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BEANS IN COLORADO AND THEIR DISEASES

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By

ALVIN KEZER & WALTER G. SACKETT

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BEANS IN COLORADO

By ALVIN KEZER

SUMMARY

Beans are becoming an increasingly important crop in Colorado.

They are well adapted for both dry farming and irrigated conditions.

The "Plains" section is almost entirely adapted for the growing of beans. They do well also in mountain valleys at altitudes not to exceeded 7,000 feet. In many localities 6,000 feet is too high for their proper growth because of the shortness of the season and the tendency of early and late frosts.

Beans are an excellent cash crop, with a well established market and market facilities.

In Colorado the chief market bean is the pinto. Navies, teparies and the Red Mexican or Red Miner are grown to some extent. A white Mexican bean, closely related to the pinto is gaining popularity in certain sections.

Many beans are being grown under contracts with seed houses. These beans represent a number of different varieties produced for seed, because of peculiar advantages for clean seeed which the semi-arid climate possesses. The chief danger of seed bean contracts is injury to standard markets by growers attempting to throw rejected seed onto the standard markets.

Beans are a hot weather crop, consequently, they should not be planted until frost danger is past. In most localities this will be approximately June 1st.

Planting should be shallow. Planting may be done preferably with the regular bean planters. Corn planters with bean plates may be used. The ordinary grain drill, stopping the proper number of holes, is feasible where necessity requires.

Beans are a shallow rooted crop. Consequently, the first cultivation should be the deeper. Later cultivation should be as shallow as the first cultivation or even shallower. Cultivation should not be over 3 inches.

In irrigated districts, beans should be irrigated so as to keep the beans growing. A very dark green color is generally indicative of a need of water. Beans should not be irrigated later than full bloom on most soils, as later irrigation will delay maturity and not increase yield materially. Ordinarily one to two irrigations are sufficient.

Harvesting should be done preferably with a bean harvester. This is especially true where any considerable acreages are planted. On very small acreages, they may be harvested by taking the mold board off the plow or by using a shovel.

Beans shatter in thrashing very easily, consequently the bean huller should be used unless the acreages are very small. There are special attachments which may be used on the regular grain separator, provided the separator is run at very low speed. Patches of one to two acres can be thrashed with a flail as cheaply as by machine unless a machine is near. Machines for cleaning are available and should be used, as they increase market value.

Pinto beans, the chief Colorado market sort, will average from 300 to 800 pounds under dry lands and may yield as high as 1,800. The same beans will average from 1,200 to 2,000 pounds under irrigation; and may yield as high as 3,000 pounds or even above.

Market prices may be increased by putting beans up in uniform packages and having them thoroly cleaned.

Bean straw should be carefully saved, as it is a valuable feed. This applies especially to dry lands.

Beans make an excellent rotation crop. Wheat on the dry land after beans will do as well as after clean summer fallow most seasons.

The yield of beans may be increased and their quality improved by wise field selection.

Seed beans should be hand picked to get uniform quality and freedom from disease. Care should be taken not to plant beans which have been frost bitten.

There are many diseases which affect beans. The best methods of controlling these diseases is the picking of clean seed and following a rotation. Beans should not be planted on the same land two years in succession. Two to three years should elapse before beans are again planted on the same land.

INTRODUCTION

The Colorado bean acreage has been steadily growing for the last ten years. The rate of growth in 1915 and 1916 has been as great as in the previous eight years. According to the Bureau of Statistics, United States Department of Agriculture, 38,000 acres were grown in Colorado in 1916, a jump from 21,000 acres in 1915, and 20,000 acres in 1914. The total production of the State in this period has jumped from 18,000,000 pounds to 25,440,000 pounds, in round numbers. In other words, the acreage has increased 81% and the total production has increased in the same period about 41%. The 1916 yield per acre was low on account of one of the worst drouths in the history of the Colorado Plains. The seasons of 1914 and 1915 were especially favorable, with high average acre yields. In 1917, 243,000 acres of beans were planted in Colorado. Owing to poor farming, very unseasonable weather conditions, hail and other vicissitudes only about 190,000 to 200,000 acres were harvested. The difference between the area planted and the area harvested represents the mortality due to unfavorable conditions. Of this area about 40,000 acres was irrigated. There were grown for seed, under contract with seed houses, about 20,000 acres. These seed beans represented about a dozen different varieties and were produced mostly for eastern seed houses. The total 1917 yield was approximately 90,000,000 pounds.

