writers on cookery consider such addition as adulterations of bread, but they deserve recognition for the variety thus afforded.

REVIEW QUESTIONS, LESSON IX.

1. Describe any mushrooms you know to be edible.
2. Can you describe any poisonous fungi?
3. How do mushrooms rank in nutritive value?
4. What is the source of the various leavening agents used in breads, etc.?
5. Tell all you can of yeast, its nature, method of use, etc.
6. What vegetables are sometimes combined with flour for making bread?
7. In what proportions are cream of tartar and soda used and why?
8. Mention uses for soda without cream of tartar.
9. How may foods be guarded from ill effects of molds and ferments?
10. What form of fungi commonly attack fabrics?

LESSON X. CONDIMENTAL VEGETABLE FOODS AND FOOD ACCESSORIES.

The value of appetizers or food accessories is generally recognized. The words condiment, herb, and spice are used somewhat indiscriminately, but together refer to various vegetable products used in small quantities to add flavor where it is lacking or to develop natural flavors in food. The terms may include such vegetables as radishes and water cress, which are served in their natural state; flavoring materials, such as spices, savory herbs, and extracts used in general cookery; and prepared sauces, pickles, etc., in which some mild-tasting material like watermelon rind usually serves to carry a combination of flavors. In whatever form they may finally appear, the majority of these flavors are due to the volatile oils or similar bodies developed in the plants from which they were obtained.

The actual quantity of these articles in any one dish is usually so small that their nutritive value can hardly be counted, but nevertheless they are important, because they may make otherwise insipid or monotonous foods more palatable and so render them more digestible.

Beverages like tea and coffee, such materials as sugar and oil when used mainly for flavor, vinegar, and other food accessories are also considered in this lesson.

CONDIMENTAL VEGETABLES AND PREPARED RELISHES.

Under this head may be included many vegetable products, such as peppers of various sorts, mustard, and horse-radish, and a host of preparations or compounds designed to give zest or enjoyment to the act of eating and to aid digestion. Various pickled fruits and vegetables, the preparation and use of which is discussed in a later lesson, should be mentioned in this connection.

Some materials of East Indian origin, such as curry, chutney, catsup, and tamarinds, are well-known relishes. Tomato, apple pulp, etc., are likewise used as a medium for combining many spices and condiments. Mushroom and walnut juices are used for the basis of table sauces. Sassafras leaves, when young and tender, are used in some localities to thicken soups, etc., and, like okra, supply a mucilaginous material.

FLAVORING MATERIALS.

HERBS.

The herbs properly include the herbaceous or green portion of certain annuals, biennials, and perennials that are used green or dried, and usually in a chopped or sifted form, in sauces and stuffings. The word is also used to include the medicinal plants which once were grown or gathered and stored by every housemother. By the way of further distinction, the herbs used for flavoring were often called savory herbs, and those which were cooked for use alone were called potherbs. (See p. 14.) Among the herbs most used in the kitchen are marjoram, sage, summer savory, thyme, mint, parsley, dill, tarragon, bay leaves, and sweet basil. These are combined with meats or used generally in unsweetened dishes.

SPICES.

Spices, with the exception of pepper, red pepper, and mustard, are associated mainly with sugar in common household use. Some spices, as nutmeg and mace, are used in meat dishes and with vegetables in continental cookery, and much less commonly by American cooks. Cloves are also used in a limited way in meat cookery; for instance, they are often stuck in a ham before baking.

Other common spices are allspice (pimento), cassia, cinnamon, ginger, mace, nutmeg; aniseed, caraway, cardamom, and coriander are less generally used.

FLAVORING EXTRACTS.

Vanilla is perhaps the most popular flavoring extract used in home cooking. Almond and lemon extracts, too, are common. These three and rose and orange, when true to name, are made directly from the natural products. There are some kinds of flavoring extracts, however, which apparently are made from the fruits, but really are made synthetically. Since true vanilla is the most expensive flavoring material, it is wise to reduce its use where economy must be practiced and to substitute other flavors and spices in small amounts. They are often used too freely and the result is unpalatable.

Condimental foods are especially liable to adulteration and sophistication. There are usually several grades of the pure article, and the housekeeper should try to learn the differences between them.

BEVERAGES.

TEA.

Tea has been used as a beverage from remote ages by the Chinese, and is probably in more general use than any other hot beverage. Leaves of many other plants have been substituted for tea—Labrador tea or pennyroyal, for instance, in the United States—particularly in times of scarcity. The maté or Paraguay tea is a common beverage of South America, made from the leaves of a species of holly.

COFFEE.

Coffee has been known in Arabia and Persia from ancient times. Its introduction into England was accomplished with difficulty. The United States consumes about half of the world's supply. The amount used is not far from 1 pound per person a month.

CEREAL COFFEE.

Parched cereals are commonly used for making a hot beverage. Many sorts are on the market, and home parched grains for this purpose are easily prepared.

CHOCOLATE AND COCOA.

Chocolate and cocoa may be classed with other beverages, though they are foods in themselves, and, as usually served, are combined with a larger proportion of milk and sugar than are tea and coffee. These are products of an American plant apparently introduced into the Old World shortly after the discovery of this country.

FOODSTUFFS WHICH HAVE CONDIMENTAL USES.

Sugar and olive oil, peanut oil, cottonseed oil, and other vegetable oils have condimental uses, but should not be thought of simply as food accessories, since they are valuable foods and have a high energy value. Sugar is, of course, used in large quantities, and vegetable oils, already fairly common, are each year assuming more importance for culinary and table purposes.

Vinegar, which is one of the oldest condiments, may be classed as a food accessory, and has little or no food value. It will be considered further on in relation to the preservation of food materials.

EXERCISES, LESSON X.

FLAVORING MATERIALS.

Materials needed.—Samples of spices, herbs, etc., in different stages of preparation; 2 lemons, 2 oranges, 1 vanilla bean, a few lumps of sugar, some powdered sugar, alcohol, bottles—lemon extract.

Spices and herbs.—Cover the labels on the spices and see how many the students can distinguish by sight and taste. Other tasting contests may be arranged. Cook whole spices in water or sugar sirup and taste each combination. Try similar tasting exercises with herbs, steeping in vinegar instead of boiling in sirup.

Flavoring extracts.—Wash and dry lemons and oranges. With lumps of sugar rub surface of one of each till sugar absorbs some of the yellow flavoring oil. Use them to sweeten and flavor sirups or custards.

Cut fine, thin strips of the yellow rind only, put in bottles, cover with alcohol, and leave for several days. The extract may after a time be drained off and the peel discarded.

Divide the vanilla bean and pound part of it in a small mortar with powdered sugar. Sift the sugar and keep it to sweeten and flavor. The particles of the bean removed may be steeped in milk for custards, etc. The other portion of the bean may be put into alcohol.

BEVERAGES.

Materials needed.—Any available samples of teas, coffees, cocoa, and chocolate; filter coffeepot.

Tea, coffee, cocoa, and chocolate:

1. Soak tea or coffee in cold water; notice color and flavor or lack of it. Bring to boiling point and again taste.

2. Pour rapidly boiling water over tea, or infuse with tea ball. Let boiling water drip through coffee in a strainer or filter coffeepot.

3. Boil tea and compare color and strong flavor with that made properly, as in experiment 2.

4. Boil coffee in uncovered saucepan. Note loss of aroma.

5. Any available "patent" coffeepots may be tested and the result compared with the right use of the simplest appliances.

6. Soak different grades of tea in water, unroll the leaves, noting size of leaf, proportion of stem, etc.

7. Test different samples of coffee for chicory and other adulterations. When mixed with cold water pure coffee floats on top, while adulterations, especially chicory, sink and give a brownish color to the surrounding water.

8. Prepare cocoa and chocolate in different ways and compare flavor, nutritive value, and cost of each.

REVIEW QUESTIONS, LESSON X.

1. How does the cost of flavoring materials compare with their actual nutritive value?
2. What can you say of the food value of the three principal beverages commonly served hot?
3. What is the best method of making tea, and in its preparation what special points must be safeguarded?
4. What simple tests will indicate presence of adulterations in coffee?
5. Distinguish between chocolate and cocoa. Tell how to prepare each.

LESSON XI. SUMMARY OF COOKERY.

Having briefly studied some of the most important groups of vegetable foods, the students are better prepared to classify methods of cooking and see how they may be adapted to developing the best qualities of plant foods.

The chief objects of cooking vegetables are these: To sterilize any from doubtful sources; to soften or separate the woody fibers; to make the carbohydrates more accessible to the digestive juices; to modify and develop flavors; and to put into attractive form for the table.

The principal processes of cookery for vegetables are the same as for meats—baking, boiling, and frying, with their modifications; but these must be adapted to the nature of the specific vegetable.

There are classifications of vegetables according to their botanical families and the parts of plants represented or according to their composition as green or watery, starchy, nitrogenous, fatty, etc. In discussing the use of different varieties in the kitchen these groups are not always considered as they should be. Instead of studying the structure and the food value of a vegetable, which would aid in showing the best way to prepare it, too often every type is treated in the same fashion.

For convenience of the cook, all vegetables may be classed as either the fresh, which are ready for cooking, or the dry, which must be thoroughly soaked before using, and the canned, which may be used by simply heating and seasoning, or in many other ways. Furthermore, with both fresh and dried vegetables, it should be considered whether they are strong in flavor, in which case they should be cooked in water first to remove some of their juices, or sweet or well-flavored, and to be prepared in such a way as to retain as much of their natural flavor as possible. Yet here the age and condition of each specimen must be considered and the dividing lines between sweet and strong can not be made hard and fast; the young and perfect forms of the stronger types may be much sweeter and better flavored than old and imperfect samples of the sweet-flavored kinds.

CHOOSING, SORTING, AND CLEANING VEGETABLES.

Careful choosing, sorting, and cleaning should precede any process of cookery.

Medium-sized vegetables are always to be preferred to the over-large.

Plants grown slowly are liable to be tough and corky, while those having abundant moisture and sunlight are crisp, tender, and well flavored.

The shorter the time and journey between garden and table the better for green plants. It is wiser not to gather vegetables while they feel the effects of the midday sun, but rather to pick them after the dew has evaporated in the morning, or, if that is not possible, in the cool of the late afternoon.

Wilted vegetables can never be wholly satisfactory, but may be improved by careful washing and removal of inferior portions, and then soaking in cold water, or, in the case of salad plants, by wrapping in a damp cloth.

The soaking of vegetables in cold water to freshen them probably extracts some of the valuable saline matter. When they are blanched in hot water or parboiled still more mineral matter is lost. If boiled in considerable water, of which no use is made, some of the soluble saline matter is wasted. This mineral matter is generally conceded to be valuable. It would be of great importance if the dietary were such that little was obtained from other sources, such as fresh fruits, salad plants, and other foods with a reasonably high ash content. It has already been indicated how the waste may sometimes be avoided by using the water for soup.

Often it is convenient and wise to cook a double portion of a vegetable and serve part of it a second day in a different form. This should not be attempted in warm weather unless a refrigerator is available. Ordinarily a vegetable well salted while cooking and drained and cooled quickly will keep 24 or 48 hours in cool weather.

A double quantity of potatoes may be cooked one day, part to serve as plain boiled or mashed to-day while the firmer ones are reserved to broil or grill in slices, fry, or cream the next day. When gas or oil is the fuel this is an economy as well as a convenience, for it would take 30 minutes to boil fresh potatoes and only 10 minutes to reheat them.

Most vegetables are lacking in fat, so it is added in some form while preparing them for the table or they are served with fat meats, etc. So far as the need of the human body goes it makes little difference whether this fat is in cheap or expensive form, whether the vegetable is cooked with fat or dressed with cream or salad oil; one form may be more agreeable to some than another.

Beef suet, bacon fat, cream, butter, and olive and other vegetable oils are all used. Better results often are obtained by combining cream with vegetables than by using butter and milk costing quite as much. There is little difference in expense between the best olive oil and thick cream. The oil keeps better and hence always may be available. A taste for salad oils is desirable and should be acquired.

Whenever a vegetable dish, other than beans, etc., is to be the principal part of a meal, it is easily possible, as well as reasonable, to increase its food value by the addition of milk, cheese, or eggs. Skim milk may be heated uncovered until considerable water has evaporated, then little or no thickening is needed.

For composition of cereals, rice, etc., which are used as vegetables, see reference No. 9.

Although almost any vegetable may appear as soup or purée, scalloped, in salad, or as the basis of croquettes, fritters, or soufflés, the simplest way of preparing each is usually the best to develop its natural advantages, and a fair sample of any vegetable is not improved by overmanipulation or additions that disguise its own flavor. Intricate dishes have their place for emergency or variety. If the supply of any given vegetable is limited, combinations with other materials are in order. When there is an abundance of one kind, and it must be the main dependence for weeks, the form of serving it must be varied or it becomes tiresome.

Just as one kind of starch may be used in place of another, so the pulp and fiber of one kind of vegetable may be substituted for those of another in such dishes as "cream" vegetable soups. Similarly any two or more vegetables whose flavors combine well may be used in the place of one, as for example, beans and squash or potato and turnip.

COMBINATIONS OF VEGETABLES.

There are many combinations of vegetables which have proved satisfactory, and no one need hesitate to experiment with others. In general it is safe to combine a starchy vegetable with a succulent one, or one lacking in flavor with another that will give relish.

Cooked celery is agreeable with creamed potato. It may be added to Brussels sprouts or cabbage.

Contrasts in color often add to the value of a compound by making it attractive to the eye, as in carrots and green peas. Since some combinations of color are not considered pleasing, on this basis it is well to beware of serving tomato and red beets together, etc.

Green corn with potatoes and onion, with the addition of milk, etc., makes as good a chowder as fish in the opinion of many.

Potatoes boiled and cut into slices or cubes may be used to extend expensive, highly flavored vegetables in salads, etc.

Potatoes with onions or white turnips make a more agreeable soup for some palates than the stronger vegetables alone.

Carrots often are more palatable cut into dice and blended with green peas than served alone.

Large white beans may be served in a tomato sauce with onion and green or red sweet peppers or both.

Mint, parsley, sweet peppers, onions, etc., may be added in small portion to many vegetables to give a new flavor when the usual methods of serving have become monotonous.

UTENSILS USED IN COOKING VEGETABLES.

The following suggestions as to utensils may be of practical use: A small scrubbing brush is essential for washing all vegetables that have grown in the earth, and should be kept in a convenient place, and used for this purpose only.

Knives of different types are desirable. A small, sharp point is needed for the removal of eyes from potatoes and small blemishes from any vegetables.

Fancy cutters are not essential, but convenient, especially when it is necessary to give variety to a monotonous diet.

A wire basket is convenient to hold greens, string beans, or even potatoes while cooking, as thus they are less likely to adhere to the bottom of the kettle, and often it is easier to remove the basket than to drain off the water.

Colanders, purée strainers, potato ricers, etc., are all helpful in washing and straining potatoes, squash, etc.

A potato masher of strong, continuous wire, the two ends inserted in a wooden handle, is inexpensive and fully as satisfactory as a more costly style.

TIME OF COOKING.

While overdone vegetables are not desirable, underdone ones are often even less appetizing; therefore it is wise to start in season and stop the process as soon as the plant is tender, and then reheat quickly just before serving. Most time-tables in cookbooks do not take into consideration the variations in time required for the same kind of vegetables at different ages.

WAYS OF SERVING.

SOUPS.

This is one of the best ways to use left-over vegetables. A cupful of cooked cauliflower with some of the water in which it was cooked and an equal amount of milk and a slight thickening of butter and flour will provide a cream of cauliflower soup. If the vegetable already has white sauce with it, reduce it with milk to right consistency, season, heat and strain, and the soup is ready.

A purée is halfway between a cream soup and mashed vegetables; it is sometimes a thick soup, but oftener strained vegetables made soft with milk or stock and butter, and served with meats.

SALADS.

The derivation of the word—something to be eaten with salt—shows its original simplicity. Now the term is applied to combinations of all sorts of food materials that may be served cold with a dressing but more particularly to those which are dressed with oil (or other fat) and vinegar (or other acid, as lemon juice), salt, and other seasoning. The young tips or tender leaves of certain plants, as lettuce, dandelion, etc., are especially suited to this purpose. (See Lesson II.)

SCALLOPS.

These consist of cooked vegetables with cream sauce or milk, seasoned, covered with buttered crumbs, and browned in the oven. The proportion and thickness of sauce varies with the dryness of the vegetable, usually half as much sauce as vegetable in the case of cabbage or onions.

FRITTERS.

Many vegetables, partially cooked, may be dipped in batter and fried in deep fat, thus giving variety and adding material of a different type from their constituents. This may be seen by looking up fritters in any large cookbook. Among the vegetables best adapted to this process are cauliflower, celery, corn, okra, and salsify.

CROQUETTES.

These may be made from mashed vegetables held together with a small proportion of beaten egg or from chopped, cooked vegetables combined with a thick cream sauce. There is justification for the additional time required for this process when left overs can be thus used economically or when variety is needed. From the potato cake or croquette it is but a short step to a potato crust for a meat pie or from the corn fritters to the tortilla, and thus to doughs.

EXERCISES, LESSON XI.

Materials needed.—Take any available vegetables not previously used in the practice lesson and prepare them in any of the standard forms.

Use any formula proved successful for some vegetable and substitute another vegetable with due variation in other ingredients to adapt the formula to the composition of the substitute.

For example, a cream soup may be made with any cooked and strained vegetable pulp, but if in one case it is potato with much starch and little flavor little thickening and more seasoning will be needed, while with celery or onion more thickening and less added flavor will be required.

Exercise.—Make two green-pea soups, using for one the dry split green peas at about 14 cents per quart, and for the other canned green peas at the same price per can. Count cost of materials, time, and fuel in each case.

REVIEW QUESTIONS, LESSON XI.

1. Briefly describe the principal processes of cooking which are applied to vegetables.
2. What general preparation would be common to all methods?
3. When may it be advisable to cook a double portion of any vegetable?
4. How shall it be decided what materials to add to a vegetable in its preparation for the table?
5. What types of knives are most helpful in preparing vegetables? Describe different processes requiring different motions.
6. Some vegetables should be scraped; others pared. Give examples.
7. Describe several utensils helpful in preparation of vegetables.
8. Suggest combinations of vegetables and explain why they are acceptable.
9. Give general plan for making soups from one kind of vegetable. Mention combinations that might be used in the same way.
10. Describe process of making croquettes or some scalloped vegetable.

LESSON XII. DRYING, EVAPORATING, AND SALTING VEGETABLES.

Most foods are best when fresh, but since they can not always be had in this condition some means must be found for preserving them. Decay in fruit or vegetables changes texture and flavor and is caused by the development of bacteria, spores, molds, and other low forms of life. Methods of preserving are simply means of checking their growth. The first step should be to protect the material from unnecessary contamination from them, but since they are everywhere present in the air even the most scrupulous cleanliness is hardly sufficient alone.

Most of these microorganisms grow only in the presence of moisture, and this fact explains the method of preserving by means of drying.

DRYING AND EVAPORATING FOODS.

The drying of foods has been practiced by primitive people from the beginning of civilization and is only aiding nature's processes. The seeds dry as they ripen and berries dry on the bushes. The Indians preserved blueberries and other fruits in this way. Pumpkin was often dried in strips by the early colonists, and sections of apple were strung and hung where they would dry readily. The bulk and weight of such foods is much less than in the natural condition, hence less room is required for storage and much less labor is involved in transporting them from place to place.

Herbs and spices were gathered, dried, and used to aid in the preservation of other foods. There was a right time for gathering each plant, it was believed, and in this lore ancient housekeepers were far more interested than modern ones.

Dried lavender, sweet grass, clover, and rose petals have from time immemorial been used by housewives to perfume their linen chests.

Dates, figs, and raisins long have been considered important foods for the traveler and explorer, containing valuable food material in concentrated and convenient form.

Modern, evaporated fruits and vegetables differ from dried, simply in that the process is shortened, and there is less opportunity for fermentation, darkening, or the accumulation of dirt.

Dried fruits and vegetables, as a general thing, are less expensive than canned, mainly because they have required less labor in preparation and transportation. Their value is not generally appreciated, partly because they are cheaper, partly because the older dried products were often damaged by dust and insects, and partly because sufficient attention is not given to freshening them and preparing them for the table by good methods. The good modern methods of drying and marketing are a great improvement on those of earlier times, and yield a cleaner and more sanitary product. Dried fruits and vegetables, properly soaked and cooked, are very palatable and are wholesome, useful products, particularly when the fresh ones are not available.

A homemade drier is a desirable appliance for the possessor of a good vegetable garden. A simple form consists of trays in a holder; four strong, upright, wooden supports, connected by horizontal bars, will hold several trays at once. The trays are made like window-screen frames and may be covered with wire netting for some things, but cheesecloth is preferable. The supports should be tipped at the base with a large nail or piece of metal that they may safely rest on the back of the stove when sunlight is not available. Shelled beans and green peas may be dried in this fashion. Some find it an advantage to scald them in boiling water before drying. Sweet corn should be slightly cooked, cut from the cob, and spread in very thin layers on the cheescloth. Corn on the cob may be dried after scalding.

Small quantities of vegetables may be evaporated on earthen plates set over a kettle of boiling water or in an afternoon oven. While drying, they may hang in cheesecloth bags at the top of a warm closet. When very thoroughly dried, put away in tin boxes or glass jars.

Tomatoes may be cooked, strained, and evaporated to a thick paste, resembling beef extracts in texture, which must be filled at once into containers and tightly closed. In this form they are found in Italian markets, and can also be prepared by the housekeeper herself.

PRESERVING BY SALTING.

Salt hastens the drying process by drawing out water from the vegetable tissues, making them firmer; it also hinders the growth of bacteria. Young cucumbers and other green vegetables often are packed in salt as they are gathered and then kept until a convenient time comes for their further preparation for pickles. Greens, string beans, and similar vegetables used to be packed in salt like young cucumbers. Thoroughly freshened in the winter, they afford an agreeable variety. Now canned vegetables are more convenient.

Smoking is very commonly combined with drying and salting as a means of preserving foods, but almost exclusively with meats and fish.

Sauerkraut, a German preparation of cabbage, is evidently the survival of an ancient way of preserving the vegetable. The process is somewhat akin to the ensiling of forage for animals. Domestic methods vary more or less. According to one recipe, firm cabbage is sliced, packed with alternate layers of salt (sometimes a few caraway seeds are added), and the mass is pressed down solidly under a weighted cover. After a little while fermentation takes place and the liquor which rises to the top is poured off and more salt and water added. According to another method, finely cut cabbage is mixed with salt and packed solidly into a cask or other container. In about six days scum will rise to the top of the liquor which collects on the top of the sauerkraut, and should be removed. The cask or other container should stand in a cool cellar. In about two weeks more the kraut will be ready for use. Experienced housekeepers know that the sauerkraut should be covered with a piece of board scrubbed until it is clean, with a well-scrubbed stone on top of the board to weight it down. The acid developed by the fermentation works upon the tough fibers of the cabbage leaf, making them more tender. Sauerkraut should be kept in a cool place, and when needed should be squeezed as dry as may be and cooked like fresh cabbage.

Cucumbers packed in salt will undergo fermentation, a fact taken advantage of in home pickle making. The salted cucumbers can be freshened from time to time in the winter and pickled in vinegar. Dill pickles are made with cucumbers packed in a similar way and flavored with dill, a seasoning herb which finds a place in many old-fashioned gardens.

From similar methods other types of pickles may have been evolved.

EXERCISE, LESSON XII.

DRYING VEGETABLE SUBSTANCES.

Materials needed.—Frames covered with cheesecloth or white mosquito netting; these may be sections of boxes, even of heavy pasteboard.

Exercises.—The essentials in drying vegetables are cleanliness, heat, and circulation of air. The more rapid the process the less the danger of bacteria, ferments, and molds.

(1) Arrange part of the vegetables on the frame and expose in current of air, or place part in a very moderate oven with the door open, or in upper portion of an uncovered double boiler, and compare the results.

(2) Place pieces of different thickness side by side and dry under the same conditions. Cut a carrot in fancy shapes and dry for soup garnish.

(3) If possible, try (*a*) green or undeveloped tissues, (*b*) fully grown or ripe and overripe; compare results.

(4) Weigh and measure vegetables or fruits as purchased; weigh and measure after process of evaporation is completed.

(5) Dry parsley; note effect of too much heat in change of color. When dry, rub through strainer and use like fresh chopped parsley. Plunge in boiling water before drying and compare result with other not so treated.

(6) Try experiments with thick sections or with thin ones placed over each other, exposed to dust where process must be slow, without sun or heat, and note results.

(7) Test effect of alcohol, oil, vinegar, sugar, salt, and spice separately and two or three together on similar sections of the same fruit or vegetable, raw and cooked.

(8) Test effect on similar sections from the same article, thus: (*a*) Refrigerator, (*b*) in sunlight, (*c*) in moderate oven, and (*d*) in dusty room.

RESTORING DRIED FOODS TO THEIR ORIGINAL CONDITIONS.

Reverse the experiments just described by soaking dry vegetables and fruits, such as evaporated apples, beans, cherries, peas, peaches, prunes, sweet corn, etc. Weigh and measure these as purchased; weigh and measure after soaking. Make tea, unroll the leaves and note shape; make teas from herbs.

Nuts are a type of dry or condensed foods which may be studied in this connection.

Exercises.—Take 1 pound of mixed nuts in shells, or one-fourth pound of each of any available kinds. Weigh before and after shelling. Note composition of each type. (Ref. Nos. 12, 14, 26.) Suggest additions and combinations with other food materials to dilute the nuts and make a food which in composition might be similar to a meat and potato hash or legumes stewed with pork.

REVIEW QUESTIONS, LESSON XII.

1. What objects are sought in the preservation of vegetables?
2. Describe methods used before the process of canning was discovered.
3. Explain the effect of air and sunlight on canned foods.
4. Mention appliances helpful in any processes of preservation of vegetables.
5. Explain the action of salt, sugar, spice, oil, vinegar, alcohol on vegetable tissues.
6. Contrast processes of drying and canning, giving the relative merits of each.
7. How is the large percentage of water in vegetables shown in any method of preservation?
8. What is the relative proportion of nut meats to shell, both as to bulk and weight?
9. Mention points for and against buying shelled nuts or seeded raisins, etc.
10. Estimating cost of jars, fuel, etc., allowing a fair price for labor, what does it cost you per jar to can your own fruits and vegetables? How does this compare with drying?

LESSON XIII. PRESERVING AND CANNING VEGETABLES.

The home canning of fruits and vegetables is a matter of more importance to those who grow such products than to those who must buy them in any case. The cost of labor and fuel, added to the cost of the raw material, makes it wiser for many to buy the canned article. But there is no question that the surplus products of the home garden should be preserved in some form for future use. A number of the publications of the United States Department of Agriculture treat different phases of this subject fully and can be used as supplemental textbooks for lessons. (See especially Ref. Nos. 1, 4, 5, 6.)

The essential points in all canning are few—absolute cleanliness, good sterilization, and suitable containers—which mean the destruction and exclusion of molds, bacteria, and spores.

Poisonous or doubtful preservatives never should be used. The housekeeper should limit herself to the use of the approved household preservatives, such as spice, vinegar, salt, wood, and smoke. The use of sugar, salt, vinegar, and spices as flavorings has gone on so long that it is frequently forgotten that such use is very often secondary to their preservative effect.

A practical point worth remembering in canning and preserving is that, roughly speaking, 1 quart of some vegetables, for instance, spinach well packed down, onions, and cranberries, will weigh practically a pound, while with others, such as apples, cucumbers, and peas, the weight of a quart would be more nearly 2 pounds. When canning vegetables or preparing them for the table it is well to remember that on an average a quart of vegetables, as purchased, will be required to fill a pint jar or dish; the shrinkage being due to loose measure, the removal of skin, and other inedible portions, and condensation in cooking.

PRESERVING WITH SUGAR.

The earliest method of preserving fruit aside from drying appears to have been to coat it with honey and allow it to dry somewhat. From that may have been derived the plan of packing in jars and filling the spaces with strained honey. This might have been the result of observation of the way in which flowers, etc., accidentally coated with honey retained their original freshness. In any case it was unconscious application of the fact that bacteria and molds do not grow readily in the presence of concentrated sugar solutions.

Preserving with sugar is, of course, more important for fruits than for vegetables, but is worth consideration here, partly because it shows an important principle in the general science of food preservation, and partly because a few vegetables are sometimes put up in sugar. (Ref. No. 7.)

Dates, figs, grapes, and other fruits rich in sugar have always been known to keep well when only partially dried, and others less sweet have been dried with the addition of a little sugar. The old-fashioned New England custom of drying wild raspberries with maple sugar is an illustration of the latter, and also of how necessity sometimes leads to the discovery of pleasant flavor combinations.

Although sugar is a good preservative against bacteria and molds, it is not so efficient against the yeasts which cause fermentation; hence the occasional "spoiling" of even fairly sweet fruit preserves and the need of keeping them in clean, tight jars.

If the products commonly classed as vegetables were preserved in sugar, their sweetness would spoil them for their ordinary uses in the bill of fare. Where fruits are scarce and expensive, women have been ingenious in the use of vegetables in place of them. Thus the seed vessels of roses are sometimes made into preserves in northern Europe. Pumpkin, squash, carrot, even beet and cabbage are used in this way and flavored with lemon, ginger, etc. Certain kinds of tomatoes, also, such as the yellow plum variety, are frequently preserved in sugar, but they are so sweet in this form that they are used as a dessert rather than in the meat or salad course. Small quantities of sugar are sometimes used in canning such vegetables as green corn and peas.

Since sugar and other sweetening materials are of vegetable origin they may be briefly mentioned here. Honey already has been considered among the flowers. Maple sirup and sugar making were known to the Indians, who recognized a "sugar-making moon" in the spring. A study of the history of methods of condensing the sirup, from the primitive appliances of a century ago to the improved evaporators of the present, would be of interest and suggest possible advance in household methods of cookery.

Cane sugar is a popular and valuable food, and its use appears to be increasing everywhere. That large quantities of it taken at any one time are generally conceded to be unwholesome is not surprising, since overeating of any food is likely to result in unpleasant consequences and is to be avoided.

Statements are sometimes made that sugar is not a wholesome food but this is by no means the commonly accepted view. As a recent writer on hygiene states, "Sugar is of especial value because it is so readily available for use by the system. It needs but little change in the chemistry of the body before it becomes capable of absorption and utilization." (Ref. No. 15.)

Granulated and other white sugars are the most important products of sugar cane, but brown sugar and molasses also play a useful part, not only in those sections of the Southern States where molasses is a large factor of the diet but also in general cooking. The old-fashioned somewhat acid molasses was the result of evaporation in open kettles, a process rarely followed now.

During the last half century there has been a marked increase in the production of sugar from special varieties of beets. So far as the chemist can discern, this sugar is identical with that made from sugar cane.

The use of a natural sweet sirup, honey, has been spoken of elsewhere (p. 36).

Sorghum sirup, which is not an uncommon domestic product, is less used since corn sirups have been manufactured.

That sugar is present in a number of vegetables can be easily shown by evaporating the water in which sweet vegetables, like carrots, peas, or squash have been boiled. A small amount of sweet sirup will be obtained, but it is not always palatable since it contains mineral substances and other constituents as well as sugar.

PRESERVING BY STERILIZATION—CANNING.

In ordinary sweet preserves the heat of cooking may increase their keeping qualities by killing some or all of the microorganisms present in the raw material. It has been shown that such sterilization is one of the reasons for cooking vegetables. It is the most important factor in canning vegetables, whether in the home or in the factory.

Prolonged or extreme heating tends to change the flavor and texture of foods, sometimes for the worse. The best method of canning, therefore, will be the one which kills the most of the undesirable microorganisms, while it occasions the least injury to the material. Whatever method is used, the receptacles in which the food is put must be sterilized as carefully as the food and finally closed so tightly that no fresh organisms can find entrance.

The method known as intermittent or fractional sterilization usually answers all these conditions. In this method, the vegetables, after blanching in boiling water, are put into jars, the rubber rings and glass covers are laid on but not clamped, sterilized water is added, and the jars heated to the boiling point of water for about an hour; then the jars are fastened. This process is repeated with clamps up 24 hours later, and again the third day. This method is tedious, time consuming, and expensive, and hence not best suited from a practical standpoint to the canning of cheap products, such as greens, peas, okra, sweet corn, and Lima beans. It is, however, considered the only thoroughly safe method under certain conditions, such as prevail at high altitudes and in damp, warm regions, and for this reason is recommended by the Department of Agriculture for use in the home-canning work in the South. In the home-canning work in the Northern and Western States, on the other hand, simpler and cheaper methods have been used with marked success. The one preferred and now in general use is known as the cold-pack method. In this method the vegetables are first blanched in live steam for a few moments, then plunge quickly into cold water, from which they are removed and packed in the containers. A little salt and hot water is added immediately, the containers sealed (glass jars partially, tin cans completely), and processed for a period of time, depending upon the outfit used and the product being canned. (Ref. No. 6.)

Vegetables should, if possible, be canned the same day they are gathered.

Where the source of the vegetables is uncertain it is a safeguard to blanch or parboil them in well-salted water and drain thoroughly before packing them in the jars for either the fractional or the continuous process. A small quantity of cooking soda may be added to the water in which string beans are parboiled and which is not used in the canning process. As vegetables are salted before serving, from 1 teaspoon to 1 tablespoon of salt is frequently added to each jar.

The relative economy of the use of fresh vegetables and canned ones involves many problems, including convenience, value of time and labor, as well as variety and quality of the foods.

Compare canned green peas with fresh ones in the pods out of season and the advantage is with those from the can as to quality as well as cost. But canned or fresh at the lowest rates for either are expensive compared with the amount of nutriment obtainable for the same money from the dry green or split yellow peas.

To illustrate this matter in detail: A 15-cent (pint) can of Lima beans yielded 150 beans. The same number of dried Lima beans, which are a common domestic as well as a commercial product in some localities, would weigh a little over 5 ounces, or a third of a pound, and measure less than 1 cupful. The cost of these beans was 9 cents per pound. In other words, the dried beans would cost 3 or 4 times less than the canned beans, and with a fair allowance for fuel and labor the total cost, when prepared for the table, would be less than one-half that of the canned beans.

The larger the family the greater the gain in the use of such dried beans, for even at wholesale rates the cost of the canned would be greater than that of dry beans plus the labor and fuel required for the preparation of the latter.

However, both kinds are wholesome and palatable. Knowing this the housekeeper can choose according to her circumstances and preferences.

Because this happens in one instance it does not follow that it will in others. Some of these questions, as that of canned beets versus fresh, etc., may be worked out in the practice period. In general, it will prove that the fresh vegetable directly from the garden in its season is always superior to the canned, and that a dried fruit or vegetable properly soaked and cooked will rival all but the very highest grades of canned foods of the same kind.

To use canned vegetables, open an hour or more before using; empty the can as soon as opened and expose the contents to the air to freshen. To freshen quickly, drain the vegetables and rinse with cold water. Taste of the liquor in the can and use or discard as seems best; do not keep it long after opening.

EXERCISES, LESSON XIII.

ACTION OF BACTERIA, MOLDS, ETC.

Exercises.—Expose bread, cheese, fruit juices, cut raw and cooked vegtables, milk, etc., to dusty air and leave for some time. Note changes in each. Note the cloudy appearance of fruit sirup, indicating presence of bacteria. Scald the sirup, remove scum, and sirup will be seen to be clear again.

Leave stewed fruit in glass jar uncovered. Note the difference in lower portions which do not come in contact with air. After a time stir slightly so that part of top layer is distributed throughout the jar. Note the groups of bacteria, etc., forming where portions of the top layer remain.

Note the need of sterilization of jelly bags, jars, utensils, and the danger from sweeping, dust from open windows, etc.

SUGAR.

An entire lesson might be given to a study of sugar and the way it is affected by heat and moisture. In reference No. 1 Miss Parloa has explained the preparation of sirups for canning.

CANNING.

Materials needed.—Any vegetables available, including tomatoes, either fresh or canned; apple or green-grape jelly, fresh mint, spinach extract for coloring. Several types and sizes of jars.

Exercises.—(1) Can any available fresh vegetable.

(2) When fresh tomatoes are not available open a quart can, reheat, and seal part in half-pint jar. This is a practical point for the small family where a larger can is too much to use at once. Another portion of the tomato may be strained and canned in a half-pint jar. The remainder, strained, may be evaporated to half its first bulk, seasoned with spices, salt, and vinegar, and put into bottles as catsup.

Note whether varying the kind of spices and the proportion of vinegar affects the flavor materially.

(3) Note results with different types of jars. Have different sorts of tops any special advantages?

Another lesson on this general subject might deal with the use of canned foods, as already indicated in Lesson VII with the tomato. (Cream soups may be made from canned tomato, peas, asparagus, etc. Scalloped tomato and corn fritters are other dishes in which small quantities of canned vegetables may be utilized.

Combinations of high-flavored fruits with others of different flavor, or sometimes of less distinctive taste, are by no means uncommon. Thus, housewives often combine raspberries and currants for jelly making or for canning. Another combination which may prove useful, if lessons are given at seasons when fresh berries and fruits can not readily be procured, is raisins, oranges, and cranberries. The proportion is a matter of taste, so it is well for students to use different quantities and compare results.

In old domestic recipes quinces are often combined with sweet apples which have little distinctive flavor, or with pears of firm texture and also lacking in this quality. The relative proportion of the two fruits is a matter of preference; the greater the proportion of quinces the higher the flavor.

Such preserves can be made by the student if time permits. Note the texture of the different fruits when cooked.

Experiment with vegetable pulp, such as squash, pumpkin, sweet potato, or tomato, as a basis for marmalade, with flavor supplied by spice or a small proportion of high-flavored fruit like apricot or quince.

REVIEW QUESTIONS, LESSON XIII.

1. What kind of kettles would you choose for canning, and why?
2. What is the aim of this plan of preservation?
3. Has any case in your own experience shown the importance of sterilization?
4. Why are rubber rings used?
5. Give an outline of the process of canning based on your own experience.
6. How would you estimate shrinkage between market and jars, including imperfect vegetables, necessary refuse, effect of cooking, etc.?
7. What fruits and vegetables do you can at home?
8. What do you find it wiser to buy, and why?
9. Give details of relative cost to you of buying tomatoes to can or buying them already canned.
10. Does this lesson explain any failures that have troubled you?

(Ref. Nos. 1, 4, 13, Chaps. XI, XII.)

LESSON XIV. PICKLING VEGETABLES.

VINEGAR.

Vinegar is another substance which acts as a food preservative. Its name means "sour wine," and at least when a domestic product it is usually made from cider or light wine, in which bacteria give rise to fermentation and the production of acetic acid. This acid gives the vinegar its sour taste, and is very unfavorable to the growth of bacteria. When vinegar is used in pickle making the hard fibers of undeveloped vegetables, vegetable skins, etc., are softened by it. Spices and salt have much the same effect as vinegar on bacteria, though in a different degree. These preservatives, of course, entirely change the flavor of food in which they are used, and often set it among the condimental materials.

HERB VINEGARS.

Herb vinegars are useful for the housekeeper's store closet, as by their means a new flavor is easily added to a salad sauce. They may be prepared either in Lesson X or here by steeping fresh or dried herbs, such as tarragon tops, in cold or hot vinegar. Some of the more delicate flavors may be lost by heating, but the cold process is slower.

PICKLES AND SAUCES.

The word "pickle" is applied to the process of preserving foods, either with salt or vinegar, or both. Thus meats are pickled in brine, either a saturated solution of salt and water or the water which the dry salt draws out of the foods themselves, which are often three-quarters or more water. When the term is applied to vegetable foods it is commonly understood to mean preservation with vinegar, either with or without the addition of other materials, as salt, spices, or sugar. In some cases, as in dill-pickle making, the acid is supplied by the fermentation of the product itself and not by adding vinegar. The number and variety of fruits and vegetables used in pickle making is almost endless, cucumbers, tomatoes, onions, and green or unripe fruits being most common.

An old household name for pickles in which the flavor of vinegar predominates is "sour pickles." Those in which spices are particularly noticeable are frequently spoken of as "spiced pickles" or "spiced fruits," and those in which sugar predominates as "sweet pickles."

The transition is gradual from the acid fruits preserved with sugar and spice to the sweet pickles where somewhat tasteless vegetable tissue has been filled with vinegar instead of natural fruit acid and spiced and sweetened.

By using them for pickle making the thrifty housewives of earlier times contrived to make attractive most unpromising food materials as well as common fruits, etc., for instance, the rinds of the watermelon, the unripe windfalls from the fruit tree, martynias, cucumbers, ripe tomatoes, and the green tomatoes remaining when frost had killed the vines. Even young ears of corn 2 or 3 inches long are used for pickles. Though the kernels have already formed, the cobs are tender and will absorb the vinegar.

Some materials are more satisfactory for pickle making if first soaked in salt water to extract acrid flavors. Special treatment of this sort is required with such materials as green melons, but with the more common fruits and vegetables used in pickle making there seems to be little difference in results, whether they are soaked overnight in that fashion or whether they are parboiled in salt water.

By either process some water is extracted from the tissues, which are then ready to fill out with the prepared vinegar.

Old recipes for pickle making sometimes call for ingredients not now recommended. The use of alum to insure crispness or a brass kettle to "green" the pickles can not be advised. In these days when fresh fruit from all over the world is available, is the housewife justified in spending much time to provide many jars of highly seasoned condiments for her own family or her neighbors? This is a question the housewife should consider.

When the materials used in pickle making are so finely divided that the resulting product is a more or less thick fluid, they are usually called "catsups" or "sauces." Tomato is a favorite foundation, but many fruits may be cooked and strained for this purpose; decayed ones never should be used.

There are hosts of table sauces which, by their names, seem to be derived from the Orient. Consult a dictionary for the origin of some of these words: Catsup or ketchup, chili sauce, chowchow, chutney, etc., which are made in many ways from diverse materials.

CARE OF PICKLED AND CANNED GOODS.

Any canned foods or pickles should be well cared for. The stone jars with more or less tightly fitting covers formerly used may serve for very sweet or for highly seasoned material, but the glass or other jars with air-tight covers are more satisfactory for all purposes. Each household should have several sizes. Often a large jar is opened and not half its contents used. The remainder can be reheated and again canned in a smaller jar. All jars should be carefully labeled. When one lot of pickles has been used, the vinegar still may serve for partial preparation of another vegetable. The spiced sweet pickle vinegar is usable in several other ways; prunes or beets may be put into it or it may be used in mince pies or stiffened with gelatin to serve with meats.

EXERCISES, LESSON XIV.

Materials needed.—The materials needed for this lesson will depend on season and locality. Cabbage and onions usually will be available if nothing else is at hand. Citron melon, watermelon rinds, and green tomatoes are excellent for such lessons in late summer.

SIMPLE PICKLES.

A simple type of pickling may be observed by grating horse-radish or putting it through the food grinder and combining it with sufficient vinegar to moisten it.

Beets cooked in Lesson VI (p. 33) might be kept in vinegar until this lesson. If the jars were not entirely closed, mold may have formed on the top and yet the beets below be in good condition. They now might be put in a spiced sweetened vinegar, scalded to sterilize them, and canned.

COMBINATION IN PICKLING.

Almost any combination of onions, peppers, and tomatoes, ripe or green, will form an acceptable relish with vinegar and spices. The basis of the pickles may be of one kind or several, but in the latter case each should be parboiled separately, or some may be hard while others are overcooked.

Exercise.—Collect personal and family recipes for all types of pickles and refer to standard cookbooks dealing with the subject. With the aid of the blackboard, reduce these formulas to their lowest terms and arrange in tabular form. Thus it becomes apparent that it is not necessary to have so many recipes. Moreover, proportions may be adapted to conditions.

It will surprise the students to see how many recipes for sweet pickles may be condensed to some such form as this: For 2 pounds of prepared vegetables or fruit, 1 pound of sugar (or less), one-half pint vinegar, 1 ounce mixed spice.

The usual sauce for mustard pickles is some variation of this formula: Mix one-fourth to one-half cup sugar with 1 ounce ground mustard and 2 tablespoonfuls flour. Stir into 1 pint hot vinegar and cook until thickened. Turmeric may be added to give color. Combine with 1 quart mixed vegetables parboiled. Note resemblance between salads with cooked dressing and mustard pickles.

Salad oil, such as olive oil, cottonseed oil, or peanut oil, in small proportion is often added to mixed pickles or poured over the top after they are put in jars to protect them from the air and prevent the growth of molds.

To show that the natural acid of some fruits may have the same antiseptic effect as vinegar, put cranberries or rhubarb into sterile jars; fill the jars with clear, freshly sterilized water and seal; time will show that the fruit keeps as well this way as if cooked.

REVIEW QUESTIONS, LESSON XIV.

1. Define pickles.
2. What are essential steps in the process of pickling?
3. Describe the making of sweet pickles.
4. Mention some names of products of this type which indicate a universal demand for such foods.
5. Is there any reason why pickles and relishes should be less important now than formerly?
6. Why is vinegar useful as a preservative?
7. Are any fruits or vegetables ever pickled without vinegar?
8. What may be combined with vinegar to give it greater efficiency?
9. What need of caution in selecting utensils for pickle making?
10. Are exact recipes essential in the preparation of pickles?

LESSON XV. VEGETABLES FOR THE TABLE—MARKETING.

Savages found their food where they could, and dug roots, picked fruits, and pursued game from place to place. Such nomadic tribes required a large area to sustain a small population. The fixed hearthstone and planting of seeds were higher steps on the ladder of civilization, grazing succeeded the chase as a method of supplying food, and grazing and crop raising combined are the foundations of agriculture. The possibilities of intensive farming in the development of the food supply are not yet known. Moreover, the skilled efforts of the farmer must be supplemented by equal intelligence on the part of the cook who handles his products.

CULTIVATING VEGETABLES FOR THE TABLE.

There is an increasing attention given to the cultivation of vegetable foods, with the result that the quality is better and the texture less fibrous. Less attention evidently is being given in this country to production of cakes and pastries, and the per capita consumption of flour appears to be diminishing as coarser cereals, fruits, and vegetables are used more.

Farmers are beginning to see more profit in the intensive cultivation of choice vegetables than in the larger acreage of less profitable crops. Too often a type of plant is chosen for its shipping or keeping qualities rather than for flavor and texture. The improved quality of fruits and vegetables gained by improved methods in agriculture is often more than offset by carelessness in packing. Good varieties should be grown by the best methods and handled and shipped so that they reach the consumer in satisfactory condition.

What is needed is greater knowledge on the part of the producer of the relative values of different varieties of the same plant, while the consumers must be discriminating in the selection of the special article for a given purpose or know in what way the available material can best be utilized.

The housekeeper unfamiliar with the country garden hardly knows when different vegetables are at their best, and may buy them at abnormal prices out of season and rely on canned vegetables when "natives" are abundant. Easy transportation, cold storage, and cultivation under glass have changed the times and seasons to a great extent, and while this is often an advantage, there is seldom the same desire for foods obtained at any time as there is for those available for a short season only. Producer and consumer should confer frequently to secure better food for all and better methods for its transportation and use.

Cold storage has advantages, but often is carried so far that there is distinct loss of quality or flavor, or both. With the lack of suitable storerooms in modern houses in large towns, housekeeping would be almost impossible without the storage facilities whereby dealers can hold food supplies in good condition.

GROWING VEGETABLES FOR THE HOME TABLE.

Women should be encouraged to take more interest in the vegetable garden. Even the actual work there is less taxing than much that is done indoors, which gives less valuable return in health and comfort.

Too many gardens are planted all at once. It is far better to leave open spaces and plant additional rows of lettuce, radishes, beans, and corn each week until after the middle of summer. Another important point is to prevent the maturing of any seeds if it is desired that plants continue to produce. Therefore cucumbers, summer squash, etc., must be kept closely cut, even when not needed for the home table.

WEIGHTS AND MEASURES.

There is need everywhere of enforcing definite standards of measure and weight, especially in cities where the average portion sold is small; the arithmetic of the vegetable market is confusing, and more uniform methods of measuring market produce should be adopted. For example, sometimes onions are sold by the quart, sometimes by the pound, or by the bunch. Four or six or more may constitute a bunch of beets or young turnips, etc., with little regard to the size of the individual roots.

As a recent publication of the Bureau of Standards, which deals with standards for the home, points out, the law in some States requires that dry commodities be sold by weight and in such States purchasers may demand that orders be weighed before delivery and the specified weight delivered.

In other States the statutes define the bushel as consisting of a stated weight, but do not require that dry commodities be sold by weight, although it appears to be the intent of the law that the weight specified must be delivered for a bushel whether commodities are weighed or measured.

Certain other States have established a standard weight per bushel for the standard common vegetables. Thus a bushel of potatoes would weigh 60 pounds; white beans, 60 pounds; carrots and parsnips, 50 pounds; turnips, 55 pounds; onions, 57 pounds, or about 2 pounds to the quart. In some States this is limited to cases where the sale is actually made by weight.

In some of the States special contracts may be made which specify some other method of sale than that required by statute.

In States where the legal weight of a bushel of any commodity has not been established and the laws do not provide that dry commodities be sold by weight, any checking by the housekeeper must be done by dry measure. (Ref. No. 16.)

TRADE CUSTOMS AND MARKET CONDITIONS.

Certain trade customs tend to foster ignorance of the best season for each vegetable and the best way to use it. A premium has been placed on bulk rather than quality, size rather than flavor. Why should not summer squashes and cucumbers be sold by weight as well as winter squashes? Most of those in the markets now are overgrown. Asparagus 8 or 10 inches long is less desirable than if it had been cut a day earlier at half the length. The custom of keeping asparagus fresh in water increases its weight by absorption of water, but causes loss of nitrogenous and mineral matter. Celery should not have its roots spoiled by nails or its stalks bound with colored strings.

The medicinal qualities of vegetables need fuller investigation. Money spent for scientific research in establishing or refuting traditional and popular ideas about the effects of celery in rheumatism, onions for sleeplessness, etc., should give good returns. Probably in most cases green vegetables and salad plants would prove more useful than "spring medicine," in which so many have faith.

There are times when it is justifiable to pay a larger price for a food than its actual nutritive value seems to warrant, because its attractive appearance and flavor will make palatable the more familiar and less costly foods.

The wise buyer knows the nature of each article so well that when strict economy is practiced decayed vegetables are refused, while those only slightly withered but so unattractive as to be low priced are secured and promptly freshened.

The prices of vegetables in city markets seem exorbitant to those who have never had to pay cash for such products, and make the advantages of the home garden more fully appreciated. Too often in the country the garden is neglected that "money crops" may have more attention because its economic value is not recognized. If a garden plat is intelligently arranged and its products are properly prepared for the table, it often yields more profit than any corresponding area on a farm. Many a small garden, a quarter acre or even less, wisely arranged will bring to the family table more food than could be secured by any similar expenditure of money and labor.

At the present time the list of vegetables which may be easily grown is a long one and is being added to as new plants are found or new varieties produced. Some of the novel plants recently brought to this country for experiment by the Department of Agriculture are the "udo," a salad plant from Japan, Hungarian paprika, the dasheen, and the adsuki bean.

The future, judging from the recent past, will give increased facilities for the preservation and transportation of all types of vegetable products from every part of the world. Many plants now little known will be studied, improved, and made available. Fewer seeds and less cellulose or fiber will remain in many of the plants now in common use. There will very likely be greater concentration of the valuable constituents of such foods for convenience in transportation and preservation, but none of the improvements are likely to change the fact that the vegetables are at their best when the interval between their picking and their use is the shortest possible.

EXERCISES, LESSON XV.

Materials needed.—Pencils and paper.

Exercise.—Plan menus for single meals or longer periods, containing a wide variety of vegetable products and supplement any deficiencies of nutritive value by other additions.

Review any processes needing further attention.

Take this opportunity to test initiative of students in the preparation of any novel vegetable products available at the time.

REVIEW QUESTIONS, LESSON XV.

1. Tell all you can of the weights and measures commonly used for the sale of vegetables.

2. Are there any improvements that you can suggest in market customs?

3. How many varieties of vegetables are attainable in your vicinity from garden or market?

4. Are there any vegetables available which are not used in your household, and why?

5. What means have you employed to make any vegetable more popular on your family table?

5. Mention cases in your experience when vegetables were unpalatable because of careless methods of cooking.

7. What of the relative economy of animal and vegetable foods for your household?

8. Plan a menu for one week including as little meat as you think would be reasonable.

9. Compare the energy required to care for a home vegetable garden with that used in making cake, pies, and puddings.

10. What have you to say regarding the rational use of meats, vegetables, and desserts in planning wholesome meals?

APPENDIX.

REFERENCES.

[The books and pamphlets included in the following list are to be supplied by the State agricultural college for the collateral reading indicated by the specific references given in the text of the bulletin.]

1. Canned Fruits, Preserves, and Jellies, by Maria Parloa. U. S. Dept. Agr., Farmers' Bul. 203.
2. Potatoes and Other Root Crops as Food, by C. F. Langworthy. U. S. Dept. Agr., Farmers' Bul. 295.
3. The Food Value of Corn and Corn Products, by C. D. Woods. U. S. Dept. Agr., Farmers' Bul. 298.
4. Canning Vegetables in the Home, by J. F. Breazeale. U. S. Dept. Agr., Farmers' Bul. 359.
5. Canning Tomatoes at Home and in Club Work, by J. F. Breazeale and O. H. Benson. U. S. Dept. Agr., Farmers' Bul. 521.
6. Series of home-canning instructions. U. S. Dept. Agr., States Relations Service, Office of Extension Work in the South, No. A–81; Office of Extension Work in the North and West, Forms NR–22, NR–23, NR–24, NR–25, NR–26, NR–28, and NR–33.
7. Sugar and Its Value as Food, by Mary Hinman Abel. U. S. Dept. Agr., Farmers' Bul. 535.
8. Honey and Its Uses in the Home, by Caroline L. Hunt and Helen W. Atwater. U. S. Dept. Agr., Farmers' Bul. 653.
9. Chemical Composition of American Food Materials, by W. O. Atwater. U. S. Dept. Agr., Office Expt. Stas. Bul. 28, rev. ed.
10. Boston Cook Book, by Mary J. Lincoln. Boston, 1904.
11. Boston Cooking School Cook Book, by Fannie M. Farmer. Boston, 1914.
12. Principles of Cookery, by Anna Barrows. Chicago, 1912.
13. Bacteria, Yeasts, and Molds in the Home, by H. W. Conn. Boston and Chicago, 1912.
14. Chemistry of the Household, by Margaret E. Dodd. Chicago, 1912.
15. Textbook of Military Hygiene and Sanitation, by F. R. Keefer. Philadelphia and London, 1914.
16. U. S. Dept. Com., Cir. Bur. Standards, 1. ed., No. 55.
17. Dictionary.

LIST OF APPARATUS AND SUPPLIES REQUIRED.

APPARATUS FOR GENERAL USE.

[One each unless otherwise indicated.]

Stove with oven.
Scales.
Twelve glass jars, pints and half pints.
Quart measure.
Can opener.
Potato slicer.
Wire potato masher.
Frying basket.
Two to six kettles or stewpans.
Double boiler, 1 quart.

Double boiler, 2 quarts.
Dover egg beater.
Wire egg beater.
Food chopper.
Vegetable cutters of different types.
Chopping bowl and knife.
Mortar and pestle.
Molds.
Bean pot.
Pudding dishes.
Colander.
Microscope.
Blackboard and chalk.
Fruit funnel.
Dish pan.
Garbage can.
Box of labels.
Roll of paper.
Paper bags.
Twine.
Scissors.
Pins.
Dish towels.
Cheesecloth.
Paper towels.
Alcohol or oil for stove.
Iodin.
Ether.
Nitric acid.
Test tubes.
Filter paper.
Petri dishes.
Thermometer.
Sirup gauge.
Charts.
Thumb tacks.

APPARATUS FOR GROUPS OF FOUR STUDENTS.

[One-fourth as many of each as there are students in the class.]

Measure cups.
Tin or agate pans.
Tin or agate plates to cover pans.
Earthen bowls, 1 quart each.
Strainers to fit measure cup (fine).
Strainers to fit bowl (coarser).
Palette knife.
Saucepans.
Frying pans.
Graters.

APPARATUS FOR INDIVIDUAL USE OF STUDENTS.

[As many of each article as there are students in the class.]

Tablespoon.
Teaspoons.
Knife and fork.
Paring knife.
Notebooks and pencils.
Dishes and spoons for testing.

SUPPLIES.[1]

[Whatever green vegetables are available, as mentioned in each lesson, or any canned vegetables that will aid in the lessons when fresh vegetables are not available. Also the following, as required in the different lessons.]

Dry beans and peas.
Nuts.
Peanut butter.
Potatoes.
Squash seeds.
Olive, cottonseed, or other salad oils.
Vinegar.
Flour.
Sugar.
Butter.
Cream.
Milk.
Eggs.
Rice.
Tapioca.
Cornstarch.
Salt.
Pepper.
Spices, etc.
Tea.
Coffee.
Chocolate.
Vanilla bean.
Cream of tartar.
Soda.
Soap.
Sand soap.

[1] The class and not the college is to furnish these.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 124

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
August 28, 1914.

THE ALFALFA CATERPILLAR.

By V. L. Wildermuth,

Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

The alfalfa butterfly, *Eurymus eurytheme* Boisd. (fig. 1), is one of the most beautiful and interesting of the group of butterflies known as "the yellows"; beautiful because of its golden and orange colors which contrast so conspicuously with the bright green of alfalfa fields, and interesting because of the wide individual variation, extending from the white or albino forms to those that are deep orange. To the alfalfa grower in the Southwest, however, its chief interest lies in the great destructiveness of the larvæ (fig. 2.) One seeing the yellow butterflies darting here and there over a green alfalfa field would hardly suspect that a few weeks hence they would cause the same field to appear as brown, dead stubble. Yet this is what happens nearly every year to a greater or less degree in the Imperial Valley of California and in the Salt River Valley of Arizona.

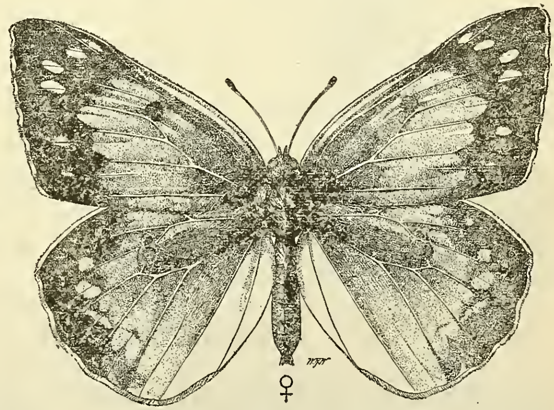


Fig. 1.—The alfalfa caterpillar (*Eurymus eurytheme*); Female in the adult, or butterfly stage. One-half enlarged. (Author's illustration.)

It was not until 1910 that this butterfly was known to entomologists as a serious pest. Previous to that time reports received from

Note.—This bulletin is especially applicable to the Southwest, where the alfalfa caterpillar occurs in destructive numbers in irrigated alfalfa fields.

the Southwest, placing on this species the blame for injury to alfalfa, were doubted. In the spring of that year, however, the writer was detailed to investigate these reports in the Imperial Valley and discover whether the butterflies bore any relation to the destruction of alfalfa by a "green worm." His observations showed that the accusations were well founded, for in July, 1910, the butterflies were seen to lay the eggs that hatched into the green larvæ which ate up the alfalfa crop, causing a loss of thousands of dollars.

At the end of the first year's investigation, experiments and observations had been completed which were thought to be of immediate benefit to the ranchers in controlling the pest, and a preliminary report was made and published as Circular 133 of the Bureau of Entomology. During the three years subsequent to this preliminary

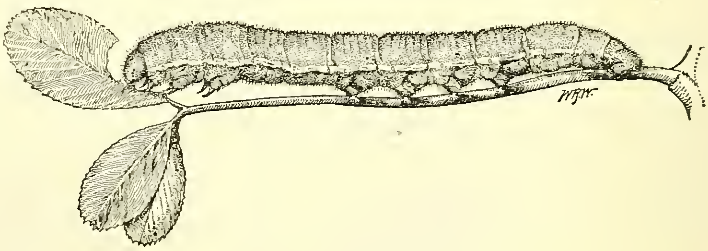


FIG. 2.—The alfalfa caterpillar: Full-grown larva. Enlarged about three diameters. (Original.)

investigation the writer and others have made a more exhaustive study of the species, its habits, and natural or artificial methods of control, and the object of this bulletin is to record these observations as they have been interpreted.

GENERAL DISTRIBUTION.

According to Scudder[1] this insect is well distributed over the United States, but is found in its greatest numbers in the Mississippi Valley (see map, fig. 3) and to the westward. In only a few cases does it appear east of the Allegheny Mountains, but its range extends northward into Canada, even as far as Hudson Bay. In 1911 Mr. R. A. Vickery made observations on the species at Brownsville, Tex., thereby considerably extending the southern range from that included in Scudder's map. In past years the species has been especially abundant throughout the alfalfa-growing sections where irrigation is extensively developed.

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, pp. 1131–1132.

ECONOMIC HISTORY OUTSIDE THE BORDERS OF ARIZONA AND CALIFORNIA.

In regions outside of Arizona and California this species has at various times been suspected, both by agents of the Bureau of Entomology and others, of doing more or less injury to alfalfa. In 1906 a correspondent of the Department of Agriculture reported the caterpillars as infesting lucerne fields in Brigham County, Wyo. In the same year another correspondent, writing from Dell, Oreg., reported the butterflies in "countless thousands playing on the alfalfa blossoms."

In 1909 Mr. C. N. Ainslie found eggs and larvæ on alfalfa at Springer, N. Mex., but not in sufficient numbers to be doing any apparent damage. In July, 1913, on nearly the same ground, the writer found larvæ quite abundant. It is apparent that the reason Mr. Ainslie did not find them in numbers was the lateness of the season. In the same year, 1909, Mr. E. O. G. Kelly, at Wellington, Kans., reported the larvæ as rather numerous on alfalfa plants and feeding freely; and the following year, at the same place, Messrs. T. H. Parks and H. T. Osborn observed the larvæ feeding upon alfalfa, and reared parasites therefrom.

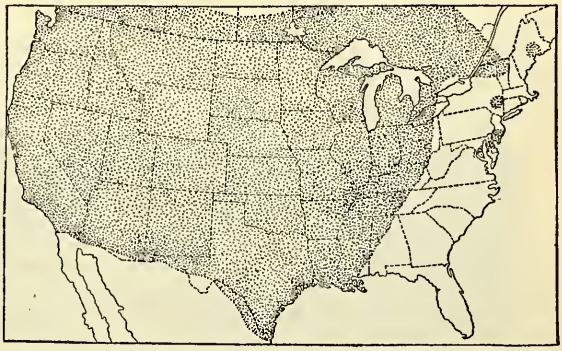


Fig. 3.—Map showing distribution of the alfalfa caterpillar. (Original.)

In 1910 Mr. R. A. Vickery, at Brownsville, Tex., reported the species as being abundant in the alfalfa fields as late as November. He states: "These larvæ are the most numerous and injurious of the several species of caterpillars that are injuring alfalfa now."

In the summer of 1911 the species was found in a number of localities, and reported by different members of the Bureau of Entomology as injuring alfalfa at the following places: Cokeville, Wyo., Idaho Falls and Blackfoot, Idaho (T. H. Parks); Ely, Nev. (C. N. Ainslie). In July, 1911, Prof. S. B. Doten, of the Nevada Agricultural College, received from The H. F. Dangberg Land & Live Stock Co., Minden, Nev., a letter reporting damage from this worm, an extract of which follows: "We are this day mailing you under separate cover a species of worm which at the present time is doing a great deal of damage in our alfalfa fields. They seem to congregate on different parts of the field, and wherever they are the crops are totally destroyed." The same month Mr. Frank C. Jones, of Gardnersville, Nev., reported: "The caterpillar of the yellow butterfly is seriously damaging the alfalfa fields of Carson Valley. It seems to develop most abundantly about the time of the first cutting and feeds on the young shoots, retarding the growth perhaps two weeks."

During the season of 1913 the species was reported by Mr. E. H. Gibson as doing slight damage at Jackson and Nashville, Tenn., and at Greenwood, Miss. Here the butterflies were abroad from early April until late November and, while everywhere present, never seemed to do a great amount of damage. Mr. W. H. Larrimer, also working at Nashville, reported larvæ in considerable numbers.

ECONOMIC HISTORY IN CALIFORNIA AND ARIZONA.

It was Henry Edwards[1] who, in 1877, reported the occurrence at various times of what since has proved to be one of the many color forms of this species. No account can be found in which he treats the species as of economic importance, but he says: "This * * * is an abundant insect in clover and alfalfa fields from July to September," thus intimating that its numbers might be great enough to cause damage. Most of his records were for California.

In 1899 Prof. T. D. A. Cockerell,[2] in studying the insects of the Salt River Valley of Arizona, noted the abundance of these butterflies, but did not stress the probability of damage to alfalfa. He says: "I never saw these butterflies so extraordinarily abundant as they were last October at Phoenix. * * * These caterpillars being very numerous must eat a great many leaves and so reduce the crop, but it is probable that their ravages would not be very noticeable under favorable conditions of moisture and temperature. At all events, it is not practicable to take any measures against them." We have here the first record of the insect as actually destructive to alfalfa.

It would seem that after this, as irrigation in the warm valleys of southern Arizona and southern California began to be more highly developed and alfalfa became a more important crop, the damage became more noticeable each year. In 1907 Mr. Geo. G. Carr, writing to the Department of Agriculture from Hanford, Cal., reports considerable damage to alfalfa. An extract from his letter follows:

---

[1] Edwards, Henry. Pacific Coast Lepidoptera, No. 24. Notes on the genus Colias, with descriptions of some apparently new forms. *In* Proc. Cal. Acad. Sci., v. 7, p. 4. Feb. 5. 1877.

[2] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them: Ariz. Expt. Sta. Bul. 32, p. 286–288, Dec., 1899.

FIG. 1.—ALFALFA PLANTS STRIPPED OF LEAVES BY ALFALFA CATERPILLARS. (ORIGINAL.)

FIG. 2.—HERDING TURKEYS AS A METHOD OF REDUCING THE NUMBERS OF DESTRUCTIVE INSECTS. (ORIGINAL.)

FIG. 3.—FIELD SHOWING IMPROPER CUTTING. THE ALFALFA CATERPILLAR THRIVES IN THE LONG STUBBLE. (ORIGINAL.)

THE ALFALFA CATERPILLAR.

As to the "cutworms," they result from the yellow butterfly, which is often noticed in the alfalfa fields in this valley. The butterfly lays an egg which hatches into the so-called "cutworm" [fig. 2]; the latter goes into the chrysalis state [fig. 6], which eventually results in another butterfly. Seemingly there are several crops of worms which hatch in one season. Whereas we have noticed these worms and butterflies in moderate numbers for years, yet never before have they attained the present great numbers.

In the fall of the year 1909, after a severe outbreak in the Imperial Valley of California during the summer, Mr. J. A. Walton, the owner of a large ranch in that valley, appealed to the Secretary of Agriculture for methods of handling the pest. Mr. W. E. Packard, of the California Experiment Station, reports that the worms are often quite numerous during certain years and cause more or less damage in the Sacramento Valley, and in the irrigated alfalfa regions of south-central California. Several fields that came under the writer's observation in 1910 made an entire failure of the third crop, while many others suffered a 40 to 60 per cent loss in a single hay crop, so that the damage for the year could be conservatively estimated at more than $500,000. (See Pl. I, fig. 1.) During that year (1910) there was also considerable damage in the Salt River Valley of Arizona, but compared with the damage in the Imperial Valley it was slight. In fact, as is explained in later paragraphs, injury was rarely as severe in any other locality as in the Imperial Valley.

During 1911 the bureau was unable to make any studies in the Imperial Valley, but Mr. Packard, who was continually on the ground, told the writer in the fall of that year that little damage was accomplished, the larvæ never being present in great numbers. As noted in a separate paragraph, the destruction of the larvæ in wholesale numbers the summer before by an apparently contagious disease had so checked the species that it was unable to make any headway during that season, and, in fact, as will be seen later, it required two years to readjust itself to conditions.

Throughout the season of 1911, during the writer's absence, Mr. E. G. Smyth, in the Salt River Valley, noted that while there was some damage the species was not numerous enough at any time to necessitate protective measures against it.

In 1912 the writer was again located in the Salt River Valley, and that year, although considerable damage was done by the alfalfa caterpillar, the work of the disease just referred to and of parasites was able to keep the species pretty well within bounds, so that only an occasional field was seriously damaged. The following quotations are from the writer's own field notes:

July 10, 1912: Butterflies are very numerous at this time and in many fields are actively depositing eggs.

July 22: Butterflies are very numerous now, filling the air everywhere. They are even flying around over town in great numbers. Over an alfalfa field north of town they are simply swarming. Millions of them present over the blooming alfalfa where they are feeding. A field just across the road that had been recently cut had the alfalfa covered with eggs. These are adults of the third generation.

Aug. 1: Eurymus larvæ are very abundant now and in a few fields beginning to do considerable damage. On Mr. Aepli's farm 1 mile south of town the caterpillars were exceptionally numerous and damage considerable. However, Mr. Aepli cut his crop of hay and stopped their work by disking. There were 257 larvæ to the square yard counted in this field.

In the Imperial Valley in 1912 the fourth hay crop, about August 1, was nearly one-third lessened by the feeding of the caterpillars, but the damage, although heavier than in the previous year, in no way compared with that of 1910 or 1913. During July, 1913, Mr. Walter Packard wrote to the author, telling him of a great outbreak around El Centro and suggesting that something should be done at once, as practically all of the third crop had been destroyed. As the writer was in northern New Mexico, engaged on other work, Mr. R. N. Wilson was instructed to proceed to Imperial Valley and investigate the outbreak. Upon his arrival there he found the damage to be very heavy, but over for the year, as the species had again been checked by the disease. The conditions are best told in his original field notes, which follow:

El Centro, July 14, 1913: Some of the fields [alfalfa] were visited this morning, and it immediately became obvious that if the bacterial disease is as prevalent in all of the fields in the valley as in those visited this morning it is now too late to try cultural methods, brush dragging, disking, etc., as most of the larvæ are dead. I am told that last week was very warm during the entire week and that the humidity was high. This was probably just the right condition for the disease to spread, and hence the cause of the death of millions of the larvæ. Many of the fields about El Centro have been cut recently and so show nothing now as to *Eurymus* conditions; many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable, but very few healthy larvæ or pupæ can be found at present. Butterflies are numerous everywhere, and in some fields they rise in clouds before the sweep-net. That the damage from larvæ to the present crop is about over is almost certain. * * * A few farmers cut the crop after it had been stripped by larvæ, and the hay was of such poor quality that it was not even gathered. Much of the hay that was gathered was of such poor quality and some of it was so foul with diseased larvæ that it was of little value.