Beans are well adapted for growing in nearly all sections of the plains. Beans are a hot weather crop and as a consequence must be produced in the frost-free period. To successfully produce a bean crop, the season should be at least 95 days in length; 95 to 100 days should be the minimum. A season of this length is seldom found above an average of 6,000 feet in elevation. There are localities where the slopes are favorable and the soils sandy, where the seasons are somewhat longer, permitting the production of beans at altitudes as high as 7,000 feet. If the season is bright and rather warm, some of the early varieties may be matured in as short a season as 60 days. A cloudy season, however, always lengthens the growing period. Cool, cloudy weather may extend the growing season, especially if rains accompany these weather conditions or if irrigation is given. In such cases the season required for maturity may be as long as 130 days, too long for many sections even 6,000 feet in altitude.

The pinto bean, which formerly went under the name "Mexican", is by far the most important market bean, as it exceeds in acreage and total production all other beans produced. The seed industry beans, which are of numerous varieties, are the only ones which begin to compete in acreage with the pintos. These seed beans are largely produced under contracts with seed houses and consequently do not reach bean markets.

While beans may be successfully grown practically anywhere on the plains at altitudes below 6,000 feet, they are most abundantly grown in Weld, Logan, Morgan, Las Animas, Washington, Otero, Bent, Prowers, El Paso, Adams and Arapahoe Counties. They may be successfully grown in other places, but development in other regions has not yet been carried to the extent which these counties have made. The realization of the value of beans as a cash crop, and the ease with which they fit into a rotation by throwing in an annual cultivated crop, will very likely tend to increase their general production.

VARIETIES

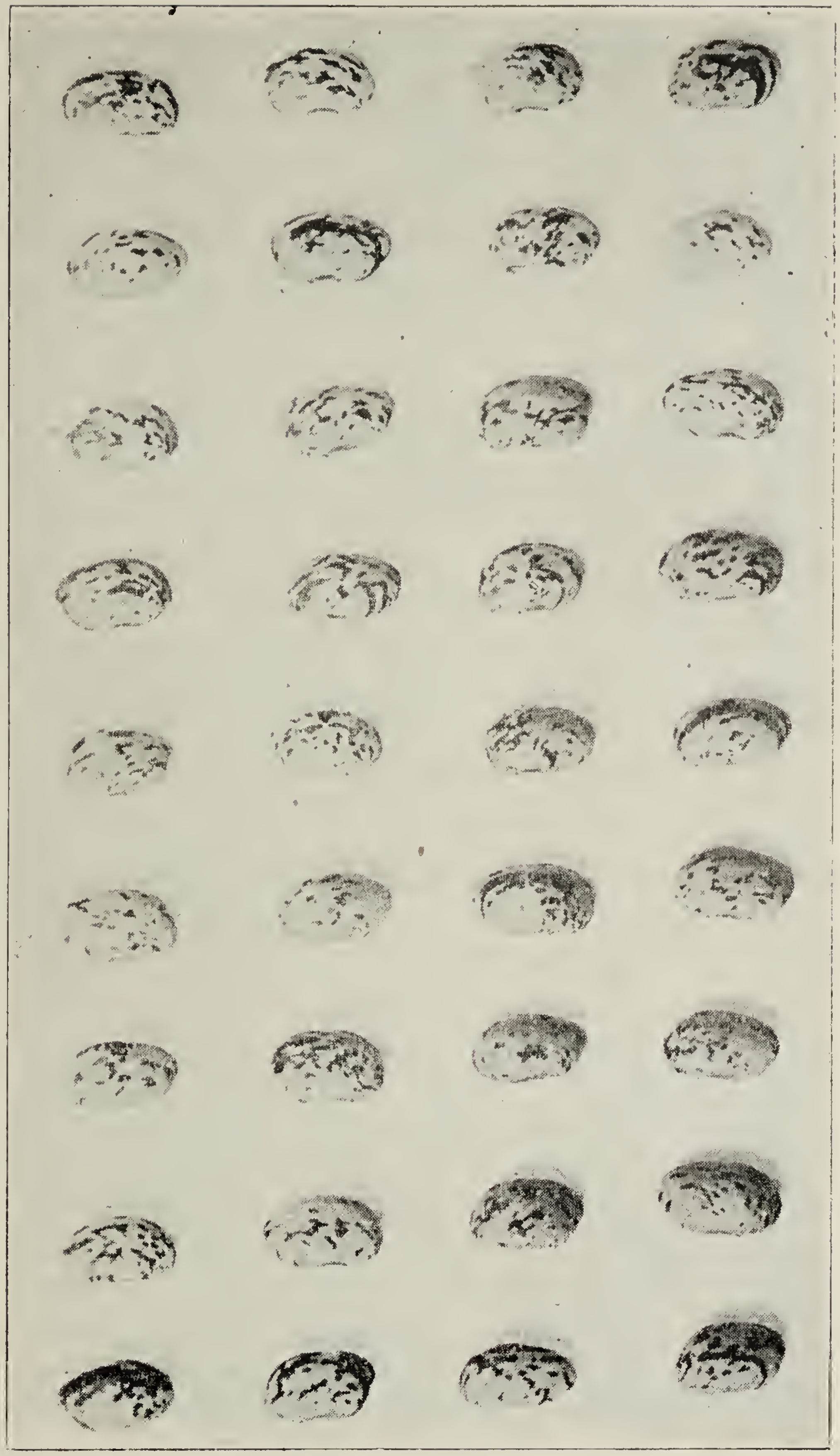
The chief market variety is the pinto. The pinto bean was formerly called the Mexican. This name, however, is inappropriate, as there are numerous other Mexican varieties. The name "Mexican" as a consequence did not mean any definite bean. "Pinto" applies to a specific bean.