On July 16 Mr. Packard said that he noticed the "worms" in some numbers in the second crop at cutting time, about the last of May. The real outbreak came in July, however, when the third generation of worms began to eat the third crop of alfalfa. He noticed the bacterial disease in the fields about the first week in July, when a large amount of damage had already been done by the larvæ, but the disease did not become widespread or really effective until after the hot, humid weather of last week.

During the season of 1913 in Arizona the outbreak was heavier in the Salt River Valley than it has been for several years—at least the heaviest since the bureau began its investigations four years ago. The report of the outbreak for this year is taken from the notes of Messrs. R. N. and T. Scott Wilson, both of whom were located at Tempe, in the Salt River Valley, this past year. The greatest amount of damage was done to the fourth crop, although the third crop was considerably reduced. The species reached destructive numbers in the eastern part of the valley, especially in the vicinity of Chandler, earlier than in other parts, so that the third crop was considerably damaged and in some fields totally destroyed. On July 22 Mr. T. Scott Wilson reported considerable damage to a field on Mr. Knepper's ranch, and stated that in large spots, perhaps as large as 50 to 100 yards across, the alfalfa was completely defoliated. On July 29 the same observer states: "Mr. Lang's field, 3 miles north of Chandler, shows more damage than any other field I have seen this year. * * * The entire field is damaged, but on spots where the land is rather poor the alfalfa did not grow as rapidly as in other places, and after irrigation it came up quickly and at this tender stage the worms attacked it, completely stripping it of leaves." Mr. R. N. Wilson had previous to this, on July 25, made a similar but more general note in which he says: "The butterflies are now very numerous, and the larvæ have stripped large patches in several fields. * * * The most serious damage began in the central part of the valley about a week or two weeks later than that described in the foregoing notes and was much more severe. On July 30 Mr. T. Scott Wilson reported very serious damage 6½ miles south of Tempe. This field had about 25 to 50 per cent of the alfalfa destroyed." Then, on August 7: "In Mr. Harmon's field, 1½ miles south of Tempe, there are a great many pupæ and larvæ. The alfalfa is almost completely bare of leaves." And on the same date he noted that Mr. Olsons's alfalfa in an 80-acre field, 1 mile south of town, was almost destroyed. Of course he meant the crop then present. On August 14 he mentions seven different ranches that had almost the entire fourth crop destroyed by Eurymus. A day later Mr. Wilson visited several fields south of Phoenix and found the fourth crop here completely defoliated. It is thus seen that the damage ran into thousands of dollars just to this one crop alone. One can hardly anticipate exactly what would have been the resulting damage had these caterpillars gone on unmolested and produced another generation of butterflies. Fortunately, however, the disease already mentioned appeared at this time and prevented a large percentage, possibly 90 to 95 per cent, from ever reaching the pupal stage.

We thus have a history of the several outbreaks during the last few years in these two larger valleys of southern Arizona and California.

There has also been damage in a smaller way, but just as important to the individual farmer, in other valleys of these States. In the Yuma Valley, near the town by that name, both the writer and Mr. R. N. Wilson have noted the occurrence of the caterpillars in destructive numbers, and in the Buckeye Valley they have made similar observations. Mr. Long reported serious damage in the Buckeye Valley, and in 1913, on the Wessex ranch 2 miles west of the town of Buckeye, Eurymus larvæ entirely stripped a 20-acre field, reducing the alfalfa to mere stubble. In the Gila River Valley, between Thatcher and Safford, Ariz., Mr. R. E. L. Wixon, a deputy State nursery inspector, reports occasional devastation and often entire fields destroyed.

In California Mr. T. D. Urbahns has at various times during 1913 reported outbreaks and very serious damage at several towns in the San Joaquin Valley. We quote the following from his notes: July 9, Corcoran: "Considerable injury where crops were left in field too long." September 13, Tulare: "Farmers generally reported heavy loss to their alfalfa crops from the 'alfalfa worm,' and on some fields the alfalfa was completely destroyed in July, then resuming its growth after the pests had subsided from natural control." September 14, Fresno: "While out a short distance north of town I observed fields yellow with butterflies. The leaves were nearly all badly eaten by the larvæ, of which many were still present." September 15, Dos Palos: "Larvæ present in moderate numbers, but causing much injury." September 16, Merced: "A 10-acre field of alfalfa south of town literally covered by larvæ and adults. Stems had been stripped of their leaves." September 17, Modesto: "West of town farmers consider the alfalfa worm a serious pest to their midsummer crops in July and August. Adults and larvæ were still present in large numbers."

At Indio, in the Coachella Valley, Mr. Bruce Drummond, of the Bureau of Plant Industry, has informed the author that considerable damage is done by these caterpillars and that at times it becomes quite severe.

It is thus seen that what was once considered merely a thing of beauty has now become one of the worst enemies to alfalfa culture, causing between $500,000 and $1,000,000 of damage annually to this crop in these southwestern sections alone. That the energetic and up-to-date farmer can greatly reduce and at times totally eliminate this damage is to be shown in the following pages.

DESCRIPTION.

All stages of *Eurymus eurytheme* have been fully described by Edwards and Scudder, and since this paper is purely economic in purpose, no detailed description will be given, but instead a brief outline, such as would enable the casual observer to recognize the different forms.

THE ADULT.

The typical wing color of the adults is an orange-yellow with a black outer border above, and a lighter yellow color on the underside with the black outer border wanting. There is a black discal spot in each of the four wings and a double discal spot of orange in each hind wing. The lower surface of the wing is the one noticed when the butterfly is at rest. The male (fig. 4.) may be distinguished from the female (fig. 1) by the fact that the outer border of the wings is solid black in the former, but broken by a line of yellow dots in the latter. A white or albino female form is frequently found with other color markings, the same as in the yellow form. The wing expanse is about 2 inches.

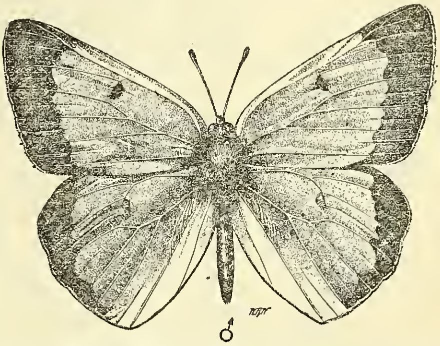


FIG. 4.—The alfalfa caterpillar: Male in the adult, or butterfly, stage. One-half enlarged. (Author's illustration.)

EGG.

The egg (fig. 5) is small, only 0.06 of an inch long, with from 18 to 20 slightly raised longitudinal ridges or ribs broken by cross lines. It is elongated, white when laid, but turning reddish brown after the second day, and is deposited upright, with the basal end attached usually to the upper surface of the leaf.

FIG. 5.—The alfalfa caterpillar: Egg, greatly enlarged. (Redrawn from Scudder.)

LARVA.

The newly hatched larva is a tiny, dark brown, cylindrical object which soon after feeding takes on a green color. Growth is rapid and the larva (fig. 2), after having shed its skin or molted four times, is a little more than an inch in length and is of a dark grass-green color, with a white stripe on each side of the body, through which runs a crimson line. Beneath this stripe on each segment or division of the body is a black spot. There is often an intermediate, narrower, broken, and less distinct white line just above each of the lateral lines. This may be wanting. In some specimens a black or dark green median dorsal line is also present.

PUPA.

The pupa (fig. 6) is yellowish green, with a conspicuous row of black dots just within the margin of each wing pad and three black dots on each side of the abdomen. It is free, having no cocoon, and is found, head up, attached closely by the posterior end to an alfalfa stalk or other support, with the anterior end hanging loosely in a threadlike swing which is joined to the same support.

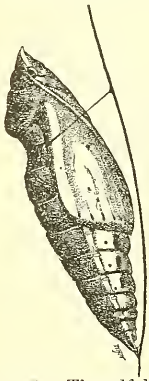


FIG. 6.—The alfalfa caterpillar: Chrysalis, or pupa. (Author's illustration.)

LIFE HISTORY AND HABITS.

The complete life cycle for this insect averages about 38 days for all generations, the minimum length being about 26 days for the third brood and the maximum 64 days for the first brood. (See Table III.) The time occupied by the different stages is as follows: Egg, 6 days; larva, 24 days; pupa, 7 days, and a resting and feeding period of 1 day following emergence of adults during which copulation takes place. Males usually complete the developmental period several days sooner than the females, and thus pass a longer period between emergence and copulation. Mr. W. H. Larrimer, working at Nashville, Tenn., made some interesting records on the life-cycle periods, as shown in Table I. It will be noted that these records were all made during the months of June and July and correspond with the tables for Arizona showing records made during weather of medium temperature.

TABLE I.—*Rearing records for the alfalfa caterpillar, Nashville, Tenn., 1913.*

Egg laid.	Egg hatched.	Egg stage.	Larva pupated.	Larval stage.	Adult emerged.	Pupal stage.	Food plant.
		Days.		*Days.*		*Days.*	
June 4[1]	June 7	3	June 26	19	July 2	16	Medicago sativa.
4[1]	7	3	July 1	24	8	7	Do.
4	7	3	3	26	10	7	Do.
27	30	3	16	16	23	7	Do.
27	30	3	16	16	23	7	Do.
July 2[1]	July 5	3	22	17	29	7	Do.
2[1]	5	3	23	18	29	6	Do.
2[1]	5	3	28	23	Aug. 1	5	Do.
2[1]	5	3	30	25	6	7	Do.
16[1]	19	3	Aug. 2	14	8	6	Trifolium hybridum.
27	30	3	13	14	20	7	Trifolium repens.
27	30	3	14	15	21	6	Do.
27	30	3	11	12	17	6	Vicia sativa.
27	30	3	12	13	17	5	Do.
27	30	3	11	12	17	6	Do.
27	30	3	15	16	21	6	Pisum sativum.
27	30	3	15	21	21	6	Glycine hispida.
1	4	3	July 28	24	2	6	Trifolium pratense.

[1] Reared under same conditions of light, moisture, temperature, and food supply.

	Days.
Average length of egg stage	3
Average length of larval stage	18
Average length of pupal stage	6½

EGG STAGE.

The egg stage varies under ordinary temperatures from 2 to 15 days, the normal period being about 6 days. The length of the egg stage as observed for the six generations during the season of 1912 is as follows: First generation, 14½ days; second generation, 4 days; third generation, 3 days; fourth generation, 3½ days; fifth generation, 3½ days; sixth generation, 5 days. In the summer of 1913 Mr. T. Scott Wilson had eggs under observation which hatched in two days during the month of August, but with an average mean temperature of 87° F., and this same season Mr. E. H. Gibson, at Nashville, Tenn., observed eggs to hatch in an equally short time, with an average mean temperature of 76° F. Mr. Gibson gathered three eggs on June 5 and noted that the time of oviposition was 3 p. m. He placed these in a box, and at 3 p. m., June 7, the larvæ were found emerging from eggshells. Thus the remarkably short period of 48 hours elapsed from oviposition to hatching.

The eggs are deposited upright, singly, on the upper surface of fresh, green alfalfa leaves. When first deposited they are white in color, but change in a few hours to reddish brown. Just before hatching the upper end becomes light colored or nearly transparent, and the caterpillar gnaws its way out.

LARVAL, OR CATERPILLAR, STAGE.

Upon hatching, the larva makes its first meal on the eggshells, often consuming the whole shell. It then feeds upon the leaf, at first gnawing out very small, tiny spots; but rapidly its appetite increases, and it is soon consuming the entire leaf, veins and all. Observations made by the writer and by Mr. Watts, a former agent of this bureau, show that one larva consumes about 25 to 30 leaves during its lifetime. Its growth increases just as fast as its appetite, and often within 12 days the larva is full grown, having cast its skin, or molted, four times and having passed through five instars, or periods between molts, and increased from less than one-tenth inch to nearly 1½ inches in length. The duration of these various instars (see Table II) is influenced greatly by temperature, and during cold or cool weather they are protracted considerably, so that often the complete larval period will cover a month or even more, the general average period for all temperatures being about 24 days.

The larva in feeding stretches itself along an alfalfa stalk and is often rather hard to find, the green color of its body proving to be exactly the same shade as the alfalfa upon which it is feeding.

TABLE II.—*Duration of larval instars and pupal stages of the alfalfa caterpillar, Tempe, Ariz.*

[The records for 1912 are by the author; those for 1913, by Mr. T. Scott Wilson. Records all made in vials under unnatural conditions.]

Cage No.	Larva hatched.	First molt.	Length of first instar.	Second molt.	Length of second instar.	Third molt.	Length of third instar.	Fourth molt.	Length of fourth instar.	Pupation.	Length of fifth instar.	Length of larval stage.	Adult emerged.	Length of pupal stage.	Sex.	Average mean temperature.
	1912.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*		*Days.*		°*F.*
1	Apr. 7	Apr. 14	7	Apr. 19	5	Apr. 22	3	....	....	May 3	11	26	May 13	10	Male	63
2	May 31	June 3	3	June 5	2	June 7	2	June 10	3	(1)	....	....	....	....	....	82
3	31	3	3	5	2	8	3	12	4	June 17	5	17	June 25	8	Female	83
4	June 28	30	2	July 5	2	July 5	3	July 8	3	July 11	3	13	July 16	5	do	81
5	28	30	2	2	2	5	3	7	2	10	3	12	15	5	Male	80
6	28	30	2	2	2	5	3	8	3	12	4	14	17	5	Female	81
7	July 25	July 28	3	Aug. 3	6	Aug. 15	12	Aug. 21	6	(1)	....	....	....	....	....	84
8	25	28	3	July 31	3	3	3	5	2	(1)	....	....	....	....	....	85
9	25	28	3	31	3	2	2	5	3	(1)	....	....	....	....	....	85
	1913.															
7	June 10	June 11	4	June 18	4	June 20	2	....	....	June 27	[2] 7	17	....	....	....	83
12	10	14	4	18	4	20	2	June 23	3	25	2	15	June 29	4	Male	83
13	10	14	4	(3)	(3)	(3)	(3)	(3)	(3)	25	....	15	30	5	do	83
14	11	14	3	(3)	(3)	(3)	(3)	(3)	(3)	25	....	14	July 1	6	do	83
15	11	14	3	(3)	(3)	(3)	(3)	(3)	(3)	25	....	14	(1)	....	....	83
17	11	14	3	June 18	4	June 20	2	June 21	1	25	4	14	June 30	5	Male	83
18	11	15	4	18	3	20	2	22	2	(1)	....	....	....	....	....	83
26	12	17	5	19	2	(3)	(3)	(3)	(3)	June 28	....	16	(1)	....	....	83
32	12	16	4	18	2	(3)	(3)	(3)	(3)	25	....	13	July 2	7	Male	83
34	12	15	3	18	3	June 20	2	June 23	3	27	4	15	1	(1)	....	83

[1] Died.

[2] Combined length, fourth and fifth instars.

[3] No record.

PUPAL, OR CHRYSALIS, STAGE.

As has been stated before, the pupæ are found hanging, head up, attached to alfalfa or other stems, and as their color blends with their environment they are often hard to see and will be overlooked unless searched for. Often, too, instead of pupating on a bare stem the larvæ will crawl to a leafy stem and pupate there, thus protecting themselves still further from their enemies and from the rays of the sun. The average length of the pupal period for ordinary field temperatures is about 7 to 10 days, but varies considerably with the temperature. Records made by the writer at Tempe, Ariz., from March to September, 1912, showed a variation of from 5 to 10 days, and records made at the same place in 1913 showed a variation of from 5 to 7 days, while Mr. W. H. Larrimer, at Nashville, Tenn., secured records during the summer of 1913, from July 2 to August 21, in which the pupal stage varied from 5 to 7 days, averaging for 18 specimens 6⅓ days. There is no doubt that the pupal period may be lengthened to 12 or 15 days, or even more, if the temperature is low enough.

ADULT, OR BUTTERFLY, STAGE.

The process of emergence from the pupa is one of short duration and usually occurs early on a bright morning. The butterfly crawls up a stalk, soon spreads and dries its wings, and is off looking for bloom upon which to feed. Copulation often takes place within a day or sometimes on the same day, and the female begins ovipositing on the day following. A large number of eggs is usually laid by one female. In the Southwest the number per individual is greater during spring and fall than during the extreme hot weather. At Tempe never more than 200 eggs were recorded for one female, the number often being as low as 50. At Tempe, also, the total number was often deposited in a single day, while specimens sent to New Hampshire deposited as many as 500 during a laying period of 11 days. This shows the relation of temperature to egg production.

The sending of gravid female moths from Tempe, Ariz., to Prof. John H. Gerould, at Hanover, N. H., a railroad trip of several days, was a matter of interest and shows well the hardiness of the butterflies. The butterflies were placed inside a tin box securely lined with moist blotting paper, and the box was then wrapped carefully and mailed. Vigorous specimens were secured and only a few to a box. While not every attempt was successful, a great many were so. Through the kindness of Prof. Gerould I quote from a letter written October 7, 1913:

The third female from Arizona produced from one laying of eggs 214 males and 206 orange-yellow females. She was mailed at Tempe on June 6 and received at Hanover in strong active condition on June 10. She began to lay on June 11 and continued until June 22. Her 420 adult offspring represent only a part of her caterpillar progeny, for, besides the loss through disease and accident, 15 pupæ succumbed to excessive cold and other unfavorable conditions in a refrigerator while undergoing an experiment to determine the effect of cold upon color. Probably 500 eggs were laid.

The proportion of males to females in Arizona is about 2 to 1, but Gerould, in New Hampshire, finds them about equal. In the field at Tempe one will always be impressed with the superabundance of males. This difference in the proportion of the sexes as between Arizona and New Hampshire is probably due to the fact that in Arizona the intestinal disease kills a large number of the larvæ; and since males develop a few days sooner than females, it is likely that the majority of the larvæ killed would have developed into females, while those escaping the disease become males. In New Hampshire Prof. Gerould is often able to rear over 90 per cent from egg to adult in confinement, while at Tempe it is rare that 25 per cent of the eggs are reared. In a blooming alfalfa field the percentage of males to females is still higher, owing to the fact that females after feeding and mating leave this older alfalfa to seek new growth. In searching out this tender growth for egg deposition it seems as if they knew that if their eggs were laid on the older alfalfa it might be cut before the larvæ could mature. One can tell at a glance an ovipositing female. She has a hesitating flight and at intervals will drop down for a moment on an alfalfa leaf and, depositing an egg, will flutter on, soon repeating the operation and depositing as many as four or five eggs per minute.

Among the yellow butterflies in a field one notices many white or albino forms. These are of the same species as the yellow ones and, according to Prof. Gerould,[1] are merely color phases, as he has shown to be the case in *Eurymus philodice* (Godart).

FEEDING HABITS OF THE BUTTERFLIES.

The butterflies of *Eurymus eurytheme* feed upon nectar from the blossoms of a great many plants. Over a blooming alfalfa field one can often see them by the millions, visiting the blossoms and extracting the nectar therefrom. This habit has occasioned many remarks, farmers quite often being under the impression that these butterflies were producing some direct results upon the growth of the alfalfa crop. The bee-keeping farmer usually insists that they are robbing his bees by taking nectar that belongs to them. In Circular 133 of the Bureau of Entomology, published in 1910, the writer ventured the remark, since he had witnessed the tripping of the pollen trigger

[1] Gerould, J. H. The inheritance of polymorphism and sex in *Colias philodice*. Amer. Nat., v. 45, p. 257–283, May, 1911.

of alfalfa bloom by this butterfly, that possibly its feeding habits might be of some benefit in assisting pollination. As this statement occasioned some comment, further observations were made upon the butterflies during three consecutive years, but not another instance of tripping was noted. It seems, therefore, that in the cases observed, the trippings were effected accidentally by the feet. As these instances are probably exceptional it is not likely that the butterflies exert any material influence on seed production. However, the relation of bees and alfalfa to butterflies and alfalfa seems to be a complex one. Hermann Müller,[1] in 1873, came to the conclusion that butterflies probably effect explosion and cross-fertilization, while C. V. Piper,[2] in 1909, in his Report of the Committee on Breeding Forage Crops, gives the records from a considerable number of well-known plant breeders, no two of whom seem to agree as to the exact relation of butterflies to alfalfa pollination, but the majority of whom think that the butterflies exert no influence.[3] Whether the butterflies rob honeybees of their just food is a question. Prof. Cockerell[4] states, in 1899, that * * * "butterflies, sucking the nectar, but making no honey, must interfere with the success of the bees, especially when they become very numerous." As mentioned above, this robbing of the bees by butterflies is a common belief among beekeepers and has been suggested to the author many times.

NUMBER OF GENERATIONS.

Mr. W. H. Edwards[5] reports two broods of this species in the mountains of northern Colorado, the adults of which appear in June and again in the latter part of July and in August. In Nebraska and Illinois, according to the same author, three broods are recorded, while in the lowlands of California he reports the insect as being triple or quadruple brooded. Mr. J. Boll,[6] in 1880, reports four broods in Texas, and this, too, during a short season, for he

---

[1] Müller, Hermann. Die Befruchtung der Blumen durch Insekten, Leipzig, 1873, p. 228–229.

[2] Piper, C. V. Report of the committee for breeding forage crops. Alfalfa and its improvement by breeding. Amer. Breeders' Assoc., v. 5, 1909, p. 94–115.

[3] Since this manuscript was submitted for publication, Bulletin No. 75 of this department, dated Apr. 8, 1914, treating of Alfalfa Seed Production; Pollination Studies, by Prof. C. V. Piper and his assistants, has been published.

In this document it is shown that tripping of alfalfa flowers may be automatic as well as effected by insects or other external agents. The authors state that this automatic tripping takes place more frequently in hot sunshine, although humidity is doubtless a factor. Also the statement is made that this automatic tripping, with consequent self-pollination, probably results in the setting of as many pods as does tripping by insect visitors, at least in the West.—F. M. W.

[4] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them. Ariz. Agr. Expt. Sta. Bul. 32, p. 273–295, Dec., 1899.

[5] Edwards, W. H. The Butterflies of North America, second series, Boston, 1884, Colias IV.

[6] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord-Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

states that the species æstivates during the summer months from June to November.

In the year 1910, in the Imperial Valley of California, there were four distinct generations up to July 15. The fourth generation, however, was almost entirely exterminated by the disease before mentioned, and, following this, later generations became so largely confused that it was impossible to separate them, since, unfortunately, no series of generation cages were then in use for this purpose. The first generation in 1913 covered the period from March 15 to April 30; the second generation from May 1 to May 28; the third generation from May 28 to June 20; and the fourth generation from June 20 to July 15. It seems quite probable that there were at least three generations during the rest of the season. As shown in Table III, during the year 1912, at Tempe, Ariz., there were six generations, adults of hibernating forms appearing in March and adults of the fifth generation disappearing in October, while a few adults of the sixth generation appeared during warm periods of the winter months.

TABLE III.—*Generations of the alfalfa caterpillar, Tempe, Ariz., 1912.*[1]

Generation.	Eggs laid.		Eggs hatched.		Length of egg stage.	Larva pupated.	Length of larval stage.	Adults issued.[2]	Length of pupal stage.	Total developmental period.	Number issued.	Average mean temperature.
	Date.	Number.	Date.	Number.								
	1912.				*Days.*		*Days.*		*Days.*	*Days.*		°*F.*
1st	Mar. 24	Many.	Apr. 7 8	12 31	14 15	May 11	34	May 19	8	56	17 females. 30 males.	63.5
2d	May 27	36	May 31	36	4	June 18	18	June 24	6	28	2 females. 1 male.	83.75
3d	June 25	Many.	June 28	Many.	3	July 13	15	July 19	5	23	3 females. 2 males.	86.5
4th	July 22	Many.	July 25	Many.	3½	Aug. 12	18	Aug. 19	7	28½	1 female. 1 male.	84.5
5th	Aug. 23	6	Aug. 26	6	3½	Sept. 9	16	Sept. 19	10	29½	3 females. 3 males.	80.0
6th	Sept. 28	Many.	Oct. 3	Many.	5	Nov. 18	45	These hibernated.				64.0

[1] The first half of this table does not give duration of time elapsing between emergence and oviposition.
[2] Date here is the day the last ones issued.

PERIODS AND DURATION OF GENERATIONS.

	Days.
First generation, Mar. 24 to May 27	64
Second generation, May 27 to June 25	29
Third generation, June 25 to July 22	26
Fourth generation, July 22 to Aug. 23	33
Fifth generation, Aug. 23 to Sept. 28	38½
Sixth generation, Sept. 28 to pupæ in hibernation.	

Mr. T. Scott Wilson, working at Tempe, secured records during the year 1913 of three distinct generations from late March to the latter part of July, his observations thus corresponding fairly well with those of the writer during the previous year. The dates of the three generations were as follows: First brood, March 27 to May 20; second brood, May 20 to June 23; and third brood, June 23 to

July 23. Following this the intestinal disease attacked the larvæ so generally that Mr. Wilson found it impossible to continue generation records. Nevertheless, he states in his field notes that a fourth generation was out by the latter part of August. We thus see that there are in the colder sections of the country two generations annually and in the extreme warmer sections at least six and possibly more generations each year.

FOOD PLANTS.

Alfalfa seems to be the favorite food plant, but there are quite a number of others. The two buffalo clovers, *Trifolium reflexum* and *T. stoloniferum*, were probably the original native food plants. For some years the species was thought not to live upon red clover (*T. pratense*), but Mr. E. H. Gibson, at Greenwood, Miss., and Mr. W. H. Larrimer, at Nashville, Tenn., proved conclusively that it does attack red clover. They collected both eggs and larvæ from red clover and reared them to adults. During the summer of 1913 the writer collected the larvæ feeding upon few-flowered Psoralea (*Psoralea tenuiflora*) at Koehler, N. Mex., and Mr. Larrimer, at Nashville, made some interesting experiments, besides those on red clover. Using larvæ that hatched indoors, he reared them from the following plants that had not already been reported as food plants: Alsike clover (*T. hybridum*), soja bean (*Glycine hispida*), Canadian field peas (*Pisum sativum*), and hairy vetch (*Vicia sativa*). Repeated attempts to rear them on cowpeas (*Vigna sinensis*) resulted in failure. He says: "On hairy vetch they seemed to thrive exceedingly well and completed their life history in a shorter period than on any other food plant." In July, 1910, the writer found larvæ feeding on sweet clover (*Melilotus alba*), which, strangely enough, they seemed to prefer to a patch of alfalfa growing close by. Eggs were observed to be very numerous upon the leaves of the sweet clover at the same time. Besides alfalfa and the buffalo clovers, Scudder[1] has recorded Hosackia, ground plum (*Astragalus caryacarpus*), and *A. crotalariæ* as food plants. The adults visit blooming plants for nectar, and they have been reported, doubtless erroneously, as feeding upon many of these. The butterfly is known to oviposit on toothed medicago or bur clover (*Medicago hispida*). Mr. E. H. Gibson, at Greenwood, Miss., reported females ovipositing on coffee weed (*Sesban macrocarpa*), which they curiously preferred to red clover growing near by.

---

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

HIBERNATION.

According to earlier records by Edwards and those a little later by Scudder, which treat of the species in its northern rather than in its southern range, the alfalfa caterpillar hibernates as larvæ and adults, whereas G. H. French,[1] in his revised edition of Butterflies of Eastern United States, reports the species as hibernating as chrysalids. The writer has observed the species hibernating in all three forms, if it could really at all times be termed hibernation. Hibernating chrysalids were found upon weed and alfalfa stems by the writer at both Tempe, Ariz., and El Centro, Cal., and at Wellington, Kans., Mr. Kelly reported the finding of hibernating pupæ beneath fence rails. Just a few larvæ have been collected by sweeping at various times during the winter season at Tempe. During the last week in January, 1912, a single larva was taken, while in January, 1913, Mr. R. N. Wilson took a third-instar larva less than two weeks after a very severe cold spell, i. e., severe for the Salt River Valley, a temperature of 13° F. having been recorded on two successive nights. On warm days adults have been observed in flight several times during the winters when the species was under observation. In 1910 adults were taken at Tempe early in December, and Mr. W. E. Packard took them during the third week in December at El Centro, Cal. In the winter of 1911–12 adults were seen on the 20th of December and again in the middle of January. Larvæ have been collected in January and, pupating within a few weeks, have issued early in March. Pupæ collected in December have issued in February, but adults have never been noted to deposit eggs during the month of January. It is thus seen that at times hibernation amounts to nothing but a prolongation of one of the three stages, the usual activity for each respective stage being resumed on warm days that occur during the hibernation period.

According to Boll[2] the species æstivates in Texas as larvæ during the dry period in summer when the food supply has become exhausted. The writer has never witnessed the æstivation of this species in the Southwest. In fact, it has always occurred in most abundance during the hotest months of the year, notably July and August. Other bureau records likewise show no report of æstivation. It seems safe to assume that the change in habit from that early reported by Boll in Texas is due to recent irrigation of tracts of land well distributed over the arid regions of the Southwest. Originally the species had to æstivate during summer when clovers

---

[1] French, G. H. The Butterflies of the Eastern United States. New and rev. ed., Philadelphia, 1900, p. 130.

[2] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

were dried up, but now, in the thrifty-growing alfalfa fields of this once arid country, it finds a place to continue its activity throughout the summer, and, as has been mentioned before, it is this very change that has enabled the species to become the pest that it is to-day.

NATURAL CHECKS TO THE SPECIES.

Were it not for the fact that this species is preyed upon by a great many natural enemies it would indeed prove a much more serious pest than it is at the present time. Parasites and predaceous insects, fungous and bacterial diseases, birds, toads, and even domestic fowls, all play a large part toward keeping the species well within bounds during certain seasons of the year.

In 1889 Scudder[1] said: "Strange to say, not a single parasite has been reported to attack this common insect." However, the author and others, during the past three years, have reared as many as nine parasites from the various stages of this butterfly, and some of these at times are quite numerous. An example of the extent of parasitism may be gleaned from the following record of a collection of 154 pupæ made at Tempe, Ariz., on August 26, 1912:

	No. of pupæ.
Infested by chalcid parasites	82
Partially eaten by *Heliothis obsoleta*, etc	28
Rotten from intestinal disease	37
Infested by tachinid parasites	6
Alive and healthy	1
Total	154

This, of course, was an exceptional collection, but often collections were made from which as few as 5 per cent of the pupæ were reared to adults. The percentage of parasitism usually reaches the maximum during the month of August, so that rarely is much damage done by the caterpillar after that time.

PARASITES OF THE EGGS.

Only one egg parasite of *Eurymus eurytheme* was found. This is the very common *Trichogramma minutum* Riley (fig. 7), which is known as an egg parasite of a great many species of insects. In its relation to eggs of this species it was first found by Mr. Harry Newton, of the Bureau of Entomology, who was working at Tempe, Ariz., during the summer of 1913. On July 26 he found three eggs which were very dark in color, and two days later three of the tiny parasites issued from one of these. Two days previous to Mr. Newton's collection Mr. T. Scott Wilson collected 100 eggs. From three

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

of these parasites issued several days later, or 3 per cent. On July 28 Mr. Newton, encouraged by his first efforts, collected 31 eggs that appeared to be parasitized. Twenty-six of these produced, in the course of five days, 76 parasites, or nearly 3 to each egg. Seventeen freshly laid eggs were exposed to female parasites by Mr. Newton on August 1, and on August 8 eight of these produced 24 adult parasites, showing the length of the combined egg, larval, and pupal stages to have been seven days. Nine failed to be parasitized, and one produced 5 parasites in six days. On August 16 Mr. Wilson collected 19 eggs, 60 per cent of which were parasitized.

FIG. 7.—*Trichogramma minutum*, a parasite of the eggs of the alfalfa butterfly, in act of oviposition in an egg of the brown-tail moth (*Euproctis chrysorrhœa*). Greatly enlarged. (From Howard and Fiske.)

It is thus seen that this tiny parasite is of considerable benefit in reducing the numbers of the alfalfa caterpillar. From the records it seems that the increase of the parasites from July to August was quite rapid. The fact that the life cycle is of so short duration is partially responsible for this, as it doubtless gives a chance for two broods of parasites upon the eggs of one generation of Eurymus.

HYMENOPTEROUS PARASITES OF THE CATERPILLARS AND CHRYSALIDS.

Four species of hymenopterous parasites of the caterpillars and chrysalids were found. Specimens of a Limnerium were reared

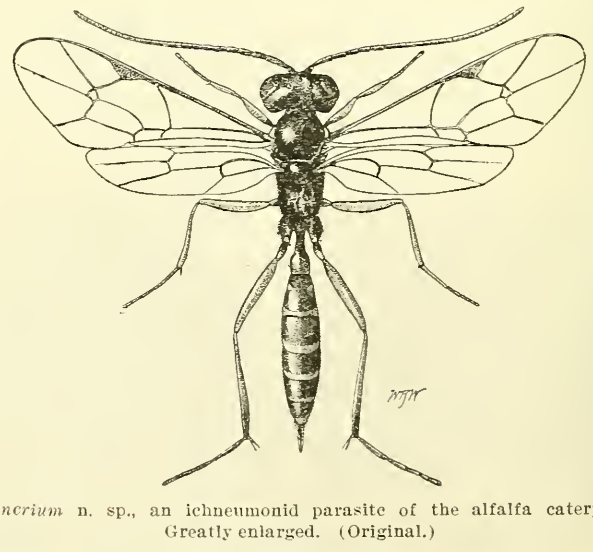


FIG. 8.—*Limnerium* n. sp., an ichneumonid parasite of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

by the author at El Centro, Cal., in 1910, and what is supposedly the same species was reared in considerable numbers by Mr. L. P.

Rockwood at Salt Lake City in the summer of 1913 and has since been determined by Mr. A. B. Gahan, of this bureau, as *Limnerium* n. sp. (fig. 8). Mr. Rockwood found these parasites of material benefit in the suppression of outbreaks in Utah and always reared them from young and only partially grown larvæ. At Salt Lake City, during the summer of 1913, he also reared a goodly number of a small hymenopteron, *Apanteles* (*Protopanteles*) *flavicombe* Riley. This species is gregarious, but was not found to be sufficiently numerous to exert any marked effect upon the abundance of Eurymus. The common *Chalcis ovata* Say (fig. 9) was first reared from this species by the writer in 1910, at El Centro. Only one specimen was secured, but in 1912 the author reared many adults, and in 1913 the Messrs. Wilson reared adults from pupæ collected in both Arizona and California.

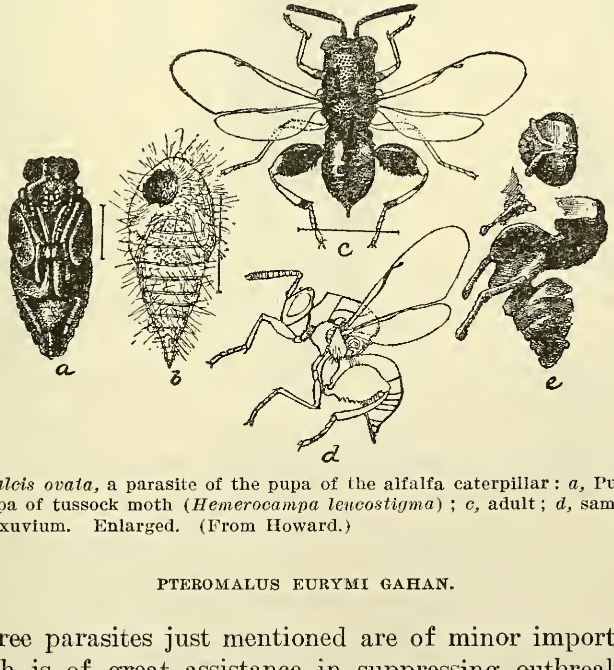


FIG. 9.—*Chalcis ovata*, a parasite of the pupa of the alfalfa caterpillar: *a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

PTEROMALUS EURYMI GAHAN.

The three parasites just mentioned are of minor importance, but the fourth is of great assistance in suppressing outbreaks of the alfalfa caterpillar. It is a new species, recently described by Mr. Gahan [1] as *Pteromalus eurymi* (fig. 10). Mr. H. T. Osborn, at Wellington, Kans., in September, 1910, reared 40 specimens of this species from a pupa of Eurymus, but the specimens were put into alcohol and not determined until November, 1913. When, therefore, Mr. R. N. Wilson secured a parasitized pupa in December, 1911, and

[1] Gahan, A. B. New Hymenoptera from North America. Proc. U. S. Nat. Mus., v. 46, p. 431–443, 1913. "*Pteromalus eurymi*, new species," p. 435–436.

reared this parasite, it was believed to be the first rearing record. During the following summer the parasites were so numerous that it was hard to understand why they had not been discovered before. Collections of pupæ of Eurymus were made by the writer in August,

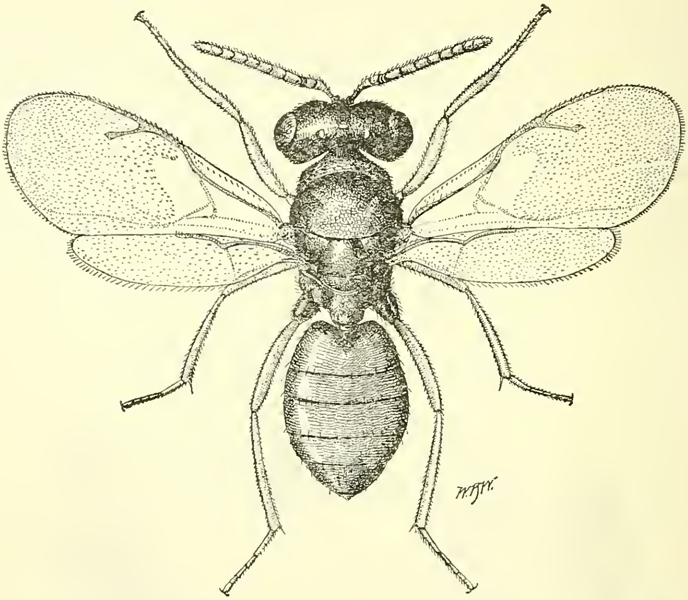


FIG. 10.—*Pteromalus eurymi*, a parasite of pupæ of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

1912, and showed that 49 per cent were parasitized by this species. The record follows:

TABLE IV.—*Parasitism of pupæ of the alfalfa caterpillar by Pteromalus eurymi.*

Date.	Pupæ collected.	Infested with Pteromalus.	Per cent infested.
1912.			
Aug. 5	65	26	40
Aug. 14	39	17	43+
Aug. 19	11	7	63+
Aug. 26	154	82	53
Total and average	269	132	49

This insect thus seems to be exerting a larger influence than any other parasite toward the control of the alfalfa caterpillar.

In 1913 Mr. T. Scott Wilson did not find it nearly so numerous in the Salt River Valley as was the case the year before. Just why this was so, it is hard to say. The extremely cold weather during the preceding winter may have killed the hibernating Pteromalus larvæ (fig. 11). In the same year Mr. R. N. Wilson found the species quite numerous in the Imperial Valley of California. As many as 20 per cent of the Eurymus pupæ were parasitized by it.

This parasite seems to be distributed over a considerable area, for, besides being present in Arizona and California and, as stated, at Wellington, Kans., it has been reared during the season of 1913 and found to be quite abundant at Salt Lake City, Utah, by Mr. Rockwood, and at Nashville, Tenn., specimens were raised by Mr. Larrimer from a single pupa of Eurymus.

It seems almost certain that this parasite winters as a larva within the pupal shell of the host. The first lot collected in a pupa of the alfalfa caterpillar in December were discovered as larvæ in January and soon thereafter turned to pupæ (fig. 12), issuing as adults in March. The eggs are laid in pupæ of Eurymus, from 40 to 114 parasites developing in one pupa. About 80 to 90 per cent of these are females and the rest males, and the adults issue from one or more tiny holes in the pupa of their host. (See fig. 13.)

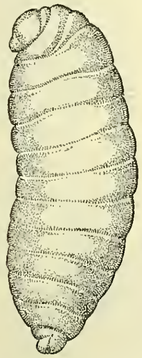


FIG. 11.—*Pteromalus eurymi:* Larva. Greatly enlarged. (Original.)

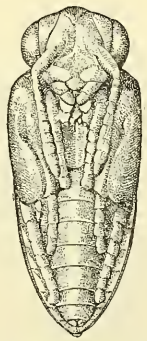


FIG. 12.—*Pteromalus eurymi:* Pupa. Greatly enlarged. (Original.)

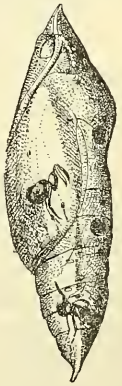


FIG. 13.—*Pteromalus eurymi:* Adults issuing from chrysalis of alfalfa caterpillar. Enlarged nearly three diameters. (Original.)

The combined length of the egg, larval, and pupal stages in the warmer weather of August is from 12 to 15 days, while the pupal stage was found to cover 4 days in the month of August and 12 to 15 days in February, the variation being due to differences of temperature. Thus several generations are possible each season, and thus, with abundant egg production and high percentage of females, gives rise to a rapid increase in the number of parasites, so that by late August the multiplication of the host species is checked.

DIPTEROUS PARASITES.

Three tachinid flies, determined by Mr. W. R. Walton, of this bureau, have been reared from the larvæ and pupæ of this caterpillar. *Phorocera claripennis* Macq. (fig. 14) is the most important of these, its wide distribution and abundance of alternate hosts causing it to be always on hand. In 1910 at El Centro, Cal., the writer observed as many as 15 per cent of Eurymus larvæ with eggs of this species attached to them; while in 1913 Mr. T. Scott Wilson, at Tempe, Ariz., observed as many as 50 per cent of larvæ with eggs upon them, and in some cases there were as many as five or six to one caterpillar. Of course a great many of these eggs are shed in molting, but a majority of them hatch, and the maggot, entering the Eurymus larva, kills it in a short time. *P. claripennis* has been reared from this species at the following other places: Salt Lake City, Utah (E. J. Vosler and L. P. Rockwood); Wellington, Kans. (H. T. Osborn); Greenwood, Miss. (E. H. Gibson); Nashville, Tenn. (W. H. Larrimer). Three specimens of *Frontina archippivora* Will. were reared from a larva and pupa collected at El Centro, Cal., by Mr. R. N. Wilson, and a single specimen of the same species was reared by Mr. Rockwood at Salt Lake City, while at El Centro a single specimen of *Masicera* sp. was reared by the writer.

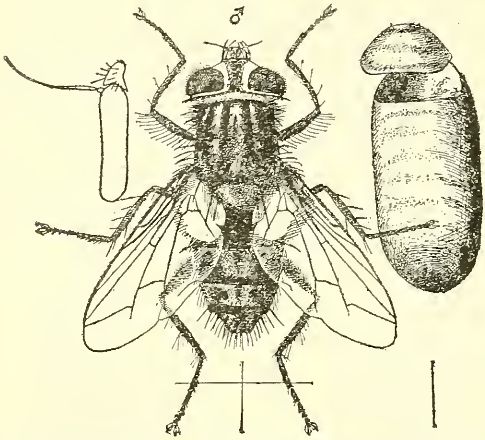


FIG. 14.—*Phorocera claripennis*, a parasite of the alfalfa caterpillar. Adult and enlarged antenna of same; puparium. Enlarged. (From Howard.)

FIG. 15.—*Aphiochæta perdita*, a phorid parasite of the pupa of the alfalfa caterpillar. Greatly enlarged. (Original.)

Besides these tachinid parasites, another small dipteron was discovered by Mr. T. Scott Wilson to be parasitic upon the pupæ. This was a small brown phorid (fig. 15) which has been determined by Mr. J. R. Malloch as *Aphiochæta perdita*, a species recently described by him[1] as new. This is supposedly a new record of habit for this species, but according to Mr. Wilson it was reared time and again from pupæ which were alive when collected; thus the flies could not be acting as scavengers, but must have been true parasites.

OTHER INSECT ENEMIES.

A large green caterpillar, known as the bollworm, *Heliothis obsoleta* Fab. (fig. 16), which can be distinguished from the alfalfa caterpillar because it is of a lighter green color, about one-fourth larger, hairy, and rough in appearance rather than smooth, with three black lines traversing its body lengthwise, is quite prevalent in the Imperial and Salt River Valleys, and is often mistaken for the alfalfa caterpillar by many farmers. As observed by the writer, and later by Mr. T. Scott Wilson, it was found to do very little damage to alfalfa, but to be a ravenous enemy of the alfalfa caterpillar, never eating alfalfa as long as it could find the larvæ or pupæ of Eurymus. Messrs. E. O. G. Kelly and T. H. Parks noted this species at Wellington, Kans., in the summer of 1909, and reported it as being of a predaceous habit.[2]

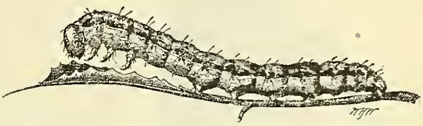


FIG. 16.—Bollworm (*Heliothis obsoleta*), an enemy of the alfalfa caterpillar. Twice natural size. (Author's illustration.)

The writer observed a bollworm larva to eat five large larvæ of Eurymus during a single day, and both the writer and Mr. T. Scott Wilson counted dozens of pupal cases with the contents eaten out (fig. 17) and many times with the Heliothis larva still feeding upon and devouring the pupæ. Mr. Wilson, on July 15, 1913, remarked in his field notes that "Heliothis was observed in great numbers feeding upon Eurymus pupæ, and in a few instances on Eurymus larvæ. The Heliothis makes a hole in the side of the pupa, through which he puts his head and eats out the contents of the pupa." The writer has observed the end of the abdomen eaten off the pupa; again, an opening would be made on the side, often the entire side being destroyed.

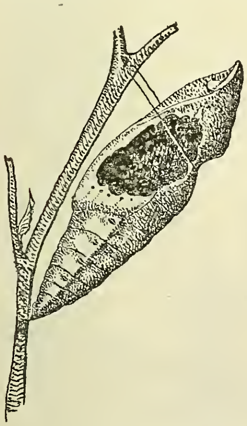


FIG. 17.—Chrysalis of alfalfa caterpillar that has been eaten out by a bollworm. Enlarged about two diameters. (Original.)

[1] Malloch, J. R. The insects of the dipterous family Phoridæ in the United States National Museum. Proc. U. S. Nat. Mus., v. 43, p. 459–460, 1912. "*Aphiochæta perdita*, new species," p. 459.

[2] This cannibalistic habit has also been observed in Texas by Quaintance and Brues. (U. S. Dept. Agr., Bur. Ent., Bul. 50, p. 79–80, 1905.)

The malachiid beetle, *Collops vittatus* Say (fig. 18), is rather numerous in the alfalfa fields of Arizona and was suspected of bearing some relation to Eurymus. Mr. T. Scott Wilson found both adults and larvæ feeding upon pupæ of the alfalfa caterpillar. He observed as many as 20 beetles feeding upon as many pupæ in a single day. This beetle seems to feed upon either live or dead Eurymus larvæ and pupæ and does not appear to have much choice between the two. It attacks a pupa or larva and, piercing it, sucks the juices that exude. In this way a hole is gradually made in the host, which, of course, is killed. Being small, the beetle does not consume much of its prey, but wanders off, and the next time it is hungry it attacks a new pupa or larva and thus kills many. Larvæ were taken in the act of feeding upon Eurymus pupæ, placed in vials, and reared to adult Collops.

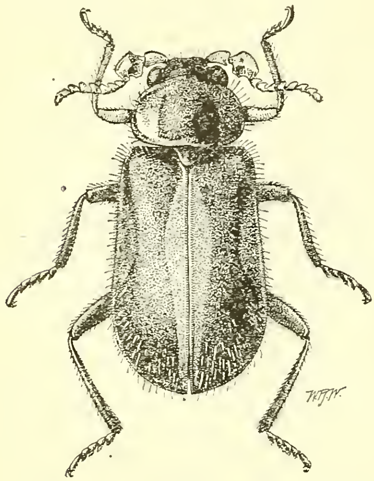


FIG. 18.—*Collops vittatus*, a beetle that preys upon the alfalfa caterpillar. Greatly enlarged. (Original.)

Two species of ants, *Pogonomyrmex barbatus* Smith and *Cremastogaster lineolata læviuscula* var. *clara* Mayr (?) were observed to attack Eurymus larvæ and kill them. Several species of robber flies have been observed to catch the adult butterflies and feed upon them. The writer took *Proctacanthus milbertii* Macq. with a butterfly in its claws, and Mr. H. E. Smith, at Koehler, N. Mex., observed the butterflies being carried off by *Stenopogon picticornis* Loew (fig. 19).

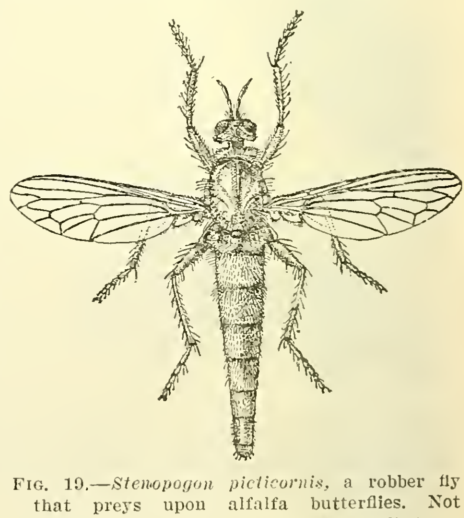


FIG. 19.—*Stenopogon picticornis*, a robber fly that preys upon alfalfa butterflies. Not quite natural size. (From C. N. Ainslie.)

A FUNGOUS ENEMY.

A fungus was found to attack the pupæ in the Salt River Valley in 1912. This is sometimes quite common, but never abundant, although more prevalent about August than at other times, probably owing to higher humidity. Dr.

Flora W. Patterson, of the Bureau of Plant Industry, has determined this as a Fusarium. In her letter she says: "The fungus, which bears strong evidence of being parasitic, has quite filled the body cavity and is either a Fusarium or Microcera," and states that the majority of similar fungi are reported upon scale insects. Later she says, "Cultures of the above fungus, parasitic upon *Eurymus eurytheme*, have developed in the most satisfactory manner, and it is probably an undescribed parasitic Fusarium."

A DISEASE.

As has been mentioned earlier in this paper, a disease which is probably bacterial and resembles flacherie of the silkworm is quite common upon larvæ and pupæ of Eurymus. At times, evidently during periods of higher humidity accompanied by warm weather, as in July and August, it becomes so widespread as to kill a great majority of a brood and often nearly annihilates it. This disease is by far the greatest natural check against which the alfalfa caterpillar has to contend and is one of the most important factors looking toward its control.

The dead worms, which are nothing but soft decayed masses found hanging to the alfalfa stalks, are sometimes so numerous as to make sweeping with an insect net impossible, the net in a few sweeps becoming so foul as to render other insect specimens of little value. The disease has proved a great detriment to the successful carrying on of life-history experiments and the rearing of parasites, owing to the fact that large percentages of larvæ taken to the laboratory and confined often die from it. Frequently, where a hay crop is not totally destroyed by a brood of caterpillars before they are killed by this disease, the decayed remains on the hay become so foul as to render the hay quite unpalatable for horses and hence of low value.

As has been suggested, the development of the diseased condition in either larvæ or pupæ—for it attacks both—depends largely upon moisture. The disease is present at all times, and a few larvæ from each brood are killed, but it is only when a period of high humidity accompanied by warm weather occurs that it becomes so prevalent as to attack the worms in large numbers. It has been found that at certain times these conditions of moisture may be produced artificially by irrigation, and, as is discussed in a later paragraph, the disease, thus fostered, is utilized as a factor in controlling the pest. That the disease does not at all times keep the caterpillar in check is doubtless due to the dry climate of these southwestern countries, and a comparison of the conditions in the Imperial Valley of California with those in the Salt River Valley of Arizona supports this view. The Imperial Valley is unique in location, being below sea level and having an average annual rainfall of probably less than 2 inches, while the Salt River Valley has an elevation of some 1,200 feet and an annual rainfall of about 8 inches. A study of the outbreaks of Eurymus in the two valleys shows them to vary inversely with the rainfall. In the dryer Imperial Valley the outbreaks are more numerous and severe and the resultant damage is greater than in the Salt River Valley with its greater rainfall and its longer period of humid weather during the hot summer months.

The worms when first attacked take on a lighter green color and become sluggish; but in a few hours they change to a brownish black and melt down into a decaying mass. A first sign of the breaking down of tissues may often be noted when the worm is still active, a slight exudation at some small broken place, usually in front; and the writer has noted specimens with the anterior end blackened and the posterior end still slightly moving, showing that life was not yet extinct. The attack upon a pupa is similar, except that the stronger pupal covering usually prevents the melting down of the specimen, and later the decayed contents of the interior dry up, leaving the empty black shell still intact.

BIRDS AND DOMESTIC FOWLS.

Few records are available showing the relation of wild birds to the alfalfa caterpillar. Several times the writer has observed birds with larvæ in their bills, but he was unable to capture these, not having the necessary firearms. Domestic fowls, however, play an important part in the history of this insect. In alfalfa adjoining farmhouses where chickens or turkeys have the run of the field one rarely finds alfalfa caterpillars in numbers, whereas fields adjoining chicken lots inclosed with wire fence, keeping the poultry out of the alfalfa, suffered severe damage. In Mr. R. N. Wilson's notes for 1912 he reports that "Mr. Carlos Stannard, living 4 miles northeast of Glendale, Ariz., killed a young rooster and found 24 Eurymus larvæ in the rooster's crop." Mr. T. Scott Wilson was informed by Mr. Everett, living near Tempe, that he and his wife had found a dozen larvæ in a chicken's crop, the chickens having access to an alfalfa field growing near the house. By the same observers, turkeys have been noted feeding greedily upon the larvæ, a flock in traveling across an alfalfa field eating hundreds of them. Mr. T. Scott Wilson, on July 21, 1913, at Chandler, Ariz., made the following note:

> I observed one dozen turkeys in a half acre of alfalfa on the lots of the United States power house feeding upon Eurymus larvæ. The alfalfa is about 12 inches high and is tender. I find only a few Eurymus feeding upon this alfalfa, while in a large field just across the fence the alfalfa is almost destroyed, except that in that portion next to the house where the tur-

keys likewise feed there are few Eurymus to be found, and consequently no damage. * * * I also observed several chickens feeding upon Eurymus larvæ.

From these observations it is seen that chickens may be utilized in small fields to keep down the numbers of alfalfa caterpillars, and that turkeys, because of their roving nature, can be used to advantage in larger fields. Mr. Charles Springer, of Cimarron, N. Mex., informs the writer that he hires a boy to herd an immense flock of turkeys on the range, so that they may feed upon the grasshoppers destroying the grama grass and other range grasses (see Pl. I, fig. 2, p. 4). It seems that the same method could be employed in outbreaks of the alfalfa caterpillar.[1] There is always a good demand for fattened turkeys, and with the cheap labor of a Mexican boy for herding the turkeys, if this additional expense is really necessary, the caterpillars could be kept within bounds at a very small cost per acre, or possibly even at a profit.

OTHER ENEMIES.

Quite a few observations have been made upon the food habits of toads. These batrachians have been found to feed upon both adults and larvæ of Eurymus, as many as 45 adults and 1 larva having been found in a single stomach on one occasion, while on another 15 Eurymus larvæ were found, besides 4 of Heliothis, 3 geometrids, 3 larvæ not classified, a cricket, and the remains of a few beetles. As toads are quite numerous throughout the alfalfa fields of the Salt River Valley, they must exert a considerable influence toward the suppression of outbreaks of the alfalfa caterpillar.

THE CONTROL OF THE ALFALFA CATERPILLAR.

PASTURING VERSUS HAYING.

It was first noted by the writer in 1910, during his early study of the subject, that fields in pasture are never troubled as much by the alfalfa caterpillar as are haying fields. Since then this has been clearly verified, not only by the writer but by others connected with the work. On July 14, 1913, Mr. R. N. Wilson makes the following note, which bears out this statement:

Many of the fields about El Centro have been cut recently and so show nothing now as to Eurymus conditions. Many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable.

There are several factors which explain this. At first it was thought to be owing entirely to the lack of bloom for the butter-

[1] Of course care should be exercised not to allow the turkeys in the alfalfa after it has become too high and rank, nor should too great a number be used in any one field, as in such cases the alfalfa might be badly trampled.

flies to feed upon and to the fact that the greater part of the fields was kept closely grazed, making the alfalfa less favorable for the laying and development of the eggs. Under such conditions the number of eggs deposited in a given field is greatly reduced. Many of the eggs laid on the young growth under such conditions are destroyed by the grazing of the stock, and the percentage that develops is kept at a minimum. Later on it was noted that on the stock ranches visited the disease previously mentioned, which is common to lepidopterous larvæ, was more prevalent in pastured ranches than in hay ranches. The prevalence of the disease in such fields is due to the fact that usually a few days after stock are turned in the alfalfa becomes trampled. The ground and the alfalfa are very moist, there being more or less dew every morning, and droppings from the cattle bring about a foul condition in the field, thus assisting in the retention of moisture, which, in turn, is conducive to the development of the disease.

If fields can be systematically and carefully pastured, damage from the caterpillar will accordingly be at a minimum. Cattle should never be allowed on a field when wet nor for too long a period, say from 24 to 35 days, and disking or renovating should always follow so as to loosen the soil and place it in a receptive condition for future irrigation.

It is on ranches and fields from which successive crops of hay are taken that the height of the damage is reached. In such fields the conditions for the development of the species are as nearly ideal as possible, and here the worms are ordinarily unmolested in their feeding and growth. The period elapsing from the time that one crop is cut until another is ready for harvesting so nearly coincides with the length of the period necessary for the development of any one generation of the butterfly that the cutting of the hay, as ordinarily carried on, does not reduce their numbers or disturb their work, since the worm will likely be in the advanced stage, or, perhaps, have passed into the pupal stage. before the crop is cut.

CONDITIONS AFFECTING INJURY.

As has been pointed out, this insect is ordinarily kept in control by its natural enemies, such as insect parasites and diseases, and it is only upon the occurrence of conditions unfavorable to the development of these enemies that serious outbreaks occur. It has also been noted time and again, both by the writer and others, that the seriousness of the damage quite often depends upon the farming methods used by the individual whose fields are attacked, or upon certain other conditions, such as character of soil, quantity of water for irrigation, location of land, etc. The former are conditions that the individual may remedy by changing his methods, while the latter may be practically alleviated by proper handling of the farm in question.

The damage in some alfalfa fields is quite often apparently correlated with the condition of the soil. A field seriously damaged often reveals a poor soil—at least a soil not well adapted to alfalfa culture, and consequently producing a slow-growing crop. Of course not all of the fields damaged were of poor soil; some of the very best alfalfa fields were seriously ravaged, but in these cases this was often attributable to other factors. Sandy loams or light soils are the best for alfalfa production, and consequently are the least damaged, owing to the fact that the alfalfa, growing more rapidly, is often able to recover from insect attacks and be ready for harvest before any noticeable damage has been done. A heavy soil can be improved and the growth of the alfalfa increased by deep plowing and thorough preparation of the seed bed at time of seeding the crop and then by renovating the alfalfa several times a year, either by disking or by the use of an alfalfa renovator. By such a procedure in irrigated regions the soil will more readily take water, and thus plant growth will be stimulated.

A farmer who attempts to use up-to-date and proper cultural methods is unfortunate indeed when his alfalfa fields, for which he is caring properly, are just across the fence from fields that are run down, and hence are breeders of insects. No matter how careful his efforts, some damage may be done owing to reinfestation of his fields from the butterflies supplied by his neighbor's field. Nevertheless enough may be accomplished through his own efforts to pay many times.

Again, the amount of water applied is often insufficient, sometimes because of neglect on the part of the rancher, and sometimes because of scarcity of supply. The former case is under the rancher's control; he should use care in applying the water and should eliminate waste. Sufficient water should be used to provide for the prompt development of the alfalfa crop, for in this way the farmer can reap his crop earlier and before the caterpillars have effected much damage.

Soon after agents of the Bureau of Entomology began observations and experiments looking toward the control of the species it was noticed that damage to alfalfa was often, although not always, associated with careless methods of farming and a lack of appreciation on the part of some ranchers of the benefits to be derived from careful, clean cultural methods. This is sometimes due to the fact that the rancher is trying to cultivate more land than it is possible for one man to farm successfully with the limited amount of labor and capital at his disposal. A great many times poor management is responsible for a failure where other methods would have meant success.

CLOSE CUTTING AND CLEAN CUTTING.

In harvesting the hay crop ranchers usually have to depend upon labor that, while often the best obtainable, is not by any means of the best class, and thus cutting is often done in a careless manner, stubble is left high and ragged, bunches of hay are left uncut at turning rows or on borders, ditch banks and fence rows are rarely or never cut, and the field presents the spectacle shown in Plate I, figure 3, page 4, and Plate II, figure 3. Thus any caterpillars that may still be present have a considerable amount of alfalfa upon which to feed and develop, and soon do so, so that the butterflies from these are ready for the next crop. Such places also afford bloom which attracts adult butterflies from other fields, and these lay eggs on the new alfalfa that soon springs up. If such neglected fields are treated as are those shown in Plate II, figures 1 and 2, there will be no food to enable any remaining caterpillars to complete their development; besides this, there will be no protection for them from an early irrigation or the rays of the hot sun, either one of which will kill them. Heat of the midday sun, accompanied by prompt irrigation immediately following such clean cutting, will nearly always kill Eurymus larvæ, especially in the warm Southwest. This is such an important item that one should not hesitate to go to the necessary expense in order to secure such a condition of cleanliness. In two cases in the Imperial Valley in 1910 it became necessary, because the hay had lodged badly, to remow a field at a cost of from 30 to 50 cents per acre, and in each case the results obtained in the following crop more than paid for the cost of the experiment.

EXPERIMENTS AND OBSERVATIONS IN CALIFORNIA.

In California, in 1910, 10 fields were selected in which good cultural conditions were to be created and in which methods were to be inaugurated that would not further the development of the caterpillars. The thing done in these fields was to put them under a system that would remedy as far as possible all or part of the defects recorded on a previous page. During that season (1910) a large part of the damage was due to the caterpillars of the third and fourth generations, the first and second not being numerous enough to assume any serious aspect. The task, then, was to keep their numbers below the point at which they could do any considerable damage. The time to start this control work was naturally with the earlier generations. The 10 fields mentioned (no two of which had had the same conditions of culture previous to that year, and which had all suffered more or less damage the year before, namely, in 1909) were given what might be termed clean culture, or careful management. Just as soon as possible after removing a crop of hay

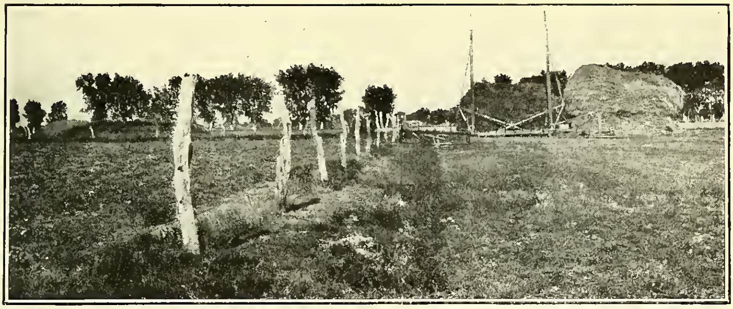


FIG. 1.—FENCE ROW BORDERING ALFALFA FIELD, SHOWING CLEAN CUTTING, WHICH HELPS TO REDUCE THE ALFALFA CATERPILLAR AS WELL AS OTHER INSECT PESTS. (ORIGINAL.)

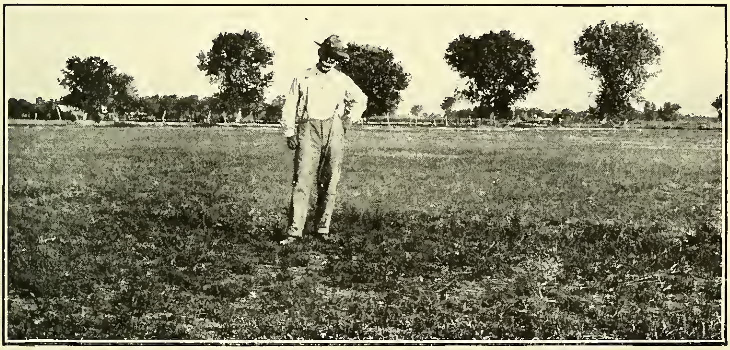


FIG. 2.—ALFALFA FIELD SHOWING CLOSE, CLEAN CUTTING NECESSARY FOR REDUCING A GENERATION OF ALFALFA CATERPILLARS. (ORIGINAL.)

FIG. 3.—FENCE ROW AND DITCH BANK SHOWING NEGLECTED GROWTH OF ALFALFA AND GRASS, WHICH OFFERS PROTECTION AND HIBERNATING QUARTERS FOR THE ALFALFA CATERPILLAR AND OTHER INSECT PESTS.

CLEAN CULTURE AND THE ALFALFA CATERPILLAR.

the field was irrigated thoroughly, thus starting the growth quickly. The field was again irrigated as soon as the dry condition of the crop required, and thus the growth was forced and not allowed to be checked.

It requires about 28 days to produce a hay crop in the Imperial Valley—a little longer than this in the spring and fall, and a few days less in warmer weather. It also takes practically the same period of time, as has been shown on a previous page, for the butterflies to develop from egg to adult. Now, if the crop of hay be forced by frequent watering, or because of good soil conditions, the worms will not have gone into the resting stage at time of cutting, but, instead, will still be feeding on the green alfalfa, and when the hay is cut and removed conditions will be unfavorable for their development and their food supply will be reduced. The hay in these fields was cut just as it was coming into bloom, which is a few days sooner than it is generally thought advisable to cut it. The advantage of this early cutting is often very important, for if worms are present in damaging numbers they will take a whole field in a short time. In this case not only will the hay be saved, but a major portion of the larvæ, if clean cultural methods are used, will find a lack of the food necessary for their complete development, and this, associated with hot weather and irrigation following the removal of the cured hay, will cause them ultimately to perish.

Of the 10 fields handled according to these methods only 1 was damaged to any considerable extent. The other 9 were not entirely free from larvæ, but the numbers were so reduced as to preclude any chance of noticeable injury to the alfalfa. In the one exceptional field the damage was due to the fact that irrigation had been delayed for nearly two weeks after the cutting of the second crop, owing to a new ditch which was under construction. Being a thrifty field naturally, the alfalfa had made a start, assisted by the moisture still present in the ground, and butterflies coming in from an outside field deposited eggs on this new growth, thus enabling the worms to destroy the best of the crop after it was finally irrigated. As a result almost an entire crop was lost. A field adjoining on the south, which had been irrigated immediately after cutting, was not in the least damaged. This was a lesson in itself, as it indicated the necessity for prompt work.

These observations in California in 1910 have been further supplemented by observations at Tempe, Ariz., and El Centro, Cal., in 1912. This year (1912) the writer made two trips into the Imperial Valley. Several ranchers had kept records of their methods of handling alfalfa, and these records show conclusively the same results as those of 1910. Two ranchers especially were found who had practically controlled the pest in the last few years, and they have accomplished it altogether by such methods as have just been described. One of these men, Mr. Henry Stroven, whose ranch is north of Holtville, says that he has had a minimum of damage. His ranch evidences his careful and systematic cultural methods. Ditch banks and fence rows are clean, and there is scarcely a weed noticeable on the entire ranch. Mr. Stroven informed the writer that he always renovates twice a year and sometimes oftener and also aims to keep his alfalfa abundantly watered in order to get a quick, thrifty growth. The other rancher, Mr. William Mansfield, of Brawley, practices the same methods in use by Mr. Stroven, and his ranch also shows this. Neither of these ranchers aims to allow his alfalfa to stand longer than five years in a certain field. Instead, he plows it up, raises some other crop for a year, and then reseeds to alfalfa, thus bringing into play a system of crop rotation which not only keeps the soil in excellent condition, but prevents insect increase. Mr. Mansfield told the writer that in 1908 he had considerable damage when his May cutting was getting a little more than two-thirds grown. One day he noticed that damage from the caterpillar was very apparent. The next day the effect was much more noticeable. So he mowed the alfalfa, taking it up at once, and irrigating as soon as possible. He thus saved by far the greater part of the crop infested and, besides, was not troubled again that year.

The following observations, made by Mr. R. N. Wilson in July, 1913, also bear out the foregoing statements:

> One farm was examined near Meloland, Cal., to-day. This is a dairy farm belonging to Mr. Cook. In order that the hay may be in the best condition, Mr. Cook cuts it just as it comes into bloom. He in this way gets two more cuttings of hay per year than his neighbors, who allow their fields to come to full bloom before cutting. His crops have never been badly injured by Eurymus, while his neighbors have more or less injury every year. He also keeps his alfalfa in a thrifty condition, and the rapid growth is another element in Eurymus control.

These three examples show the practicability and the success of the methods proven by observation and experimentation to be means of controlling outbreaks of the alfalfa caterpillar.

EXPERIMENTS AND OBSERVATIONS IN ARIZONA.

Observations similar to those in California were made in Arizona by the author in 1912 and in 1913 by Mr. T. Scott Wilson. The same relation has been noted to exist between clean culture and good farming methods in general and damage by the alfalfa caterpillar as existed in California. But in Arizona, as the soil conditions are somewhat different from those in California, it is necessary for the application of water to be even more timely. In many parts of the

Salt River Valley there is a layer of subsurface water. This is lacking in the Imperial Valley. Thus when a crop has been removed in the former place alfalfa soon sprouts, and eggs are laid sooner and have made some headway when irrigation has finally been accomplished. While there is a limit to the promptness with which a crop can be removed from the ground after being cut, and consequently a limit to the promptness with which the ground can be irrigated, yet these measures should always be carried out just as soon as possible, thus avoiding damage by reason of the difference noted.