The pinto bean is about the same size and shape as the kidney bean, so well known as a garden variety. The pinto is buff-colored, is speckled with tan to brown spots and splashes. It is further characterized by a characteristic yellow rim or border about the germ. In many places in the southwest the pinto is called the Mexican tick bean. In other places in the southwest it is known as the Colorado bean. In a few places it has acquired the name army bean. The name "pinto", however, has become so well established that it should be universally used.

While the pinto is the chief market bean, other beans are grown and frequently do well. The navies are grown and produced to a small extent—both the pea bean and the little navy. For garden purposes considerable quantities of kidney beans and "snaps" are grown. In most of our territory the season is too short for the proper development of limas; consequently, they do not figure in our bean problem to any extent. In parts of Colorado the Red Mexican or Pink Mexican, or Red Miner, is grown. This bean, however, is more extensively grown in New Mexico and Arizona and other points of the Southwest than in Colorado.

PREPARATION OF THE SOIL

Beans will grow on almost any kind of soil, from adobes to light sandy loams. They do best, however, on warm, sandy loams and sandy silts. Preparation of the soil for beans should commence prior to the season in which the beans are grown and should take into consideration proper rotation and manuring. The soil should be prepared by plowing. Wherever fall plowing may be done without danger of serious fall blowing, the soil should be plowed in the fall. In the spring



Colorado Pinto Beans about natural size (Courtesy C. & S. Ry.)

this land should be worked down into a seed bed, making as good a seed bed as would be made for beets or corn. Where spring plowing is done it should be done early.

Beans respond to good preparation. Consequently enough attention should be paid to disking, harrowing and compacting the seed bed. In some sections listing has been attempted as the method of preparing the soil for bean planting. Listing, however, is poor practice, except upon soils which cannot be safely plowed, because of their very strong tendency to blow. Where the land is prepared by listing, there is a tendency to slow up the development of the crop and delay maturity. In addition to these handicaps, beans planted by the listing method are more difficult to harvest; especially if there is damp weather during the harvest there is likely to be much damage to the pods by coming in contact with the soil. The tendency to pick up adobe soil or stones is increased at harvesting time. If listing is done at all, it should be very shallow so as to make the furrow to be filled about the growing plants as shallow as possible.