In 1912 Mr. Peter Aepli, living a mile south of Tempe, began cultural methods especially meant to control outbreaks of the alfalfa caterpillar. It is to be noted that even previous to this time Mr. Aepli had carried on a system of crop culture that would secure the maximum returns from his land; so that about the only change in his methods was an addition of factors that take into consideration the status of the alfalfa caterpillar at the time of each cutting; that is to say, he cuts at a time that will do the most harm to any larvæ that may be present and before any damage is done to the alfalfa. August 1, 1912, it was found that a considerable number of caterpillars were present in Mr. Aepli's field and that he would have to cut earlier than he had intended in order to save it from serious damage. On August 3 he cut the hay, doing a fine clean job. On August 5 he removed the hay from the ground and then followed this with disking and irrigation. The worms were all killed, the present crop saved, and no further damage was done to the alfalfa in that field that year. The effect of these careful and painstaking methods was also noted in the field the year following. From Mr. T. Scott Wilson's notes of August 4, 1913, is quoted the following:

> An 80-acre field of alfalfa across the fence from Mr. Aepli's is almost completely destroyed, while Mr. Aepli's is damaged but very little. Mr. Aepli is cutting his hay to-day. The larvæ are not full grown yet, so he is taking their food from them before they mature. He usually cuts his hay close to the ground and before it gets too ripe, hence Eurymus do not bother him much.

Another example of the effect a careful system of clean cultural methods will have upon caterpillar devastations is noted in a 640-acre ranch just south of Tempe, Ariz. Here the clean-up methods are accomplished by a combined system of haying and pasturing and are quite successful. The ranch should really be termed a cattle ranch, but after the owners' young steers that have been raised on their range in northern Arizona are fed out in the winter and spring, several crops of hay are made, stacked up in the field, and fed the next winter. The hay from such crops is cut often, not allowed to get overmatured, and as the owners employ a large force of men it is hastily stacked and then, following this, 40 to 60 head of steers are turned in for about three days, during which time they clean up every growing sprig in the field. They are then sent to another field, and so on and on, the owners in this way keeping their alfalfa ahead of the butterflies, and by the clean-up method few larvæ are allowed to develop to adults. Of course, not everyone can have stock available at just the right time, but this is another example of what clean-up methods will do.

IRRIGATION AS A FACTOR IN CONTROL.

As has been stated in a previous paragraph, moisture is conducive to the development of the disease which plays an important part in the control of this insect. A number of experiments were therefore tried by which, with the use of irrigation water, an attempt was made to supply moisture artificially so that the worms would become diseased. This was found to be quite successful. In fields where clean methods of cutting are used at haying time and this is immediately followed by irrigation, there seems little doubt that a part of the mortality of the larvæ is due to the effect of irrigation. The beating sun, of course, kills a great many, and then, as has been shown, under such a procedure the food supply is cut off and the decayed remains of larvæ are found hanging in great numbers to the alfalfa stubs about two days after such a procedure. This led the way for other experiments; accordingly, during the summer of 1913, Mr. T. Scott Wilson made a number of observations on irrigation of alfalfa at a time when the worms were beginning to appear numerously, and he found that invariably this gave the disease the necessary moisture and the worms soon died. For a rancher to take advantage of this would, of course, mean that he must have water available any time he wants it, which is not the case in all irrigated regions, as water is usually distributed in turn. However, in cases where the time for irrigation corresponds with the occurrence of an outbreak the water can be utilized and the worms killed.

VALUE OF DISKING AND RENOVATION.

It has been suggested before that an alfalfa field should be disked or renovated annually, or oftener, in order to keep the sod in good loose condition, so that it will take water readily and be aerated, and also to kill weeds. If teams are available, the best procedure would be to renovate several times, or at least twice a year. The usual method is to renovate once, and this during the winter. Now, if the alfalfa can be renovated in August, immediately after the third crop is removed, not only will the ground be placed in an excellent condition and weeds killed, but any larvæ or pupæ on the ground will be killed and future crops protected from damage. Some ranchers do this already and claim great results for it, and a few even renovate oftener. Mr. Stroven, of Holtville, Cal., renovates just as often as it is possible for him to do so, and in 1911 this was four times. Leaving the matter of insects entirely out of consideration, enough benefit is derived from renovation to pay many times for the cost of the work. If a disk harrow is used, it should not be set at an angle, as this would be likely to cause injury to the crowns, but should be run straight and forced into the ground by weights.

DIRECT METHODS OF CONTROL.

INSECTICIDES.

In dealing with insect pests affecting cereal and forage crops it has proved possible in only a few instances to control them by the use of any of the various insecticides or poisons. The reason for this lack of success lies largely in the fact that such crops are distributed over a wide area, and the expense of application of any insecticide as a control measure is necessarily high, while a lack of thoroughness is likely to arise when one tries to keep the expense of treatment down to an economical basis.

Since the alfalfa hay is fed to stock, it is not possible to use any of the arsenical poisons against the caterpillar of the alfalfa butterfly. A few experiments, however, were tried with pyrethrum, or "buhach." As this is not a poison, and since its fatal effect upon the larvæ of butterflies is produced externally through their breathing pores, there would be no danger to stock. Pyrethrum was used in one case in 1910 in full strength, and in another instance it was diluted with equal proportions of flour. An application was made by dusting this substance from a cheesecloth sack, following the primitive method of applying Paris green to potato vines, at the rate of 3 pounds of pyrethrum to the half acre, which in the case of diluted material would make 1½ pounds of pyrethrum to the half acre. This first test was made on July 8, 1910, and no results were obtained, because of the fact that just two days later practically all of the worms in the field where the test was being made were destroyed by the malady before mentioned. The same experiment was repeated, however, on September 22, and in this case the results were negative, not a caterpillar being killed. It would seem, therefore, that the application was not sufficiently heavy to kill the worms, and that to have increased the amount of pyrethrum applied might have resulted in the eradication of the pest; but as the cost of pyrethrum at the rate of 3 pounds to the acre is already nearly $2, without considering the expense of application by hand, this could not be considered from an economic point of view.

In 1913 some additional experiments were tried with the same material by Mr. T. Scott Wilson at Tempe, by using it full strength. This killed about 50 per cent of the larvæ, but the cost of application was again too high, and a large enough number of worms were not killed to justify the expense incurred.

ROLLING AND BRUSH DRAGGING.

At the time a field is being damaged by the worms the hay that remains undestroyed can be cut and then either a brush drag or a roller run over the ground, by which a great many of the larvæ will be destroyed. Some experiments tried along this line by Mr. T. Scott Wilson were quite successful. On August 15, in a 5-acre patch a brush drag was used and a great many larvæ were killed. This field was overrun by Bermuda grass, which protected many larvæ that would have been killed. A roller here would doubtless have

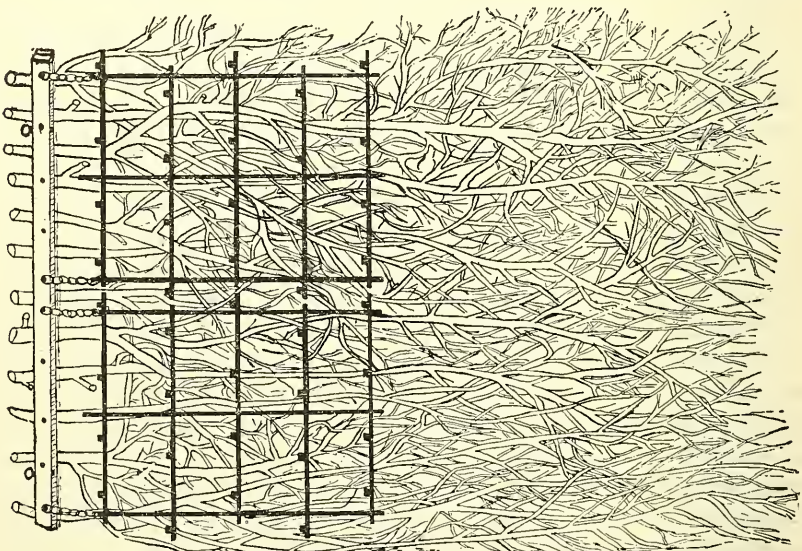


Fig. 20.—Brush drag used to crush alfalfa caterpillars in the fields. (Original.)

mashed all larvæ. On the 26th of August another test was made, using the same drag. In this case the larvæ were about full grown, and 55 per cent were killed by the operation. The latter experiment, however, was carried on in alfalfa of considerable height, and consequently the larvæ were afforded much protection and as large a percentage was not killed as would have been the case had the dragging immediately followed cutting.

A good brush drag and one that is well adapted to dragging alfalfa is shown in figure 20. The plan for constructing this, as given by Mr. E. S. G. Titus, in Bulletin No. 110 of the Utah Agricultural Experiment Station, is as follows:

The drag is made by laying the butts of rather short brush, five or six feet long, in a row on a plank twelve or fourteen feet long, then another row should be laid upon the first, consisting of longer brush, with the butts trimmed a little further back so that you will have in effect two brush harrows, one following the other. Another plank should then be laid on the brush butts and bolted to the under plank. In weighting this drag, lay an ordinary tooth harrow, with the teeth down, directly on the brush drag. This makes a very even weight, at the same time it is so flexible that the drag will work its way down into the small depressions as well as over the larger elevations of the fields.

A larva exposed to dust and hot sun soon dies. On September 4 three larvæ were placed in a dusty spot by Mr. Wilson, and within a few minutes all were dead. The next day the experiment was repeated, and all larvæ died. In all about 50 larvæ were exposed to the dust and sun, and of this number only 1 was able to crawl back to alfalfa, the rest dying before they had crawled 10 inches on the dust and dry dirt. The sun was very hot, and the temperature, 4 feet from the ground, was 97° F. These experiments show why so many larvæ die following careful methods of haying. They have no protection from the hot sun when such methods are carried on.

CONCLUSIONS REGARDING CONTROL.

Keep the ranch in the best possible cultural condition. Irrigate it often and thoroughly and as soon after cutting as the crop of hay can be removed from the ground.

Renovate every winter and during the month of August, or even oftener if possible, either by disking or by the use of an alfalfa renovator, thus disturbing any pupæ that may be present, and putting the land and alfalfa in condition for good growth of succeeding crops.

Cut the alfalfa close to the ground and clean, especially along the ditch banks, borders, and turning rows, as well as in the main part of the field.

Cut the alfalfa earlier than is the general rule. The proper time is when it is just coming in bloom or is one-tenth in bloom. Watch for caterpillars in the early spring crop, and if many are observed about grown, cut the hay a few days before it is in bloom, and thus save the next and future crops.

A minimum amount of damage occurs in fields that are systematically pastured all or a part of the time.

A field should never be abandoned because the caterpillars threaten the destruction of a crop of alfalfa before the hay can possibly mature. Mow it at once, cutting it low and clean, thus saving part of the present crop, and in so doing starve, and allow the heat of the sun to kill, a great many of this generation of worms. Follow this by disking and then by either rolling or brush dragging, and a great majority of any remaining larvæ will be killed. The ground should then be thoroughly irrigated, and by these efforts the coming crop will be assured.

Turkeys and chickens when allowed the run of a field will keep the numbers of the caterpillars at a minimum.

The protection of toads should be encouraged, as they eat many of these insects, as well as other injurious forms.

It has been noted that a carrying out of only part of these recommendations will not at all times save one's crop. The best results come to the one who is thorough in methods.

Cooperation among all farmers is necessary to suppress an insect attack completely. An occasional outbreak has been known to occur upon a farm or ranch that is under the best possible condition of crop culture, but in each case it was noted that the careless methods of a neighbor were responsible for the reinfestation.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
V

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 125

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief, and the Bureau of Animal Industry, A. D. Melvin, Chief

Washington, D. C. PROFESSIONAL PAPER May 13, 1915

ZYGADENUS, OR DEATH CAMAS

By

C. DWIGHT MARSH and A. B. CLAWSON, Physiologists
and HADLEIGH MARSH, Veterinary Inspector

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 125

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief, and the Bureau of Animal Industry, A. D. Melvin, Chief.
May 13, 1915.

(PROFESSIONAL PAPER.)

ZYGADENUS, OR DEATH CAMAS.

By C. Dwight Marsh and A. B. Clawson, *Physiologists, Drug-Plant and Poisonous-Plant Investigations*, and Hadleigh Marsh, *Veterinary Inspector, Bureau of Animal Industry.*

INTRODUCTION.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

Chesnut and Wilcox (1901, p. 52)[1] say that "the earlier explorers of the Western, and especially of the Northwestern, United States frequently mention the poisonous character of the bulbs of one or the other of the various species of Zygadenus and refer to them as poison camas or poison sego in order to distinguish them from bulbs of two other groups of plants, Quamasia and Calochortus, which were commonly known as camas and wild sego and were much used for food, both by the Indians and by travelers. Accounts of the poisoning of stock from eating the roots and leaves of various species have but recently been sent to this Department."

This statement, perhaps, covers the knowledge of the subject up to that date, although the writers have failed to find much in the way of definite statement among the earlier writers that can be referred to this plant.

In Wyeth's journal of his second expedition to Oregon (Wyeth, 1899) occurs this statement:

> 16th. Made down the Sandy S. W. by W. 15 miles then 4 S. E. by E. and camped on this stream so far the grass is miserable and the horses are starving and also at last night's camp they eat something that has made many of them sick the same thing happened two year since on the next creek west.

This happened on June 16, 1834, somewhere between Big Sandy Creek and Leckie, in Fremont County, Wyo. The present knowledge of the botany of that region makes it almost certain that the poisonous plant in that place at the time of year mentioned must

[1] For the complete titles of works cited, see the list of literature on pages 45 and 46.

Note.—This paper is intended to supply general information on the relation of Zygadenus to the losses of live stock on the western stock ranges; it is suitable for distribution throughout the western third of the United States.

47698°—Bull. 125—15——1

have been Zygadenus. This is the earliest reference to probable poisoning by Zygadenus which has been found by the writers.

Asa Gray (1848) says of *Amianthium nuttallii*, now known as *Zygadenus nuttallii*, "Crescent cum *Kamassa* esculenta, quo bulbi nocentes viatoribus saepe confusi sunt."

Hooker (1838) says of *Leimanthium nutallii*, which is the same as the species mentioned by Gray, "'Poison or Death Camass' of the Chenooks, from the violent effects of the roots, which create vomiting."

Watson (1880) speaks of *Zygadenus venenosus* as poisonous and known to the Indians as "Death-Camass," and says, on page 184, that the bulb of *Z. paniculatus* is also poisonous.

Apparently the Lloyds (1887) were the first to state definitely the symptoms produced by the plant in human beings.

Irish (1889) fed "cammers" to steers without effect.

Hillman (1893) published a newspaper bulletin calling attention to the poisonous character of Zygadenus, and in 1897 he published another newspaper bulletin on the same subject. Also, in another publication (1897*b*, p. 115), he states that a horse is reported to have been made sick by the seeds of *Zygadenus paniculatus* in hay.

Coville (1897) says that *Zygadenus venenosus* causes extreme vomiting and that it is sometimes used by medicine men of the Klamath Indians, mixed with the dried roots of *Iris missouriensis* and a little tobacco, to give a person a severe nausea, in order to secure a heavy fee for making him well again.

Chesnut (1902, p. 321–322) tells of the knowledge of this plant by the Indians of Mendocino County, Cal., and their use of it for medicinal purposes.

Hunt published an abstract in 1902 announcing the discovery of the alkaloid.

In a copy of McCarthy (1903), apparently annotated by the author, the statement is made that *Zygadenus glaberrimus* and *Z. leimanthoides* are poisonous.

Nelson (1906) demonstrated by feeding experiments the poisonous effect of Zygadenus upon sheep.

REVIEW OF PHARMACOLOGICAL WORK.[1]

The bulbs of *Zygadenus paniculatus* were found by Collier (1882) to give several alkaloidal reactions, but the first attempts to isolate and determine the chemical and toxic properties of the poison of Zygadenus seem to be those of Reid Hunt,[2] special expert of the Bureau of Plant Industry in 1901, who worked with the leaves and flowering tops of *Z. venenosus*. Hunt prepared an alcoholic extract

---

[1] The review of pharmacological work was prepared by Dr. Reid Hunt, of the Harvard Medical School.

[2] Hunt's results were submitted in a report to the Department in 1901 and also reported at a meeting of the American Physiological Society. (Hunt, 1902.)

and removed various oily and resinous substances by precipitation with water and extraction with petroleum ether. These resinous bodies were not toxic. Vejux-Tyrode (1904) later obtained similar resinous bodies to which he ascribed a high degree of toxicity, but Heyl and Hepner (1913) could not confirm this.

Hunt purified the extract further, and then, by extraction with chloroform, obtained an amorphous substance alkaline to litmus and giving the usual alkaloidal reactions. It was very slightly soluble in water, but readily soluble in dilute acids. When treated with concentrated sulphuric acid this substance dissolved with the formation of an orange-yellow solution; the color soon became a blood orange, and finally a bright cherry red. This play of colors corresponds almost exactly to that caused by cevadin and to that recently described by Heyl, Hepner, and Loy (1913) for zygadenin, an alkaloid obtained by them from *Zygadenus intermedius*. Hunt found, as did Heyl, Hepner, and Loy later, that the alkaloid was not readily extracted with ether. When the alkaloid or mixture of alkaloids was further purified, dissolved in alcohol, and the alcohol allowed to evaporate, a clear, glassy residue with a few cubes or prisms was obtained. This began to darken at 185° C. At 197° C. part of it melted to form a red solution, but all of it did not melt until a temperature of 220° C. was reached. It is quite probable that this mixture consisted in part of the alkaloid since isolated by Heyl, Hepner, and Loy and named by them zygadenin. Zygadenin crystallizes from alcohol in "orthorhombic blocks" and melts to a red oil at 200° to 201° C. Hunt pointed out a number of resemblances and also certain differences between the reactions of the alkaloids obtained from Zygadenus and those given by cevadin and other veratrin alkaloids and concluded that both chemically and pharmacologically the two series were closely related.

Torald Sollman, in a report submitted to the Department of Agriculture in 1903, stated that he could find no poisonous principle in Zygadenus other than the alkaloid or mixture of alkaloids found by Hunt.

These results were confirmed by Slade (1905) and by Heyl, Hepner, and Loy. The latter authors carried the work to the point of isolating in pure form an alkaloid which they named zygadenin, although the question whether this may not be identical with some one of the veratrin alkaloids is, perhaps, still open. It may also be doubted whether zygadenin is the most important toxic agent in Zygadenus, for these authors quote Mitchell as reporting that "it (zygadenin) kills guinea pigs slowly and only in comparatively large doses." Hunt found 4 milligrams per kilo of his alkaloidal preparation to be fatal to rabbits in an hour or two. Sollman found about the same amount of cevadin to be fatal.

Hunt found, as did Heyl and Raiford (1911), that the leaves and flowering tops contain more of the alkaloid than the bulbs. By performing an extensive series of experiments on animals with the Zygadenus alkaloids, he found that their action was in all essential particulars the same as that of veratrin. They were very irritating to the mucous membranes, as was the powdered plant itself; they produced an intense burning sensation and a very acrid, bitter taste in the mouth; when applied to the skin in alcoholic or chloroform solution, they caused a burning, painful sensation, but the spot later became anæsthetized; they had the typical veratrin effect upon the muscles and, as kymograph experiments showed, affected the respiration, blood pressure, and heart in the same way as does veratrin. It was also shown that the death of animals poisoned with Zygadenus was hastened by attempts to arouse them. This was attributed to the rapid failure of the respiration, circulation, and the muscular system. It was concluded that under laboratory conditions (and probably under field conditions) an essential part of the treatment should consist in allowing the animals to rest.

Hunt also isolated the alkaloids from the urine of animals poisoned with Zygadenus. He found that they were excreted with the urine quite rapidly and demonstrated that under laboratory conditions it was often possible to save the life of poisoned animals (rabbits, sheep, etc.) by the administration of diuretic drugs (caffein, theobromin, sodiosalicylate). Atropin and strychnin seemed to hasten death.

Sollman, after satisfying himself that the toxic action of Zygadenus is identical with that of veratrin, made a study of poisoning by the latter. He found that a single dose often caused prolonged sickness and that small, repeated doses caused no tolerance, but increased the susceptibility, and suggested demulcents, such as linseed decoction, to counteract the corrosive action on the alimentary tract.

It is evident from these chemical and pharmacological studies that the poisonous properties of Zygadenus are essentially those of veratrin, the indications for treatment being the same in the two cases.

DESCRIPTION OF ZYGADENUS.

The genus name Zygadenus is used in this paper as defined in Robinson and Fernald's revision of Gray's Manual and in Coulter and Nelson's New Manual of Botany of the Central Rocky Mountains. It includes the three genera, Zygadenus, Anticlea, and Toxicoscordion, of Britton and Brown's Illustrated Flora. The plants are erect, perennial, glabrous herbs, growing from a rootstock, or, as in the case of all the western species, from a tunicated bulb, with a leafy stem. The leaves are grasslike, long, narrow, and keeled. The flowers are greenish yellow or white, borne in a terminal raceme or panicle. This raceme varies in the different species from an almost solid head, as seen in Plate I, to a very loose, elongated panicle, there being a considerable range of variation in the inflorescence within the limits of the same species. The perianth is spreading, withering-persistent, the sepals bearing one or two glands near the base. The stamens are free or attached to the bases of the segments. The capsule is three lobed and dehiscent to the base in maturity.

The species of Zygadenus are spring and summer plants. On May 8, 1913, in the neighborhood of the Greycliff station, Mont., *Z. venenosus* was about 4 inches high, the largest plants not exceeding 6 inches, and the flower scape was not visible. On May 11 the plants were in bud, and they blossomed through the month of June. Seeds were formed the last of June and early in July, and after the middle of August the plants had largely disappeared.

Zygadenus elegans was in full blossom near Red Lodge, Mont., on July 20, at an altitude of approximately 6,000 feet. In 1910 *Zygadenus coloradensis* was in blossom in Colorado at about the same time (July 20) at an altitude of about 10,000 feet.

In Montana, *Zygadenus venenosus* grows typically at lower levels than *Z. elegans*. As stated by Chesnut, its favorite habitat is in the shallow ravines occurring on hillsides. It does not grow abundantly on dry hillsides nor in wet ravines, but it is very commonly found in the shallow depressions on the north slopes of bench lands. *Z. elegans* grows at higher levels (Rydberg gives as its limits 6,500 to 12,500 feet) and in locations where more water is available than is necessary for *Z. venenosus*. While it grows readily on hillsides, it reaches its best development in size in distinctly wet places, sometimes immediately in contact with rivulets.

In California and Oregon, *Zygadenus venenosus* grows in the meadows, while *Z. paniculatus* grows upon the hillsides. *Z. venenosus* is more common on north slopes and *Z. paniculatus* on south slopes.

The species of Zygadenus may grow as more or less scattered individuals, but sometimes they are massed together in large areas, including, perhaps, several acres, in which, at the time of flowering, they seem to be the principal vegetation and give a characteristic greenish yellow color to the landscape.

The species of Zygadenus are distributed very widely in the United States and are found as far north as Alaska. They occur most abundantly from the Rocky Mountains west to the Pacific, and their importance as stock-poisoning plants is confined almost entirely to this part of the United States. Plate I shows the general appearance of *Zygadenus venenosus*. This is an Oregon plant and shows the flowers as they appear at the beginning of blossoming. Later, the raceme is more extended, as shown in Plate II, which is reproduced from a photograph of a Montana plant. Plate III shows the plant after the seed is formed.

COMMON NAMES OF ZYGADENUS.

The species of Zygadenus are known under a large number of popular names. The most common perhaps is death camas. In the Northwest perhaps lobelia is the name used even more generally than death camas. Other names are soap plant, alkali grass, water lily, squirrel food, wild onion, poison sego, poison sego lily, mystery grass, and hog's-potato. *Z. glaberrimus* is said to be called cow-grass.

POISONOUS SPECIES OF ZYGADENUS.

The following species of Zygadenus are said to be poisonous: *Z. elegans*, *Z. falcatus*, *Z. fremontii*, *Z. glaberrimus*, *Z. intermedius*, *Z. mexicanus*, *Z. nuttallii*, *Z. paniculatus*, *Z. venenosus*.

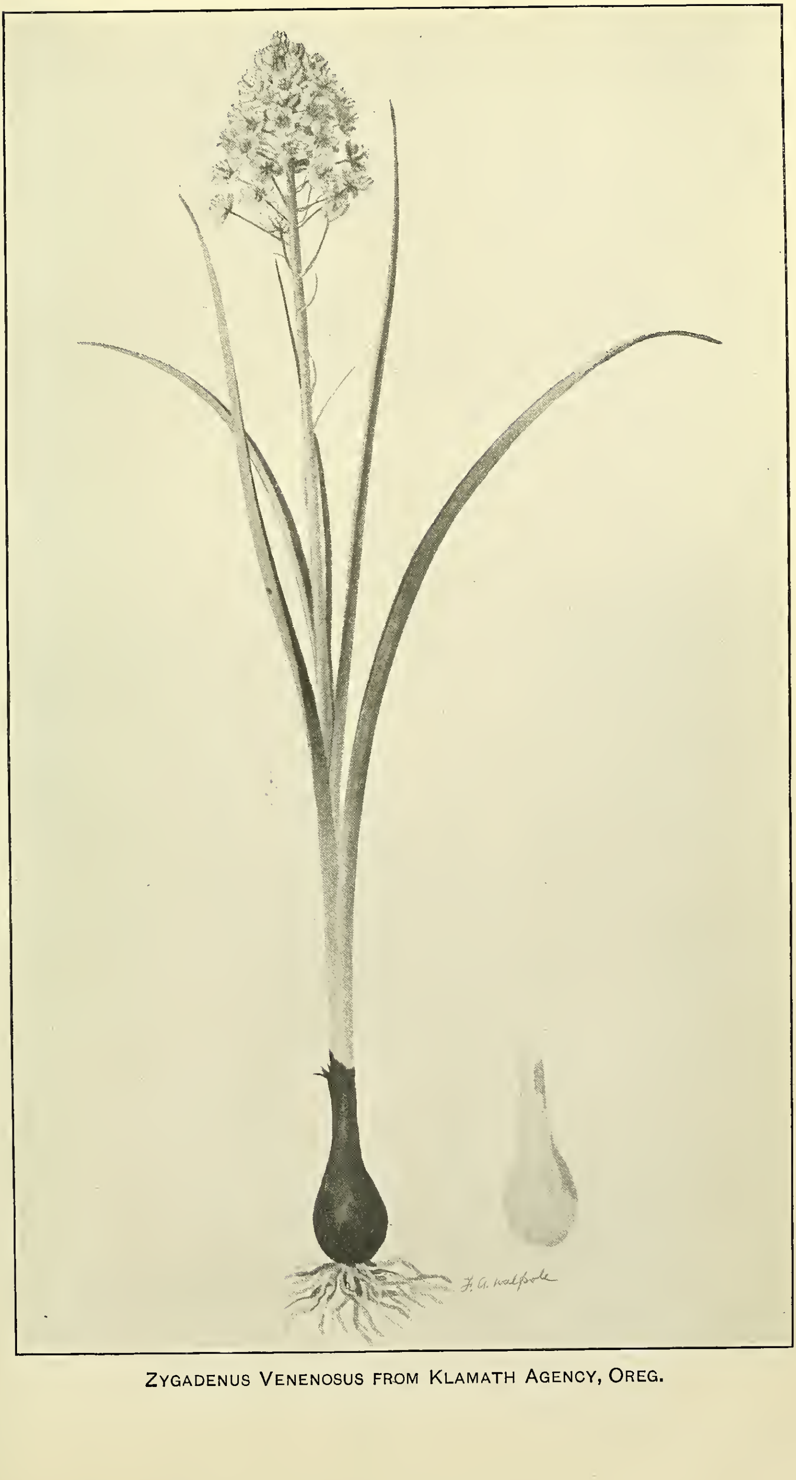
This list is given in accordance with the statements of various authors, and no attempt has been made to revise it from the standpoint of the systematic botanist. Apparently all species of this genus may be presumed to be poisonous. Even *Zygadenus coloradensis*, which has been shown not to be injurious to stock in Colorado, has the same poisonous principle as the other species, but in smaller quantity.

LOSSES OF LIVE STOCK BY ZYGADENUS.

As already stated, there is reason to think that deaths of cattle and horses from Zygadenus poisoning are not numerous. With sheep, however, the losses are very heavy, but it is impossible to make even an approximate estimate of these losses. It is probable that they are much greater than is generally supposed, for in the sheep-grazing regions many, perhaps most, of the herders do not know the plant and consequently do not recognize it as the cause of illness and death in the bands under their charge. The lupines, without any doubt, have been blamed for many of the cases of poisoning by Zygadenus.

Chesnut and Wilcox (1901, p. 53) state that 636 sheep died from Zygadenus poisoning in Montana in 1900 and that 3,030 were poisoned. In one locality in Wyoming 500 sheep died out of a total of 1,700 poisoned, and in one county it was said that 20,000 died in 1909. The writers of this paper investigated a case in Montana in which 500 sheep died within a few hours, the probable cause being Zygadenus.

There is no doubt that this plant is one of the sources of heaviest loss to sheep owners, especially in Wyoming and Montana. There is good reason, too, for thinking that many of the losses in Oregon, Utah, and California which have been ascribed to other plants were really caused by Zygadenus.



ZYGADENUS VENENOSUS FROM KLAMATH AGENCY, OREG.

ZYGADENUS VENENOSUS FROM MONTANA, IN BLOOM.

ZYGADENUS VENENOSUS FROM MONTANA, IN FRUIT.

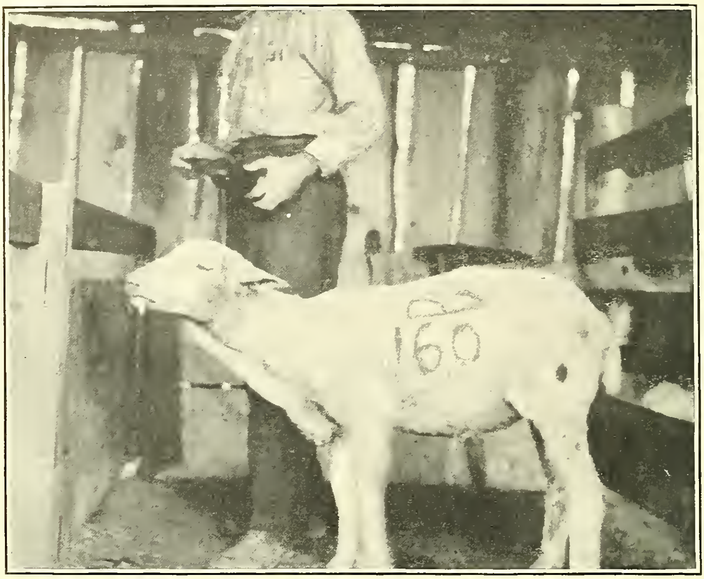


FIG. 1.—SHEEP NO. 160, SHOWING SALIVATION AND POSITION INDICATING NAUSEA.

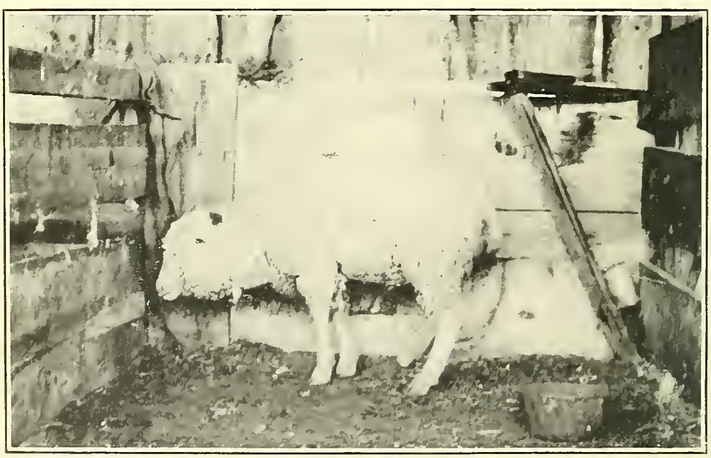


FIG. 2.—SHEEP NO. 192, SHOWING SALIVATION AND ATTITUDE INDICATING NAUSEA AND GENERAL DISCOMFORT.

ANIMALS POISONED BY ZYGADENUS.

Swine are said to eat Zygadenus bulbs with no bad results (Parsons, 1904, p. 8).

Cattle are susceptible to the poison and there are reports of resulting deaths. So far as has been learned, however, deaths of cattle from this cause are not common, and it is not especially to be feared by the cattlemen.

Many cases of horses poisoned by this plant are reported. The animals are made very sick, but apparently most of them recover. Mr. Uttermohl, of Bigtimber, Mont., who has had considerable experience with Zygadenus, is of the opinion that some of those that recover are permanently injured.

Sheep are the animals most frequently poisoned. This is probably due in part to a greater susceptibility to the toxic principle of Zygadenus, but very probably it is to a considerable extent due to the way in which sheep are managed upon the range. While grazing, they are frequently herded rather compactly, so that they eat the forage closely, and when passing over a Zygadenus area many of them may eat a large quantity of this plant.

The cases of human poisoning are mostly of children, who find the bulbs attractive and sometimes collect them instead of the edible camas, species of Calochortus and Camassia. Most of these cases recover, but there have been a number of fatalities.

SYMPTOMS PRODUCED BY ZYGADENUS POISONING.

With the exception of the work of Chesnut and Wilcox, nothing has been published in regard to the symptoms exhibited by grazing animals. These authors (1901, p. 61) state that the principal symptoms of poisoning in sheep are salivation, nausea, uneasiness, staggering, muscular incoordination, paralysis, and convulsions. The animals sometimes lie many hours before death. The writers mentioned state also that cattle and horses have spasms.

Several investigators have mentioned some of the symptoms in man. Heller (1909, p. 52) gives the symptoms (quoting from Dr. Lee, of Carson) as "nausea, headache, followed by more or less stupor." He states that the heart's action was lessened in frequency, while the strength of the pulse remained normal. The respirations were almost normal. In another case vomiting was followed by the loss of all power of feeling.

Heyl and Raiford (1911, p. 64) and Hunt (manuscript) speak of the irritating character of the dust when the dry plant is being ground, which leads to sneezing on the part of those doing the work.

The Lloyds (1887) give as symptoms in man "extreme thirst, constant vomiting, dilation of the pupil, coma, and inflammation of the stomach." They also say that one case had very violent convulsions.

Chesnut (1902, p. 321) says that the symptoms in poisoned Indians are "burning and smarting in the mouth and esophagus, dumbness, nausea, profuse vomiting, foaming at the mouth, dizziness, and mania."

Mitchell and Smith (1911) experimented with the extract on guinea pigs, both by subcutaneous injection and by feeding per os, and found salivation, vomiting, excitement, paralysis (first of the hind legs), rapid respiration becoming slow and labored, heightened reflexes, spasms, heartbeat slowed, and death, under fatal dosage, in 20 to 30 minutes. When injected into dogs under anæsthesia, the general effect was to reduce the rate of heartbeat and respiration and to produce marked intestinal peristalsis. The heart stopped before the cessation of respiration.

Hunt, Vejux-Tyrode, and Mitchell and Smith experimented on frogs, producing paralysis, which showed itself in an inability to draw up the legs readily after extension. Hunt considers that it produces an effect directly on the muscles as well as on the central nervous system.

Chesnut and Wilcox (1901) and Hunt (manuscript) experimented with rabbits, Hunt stating that the rabbits exhibited salivation, nausea, muscle changes, heightened reflexes, and convulsions.

Summarizing the published statements in regard to the symptoms of Zygadenus poisoning, it may be said that the most evident symptoms in the higher animals are salivation, nausea, more or less complete paralysis, reduced rate of heartbeat and respiration, and convulsions. The results on frogs are not so marked, as would be expected from the less complicated nervous system, and the principal thing noticed apparently is paralysis.

GENERAL STATEMENT OF EXPERIMENTAL WORK.

Experimental work upon Zygadenus has been carried on for five seasons, in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont. Table I gives a summary of these experiments. In 1909 six head of cattle were fed experimentally on *Zygadenus coloradensis* (Table I, section A). In 1910 a steer and four sheep were fed (Table I, sections B and E). In 1912 there were 18 cases of experimental feeding of *Zygadenus venenosus* to sheep (Table I, section F). In 1913 *Zygadenus venenosus* from the neighborhood of the station was fed to 61 sheep. In this section of the table are also given the results of one experiment in feeding *Zygadenus venenosus* from the Stanislaus National Forest, Cal., to a sheep. In 1913 *Zygadenus elegans*, collected near Red Lodge, Mont., was fed to 6 sheep (Table I, section H). In 1914 there were 110 cases of feeding of *Zygadenus venenosus* to sheep (Table I, section I) and five experiments of feeding to sheep *Zygadenus elegans* from the

Fishlake National Forest, Utah (Table I, section J). There were also two experimental feedings of *Zygadenus paniculatus* from Ephraim, Utah (Table I, section K). Three head of cattle in 1913 were fed upon *Zygadenus venenosus* (Table I, section C), and a horse was fed twice upon *Zygadenus venenosus* and once upon *Zygadenus elegans* (Table I, section D).

So far as possible, the feeding experiments were carried on under natural conditions. To this end the animals were, ordinarily, deprived of food for about 24 hours, and then the plant to be tested was offered to them. If they did not eat readily, they were tempted by mixing the plant, sometimes ground up, with hay or grain. As it was difficult to get any large number of cases by feeding, on account of the dislike of the animals to the plant, resort was had to drenching and forced feeding. In the drenching experiments, the plant was ground and suspended in sufficient water to make the administration possible, the drenching being done in most cases with the animal upon its haunches. Forced feeding was conducted in some cases by placing the plant by hand, a little at a time, in the animal's mouth. In the majority of experiments in forced feeding, however, a veterinarian's ordinary balling gun was used, and the ground material was fed as fast as the animal would swallow it.

The terms under "Severity of illness" are used in the following way:

"Not sick" includes cases in which no symptons appeared.

"Symptoms" includes cases in which there was slight salivation for a few minutes, some regurgitation, some licking of the lips, indicating nausea, or indications of uneasiness.

"Slightly sick" includes those in which salivation was continued for an hour or more, with considerable regurgitation. Depression, slightly labored respiration, and temperature reduction may occur.

"Sick" includes cases exhibiting vomiting, weakness, and sometimes hypersensitiveness and trembling.

"Very sick" cases were characterized by prostration, extreme respiratory difficulty, and subnormal temperature.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*

[Animals designated by an asterisk (*) preceding the serial number were given dry material; but the weight is stated in the form of an equivalent amount of green plant, the loss in drying having been determined by a number of experiments.]

Animal. Designation.	Animal. Weight.	Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
A.—Cattle given Z. coloradensis:	*Pounds.*	*Pounds.*	1909.					*Per 1,000 pounds.*	
No. 112	610	5.07	July 14 to 16	Leaves and buds	Not sick	None		8.31	
No. 117	620	1.87	July 15	Bulbs (in chop)	do	do		3	
No. 97	500	6.58	July 17 to 19	Leaves and buds	do	do		13.16	
No. 113	750	5.94	July 19 and 20	Bulbs (in chop)	do	do		7.92	
No. 115	610	12.22	July 20	Leaves, stems, and flowers.	do	do		20	
No. 107	420	7.62	Aug. 1 and 2	Leaves, stems, flowers, and bulbs.	do	do		18.14	
B.—Steer given Z. coloradensis:			1910.						
No. 119	300	97.5	Aug. 8 to 13	Leaves, stems, fruit, and bulbs.	do	do		325	North of camp.
C.—Cattle given Z. venenosus:			1913.						
No. 655	±500	2	June 6 and 7	Leaves	do	do		4	Station.
No. 660	±500	29	June 12 to 17	Leaves, stems, and flowers.	Symptoms	do	Recovery	58	Do.
No. 659	±500	55.5	June 21 to 27	do	Symptoms after eating 46½ pounds.	do	do	111	Do.
D.—Horse:			1913.						
No. 125	±700	8.5	June 15 to 18	Leaves of Z. venenosus.	Not sick	do		12.1	Do.
		9	July 9 to 12	Leaves, stems, and flowers of Z. venenosus.	do	do		12.9	Do.
		10.5	July 24 to 29	Leaves, stems, flowers, some fruit, and bulbs of Z. elegans.	do	do		15	Beartooth National Forest.
E.—Sheep given Z. coloradensis:			1910.					*Per 100 pounds.*	
No. 112	100	16	July 15 to 19	Leaves, stems, flowers, and bulbs.	do	do		16.7	North of camp.
No. 112	100	82	July 24 to Aug. 5	Leaves, stems, flowers, and fruit.	do	do		82	Do.
No. 111	72	45.5	Aug. 15 to 24	Leaves, stems, and fruit.	do	do		63	Do.
No. 118	97	39.5	Aug. 25 to 31	do	Symptoms	do	Recovery	40.7	Do.

F.—Sheep given Z. venenosus:			1912.						
No. 167	68	.771	June 25 to 27	Leaves, stems, and flowers (drench).	Not sick	do		1.134	George Hughes's.
No. 163	65 to 57½	5.5	June 26 to July 4	Leaves, stems, flowers, and fruit.	do	do		8.461	Do.
No. 175	77 to 71	14.5	June 26 to July 7	Leaves, stems, flowers, and fruit; partly dry.	do	do		18.831	Do.
No. 181	53 to 45	5.5	do	Leaves, stems, flowers, and fruit.	do	do		10.377	Do.
No. 176	75	1.322	July 6	Leaves, stems, and fruit (drench).	Sick	do	Recovery	1.762	Do.
No. 159	73	1.565	July 7	do	Slightly sick after taking 0.79 pound; very sick.	do	do	2.144	Do.
No. 172	77		do	Water control (drench)	Not sick	do			
No. 168	67½	1.102	July 10	Leaves, stems, and fruit (drench).	Slightly sick after taking 0.33 pound; very sick.	Potassium permanganate; whisky.	Recovery	1.632	Do.
No. 162	102½ to 84½	1.212	July 11	do	Slightly sick after taking 0.771 pound; very sick.	Caffein sodiobenzoate.	do	1.182	Do.
No. 161	77½	.661	July 13	Seed heads (drench)	Sick after taking 0.33 pound; death.	do	Death	.853	Do.
No. 171	83 to 75½	.771	do	Leaves and stems (drench).	Symptoms after taking 0.33 pound, slightly sick.	None	Recovery	.929	Do.
No. 174	55	.308	July 14	Seed heads (drench)	Death	Ammonia; caffein sodiobenzoate; tannic acid.	Death	.560	Do.
No. 172	78	.110	July 17	do	Symptoms	None	Recovery	.141	Do.
No. 177	51½	.121	July 18	do	Sick	do	do	.235	Do.
No. 160	92	.275	July 19	do	Death	Potassium permanganate; caffein sodiobenzoate; whisky; digitalis.	Death	.299	Do.
No. 176	75	.198	July 20	do	Sick	None	Recovery	.264	Do.
No. 181	50	.132	July 23	do	Sick from Zygadenus; killed in drenching with potassium permanganate.	Caffein sodiobenzoate; potassium permanganate.	Death	.264	Do.
No. 175	83	.143	July 24	do	Symptoms	None	Recovery	.172	Do.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal. Designation.	Animal. Weight.	Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
G.—Sheep given Z. venenosus:	*Pounds.*	*Pounds.*	1913.					*Per 100 pounds.*	
No. 196	65½ to 64	1.378	May 11 and 12	Leaves	Sick	None	Recovery	2.104	George Hughes's.
No. 191	64	.631	May 11 to 13	do	Not sick	do		.986	Station.
No. 197	66	.397	May 12 and 13	do	do	do		.601	Do.
No. 193	74	.441	May 13	Bulbs (drench)	Sick	do	Recovery	.595	Do.
No. 187	59 to 61	.441	May 14	Leaves (drench)	Very sick	Strychnin	do	.747	Do.
No. 195	72	.441	do	Bulbs (drench)	Slightly sick	None	do	.612	Do.
No. 186	64 to 64	.331	May 15	do	do	do	do	.517	Do.
No. 198	64 to 61½	1.219	May 15 and 16	Leaves	Sick	do	do	1.905	Do.
No. 188	74 to 71	.661	May 16	do	do	do	do	.893	Do.
No. 189	65	.485	May 17	Leaves (drench)	Death	Strychnin; gin.	Death	.746	Do.
No. 190	71 to 62¾	.220	May 17 to 20	Leaves	Not sick	None		.310	Do.
No. 192	59½ to 53¾	2.094	May 18 to 20	Bulbs (in alfalfa)	do	do		3.519	Do.
No. 184	64 to 58¾	.375	May 19	Leaves (drench)	Sick	do	Recovery	.586	Do.
No. 191	64 to 58¼	.375	do	do	do	Potassium permanganate.	do	.586	Do.
No. 205	48½ to 46¾	.276	May 22	do	do	Diuretin; caffein citrate.	do	.569	Do.
No. 204	71 to 63½	.441	May 22 to 24	Leaves (in alfalfa)	Not sick	None		.621	Do.
No. 200	77¼ to 72½	.452	May 23	Leaves (drench)	Very sick	Diuretin; caffein citrate.	Recovery	.585	Do.
No. 206	69½ to 67½	.386	May 24	Leaves, stems, and buds (drench).	do	None	do	.555	Do.
No. 203	97 to 91½	.551	do	Leaves (drench)	Sick	Diuretin; caffein citrate.	do	.568	Do.
No. 197	68¾	.392	May 26	do	Death	Diuretin; caffein citrate; gin; ammonia.	Death	.572	Do.
No. 198	70½	.403	do	do	Sick	None	Recovery	.571	Do.
No. 186	71	.992	May 26 to 31	Leaves	Death	Eserin; strychnin; morphin.	Death, due to morphin. (?)	1.397	Do.
No. 188	78¾	.430	May 27	Leaves (drench)	do	Apomorphin; eserin; strychnin.	Death	.546	Do.
No. 191	57½ to 53	.883	May 28 to 31	Leaves	Very sick	None	Recovery	1.536	Do.
No. 190	71 to 67½	.276	May 29	Leaves, stems, buds, and flowers (drench).	Sick	Eserin; strychnin.	do	.389	Do.
No. 192	62	.238	May 30	Leaves (drench)	Death	Gin	Death	.384	Do.

No. 195	83½	.322	....do	....do	Sick	Eserin; strychnin.	Recovery	.385	Do.
No. 196	65 to 58¼	.220	June 3 to 5	Leaves	Not sick	None		.338	Do.
No. 198	63¼	1.146	June 3 to 7	Leaves, stems, and flowers.	Symptoms	....do	Recovery	1.812	Do.
No. 206	69¼ to 69¼	.298	June 4	Leaves, stems, and flowers (drench).	Not sick	Tannic acid[1]		.430	Do.
No. 200	76	.293	June 5	....do	....do	None		.386	Do.
No. 201	79 to 73¼	.304	....do	....do	....do	Tannic acid[1]		.385	Do.
No. 199	50½ to 52	.220	June 5 to 7	Leaves, stems, and flowers.	....do	None.		.435	Do.
No. 210	80¼ to 77¼	.399	June 6	Leaves, stems, and flowers (drench).	Slightly sick	Tannic acid[1]	Recovery	.496	Do.
No. 209	79¼ to 75¼	.392	....do	....do	Sick	None	...do	.495	Do.
No. 212	93¾ to 90	.516	June 7	....do		Tannic acid[1]		.550	Do.
No. 213	91¾	.505	....do	....do	Death	None	Death	.550	Do.
No. 208	89½ to 78	3.307	June 7 to 10	Leaves, stems, and flowers.	Sick	Tannic acid[1]	Recovery	3.695	Do.
No. 207	67¾ to 59¾	.220	June 7 to 11	....do	Not sick	None		.325	Do.
No. 211	84½ to 71	1.455	June 9 and 10	....do	Sick	....do	Recovery	1.728	Do.
No. 214	64 to 57	1.146	June 10 and 11	....do	....do	Tannic acid;[1] Epsom salts.	...do	1.789	Do.
No. 216	85¾ to 77	1.834	June 13 to 19	Leaves (in bran)	Symptoms	None	...do	2.139	Avery, Cal. Station.
No. 193	71 to 66	3.274	June 15 to 17	Leaves, stems, and flowers.	Sick	Tannic acid;[1] Epsom salts; diuretin.	...do	4.606	
No. 202	72½ to 65	1.213	June 15 to 18	....do	Not sick	None		1.672	Do.
No. 215	78 to 63	1.102	June 19 to 29	....do	....do	....do		1.413	Do.
No. 200	75	.474	June 20 to 22	....do	....do	....do		.633	Do.
No. 201	73 to 69	5.247	June 22 to 28	Leaves, stems, flowers, and young fruit (in bran).	Symptoms	....do	Recovery	7.188	Do.
No. 210	83 to 67	4.894	June 23 to 30	Leaves, stems, and flowers (in bran).	Not sick	....do		5.896	Do.
No. 209	81½ to 67	2.282	June 26 to 30	....do	....do	....do		2.800	Do.
No. 196	78 to 62½	3.086	June 27 to 30	Leaves, stems, and fruit (in bran).	....do	....do		3.956	Do.
No. 190	73 to 63½	1.731	July 4 to 7	Young seed heads (in bran).	....do	....do		2.371	Do.
No. 216	89 to 76½	1.896	July 6 to 8	Leaves, stems, and flowers (dry).	Sick	Diuretin	Recovery	2.896	Do.
No. 195	84 to 70	.452	July 6 to 11	....do	Not sick	None		.538	Do.
No. 203	110 to 98½	3.472	July 6 to 12	Seed heads with a few leaves and flowers (dry).	Sick	Tannic acid;[1] diuretin.	Recovery	3.155	Do.
No. 193	73½ to 66	4.112	July 16 to 19	Seed heads in bran (dry).	....do	None	...do	5.597	Do.
No. 199	59½	.055	Aug. 13	Seed (in bran)	....do	....do	...do	.092	Do.
No. 196	73 to 70	.110	Aug. 13 and 14	....do	Symptoms	....do	...do	.151	Do.
No. 218	60	.066	Aug. 14	....do	Not sick	....do		.110	Do.
No. 185	64 to 58	.154	Aug. 15 and 16	....do	Symptoms after eating 45 grams.	....do	Recovery	.241	Do.

[1] Drench.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
G.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1913.					*Per 100 pounds.*	
No. 212	98 to 89	0.441	Aug. 16 and 17	Seed (in bran)	Not sick	None		0.450	Station.
No. 215	74 to 64	.095	Aug. 17	do	do	do		.128	Do.
No. 207	77 to 70½	.311	Aug. 19 and 20	do	do	do		.404	Do.
H.—Sheep given Z. elegans:									
No. 214	61 to 55	.441	July 25 and 26	Leaves, stems, flowers, and some bulbs.	do	do		.723	Beartooth National Forest.
No. 198	64	4.045	July 25 to 31	Leaves, stems, flowers, fruit, and some bulbs.	do	do		.632	Do.
No. 201	69 to 59	3.858	do	Leaves, stems, flowers, some fruit, and bulbs.	do	do		5.591	Do.
No. 199	60 to 54	.264	July 28	Leaves, stems, flowers, and some fruit (drench).	Symptoms	do	Recovery.	.440	Do.
No. 217	58 to 55	.412	July 29	do	Not sick	do		.710	Do.
No. 185	61 to 56	.403	Aug. 1	do	Slightly sick	Tannic acid [1]	Recovery.	.660	Do.
I.—Sheep given Z. venenosus:			1914.						
No. 278	79½ to 69½	0.254	May 27 to 29	Leaves, stems, flowers, and buds (with grass).	Not sick	None		.319	Greycliff
No. 269	96 to 88½	.287	May 27 to 30	do	do	do		.299	Do.
No. 276	85½	.551	May 28	Leaves, stems, flowers, and buds (forced feeding).	Death	Tannic acid; [1] eserin; pilocarpin; whisky; gin (enema).	Death	.644	Do.
No. 237	83½	(2)	May 28 to 30	Leaves, stems, flowers, and buds.	Not sick	None			
No. 255	89 to 85	1.543	do	Leaves, stems, flowers, and buds (with grass).	do	do		1.734	Do.
No. 234	89 to 85	.441	May 29	Leaves, stems, flowers, and buds (forced feeding).	Slightly sick	do		.495	Do.
No. 282	85 to 80	.421	do	do	do	Tannic acid [1]	Recovery.	.495	Do.
No. 232	93 to 86	.483	June 1	Leaves and some young buds (forced feeding).	Not sick	None		.519	Station.

No. 248	94 to 85½	.441	do	Leaves and some young buds (with grass).	do	do		.469	Do.
No. 267	106 to 98	.529	do	Leaves and some young buds (forced feeding).	Symptoms	do	Recovery	.499	Do.
No. 239	84½ to 78½	.465	June 2	do	do	do		.550	Do.
No. 256	83 to 78	.457	do	do	Not sick (?)	do	Recovery	.551	Do.
No. 243	80½ to 76	1.323	June 2 and 3	Leaves, some young buds, and a few flowers (with grass).	Not sick	do		1.643	Do.
No. 229	104 to 100½	.539	June 3	Leaves, stems, flowers, and buds (forced feeding).	Sick	Tannic acid [1]	Recovery	.518	Do.
No. 235	101½ to 89½	.526	do	do	do	None	do	.518	Do.
No. 245	100 to 97½	.529	June 4	do	Slightly sick	Tannic acid [1]	do	.529	Do.
No. 257	95 to 87¾	.503	do	do	Sick	None	do	.529	Do.
No. 231	107 to 101	1.323	June 4 and 5	Leaves, stems, flowers, and buds (with grass).	Not sick	do		1.236	Do.
No. 265	90 to 84	.476	June 5	Leaves, stems, flowers, and buds (forced feeding).	do	do		.529	Do.
No. 249	89 to 81	.471	June 6	do	do	do		.529	Do.
No. 266	90½ to 81½	.479	do	do	do	do		.529	Do.
No. 264	107	.666	June 8	do	Sick	Raw oil and charcoal.	Recovery	.622	Do.
No. 268	110 to 102⅗	.649	do	do	do	None	do	.590	Do.
No. 246	98 to 93	1.874	June 9	Leaves, stems, flowers, and buds (with grass).	Very sick	Tannic acid (in capsules).	do	1.912	Do.
No. 247	105 to 109	.441	do	do	Not sick	None		.420	Do.
No. 255	91 to 84	.602	June 15	Leaves (forced feeding).	do	do		.661	Do.
No. 269	92½ to 87	.612	do	do	Slightly sick	Tannic acid (in capsule).	Recovery	.662	Do.
No. 282	85 to 79	.562	June 16	do	do	do	do	.661	Do.
No. 283	75 to 71	.269	do	Stems, flowers, and young fruit (forced feeding).	Not sick	None		.359	Do.
No. 237	83 to 79	.628	June 17	Leaves, stems, flowers, and young fruit (forced feeding).	Symptoms	do	Recovery	.757	Do.
No. 238	83 to 74	.639	do	do	Not sick	do		.770	Do.
No. 235	103 to 95½	.851	June 18	do	Symptoms	do	Recovery	.826	Do.
No. 245	102 to 95	.843	do	do	do	do	do	.826	Do.
No. 239	79½ to 75	.789	June 19	do	Slightly sick	Tannic acid (in capsule).	do	.992	Do.
No. 256	79 to 75	.784	do	do	Not sick	None	do	.992	Do.
No. 231	109½ to 99½	.882	June 20	Leaves, stems, and flowers (with grass).	do	do		.805	Cabin Corral.

[1] Drench.

[2] Very few grams.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal. Designation.	Animal. Weight.	Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
I.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1914.					*Per 100 pounds.*	
No. 234	86 to 81	1.043	June 20	Leaves, stems, and flowers (forced feeding).	Slightly sick	Tannic acid (in capsule).	Recovery	1.213	Cabin Corral.
No. 249	84½ to 79	.838	do	do	Sick	do	do	.992	Do.
No. 265	85 to 78	.843	do	do	Slightly sick	None	do	.992	Do.
No. 266	92 to 88½	1.093	do	do	Symptoms	do	do	1.188	Do.
No. 251	90½ to 86½	1.300	June 22	Leaves, stems, flowers, and buds (forced feeding).	do	do		1.436	Do.
No. 263	95	1.362	do	do	Not sick	do	Recovery	1.434	Do.
No. 232	78 to 70½	1.455	June 23	do	Sick	Tannic acid (in capsule).	do	1.865	Do.
No. 253	75½ to 70½	1.413	do	do	do	None	do	1.871	Do.
No. 229	112½ to 98½	2.231	June 24	do	Slightly sick	Tannic acid (in capsule).	do	1.983	Do.
No. 264	102½	2.033	do	Leaves, stems, flowers, and buds (in 7 forced feedings).	Not sick	None		1.983	Do.
No. 268	111 to 101½	2.202	do	Leaves, stems, flowers, and buds (forced feeding).	Sick	do	Recovery	1.984	Do.
No. 240	103½ to 98½	2.282	June 25	Leaves, stems, and flowers (forced feeding).	Slightly sick	Tannic acid (in capsule).	do	2.205	Do.
No. 250	103½ to 99½	1.142	do	Leaves, stems, and flowers (drench).	Sick	None		1.103	Do.
No. 280	99 to 94½	2.183	do	Leaves, stems, and flowers (forced feeding).	Slightly sick	do	Recovery	2.205	Do.
No. 262	80 to 78	2.205	June 26	do	do	do	do	2.756	Do.
No. 278	82 to 81	2.260	do	do	do	Tannic acid (in capsule).	do	2.756	Do.
No. 247	112½ to 100	2.425	June 27	do	Not sick	None		2.156	Do.
No. 255	96½ to 95½	1.064	do	Leaves, stems, and flowers (drench).	do	do		1.103	Do.
No. 277	99	.655	do	do	do	do		.662	Do.

No. 243	85½	.377	June 29	Seed heads, nearly developed (forced feeding).	do	do		.441	Station.
No. 281	77 to 64	.679	do	do	Slightly sick	do	Recovery	.881	Do.
No. 255	95½ to 90½	1.053	June 30	do	do	do	do	1.103	Do.
No. 257	95	1.047	do	do	Sick	Tannic acid (in capsule).	Killed by choking on capsule.	1.102	Do.
No. 237	89 to 83½	1.177	July 1	do	do	do	Recovery	1.322	Do.
No. 238	88 to 82½	1.164	do	do	do	None	do	1.323	Do.
No. 281	71 to 68½	1.024	July 2	Seed heads, some fully developed and others half developed (forced feeding).	Not sick	Tannic acid (in capsule).		1.442	Cabin Corral.
No. 283	82½ to 76½	1.182	do	do	Slightly sick	None	Recovery	1.432	Do.
No. 259	115½ to 98½	3.968	July 2 and 3	Leaves, stems, flowers, and young fruit.	Not sick	do		3.435	Do.
No. 235	102½ to 101	1.582	July 3	Seed heads, very young (forced feeding).	Symptoms	do	Recovery	1.543	Station.
No. 267	105½ to 98½	1.628	do	Seed heads, half developed (forced feeding).	do	Tannic acid (in capsule).	do	1.543	Cabin Corral.
No. 282	93	1.640	July 5	do	Very sick	Tannic acid (in capsule); whisky.	do	1.763	Do.
No. 256	85½ to 80	1.508	do	do	Sick	None	do	1.764	Do.
No. 239	83½	.828	July 7	Seed heads, fully developed (forced feeding).	Death	Tannic acid (in capsule); oil and turpentine.	Death	.992	George Hughes's.
No. 245	105½ to 100½	1.047	do	do	Sick	Tannic acid (in capsule).	Recovery	.994	Do.
No. 269	101 to 95	1.002	do	do	do	None	do	.992	Do.
No. 231	112 to 111½	1.111	July 8	do	do	Tannic acid;[1] caffein sodiobenzoate.	do	.992	Do.
No. 233	130½ to 126½	1.295	do	do	do	None	do	.992	Do.
*No. 249	87	.862	July 9	do	Death	do	Death	.991	Do.
*No. 251	86 to 79	.853	do	do	Sick	Tannic acid (put into rumen).	Recovery	.992	Do.
No. 246	98½ to 92	.326	July 10	Seed heads, fully developed (drench).	Symptoms	None		.331	Do.
*No. 266	94	1.554	do	Seed heads, fully developed, mixed with potassium permanganate (drench).	do	Potassium permanganate.	Recovery	1.653	Do.

[1] Drench.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
I.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1914.					*Per 100 pounds.*	
No. 234	79 to 74	0.348	July 11	Seed heads, fully developed (drench).	Sick	None	Recovery	0.441	George Hughes's.
No. 253	77 to 76	.340	...do	Seed heads, fully developed, mixed with potassium permanganate (drench).	Not sick	Potassium permanganate.		.441	Do.
*No. 252	89 to 85	.392	July 13	Seed heads, fully developed (forced feeding).	Slightly sick	Potassium permanganate (put into rumen).	Recovery	.440	Do.
*No. 264	105 to 98	.463	...do	...do	Symptoms	None	...do	.440	Do.
No. 254	90 to 88	.683	July 14	...do	Slightly sick	Tannic acid [1]	...do	.759	Do.
No. 268	102 to 96	.899	...do	...do	Sick	Potassium permanganate.	...do	.881	Do.
No. 262	84	.741	July 15	...do	Death	Caffein	Death	.882	Do.
No. 283	81½ to 70	.719	...do	...do	Sick	Potassium permanganate.		.882	Do.
No. 290	83½ to 85	.736	...do	...do	Very sick	Charcoal; atropin.	Recovery	.881	Do.
No. 259	120 to 108	.888	July 22	Seed heads, ripening (forced feeding).	...do	Charcoal	...do	.740	Do.
*No. 247	113 to 100	.838	July 23	...do	...do	Atropin	...do	.741	Do.
*No. 263	91 to 88½	.802	Aug. 7	Seed heads, fully developed (forced feeding).	Slightly sick	Tannic acid (repeated doses).	...do	.881	Do.
*No. 269	92 to 80½	.811	Aug. 10	...do	Very sick	None	...do	.882	Do.
*No. 231	92	.612	Aug. 11	...do	Not sick	...do		.665	Do.
*No. 259	106½ to 101	.939	Aug. 13	...do	Very sick	Sodium bicarbonate (repeated doses).	Recovery	.882	Do.
No. 267	100½ to 91	.886	Aug. 14	...do	Sick	Tannic acid (repeated doses).	...do	.882	Do.
*No 294	65½ to 60½	.578	Aug. 15	...do	Very sick	None	...do	.882	Do.

*No. 296	72½ to 72½	.639	do	do	Sick	Tannic acid (repeated doses).	do	.881	Do.
*No. 265	89 to 84½	.981	Aug. 17	do	do	do	do	1.102	Do.
*No. 291	86 to 77½	.758	do	do	Very sick	Magnesium sulphate; tannic acid (repeated doses); atropin.	do	.881	Do.
*No. 293	68 to 61	.600	Aug. 21	do	Sick	Sodium bicarbonate (repeated doses).	do	.882	Do.
*No. 292	87 to 77½	.959	Aug. 22	do	Very sick	do	do	1.102	Do.
*No. 246	102½	1.506	Aug. 24	do	do	do	do	1.469	Do.
*No. 247	111 to 106½	.368	Aug. 25	Seed heads, fully developed (in bran).	Not sick	None		.331	Do.
*No. 264	95	1.047	do	Seed heads, fully developed (forced feeding).	Death	Sodium bicarbonate (repeated doses).	Death	1.102	Do.
*No. 240	80½ to 81	.705	Aug. 26	do	Sick	do	Recovery	.876	Do.
*No. 277	84 to 68	.772	do	do	Very sick	do	do	.919	Do.
*No. 299	77 to 68	.416	Sept. 8	Seed pods, with seed removed (forced feeding).	do	Bled	do	.540	Do.
No. 235	79	.087	Sept. 11	Seed (forced feeding)	Slightly sick	None	do	.110	Do.
No 251	66	.145	do	do	Death	do		.219	Do.
No. 245	75½	.149	Sept. 12	do	Very sick	Bled	Recovery	.197	Do.
No. 297	76½	.152	do	do	Death	do	Death	.199	Do.
No. 266	69½	.153	Sept. 13	do	do	do	do	.220	Do.
J.—Sheep given Z. elegans:									
No. 233	111	.244	Aug. 8	Leaves, stem, flowers, and pods (forced feeding).	Not sick	None		.219	Fishlake National Forest, Utah.
No. 246	97	.434	do	do	do	do		.447	Do.
No. 281	64 to 60	.846	Aug. 9	do	Not sick (?)	do		1.322	Do.
No. 292	82 to 78	.723	do	do	do	do		.882	Do.
No. 232	75 to 71½	1.267	Aug. 11	Leaves, stems, flowers, and some young pods (forced feeding).	Not sick	do		1.689	Do.
K.—Sheep given Z. paniculatus:									
No. 278	80½	.444	June 10	Leaves, stems, and fruit (forced feeding).	Slightly sick	do	Recovery	.551	Ephraim, Utah.
No. 281	72	.317	do	do	Symptoms	do	do	.440	Do.

[1] Drench.

Following are the details of three cases which may be considered typical:

Sheep No. 193.—This animal (Table I, section G) was a 2-year-old ewe, lent for experimental purposes by Mr. Ole Birkeland. She was received at the station on May 9, 1913. An attempt was made on May 12 to feed to her the bulbs of *Zygadenus venenosus* ground and mixed with bran. As she would not eat this, a trial was made on May 13 of feeding her with Zygadenus tops, but these also she refused to eat; so at 1.40 p. m. of the same day she was drenched with 200 grams of *Z. venenosus* bulbs ground fine and suspended in water. At 2.35 p. m. she was frothing at the mouth and vomiting, with violent contractions of the diaphragm and abdominal muscles. She was lying down, but was able to stand. At 3.50 p. m. she was still frothing at the mouth, but was fairly strong. At 5.30 p. m. her temperature was 101° F. She was fairly strong, but acted as though in much discomfort. On May 14, at 7 a. m. she appeared entirely normal, and at 8.30 she was turned out to pasture.

On June 14, 1913, she was kept in for feeding, and at 8.15 a. m. she was fed 100 grams of fresh tops of *Zygadenus venenosus,* which were collected on June 12. At this time the plant was in flower. At 4.40 p. m. she was fed 200 grams of the plant, and at 7.40 p. m. 135 grams.

On June 16, at 7.10 a. m., she was fed 200 grams; at 6.40 p. m., 200 grams; and at 7.15 p. m., 250 grams. All the Zygadenus fed on June 16 had been collected on the preceding day.

On June 17, at 6.45 a. m., all the Zygadenus given on the preceding day had been eaten. The animal appeared bright, but showed sensitiveness to sudden noises and there was some trembling of the surface muscles. At 7 a. m. she was run around the corral. It was found that she moved in a stiff-legged manner and was somewhat weak. The stiffness was most noticeable in the hind legs. She was licking her lips and rubbing her nose against the fence and moving her head about in a jerky way. At 8.45 a. m. the symptoms were about the same as at 7. a. m. At this time she was fed 200 grams of Zygadenus. At 11.30 a. m. and 1.50 p. m. she was fed 100 grams of Zygadenus. At 3 p. m. her temperature was 103.8° F. She was more nervous than in the morning and her movements were somewhat more stiff. The jerking movements were more pronounced and continuous. All the Zygadenus which had been previously given had been eaten. At 8 p. m. the symptoms as noted at 3 o'clock still continued She was fed a little alfalfa.

On June 18, at 6.45 a. m., the sheep was trembling almost constantly, with frequent spasmodic movements. Her legs were stiff as she walked about, and there was some lack of control. She was dejected and dull and without appetite. At 9 a. m. she was given 5 grams of tannic acid. At 9.40 she was given 4 ounces of Epsom salts in solution. At 10.30 a. m. she was put in a metabolism cage, in order to collect the excretions. At 2 p. m. she seemed to be decidedly better, and continued in about the same condition throughout the afternoon.

On June 19, at 6.30 a. m., the animal trembled, but showed no other symptoms. She had not urinated since being placed in the metabolism cage at 10.30 a. m. on the preceding day. At 8 a. m. she was taken out of the cage and fed some alfalfa. The general appearance of the animal was better than on the preceding day, but she was still unsteady in her gait and exhibited trembling of the surface muscles. At 1 p. m. she defecated as the result of the dose of magnesium sulphate given on the preceding day, and this defecation continued in a mild diarrhea. At 3 p. m. she urinated for the first time after being placed in the metabolism cage. At this time her respiration was 148, and she seemed in general to be worse. At 8 p. m. she was given 1 gram of diuretin in solution, and returned to the metabolism cage. During the afternoon the animal seemed to be gradually getting worse. When standing, her hind legs were drawn forward under her. The muscles of the legs were twitching almost continuously, and it was with difficulty that she could get up and down.

On June 20, at 6.30 a. m., there were about 1½ pints of urine which had accumulated through the night. This was preserved in alcohol, and a chemical examination showed that it contained the alkaloids of Zygadenus. The diarrhea still continued. The general condition of the animal was nearly the same as the preceding night, except that she appeared a little stronger. She was taken out of the cage and fed alfalfa. At 2 p. m. she was somewhat better than in the morning and had an appetite, although she still preferred to lie down. At this time she was given 1 gram of diuretin in solution. At 7.50 p. m. she was much better, standing in a more normal manner and with no noticeable trembling. On June 22 she was turned out, apparently all right.

On July 15, 1913, the sheep was again kept in for feeding, and on July 16, at 10.30 a. m., she was given 200 grams of the mature heads of *Zygadenus venenosus*, consisting of pods and seeds, ground and mixed in bran.

On July 17, at 9.25 a. m., she was fed 270 grams prepared as the day before, and at 1.25 p. m. she was fed 180 grams. At 7.45 p. m. she was fed 210 grams. At the time of the last feeding she showed the effects of the poisoning. She did not move with the usual freedom, and there was some twitching of the surface muscles of the body.

On July 18, at 9.50 a. m., she was fed 235 grams. At 6.30 p. m. she was fed 220 grams. During the day there was little change in the condition of the animal.

On July 19, at 7 a. m., the symptoms were much more pronounced than the preceding night. There was stiffness of movement of the legs, licking of the lips, and slight trembling. This stiffness and accompanying clumsiness were more pronounced in the hind legs. At 9 a. m. she was fed 255 grams and at 3 p. m. 195 grams. At this time the animal was considerably weaker than in the morning.

On July 20, at 8.45 a. m., all the Zygadenus given on the preceding day had been eaten, and the general condition of the animal was about the same as on the preceding night. She moved with some difficulty and with marked stiffness of the legs. There was trembling of the surface muscles accompanied by some shaking of the head and licking of the lips. She was unusually sensitive to noise, as she was easily startled, and at such times there were sudden contractions of the body muscles. She had much difficulty in raising her feet sufficiently to get over elevations of 3 or 4 inches.

On July 21, at 3 p. m., the animal had improved in its general condition, although the symptoms were still well marked. These did not differ from those seen earlier in the sickness, but were less pronounced.

On July 22, at 7 a. m., the animal moved about fairly well, but there was some trembling of the surface muscles, especially in the shoulders. She improved during the day and at 7 p. m. seemed to be quite normal. On July 23, at 7.55 a. m., she was turned out to pasture, appearing strong and active and showing no symptoms except some slight trembling when handled.

Sheep No. 160.—This animal (Table I, section F) was a ewe lent by Mr. Ole Birkeland on June 20, 1912. On July 19, 1912, she was taken in for feeding with *Zygadenus venenosus*. At 11.05 a. m. her respiration was 28, pulse 26, and temperature 105° F. At 11.25 a. m. she was drenched with 125 grams of the seed heads of *Zygadenus venenosus* suspended in water. These seed heads included the pods and seeds. At 11.35 a. m. there was a little frothing at the mouth. At 11.40 a. m. her respiration was very rapid and irregular. It would run as high as 200 per minute for perhaps 50 respirations, then stop, only to be resumed at the same rapid rate. At this time the animal had vomited. At 12.55 her pulse was 95 and very variable; her temperature was 104° F. At 1 p. m. her respiration was 200 or more and the heart action regular and strong. She was then given a solution of potassium permanganate. At 1.17 p. m. she was getting weaker on her legs. She would start to lie down and nearly fall, but would get on her feet after a minute or two and then lie down again. Her respiration was about 180 per minute. At 1.30 p. m. her respiration was still rapid, the mucous membranes of the mouth somewhat cyanotic, and the ears drooped. At 1.47 p. m. she was given subcutaneously 8 grams of caffein. At 1.49 p. m. she threw her head up and held her breath for about a quarter of a minute. She repeated this action several times. At 2.03 p. m., her temperature was 100° F. The animal seemed somewhat stronger. Her respiration was still variable, running as high as 180 per minute. Her pulse was about 80. She was still frothing at the mouth and appeared to be in pain. At 2.20 p. m. she had a hard time to breathe. She shook her head, staggered about, and lay down. Her respiration was slow and labored. At 2.22 p. m. her respiration was getting more rapid. At 2.23 p. m. the animal seemed to be in great pain; her breathing nearly stopped for a minute, but started again in a panting manner. Her respiration continued irregular, first fast and then slow and labored. At 3 p. m. her temperature was 100.2° F. and her respiration 84, but not as labored as at 2.03 p. m. She was still frothing at the mouth. Her pulse was 96 and strong. At 3.30 p. m. her respiration was 160. She fell upon her knees, struggled to get on her feet again, but finally lay down. At 4.15 p. m. she was groaning more or less and staggered as she attempted to walk. Her respiration was 90. At 4.30 p. m. she was lying down and her respiration was very nearly normal. Her temperature was 99.1° F. At 5 p. m. she was down again and in pain, groaning continuously, her respiration slower than for some time previous, the rate being about 60 per minute. At 5.04 p. m. the animal was lying sprawled out upon her belly. Her respiration was 168. At 5.38 p. m. she appeared very stupid, almost as if sleepy. She was given subcutaneously 6 grains of caffein sodiobenzoate. At 5.45 p. m. her temperature was 99.4° F., her respiration 120 and very variable, and her pulse 96. At 7.10 p. m. her temperature was 99.7° F. Her respiration was slow and variable. After expiration there would be a pause followed by two short and shallow inspirations close together. These would be followed by a long inspiration, then a full expiration accompanied by a groan. This was repeated over and over again, the whole cycle taking about 20 seconds. The animal on the whole seemed to be brighter than at 6 p. m.

At 8 p. m. the animal was given 5 grains of caffein sodiobenzoate. Her temperature was 100.8° F., respiration 10, and pulse 120. At 10 p. m. her temperature was 100.2° F., pulse 120, and respiration 4. The inspiration was deep and the expiration was accompanied by a groan. At 10.55 p. m. her temperature was 100° F. At 11.15 p. m. her respiration was 18 and pulse 108. Her general condition was unchanged.

On July 20, at 7 a. m., the animal's pulse was 100, temperature 100.8° F., and respiration 11. She was then lying with her head bent under her body and would probably have died in that position had she not been relieved. She seemed at this time unconscious. At 8.45 a. m. her temperature was 100.6° F, pulse 84, and respiration 12. At 10 a. m. her respiration was 10, and her pulse 84. The animal was in a comatose condition. At 10.50 a. m. her respiration seemed to be getting more shallow. At 11.15 a. m. she seemed somewhat brighter than earlier in the day. At 12 m. her temperature was 102.6° F., respiration 12, and pulse 108. During the afternoon she had been lying in practically the same position, with her head slightly raised, resting upon a support. She was too weak to move herself at all. At 3 p. m. her respiration was 12. At 3.30 she was given subcutaneously 10 c. c. of whisky. At 4.20 p. m. her temperature was 102.8° F., respiration 36, and pulse 116. At 8.05 p. m. she was given subcutaneously 5 c. c. of whisky. At 9.30 p. m. her temperature was 104.6° F., respiration 18, and pulse 120.

On July 21, at 5.45 a. m., she was found in practically the same condition as the preceding night. At 6.45 a. m. her temperature was 104° F., respiration 24, and pulse 148, and weak. At 9.50 a. m. she was given subcutaneously 5 drops of fluid extract of digitalis in 8 c. c. of whisky. At 10.15 a. m. her pulse was somewhat stronger than before the digitalis was given. At 11 a. m. her pulse was 102, temperature 104.6° F., and respiration 48. At 11.15 a. m. her respiration was fairly deep, but was somewhat spasmodic. Her pulse was weak. At 11.45 a. m. her respiration was 68. At 9.30 p. m. her temperature was 105.3° F., respiration 24, and pulse 120, but weak. The animal was given subcutaneously 3 drops of fluid extract of digitalis in 6 c. c. of whisky. During the day there had been very little change in her condition. She lay in a coma, from which she did not rouse herself except occasionally to shake the flies from her ears. Her position had been changed from time to time by the attendants. She was found dead on the morning of July 22.

At the autopsy the venous blood vessels were found congested and the lungs were congested, as were the liver and kidneys. There was considerable inflammation of the walls of the fourth stomach and of the whole length of the intestines. Sections of the kidney showed that the capillaries were much congested, and there was some degeneration of the tubule walls. Sections of the liver showed acute congestion, and the same condition was noticed in the sections of the lung.

Sheep No. 197.—This animal (Table I, section G) was a ewe 2 years old, lent by Mr. Ole Birkeland on May 9, 1913. An unsuccessful attempt was made to feed *Zygadenus venenosus* tops to her on May 12.

On May 26, at 11.25 a. m., she was drenched with 178 grams of *Zygadenus venenosus* tops suspended in water. These plants were collected on May 23. At 11.40 a. m. she was frothing at the mouth. At 11.45 a. m. she was given a drench of 1 gram of diuretin and 0.455 gram of caffein citrate. At 11.50 a. m. she was vomiting, and when observed at 12 m. the vomiting was continuing. At 12.05 p. m. her respiration was getting irregular and deeper. At 12.30 p. m. her respiration was extremely fast and she was panting. At this time she was violently nauseated and threw herself down two or three times and then jerked about in a spasmodic manner. At 12.40 p. m., being extremely nauseated she was trying to vomit, throwing herself down, and the spasmodic movements were followed by quick, panting respiration. At 12.45 p. m. her respiration was about 200. She showed weakness in her legs. At 1.15 p. m. she repeated the spasmodic movements which had been noticed at 12.30 and 12.40 p. m., evidently struggling to get breath. She threw her head from side to side and ran the length of the corral, throwing herself upon the ground and rising again as though having a fit. The mucous membranes of the mouth were cyanotic. These movements were repeated a little later. At 1.30 p. m. she was given a dose of 5 c. c. of gin. Another struggle for breath followed, and it was noted after this struggle that her heart action was very rapid and strong. The beat was audible to the observers. Five c. c. more of gin were given subcutaneously. At 1.36 p. m. she was lying upon her side. Her respiration was 160. At 1.40 p. m. she had another struggle for breath, throwing herself about violently, even throwing herself over upon her back. These struggles were repeated at 1.49 and at 1.53 p. m. The mucous membrane of the mouth at both times was very markedly cyanotic. At 1.55 p. m. she was given 5 c. c. of gin. At this time she was still strong enough to get on her feet. She was urinating freely. At 1.59 p. m. she passed through another spasmodic attempt to breathe. At 2.02 p. m. her pulse was about 200. At 2.06 p. m. there was a spasmodic struggle for breath. At 2.10 p. m. the animal was breathing with very great difficulty. Ammonia was used to stimulate her respiration. Her pulse was 130. At 2.45 p. m. she had great difficulty in respiration, but at this time it was not accompanied by a spasmodic struggle. At 3.06 p. m. she had another spasmodic struggle, and ammonia was used as a stimulant. At 3.30 p. m. her respiration some of the time was very rapid, becoming as high as 200 per minute. Then it slowed down and became labored. On the whole the animal at this time seemed somewhat better. At 3.39 p. m. she made a struggle to get upon her feet but was unable to do so. Her respiration at this time was variable and very labored, the breathing being followed by quick, panting efforts. At 4.10 p. m. her respiration nearly stopped. She was stimulated with ammonia. At 4.15 p. m. ammonia was again used. At 4.45 p. m. her respiration was 132. At

5.19 p. m. the animal was upon her side. Her respiration was labored, but seemed somewhat stronger. Her condition remained very nearly the same until 6 p. m. At 6.30 p. m. she was found dead.

The autopsy showed that the lungs were slightly congested; the inner walls of the ileum were congested and the venous blood vessels, generally speaking, were full. It was evident that death had occurred from respiratory paralysis.

The detailed report of the examination of the internal organs by Dr. Mohler, of the Bureau of Animal Industry, is as follows:

Kidney (cortex and medulla).—Many of the intertubular capillaries in the labyrinth of the cortex and some Malpighian bodies show a marked distention, but not sufficiently pronounced to be called congestion. There is also a general distention of many of the convoluted tubules and the interstices between the capsule of Bowman and glomeruli with a serous, œdematous exudate. This latter has distended the tubules and compressed the renal epithelial cells, many of which, having become atrophic from pressure, disintegrated and desquamated into the lumen of the tube. While these changes are quite marked in the convoluted tubules, the œdema, desquamation, and degeneration are absent in the straight portions of the uriniferous tubules of the medulla. The distention of the capillaries, however, is present even in the medulla. No interstitial alterations are present.

Lung.—The characteristic lesion is the intense congestion of the entire organ, the presence of small lobular areas of consolidation, and occasional minute œdematous areas. The larger pulmonary and bronchial vessels are all overdistended, but the interfundibular capillaries show not only overdistention but also diapedesis and outwandering of the leucocytes. No such capillary hemorrhages or poollike accumulations of the blood can be seen in this lung as were previously observed in lung 716. The bronchial tubes and the smaller bronchi are unaltered. There is no peribronchitis present, although the bronchial blood vessels have all participated in the distention of the other vessels of the lung.

Kidney.—No acute inflammatory changes present. Evidences of a slight subacute catarrhal nephritis accompanied by mild degenerative changes in the renal cells in the cortical portion of the kidney. No interstitial changes present.

Liver.—Moderate amount of physiological fatty infiltration and a slight congestion of the intralobular capillaries between the liver cords, but no diapedesis of red blood cells or outwandering of leucocytes. The hepatic cells proper show a slight amount of cloudy swelling in isolated lobules. No interstitial changes present.

Ileum.—Shows a slight increase in the adenoid tissue in the mucosa and slight fullness of the blood vessels in the submucosa. There is, however, no congestion, desquamation, or degeneration present.

SYMPTOMS IN SHEEP OBSERVED AT THE GREYCLIFF STATION.

The very large number of cases of illness and death observed at the Greycliff station furnished an opportunity for a fairly complete picture of the symptoms produced by Zygadenus poisoning. The symptoms were noted in detail, and the description that follows is drawn from a summarized statement formulated from these notes.

SALIVATION.

Generally salivation, or frothing at the mouth, was the first noticeable symptom and continued through the acute period of the illness. It was not invariably present; sometimes it did not appear, especially in the fed cases. It was seen in nearly all the drenched cases, and was rarely absent when the attack was acute. The salivation was in many cases accompanied by grinding of the teeth. Plate IV, figure 1, of sheep No. 160, and Plate IV, figure 2, of sheep No. 192, illustrate this stage of the illness.

NAUSEA.

Nausea was very pronounced in nearly all cases, and frequently resulted in violent vomiting, this vomiting, like the salivation, being largely confined to the acute stage of the illness.

PULSE.

Routine observations upon the pulse were made in a large number of cases. The rate of the pulse is, of course, very variable under normal conditions. When taken before the experimental feeding it varied from 52 to 144, although in most cases it was between 60 and 100. Generally speaking, when the intoxication was not acute there was very little change from what would be expected in normal variations either in the rate or character of the pulse. In the severer cases, especially in those that ended fatally, the rate was from 125 to 200. While in three cases of sheep not under the influence of a toxic substance the pulse was 144, this condition is unusual; and in a general way it seems to be true that if the rate runs much above 130 a fatal termination of the illness is likely to follow. In the severe cases the pulse was weak and sometimes intermittent.

TEMPERATURE.

Temperature observations were made in detail in a large number of cases. It was considered necessary to get the average of a considerable number, inasmuch as there is in sheep quite a range of variability under normal conditions and also a considerable difference in individuals. The extreme range of temperature was from 97.4° to 105.7° F. From the cases of 1914, 64 records were made. Of these, 8 showed no marked change, 14 exhibited an increase, and 42 a decrease, and the decrease ordinarily was not very great but in some few cases was down to between 97° and 98° F. It is evident that, in general, intoxication by Zygadenus is accompanied by depression of temperature. In some few cases, in which there were no other symptoms of poisoning, a lowering of temperature was noticed; this, however, was not sufficiently general so that it could be considered diagnostic in the absence of other symptoms. Curves are given (figs. 1 and 2) of sheep 282 and 291. These, it should be stated, are not average cases, but they may be considered typical of cases in which the lowering of temperature is more marked.

RESPIRATION.

The rate of respiration had an extremely wide range of variation. Quite uniformly in the acute stages of the poisoning, the rate was very rapid, running in some cases as high as 250 per minute. After this period the rate was very much reduced, falling to normal or below,

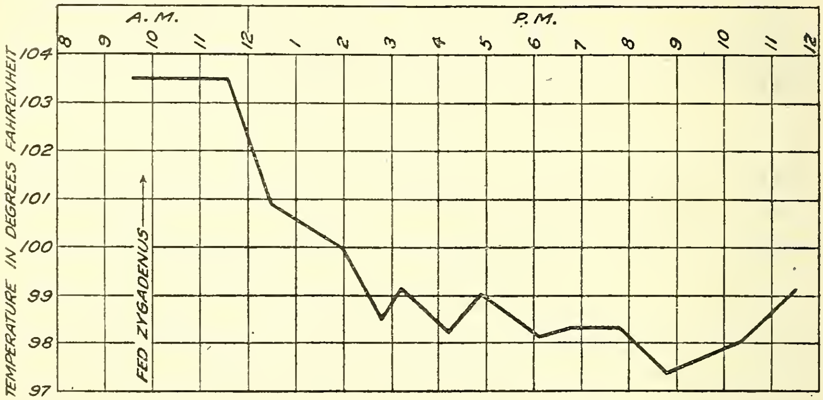


FIG. 1.—Curve of temperature of sheep No. 282.

and the animal sometimes lay for hours breathing most of the time in a slow and labored fashion. This period of comparative quiet might be interrupted, sometimes frequently, by times of rapid breathing, accompanied by panting and followed quickly by a very slow rate. Sometimes, in severe cases, there were times when the animal threw

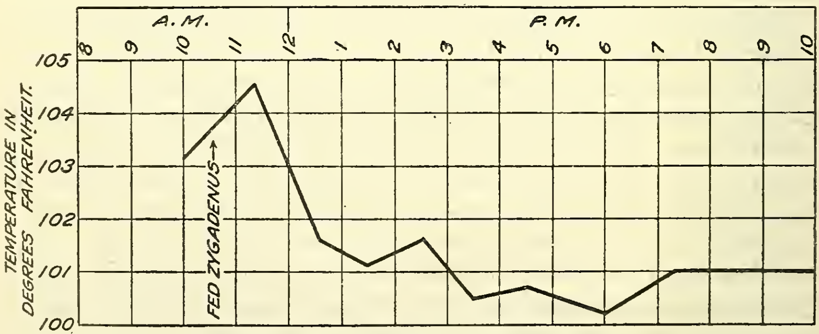


FIG. 2.—Curve of temperature of sheep No. 291

itself about violently, fighting for oxygen. This condition lasted for perhaps two or three minutes and was succeeded by a period of quiet, which was soon broken by another struggle. During these struggles the mucous membranes of the mouth were frequently cyanotic. The struggles were spasmodic, and when authors state that poisoned animals have spasms or convulsions, it is to be presumed that they refer to this condition. It should be noted, however, that in the cases observed at the Greycliff station there was no indication of any special tonic or clonic contraction of the muscles; the violent movements of the animals were simply those caused by distress from dyspnœa.

Figure 3 gives the curve of respiration for sheep No. 174 and may be considered typical of the average fatal case. The sheep was drenched at 12 o'clock noon and died at 11.15 p.m. The respiratory rate rose to 200 between 2 and 3 o'clock, when the animal had one of the spasmodic struggles for breath. It then fell to 9 and remained low, with comparatively slight variations, until the time of death.

Figure 4 gives the curve of respiration of sheep No. 160, a prolonged case. This animal was drenched with Zygadenus at 11.25 a. m., July 19, and died during the night of July 21. The respiration almost immediately after the dose was given ran up to 200 and during the afternoon varied between 60 and 168. In the evening it fell, and after that time the maximum noticed was 68, but most of the time it was near 20 or 30.

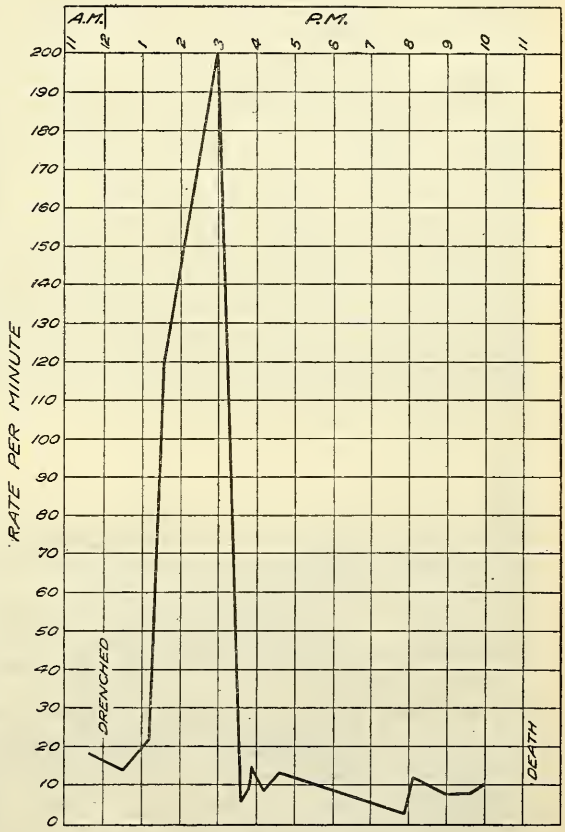


FIG. 3.—Curve of respiration of sheep No. 174.

MUSCULAR WEAKNESS.

In all cases of any severity muscular weakness was noticeable. Early in the illness the animals staggered, and in the more serious cases not only could not rise, but lay flat upon the ground. This weakness was most pronounced in the forelegs. Plate V, figure 1, shows this condition of weakness in the forelegs in sheep No. 162, while Plate V, figure 2, shows the same animal down. Plate VI, figure 1, shows sheep No. 174 when down and very sick. This picture was taken just before a spasmodic struggle for breath.

In many cases in which the animals were strong enough to remain on their feet, the gait was peculiarly stiff legged. Both fore and hind limbs were affected, but the condition was most pronounced in the hind legs. Sometimes the hind legs were moved less readily, approximating, perhaps, the condition noticed by other writers in laboratory experiments. These symptoms were especially noticeable in the cases in which the animals were fed and were not very sick.

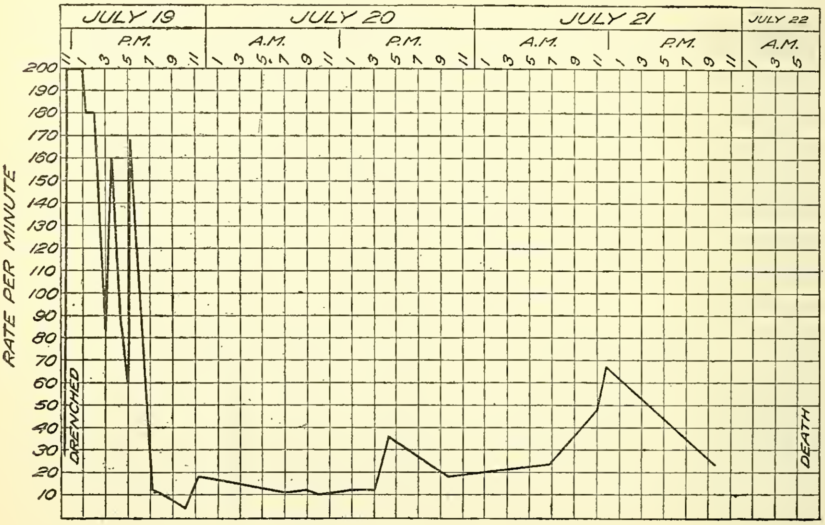


FIG. 4.—Curve of respiration of sheep No. 160.

TREMBLING AND HEIGHTENED REFLEXES.

The fed cases generally exhibited trembling and a sensitiveness to sudden noises or movements. A blow upon the corral fence was followed by a sudden start on the part of the animal, or a light blow upon the animal was followed by a quick reflex movement. This condition was not noticed in the drenched cases and seems to be more characteristic of prolonged illnesses. As stated before, this symptom of heightened reflexes had been noted by both Chesnut and Hunt.

COMA.

While, as already noted under the head of respiration, death resulted from respiratory failure and was frequently preceded by spasmodic attacks of dyspnœa, there were other cases in which the animals lay quietly hour after hour, and sometimes even for days, with labored breathing, in a condition of coma which ended in

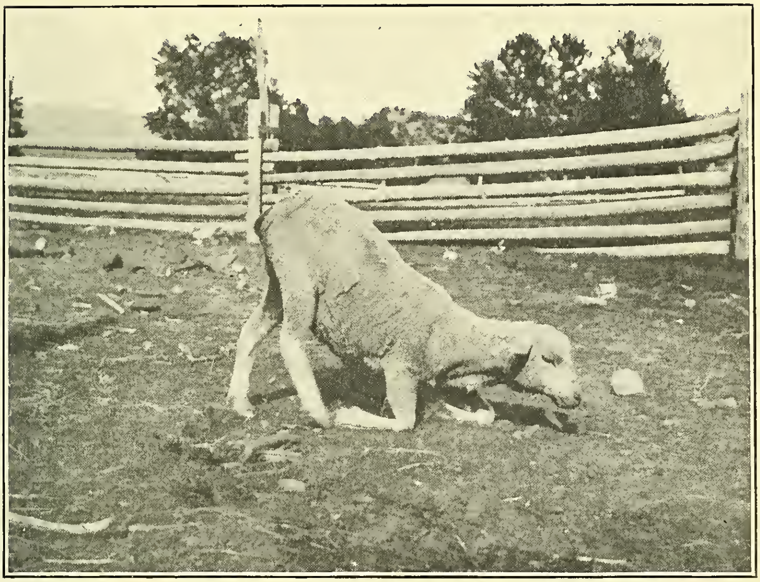


FIG. 1.—SHEEP NO. 168 AT 1.30 P. M., SHOWING WEAKNESS IN FORELEGS.

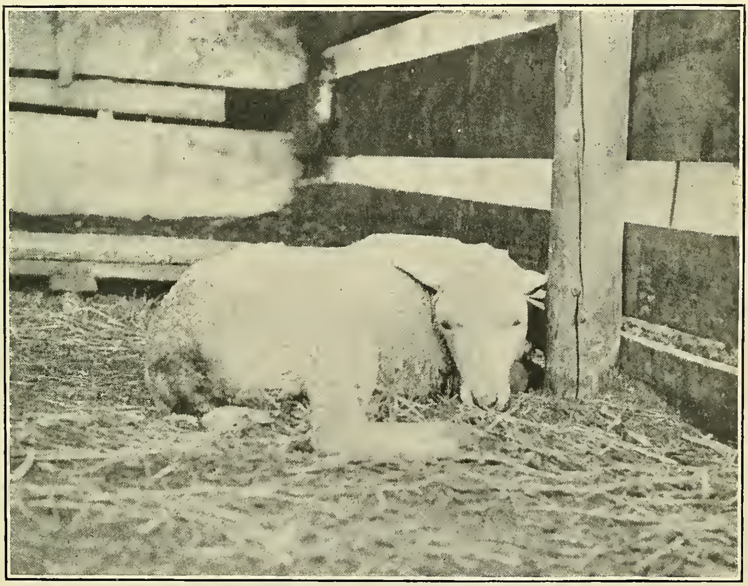


FIG. 2.—SHEEP NO. 168 AT 5.45 P. M., WHEN UNABLE TO RISE.

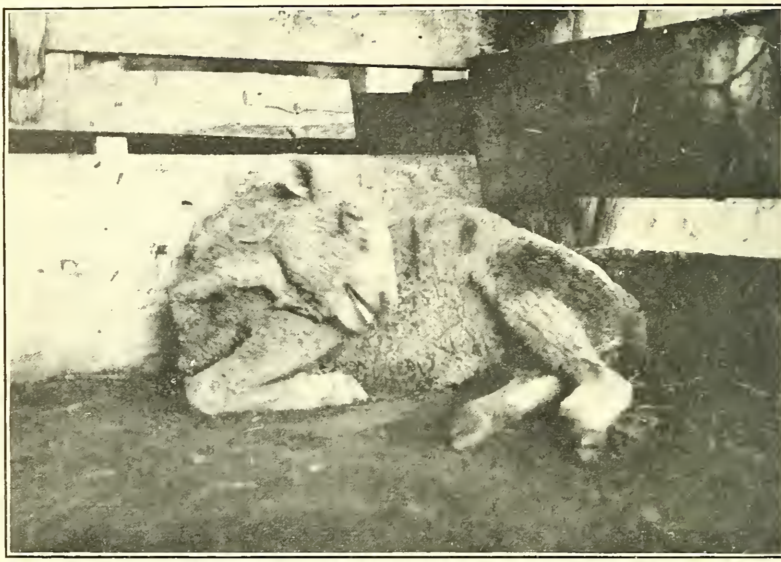


FIG. 1.—SHEEP NO. 174, DOWN AND IN BAD CONDITION. PHOTOGRAPHED JUST BEFORE A SPASMODIC STRUGGLE FOR BREATH.

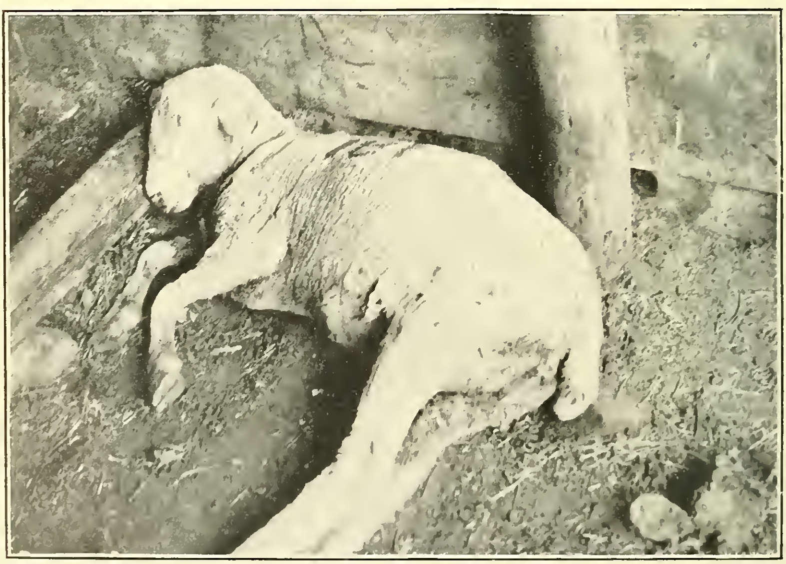


FIG. 2.—SHEEP NO. 161, DOWN ALMOST TWO HOURS AND UNABLE TO RISE.

death without any exhibition of spasms. Plate VI, figure 2, shows sheep No. 161 in this condition of coma. Sheep that are poisoned on the range are more apt to be in this condition of prolonged coma than to show the more violent symptoms of dyspnœa exhibited by animals that are drenched or forcibly fed.

SYMPTOMS IN HORSES AND CATTLE.

No results on horses were reached in the experimental work at Greycliff. From conversations with stockmen who have had experience with horses poisoned by Zygadenus, it appears that, in general, the symptoms resemble those exhibited in sheep.

In the cases of the two head of cattle which showed symptoms, the experiment was carried only to the point of proving the toxic effect of the plant, and no attempt was made to get a complete symptomatic picture. The animals became uneasy, displayed heightened reflexes, and one dragged the hind legs slightly. So far as they went, the symptoms were like those observed in sheep.

AUTOPSIES.

Autopsies were made on four cases in 1912, six in 1913, and seven in 1914. Of the cases in 1913, sheep No. 186, while showing distinct symptoms of Zygadenus poisoning, died as the result of the administration of morphin.

The appearances presented by these animals at the autopsies were quite uniform, though not alike in all details. In six cases there was epicarditis. In nearly all, the inner wall of the ileum was hyperæmic or congested, and in all but one the lungs were congested. The kidneys were congested and more or less degenerated in most cases. Generally the heart was in systole, the contraction being most marked in the left ventricle.

Generally speaking, then, the post-mortem appearances may be stated as including inflammation of the inner wall of the ileum and occasionally of the fourth stomach and large intestines, the heart in systole, congestion of the lungs, and congestion and more or less degeneration of the kidneys. Possibly the condition of epicarditis may be considered typical, although it was not noted in all the cases.

The preserved material from the autopsies was examined by Dr. Mohler, and the following summarized statement of the pathological findings and the inferences to be drawn has been furnished by him:

> The most conspicuous phenomenon shown in all six cases was the high capillary blood pressure, manifested principally in those organs which eliminated the active principle of the ingested substance, that is, kidneys, lungs, and liver, being also shown to a less extent in the intestine.
>
> In the kidney the changes in the capillary varix were fullness to overdistention, which was accompanied by outwandering of leucocytes, diapedesis of the red blood

corpuscles, and all the phenomena of a congestion or an acute or subacute inflammation. Occasional ruptures of the capillary vessels were noted, forming poollike capillary hemorrhages.

The distention of the capillaries in some instances had brought about cloudy swelling, or the early stage of degeneration of the renal epithelium, which in some instances had become desquamated. The supporting or interstitial tissue was not affected.

In the lung the high capillary pressure is even more manifest than in the kidney, owing to the presence of a greater number of capillaries. The variations were from moderate fullness to overdistention, followed by inflammation in the more acute cases, resulting in localized areas of œdema where the serum had oozed out and filled one or more lobules of the lung.

In spite of the fact that the fullness, congestion, and inflammation were more marked in the lung than in the kidneys, the degenerative changes and the desquamation of the pulmonary epithelium were less evident and not as frequent, owing to the greater resistance of the pulmonary cells. While no interstitial changes were present in the kidney, slight interstitial changes in the lungs were present in the peribronchial areas in some of the cases. In others, the interstitial changes were also present in the visceral pleura.

In the liver the vascular changes were either entirely absent or so slight as not to deserve any mention, but the epithelial changes were quite marked, owing to the more delicate composition of the cytoplasm. The absence of vascular changes indicates that the elimination by this organ is but very slight and that the metabolic function is quite able to take care of any of the irritant products that may have reached the liver.

In the intestine the vascular changes are likewise very slight.

TOXIC AND LETHAL DOSE OF ZYGADENUS VENENOSUS FOR SHEEP.

The very large number of feeding experiments with sheep at Greycliff made it possible to determine the toxic and lethal dose with considerable accuracy. Inasmuch as very little has been known in regard to the toxic dose of Zygadenus for sheep, the results of these cases are especially interesting. Table II summarizes the nonfatal cases, showing their number and the quantities of the plant necessary to produce illness.

TABLE II.—*Nonfatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., in 1912, 1913, and 1914.*

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1912:		*Pounds.*	*Pounds.*	*Pounds.*
Drenched with leaves, stems, and fruit	2	1.324	0.79	1.057
Drenched with stems and leaves	1			.33
Drenched with stems, fruit, and some leaves	2	.771	.33	.55
Drenched with fruit	5	.264	.141	.228
Season of 1913:				
Fed on leaves	4	2.1	.893	1.607
Drenched with leaves	8	.747	.385	.5746
Drenched with bulbs	3	.612	.517	.5746
Drenched with leaves and buds	1			.555
Drenched with buds and flowers	1			.389
Fed on leaves and flowers	6	4.6	1.728	2.7513
Drenched with leaves and flowers	2	.496	.495	.4955
Fed on leaves, flowers, and fruit	2	7.188	3.155	5.1715
Fed on seed heads	1	5.597		5.597
Fed on seeds	3	.241	.092	.1613

TABLE II.—*Nonfatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., in 1912, 1913, and 1914*—Continued.

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1914:		*Pounds.*	*Pounds.*	*Pounds.*
Forced feeding of leaves	2	0.662	0.661	0.6615
Forced feeding of leaves and some young buds	2	.499	.550	.5245
Fed on leaves, some young buds, and a few flowers	1			1.643
Forced feeding of leaves, stems, flowers, and buds—				
Material collected near the station	8	.622	.495	.5495
Cabin Corral collections	4	1.983	1.436	1.789
Fed on leaves, stems, flowers, and buds	1			1.912
Forced feeding of leaves, stems, and flowers (Cabin Corral collections)	9	2.756	.992	1.712
Forced feeding of leaves, stems, flowers, and young fruit	4	.992	.757	.851
Forced feeding of very young seed heads	1			1.543
Forced feeding of seed heads, some fully developed and others half developed	1			1.432
Forced feeding of half-developed seed heads (Cabin Corral collections)	3	1.754	1.543	1.69
Forced feeding of nearly developed seed heads	6	1.323	.881	1.175
Forced feeding of fully developed seed heads	18	.994	.440	.859
Forced feeding of ripening seed heads	2	.741	.740	.7415
Forced feeding of pods with seeds removed	1			.540
Forced feeding of seeds	2	.197	.110	.153

Table III summarizes the fatal cases in the three seasons.

TABLE III.—*Fatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., 1912, 1913, and 1914.*

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1912:		*Pounds.*	*Pounds.*	*Pounds.*
Drenched with fruit	3	0.853	0.299	0.571
Season of 1913:				
Fed on leaves	1			1.397
Drenched with leaves	4	.746	.384	.537
Drenched with leaves and flowers	1			.550
Season of 1914:				
Forced feeding of leaves, stems, and flowers	1			.544
Forced feeding of fully developed seed heads	2	.991	.882	.936
Forced feeding of seeds	3	.220	.199	.213

As these feedings were carried on during the season as long as the plants could be obtained and as it was practically impossible to have any considerable number of cases at one time, it is evident that the number of cases under any given set of conditions must have been small. As a matter of fact, none of the cases of 1912 were strictly comparable with those of 1913. Consequently, the actual averages of dosage were based on a comparatively small number of cases.

In 1914, there was a much larger number of cases, and some stages of the plant were fed upon which no experiments were made in the preceding years. Even in this year, however, there were only a few cases in which the experiments were under identical conditions.

In the compilation of Tables II and III some of the cases have been excluded. In Table II all cases in which the remedy given was clearly effective were excluded, for some of these received what would have been a lethal dose had it not been for the remedy. In Table III cases were excluded which were known to have received much more than a lethal dose. The uniformity of dosage in 1914 is explained by the fact that the preceding work had shown clearly that the toxic dose was not far from 0.5 pound, and the experiments were made on this basis. It should be noted, too, that most of the work of the summer of 1914 was with reference to the experimental use of remedies, so that the quantity of the plant administered was estimated to be sufficient not simply to produce symptoms, but to make the animal very sick, in order to get a fair test of the remedy. Hence, the average figures for the toxic dose will be rather high.

The "forced feeding" cases of 1914 can be fairly compared with the "drenched" cases of 1912 and 1913, as the difference between the two methods is mainly in the fact that in forced feeding no water is used while in drenching considerable water is necessary as a vehicle for the weed.

The age of the animal played a comparatively small part in these experiments, as all the animals were mature, most of them being 2 years old or older.

It will be noticed that when the plant was given in the form of a drench or by forced feeding, the dosage, as would be expected, was considerably less than when it was given with food. An examination of the complete table of feeding (Table I) shows also very clearly that the size of the dose varied inversely with the time during which the material was eaten. In a large number of cases in which the plant was given with food, the feeding extended over two or more days. In those cases the dosage was considerably greater than when the material was fed in a single day. It may be assumed that if the same quantity of the plant which was received in a drench could have been fed within a short period of time, the effect would have been the same.

The average dose which produced illness when administered in the form of a drench or by forced feeding was practically the same for all parts of the plant except the pods and seed. It appears that the plants are less toxic at the time when the pods are forming, which may be due, in part at least, to the diminished toxicity of the leaves as they dry up. It is not clear, however, from this work, that the leaves lose any appreciable amount of toxicity, and the more probable explanation is that the pods at this time are only slightly toxic. In the single experiment of feeding pods without seeds, the dosage was about like that of other parts of the plants, but it is probable from the detailed history of this experiment that this is not a fair representative of such cases.

The seeds are very much more poisonous than any other part of the plant. Heyl, Loy, Knight, and Prien (1912, p. 17) give the results of determinations of alkaloids in different parts of the plant. Their statement is obscure and contradictory, but apparently they reach the conclusion that the bulbs and leaves contain approximately the same quantity of the alkaloid, the roots much less, and the flowers about twice as much as the bulbs and leaves. This compares very well with the results of the experimental feeding at Greycliff, except that it did not appear that the flowers were more toxic than other parts of the plant.

Table II gives the maximum and minimum dosage, and it will be noticed that there is a considerable range of variation between these two. The individual peculiarities of the animal in cases of poisoning doubtless must be taken into account, and the detailed table of the experiments shows that in some cases a larger quantity of plant than that which this table indicates to be toxic may be administered without effect. In most of the cases, however, where the larger amount was used, the feeding was distributed over a longer time.

In general, the experiments seem to indicate that when any part of the plant except the seed is used the toxic dose varies from 1.6 pounds per hundredweight of animal to 5.6 pounds, this wide range of variation being accounted for by the more or less extended time of feeding. In the drenching and forced-feeding experiments, more uniform results were reached, showing that the toxic dose of all parts of the plant, except the seed, is not far from 0.5 pound per hundredweight of animal.

There is considerable difference in the items of the summarized tables in the exactness of the averages, and some explanation is necessary to indicate their actual value.

In the feeding of leaves in 1914, there were three cases, two becoming sick. The third case received 0.661 pound without symptoms, the same quantity that was received by No. 282, which became sick. It seems probable, then, that the average figure 0.6615 must be pretty close to the toxic limit. In the feeding of "leaves and some young buds" in 1914, while the minimum of sick cases received 0.499 pound, another animal received 0.551 pound without ill effect; it is evident that the toxic limit must be not far from 0.5 pound. In the feeding of eight cases on "leaves, stems, flowers, and buds," with material collected near the station, the toxic limit was practically the same as in the preceding cases. A perusal of Table II shows that during the growth of the seed heads the toxicity was reduced and that the fully developed seed heads were somewhat less toxic than the plant in the earlier stages.

In the two cases of forced feeding of seeds in 1914 the average toxic dose was 0.153 pound; inasmuch as the animal receiving the maximum amount was very sick, the actual toxic limit must be considered to be close to the minimum figure of 0.11 pound. It will be noticed that the cases of feeding of seeds in 1913 had practically the same average dose as the cases of forced feeding in 1914; this is accounted for by the fact that these animals ate the seed in such a short time that the results were similar to those from forced feeding.

It is interesting to note in Table III that the lethal dose is only slightly larger than the toxic dose.

In transferring these results to the probable dosage when sheep are range fed, the feeding habits of the sheep must be taken into consideration. In the corrals the sheep do not, as a rule, eat as readily as when on the range. When the sheep in a band are grazing together, both imitation and jealousy affect the quantity of any plant which a sheep eats in a given time; so it is reasonable to suppose that if feed is short and Zygadenus fairly abundant, sheep may eat much more in a short time than they would under corral conditions. Under such circumstances, the dosage might approximate that of the drenching experiments. Therefore, it appears probable that animals feeding on the range might, because of the more rapid eating, be poisoned with much less than when in corrals.

EXPERIMENTS WITH HORSES AND CATTLE.

Three experiments were made of feeding Zygadenus to a horse, as shown in Table I (section D), *Z. venenosus* being used in two tests and *Z. elegans* in one. The smallest quantity fed in these experiments was 12.1 pounds per 1,000 pounds of weight, and the largest was 15 pounds. In each instance the feeding was extended through several days, and the feeding of 15 pounds extended through 6 days. If the quantity necessary to poison a horse should be in the same proportion to its weight as that required to poison a sheep, it would be, according to our dosage, at least between 11 and 12 pounds, and probably much more. It may be presumed, therefore, that in these cases the amount fed was not sufficient to produce toxic effects. There is, however, abundance of evidence that horses are poisoned by Zygadenus, although not ordinarily with fatal results.

Section C of Table I shows the results of feeding *Zygadenus venenosus* to three cattle. Two of these animals, both of which received leaves and flowers, showed symptoms of poisoning, one on 58 pounds per 1,000 pounds of weight and the other on 46.5 pounds per 1,000 pounds of weight. In these cattle, therefore, the average toxic dose was 52.25 pounds, which was fed in an average of 6½ days. This compares fairly well with the results reached with sheep and would indicate that the toxic dose for cattle, computed in terms of the weight of the animal, does not differ materially from the toxic dose for sheep.

COMPARATIVE TOXICITY OF DIFFERENT SPECIES OF ZYGADENUS.

In the course of the experiments, four species of Zygadenus were used, *Z. venenosus*, *Z. elegans*, *Z. paniculatus*, and *Z. coloradensis*, by far the greater part of the work being done with *Z. venenosus*. The number of experiments with *Z. elegans* and *Z. paniculatus* was very small, and the material, especially in the case of *Z. paniculatus*, had been shipped a long distance, so that there was some question of the water content of the plant. Apparently, however, *Z. elegans* and *Z. paniculatus* do not differ materially in toxicity from *Z. venenosus*. *Z. coloradensis*, however, produced no toxic effects whatever with the exception of slight symptoms in one sheep, although the plant was fed in quantities several times as great as the toxic dose of *Z. venenosus*.

It is evident that in the feeding of cattle with *Zygadenus coloradensis* at Mount Carbon in 1909, the results of which are given in Table I, the quantities fed were too small to produce results, even if the plants were as poisonous as *Z. venenosus*. In the experiment of 1910, however, a large quantity was fed, and sufficiently large quantities in single days to produce symptoms of poisoning if the plant were as toxic as *Z. venenosus*.

In this connection it should be added that Dr. C. L. Alsberg made a laboratory examination of the Colorado plants and found in them a very small quantity of alkaloid. It would appear, then, that the form which is identified by some botanists as *Z. coloradensis* contains the same toxic substance as the other form, but that this substance is present in so small a quantity that it is unlikely that it ever produces toxic effects on domestic animals. While it is not in the province of this paper to discuss the systematic relations of plants, it may be suggested that this difference of toxicity between *Z. elegans* and *Z. coloradensis* may indicate a valid specific distinction between these two forms which are so closely related that by some botanists they are considered identical.

DOES TOXICITY VARY WITH LOCALITY?

The collections of *Zygadenus venenosus* with which experiments were made were obtained at the "Station" (by which is understood the region within a radius of 2 miles of the station), at an elevation of about 4,050 feet; at "Greycliff," 2½ to 3 miles distant from the station, at an elevation of about 3,920 feet; and at "Cabin Corral" and "George Hughes's" (locations from 4 to 7 miles from the station), at an elevation of something over 5,000 feet. Material of this species was also used from Avery, Cal., collected at an elevation of 3,500 feet. The material of *Z. elegans* was from two localities, from near Red Lodge, Mont., at an elevation between 5,500 and 6,000 feet, and from the Fishlake National Forest, Utah, at an elevation of something over 9,000 feet. The *Z. paniculatus* material was collected near Ephraim, Utah, at an elevation between 5,500 and 6,000 feet. All the *Z. coloradensis* material was collected within 4 or 5 miles of the Mount Carbon station, at an elevation of something over 10,000 feet.

As has been stated already, the lack of toxic properties in *Zygadenus coloradensis* is assumed to be characteristic of the species. The experiments with *Z. elegans* and *Z. paniculatus* were few in number, and too much importance must not be attached to the results. Apparently, however, not only did they have, practically, the same toxicity as the *Z. venenosus* collected near the station, but there was no evident difference between the *Z. elegans* of Montana and that collected in Utah. The *Z. venenosus*, collected in California gave the same results as that produced by material from the neighborhood of the Greycliff station.

An entirely unexplained variation in toxicity was exhibited by material collected at Cabin Corral, about 5 miles from the station and at a greater elevation of about a thousand feet. When Table II was being compiled, it was noticed that the cases receiving "forced feeding of leaves, stems, flowers, and buds" fell into two distinct divisions, one with an average dosage of 0.5495 pound and the other with an average of 1.789 pounds. This difference was so marked that the two sets were separated in the summary. In searching for some possible explanation of this difference, it was found that all the cases with the larger dosage were treated with material collected at Cabin Corral. Note was then made of the other items in this table which were collected in this locality, and a glance at the table will show that in the other cases the Cabin-Corral material showed much less toxicity. It has been entirely impossible to explain this difference. The number of cases would seem to make it certain that this result was not due to an error of experimentation. There are no local conditions to account for it. The George Hughes place, at which collections were made giving the same results as those produced by the station material, is situated at about the same distance from the camp as Cabin Corral, at about the same elevation, and it has the same soil conditions. The question of the correlation of variation in toxicity with changes in altitude was raised, but the experiments do not indicate any such relation. The fact that the Cabin-Corral material was less toxic is nevertheless substantiated, and it would appear that while *Zygadenus venenosus, Z. elegans,* and *Z. paniculatus* have ordinarily the same degree of toxicity wherever grown, there is a possibility of marked variation.

EFFECT OF REPEATED FEEDING IN PRODUCING IMMUNITY OR INCREASED SUSCEPTIBILITY.

During the course of the experimental work at Greycliff a number of sheep were treated with Zygadenus several times during the same season. It was important to decide whether a sheep after having been poisoned once was more or less likely to be affected a second time. A careful analysis of the results showed that no effect either of immunity or of increased susceptibility was produced. The fact that an animal had suffered from poisoning once neither lessened the effect of another dose, nor, on the other hand, was the sheep any more likely to suffer from a second experience.

REMEDIES.

Because of the heavy losses of sheep from Zygadenus poisoning it was deemed important to investigate thoroughly the possibility of finding some remedial measures to reduce the number of deaths. To this end a large number of experiments were made, as can be seen by an examination of the table giving the summarized account of the work.

It has been shown by Hunt that the poisonous principle of Zygadenus is excreted in the urine, and this has been verified by the authors in the cases of some of the sheep used in the Greycliff experiments. Hunt concluded that the logical remedy is some diuretic which will insure excretion rapid enough to prevent serious effects from the poisoning, and his experiments seem to substantiate this position. He also advised the use of permanganate of potash administered per os to destroy the alkaloid in the stomach.

The experimental work on remedies in 1912 was based upon these conclusions of Hunt. Later, a number of remedies were used in the hope that some method might be found sufficiently simple to be used under range conditions. This work was carried on for three summers in order to get the average of a considerable number of cases, and a brief statement of the results of the more important experiments follows.

CAFFEIN AND DIURETIN.

The conclusions reached by Hunt led to a series of experiments with caffein. In 1912, caffein sodiobenzoate was administered to five animals subcutaneously; in two of these cases potassium permanganate was also used, and in one tannic acid. It was evident that by the use of this drug the excretion of urine was increased, but the observers could not see that any marked improvement followed in the condition of the animals. In the summer of 1913, diuretin and caffein citrate were given per os in four cases, of which one died and three recovered. In these cases, as in those of the preceding year, there was no evidence of any good result. All these experiments had been with single doses. In 1914 two animals were treated, one with two doses of 10 grains each of caffein sodiobenzoate administered subcutaneously, and one with three doses of 5 grains each. One of these animals died and one recovered, but in neither case could it be seen that the remedy was advantageous. It seemed to be clear that while caffein might be considered a logical remedy it failed in practical application.

STRYCHNIN.

Although the work of Hunt quite clearly indicated that strychnin was not beneficial, it seemed best to try a few experiments to see whether, by its stimulating effect, it might not aid in relieving the depression of the animals. Six cases were treated by subcutaneous injections. In two of these cases eserin was also used, and in one case gin. There was an apparently beneficial effect in one case, but a study of all fails to show any good results which could be fairly considered as due to strychnin.

ESERIN, EPSOM SALTS, LINSEED OIL.

With the idea that relief might be brought about by an increase in intestinal elimination, eserin was administered subcutaneously, and Epsom salts and linseed oil per os; no reduction of toxic symptoms could be seen.

CHARCOAL.

Dr. Sollman suggested to the writers that charcoal, by adsorption, might be beneficial. Three experiments were made with this, in one case combined with linseed oil. No beneficial results followed.

WHISKY AND DIGITALIS.

In some cases of extreme depression whisky seemed to have an effect in bridging over a period when death might otherwise have followed. The same thing is true of digitalis, which in one or two cases may have saved the life of the patient. Neither drug, however, had any marked effect. It can only be said that if the symptoms of the animal are carefully watched, times will be found when whisky or digitalis may be administered advantageously. Inasmuch as the life of the individual sheep is of small importance, these remedies are of little practical use.

POTASSIUM PERMANGANATE.

Especial interest attaches to the experiments with potassium permanganate, since it is the remedy that has been most commonly recommended for plant poisoning. The dosage advised for a mature sheep has been 5 to 9 grains. This was used at first in the experimental work, and when no beneficial results appeared it was increased to 30 grains, but still with no evidence of a reduction of the toxic effect. In two cases, 15 grains were introduced directly into the rumen with no better results.

Because of this lack of success it was deemed best to try mixing the permanganate with the Zygadenus before administration to see if the alkaloid would be destroyed in vitro. On May 19, 1913, two sheep of equal weight, Nos. 184 and 191, were each drenched with 0.586 pound of *Zygadenus venenosus* in water. In the dose given to No. 191 there were dissolved 7½ grains of potassium permanganate and 7½ grains of aluminum sulphate. Both animals were sick, and there was no recognizable difference in the degree of illness. The experiment tended to show that the administration of the potassium permanganate was without any definite effect upon the toxicity of the plant, but a similar experiment on July 11, 1914, on sheep No. 253 showed quite clearly that the dosage of the former experiment was insufficient. In this case 0.441 pound of seed heads of *Z. venenosus* was mixed in water with 15 grains of potassium permanganate and 15 grains of aluminum sulphate and the mixture allowed to stand for 20 minutes before being administered. The sheep displayed no symptoms of poisoning, although other cases of the same date receiving the same quantity of Zygadenus, with no remedy, showed distinct symptoms. It seemed clear that a sufficient quantity of permanganate will diminish the toxicity of the plant, when mixed with it before administration. When given after symptoms of poisoning are exhibited, however, the remedy is of no value. This, too, has been demonstrated by practical experience upon the range. Potassium permanganate has been used by many sheep owners in Montana, and it is the almost universal testimony that it is worthless.

TANNIC ACID.

Sheep No. 206, on June 4, 1913, was drenched with 0.43 pound of Zygadenus tops, including leaves and flowers. To this drench were added three grams of tannic acid. The animal showed no signs of illness. On May 29 a sheep was made sick on 0.389 pound, and on May 30 one was made sick on 0.385 pound and one died on 0.384 pound. It seems fair to presume, therefore, that the tannic acid had been of benefit to sheep No. 206.

Sheep No. 210, on June 6, 1913, was drenched with 0.496 pound of leaves and flowers of *Zygadenus venenosus* to which 3 grams of tannic acid had been added. On the same date sheep No. 209 received 0.495 pound of the same material, but without the tannic acid. Both animals were sick and recovered, but it was the impression of the observers that sheep No. 210 was not as sick as sheep No. 209.

On June 7, 1913, sheep Nos. 212 and 213 were each drenched with 0.55 pound of leaves and flowers of *Zygadenus venenosus*. In the drench given to No. 212 were included 4 grams of tannic acid. This sheep had no symptoms of illness, while No. 213 died 1 hour and 17 minutes after the administration of the drench. These two sheep were of very nearly equal weight and the dose was the same (0.55 pound) per hundredweight of animal. There was every reason to expect similar results except for the effect of the tannic acid. Difference of individual susceptibility would seem to be eliminated in this instance, in which one animal died and the other showed no symptoms of poisoning.

During the season of 1913, four animals which had been fed on *Zygadenus venenosus* were given doses of tannic acid after toxic symptoms were well developed. All of these animals recovered. These cases, however, were not connected up with control cases, and it is possible that all would have recovered without any remedial aid.

The general result of all the experiments in 1913 with tannic acid indicated that it can be used with beneficial results. The experiments seemed also to indicate very clearly that, in vitro, the tannic acid was much more effective than potassium permaganate as an antidote for the Zygadenus alkaloid.

In 1914, a large number of cases were treated with tannic acid, in order to try it out thoroughly. In most of these experiments one or more control animals were used. Where the tannic acid was administered in a single dose, in 19 cases, there were only two deaths; in most of these cases, however, the Zygadenus was not given in a quantity necessarily fatal.

A study of the cases in which there was a control shows apparently beneficial results in some instances. For example, sheep Nos. 249 and 251 received the same quantity of Zygadenus on July 9; No. 249 died, while No. 251, which received a dose of tannic acid, lived.

Sheep Nos. 229 and 235 were fed the same quantity of Zygadenus on June 3. No. 229 was treated with tannic acid and was not so sick as No. 235. On the other hand, Nos. 239 and 256 were fed on June 16 with the same quantity, and No. 239, which received the tannic acid, had more marked symptoms than No. 256. Sheep Nos. 269, 255, and 282 were fed the same quantity of Zygadenus on June 15 and June 16. Tannic acid was administered to Nos. 269 and 282; both of these animals were sick, while No. 255 exhibited no symptoms. A consideration of all these cases shows that tannic acid in single doses can not be considered an effective remedy, although under favorable conditions some cases may be benefited.

SODIUM BICARBONATE.

It was suggested by Mr. O. F. Black that, inasmuch as alkaloids are, to a large extent, insoluble in an alkaline solution, sodium bicarbonate might serve to prevent the solution and absorption of the poisonous principle of Zygadenus and thus prove valuable as a medicinal remedy. This was used only in repeated doses, and the results will be discussed under the next head.

REPEATED DOSES OF TANNIC ACID AND SODIUM BICARBONATE.

Inasmuch as tannic acid is a recognized remedial agent for poisoning by alkaloids, it seemed strange that so little benefit followed its use. In seeking for an explanation, it occurred to the writers that it might be accounted for by the fact that, because of the character of a ruminant's stomachs, the remedy does not actually come in contact with any considerable quantity of the poisonous substance. The first stomach of a ruminant always contains a large quantity of material. When an animal feeds upon a poisonous plant, the material taken up goes to the first stomach; some of this, after maceration, proceeds to the third and fourth stomachs, while another part goes on only after rumination. If the remedy is given in the form of a drench, it will be distributed in all the stomachs, although ordinarily the larger part of the drench goes directly to the third and fourth stomachs. That part of the drench which goes to the fourth stomach, we can assume, takes effect on the alkaloid which has arrived at that part of the digestive canal. The portion of the drench which stops in the first stomach meets a mass of organic matter, in which it is lost; there is no reason to think that any antidote for an alkaloid will have any selective effect, so as to attack the Zygadenus alkaloid rather than the multitude of other substances in the stomach with which it can unite. The only hope of destroying the alkaloid under such circumstances would be by flooding the first stomach with the antidote, and that is practically impossible. So even when the antidote is introduced by a canula directly into the first stomach, it would be impracticable to use a quantity sufficient to produce any marked effect.

On the other hand, inasmuch as no absorption takes place in the stomachs, if the antidote could meet the poisonous material as it passes through the fourth stomach good results might be expected. On the basis of this conclusion, it seemed best to the writers to try the effect of antidotes repeated at frequent intervals; it was thought that if the antidote could reach the fourth stomach frequently enough to catch the alkaloid as it passed from the first stomach and render it more or less innocuous before passing into the intestine, the remedy might be distinctly beneficial.

Four experiments of this character were conducted with tannic acid, all with controls, which received no remedy but were fed with the same quantity of Zygadenus. The tannic acid was given in doses of 1 and 2 grams, repeated at intervals varying from 10 to 30 minutes, or longer in some cases, at the latter part of the experiment.

The total time of treatment varied from 4 to 7½ hours, and the total quantity of tannic acid given varied from 14 to 16 grams. The doses and intervals were as follows:

Sheep No. 263: 9 doses, 1 gram each, once in 10 minutes; 2 doses, 1 gram each, once in 30 minutes; 1 dose, 1 gram, in 20 minutes; 2 doses, 1 gram each, once in 30 minutes. Total, 14 grams.

Sheep No. 216: 7 doses, 2 grams each, once in 30 minutes. Total, 14 grams.

Sheep No. 267: 5 doses, 1 gram each, once in 10 minutes; 3 doses, 1 gram each, once in 15 minutes; 8 doses, 1 gram each, once in 30 minutes. Total, 16 grams.

Sheep No. 291: 3 doses, 2 grams each, once in 30 minutes; 1 dose, 2 grams, in 60 minutes; 1 dose, 2 grams, in 30 minutes; 2 doses, 2 grams each, once in 60 minutes; 1 dose, 2 grams, in 3 hours. Total, 16 grams.

All these animals recovered and were not as sick as the controls, Nos. 269 and 294. Sheep No. 291 suffered more than the others, but the tannic acid in this case was administered later in the illness, after a course of small doses of Epsom salts had failed to produce any effect. All these animals and the controls were given Zygadenus collected on the same date. The experiments were considered to prove conclusively that repeated doses of tannic acid are beneficial.

A similar set of experiments was conducted with sodium bicarbonate. Seven animals were used, and all, with one exception, were fed Zygadenus material collected on the same date, and in the exceptional case the material was collected only a few days later. Doses of sodium bicarbonate of 2 and 4 grams were given at intervals varying from 15 to 60 minutes. The total time of treatment was from 2½ to 5 hours, and the total amount of sodium carbonate given varied from 20 to 48 grams. The doses and intervals were as follows:

Sheep No. 246: 10 doses, 4 grams each, once in 30 minutes. Total, 40 grams.

Sheep No. 259: 8 doses, 4 grams each, once in 15 minutes; 4 doses, 4 grams each, once in 30 minutes. Total, 48 grams.

Sheep No. 264: 6 doses, 4 grams each, once in 60 minutes. Total, 24 grams.

Sheep No. 292: 10 doses, 4 grams each, once in 30 minutes. Total, 40 grams.

Sheep No. 293: 4 doses, 4 grams each, once in 30 minutes; 2 doses, 2 grams each, once in 30 minutes. Total, 20 grams.

Sheep No. 277: 5 doses, 4 grams each, once in 30 minutes; 2 doses, 2 grams each, once in 30 minutes; 1 dose, 2 grams, after 1¼ hours. Total, 26 grams.

Sheep No. 240: 3 doses, 8 grams each, once in 60 minutes; 2 doses, 4 grams each, once in 60 minutes. Total, 32 grams.

Of these animals all recovered but one, No. 264. This sheep received a total of 24 grams, given at hour intervals. No. 240 also received the remedy at hour intervals and recovered very slowly, being unable to stand on the morning after the poisonous dose had been given. All the other cases, except No. 277, recovered rather quickly. No. 277 was as slow as No. 240, although the doses of sodium bicarbonate were given frequently, and the total amount was greater than that given to No. 264 and to No. 293, which recovered. If we exclude No. 277, it would appear clear that sodium carbonate given in sufficiently frequent doses is distinctly beneficial. The Zygadenus in the case of No. 277 was given in three doses, and it is possible that there was some accumulative effect, which may explain in part the slow recovery.

The general conclusion from the experiments with sodium bicarbonate is that if the remedy is given at frequent intervals it will prove distinctly beneficial. The dose should be 4 grams, and this should be repeated as often as every 30 minutes.

These experiments with repeated doses of tannic acid and sodium bicarbonate were interesting from a theoretical standpoint and indicate a line of treatment which can be used successfully with valuable animals. It is evident, however, that remedies used in this way can not be recommended for the ordinary band of sheep, for the expense of the treatment would be greater than the value of the animals.

No experiments of repeated doses were made with potassium permanganate; but it is probable that it could be used successfully, although the general trend of the experimental work is to indicate that the potassium permanganate is not, as a remedy, so efficient as tannic acid and sodium bicarbonate.

BLEEDING.

It is customary among sheep herders to bleed sheep poisoned by Zygadenus, the favorite place being the angular artery and vein of the eye. Although there seems to be no logical reason for this practice, it seemed wise to try it, and three sheep were treated in this way; two of the three died, and no beneficial result appeared in any of the cases.

METHODS OF PREVENTING LOSSES.

The most obvious thing to do is, of course, to keep the animals from eating the plant. With this end in view, it is important that all herders should be taught to recognize Zygadenus. When the plant is in flower this is not at all difficult, but it has been a matter of surprise to find to what extent, among the herders and sheep owners, the plant is not known, even at this stage. Before flowering, its grasslike leaves are not so easily recognized, but there is no reason why a fairly intelligent man should not be taught to know it even then. If one knows the plant in the preflowering and flowering stages, he will readily recognize it in the later dried-up condition, when, it will be remembered, it is fully as dangerous as earlier in the season.

When the plant is recognized care should be taken that the sheep do not have an opportunity to eat any large quantity of it. If it be necessary to drive the sheep over a patch of Zygadenus, the herder should take the precaution to have the band well fed before making the drive. If hungry sheep come upon a thick growth of Zygadenus, some of them, in their haste to satisfy their hunger, are almost certain to become poisoned, while if already well fed they are likely to choose their food with more care and to eat less of the Zygadenus.

Special care should be used early in the season, not because the plant is more poisonous at that time, but because, on account of the dry condition of other forage, it is more likely to be eaten. Later in the season sheep are less likely to eat a large quantity, because of the greater abundance of other food. As a matter of fact, most of the cases of extensive poisoning have occurred before the flowering of the plant.

If sheep become poisoned, they should be kept as quiet as possible. Any attempt to make them move about is likely to have disastrous results.

So far as remedies are concerned, none has been found so far that gives much promise of being really useful. The experimental work at Greycliff shows that repeated doses of tannic acid or sodium bicarbonate will aid in recovery, but this method of treatment is not practically possible for animals upon the range.

GENERAL SUMMARY.

Zygadenus grows abundantly on many of the stock ranges of the West and is one of the most important sources of loss to sheepmen. Apparently all species of Zygadenus are poisonous. The plants are poisonous through the whole season of their growth, but the tops are somewhat more poisonous at the time of flowering. The toxicity of the bulbs and tops is about the same, while the seeds are much more toxic than other parts of the plant. Cases of poisoning are more likely to occur before the maturity of the plant, because at that time other forage is scanty.

The toxic dose varies according to the conditions of feeding. In drenched animals it may be put at about one-half a pound for an animal weighing a hundred pounds. In fed animals it varied from 1.6 pounds to 5.6 pounds.

The poisonous principle is an alkaloid or alkaloids allied to veratrin and cevadin.

Sheep, cattle, and horses are poisoned by the plant, but the fatalities are almost entirely confined to sheep.

The principal symptoms are salivation, nausea, muscular weakness, coma, and sometimes attacks of dyspnœa.

To prevent losses, it is important to recognize the plant and avoid grazing upon it. If animals become sick they should be kept quiet, and under this treatment many will recover. There is no satisfactory medical remedy.

LITERATURE CITED.

BRITTON, N. L., and BROWN, ADDISON.

1913. Illustrated Flora of the Northern United States, Canada, and the British Possessions . . . ed. 2, v. 1, New York, p. 490–491.

CHESNUT, V. K.

1902. Plants used by the Indians of Mendocino County, California. Contributions, U. S. National Herbarium, v. 7, p. 321–322, 327.

——— and WILCOX, E. V.

1901. The stock-poisoning plants of Montana; a preliminary report. U. S. Department of Agriculture, Division of Botany, Bulletin 26, p. 51-64, pl. 1.

COLLIER, PETER.

1882. Proximate analysis of Zygadenus paniculatus. Report, [U. S.] Commissioner of Agriculture, 1881/82, p. 547–548.

COULTER, J. M.

[1909.] New Manual of Botany of the Central Rocky Mountains . . . rev. by Aven Nelson. New York, p. 118–119.

COVILLE, F. V.

1897. Notes on the plants used by the Klamath Indians of Oregon. Contributions, U. S. National Herbarium, v. 5, no. 2, p. 93.

GRAY, ASA.

1848. Melanthacearum Americae Septentrionalis revisio. Annals, Lyceum of Natural History, New York, v. 4, p. 124.

———

[1908.] Gray's New Manual of Botany, ed. 7, rev. by B. L. Robinson and M. L. Fernald. New York, Cincinnati, p. 284.

HELLER, A. A.

1909. The death camus. Muhlenbergia, v. 5, no. 3, p. 50–52.

HEYL, F. W., and HEPNER, F. E.

1913. Some constituents of the leaves of Zygadenus intermedius. III. Journal, American Chemical Society, v. 35, no. 6, p. 803–811.

——— ——— and LOY, S. K.

[1912.] Zygadenine. The crystalline alkaloid of Zygadenus intermedius. Second paper. Wyoming Agricultural Experiment Station, 22d Annual Report, 1911/12, p. 51–57, 2 fig.

——— ——— ———

1913. Zygadenine. The crystallin alkaloid of Zygadenus intermedius. Journal, American Chemical Society, v. 35, no. 3, p. 258–262, 2 fig. See also Wyoming Agricultural Experiment Station, Bulletin 101.

——— LOY, S. K., KNIGHT, H. G., and PRIEN, O. L.

1912. The chemical examination of death camas. Wyoming Agricultural Experiment Station, Bulletin 94, 31 p., 3 fig.

——— and RAIFORD, CHARLES.

[1911.] Analysis of Zygadenus intermedius. First paper. Wyoming Agricultural Experiment Station, 21st Annual Report, 1910/11, p. 62–69. See also Journal, American Chemical Society, v. 33, no. 2, p. 206–211, 1911.

HILLMAN, F. H.

1893. A poisonous plant. Nevada Agricultural Experiment Station, Newspaper Bulletin 5, 1 p., 1 fig.

———

1897*a*. A dangerous range plant. Nevada Agricultural Experiment Station, Newspaper Bulletin 21, 1 p., 1 fig.

———

1897*b*. Nevada weeds. III. Nevada and other weed seeds. Nevada Agricultural Experiment Station, Bulletin 38, p. 114–116, fig. 116–117.

HOOKER, W. J.

1838. Flora Boreali-Americana . . . v. 2, London, p. 177.

HUNT, REID.

1902. Experiments with Zygadenus venenosus (poison camass). American Journal of Physiology, v. 6, p. xix.

IRISH, P. H.

1889. Plants poisonous to stock. Oregon Agricultural Experiment Station, Bulletin 3, p. 25–26.

LLOYD, J. U., and LLOYD, C. G.

1887. Zygadenus nuttallii: the death camoss of the West. American Druggist, v. 16, no. 8, p. 141.

McCARTHY, GERALD.

1903. The poisonous plants of North Carolina. Report, Commissioner of Agriculture, North Carolina, 1902, p. 167.

MITCHELL, P. H., and SMITH, GEORGE.

1911. Physiological effects of alkaloids of Zygadenus intermedius. American Journal of Physiology, v. 28, no. 6, p. 318–329, 3 fig.

NELSON, S. B.

1906. Feeding wild plants to sheep. Washington Agricultural Experiment Station, Bulletin 73, p. 51–54, 1 fig.

PARSONS, MARY E.

1904. The Wild Flowers of California . . . illustrated by Margaret W. Buck. San Francisco, p. 6–8, 1 fig.

SLADE, H. B.

1903. Some conditions of stock poisoning in Idaho. Idaho Agricultural Experiment Station, Bulletin 37, p. 181–183, 1 pl.

———

1905. Some alkaloids of the death camas. American Journal of Pharmacy, v. 77, no. 6, p. 262–264.

VEJUX-TYRODE.

1904. The composition of Zygadenus venenosus and the pharmacological action of its active principle. Journal of Medical Research, v. 11 (n. s. v. 6), no. 2, p. 399–402.

WATSON, SERENO.

1880. Botany. [Geological Survey of California.] v. 2, Cambridge, Mass., p. 183.

WYETH, N. J.

1899. Correspondence and journals . . . 1831–6 . . . Sources of the History of Oregon, v. 1, pt. 3/6., p. 225.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C
AT
15 CENTS PER COPY

INDEX.

44413—16——3