It is not always necessary to plow land in preparing a bean seed bed. Where the land was well plowed the year previous and in wheat, a good seed bed may be prepared without plowing, provided the wheat stubble is disked right after the binder to keep down weeds in the fall. The spring preparation may consist of disking when the weeds start, which will destroy the weeds and prevent the formation of a crust, and then disking and harrowing immediately before planting. After a cultivated crop such as corn, which has been well cultivated, a seed bed may often be prepared by disking and harrowing.

On irrigated lands after sugar beets or potatoes, it is not necessary to plow in preparing a bean seed bed. Disking, leveling and harrowing will be sufficient in these circumstances.

PLANTING

Care in Selecting Seed Beans.—The importance of getting good seed beans is sufficient to warrant special care in picking the seed. It is worth while taking a little extra care in Colorado on account of the short seasons. In many localities there is danger of beans being frost bitten in the early fall. Sometimes this light freezing will very materially weaken the germ so that the crop will have very small germinating power, altho the frost may not be sufficient to injure the beans seriously for market purposes. Care should therefore be taken not to use beans for seed which have been frost bitten before full maturity.

Many of the diseases which affect beans leave spots on the beans themselves. One of the most effective remedies in combatting bean diseases is to pick out plants for seed which are not affected by the disease. Accordingly all seed beans should be from plants selected in the field and hand picked. Plants having discolored beans with strange colored spots should be rejected, planting only from those having bright, clean seed.

These statements hold, no matter what variety of beans is planted.

Time to Plant.—Beans are a hot weather crop. Seed is injuriously affected if it is planted in cold soil. Germination will not take place while the soil is cold, and if the soil happens to be wet enough, rotting may take place before the soil warms up sufficiently to permit germination.

Beans will not stand any frost. The very slightest degree of frost is apt to kill them entirely. On account of these reasons, beans should not be planted until the soil is thoroughly warmed up. In most Colorado sections this will be the last week in May or early in June. Successful plantings have been made as late as the first week in July, but the grower is tempting fate too much to make a practice of such planting, as frosts are likely to occur as early as the 25th of August.

While pinto beans and some of the teparies and a few of the Mexican and Indian varieties have been matured in 60 days or less, it normally takes about 90 days to mature a crop even for these short-season beans. In those seasons when frosts hold off until late in the fall, late planting will often make a crop, but frosts do not always hold off until late.

Method of Planting.—If there is any considerable acreage of beans to be put in, a bean planter should be procured, or a corn planter with bean plates. In Colorado beans should always be planted in drills so that the bean planters or corn planter should be so arranged as to drill the seed one in a place. It is possible to make use of a grain drill by stopping up the proper number of holes, in fact, many beans are successfully planted with such an implement. The type of grain drill having a revolving cup feed is adapted for this kind of planting.

Most of our grain drills have 7 or 8 inches between the drill holes. Stopping up three drill holes would therefore plant 28 inches apart, which is about right for irrigated planting. With a 7-inch drill, stopping up 5 holes, that is, leaving open the first and sixth drill, would plant 42 inches apart, which is about right for dry land. Some dry lands are strong enough to justify planting 36 inches apart. Stopping up four drill holes, leaving the first and fifth open, would plant 35 inches apart, which is about right.

Under irrigated conditions the rows should be about 28 inches apart. On dry lands, they should be from about 3 to 3½ feet apart. Under very dry conditions it is sometimes advisable to plant 7 feet apart and cultivate all of the intervening space. For irrigated conditions the drill should be thick enough to make one plant every 4 to 6 inches. This will require around 30 to 35 pounds per acre of seed for pinto beans. It will require a greater number of pounds for larger beans and a somewhat smaller number of pounds for the small pea beans.

For dry land conditions beans should, under normal conditions, be planted in rows about 3½ feet apart and in drills in the row 10 to 12 inches apart. If dry land conditions are a little severe, or uncertain, the space can be made a little further in the drills, say from 12 to 16 inches. According to the rate of drilling, it would take from 8 to 20 pounds of seed to plant an acre under dry land conditions. For an average planting, probably about 15 pounds per acre will be used. Where the rows are made 7 feet apart, under very severe conditions, the planting should be 6 to 8 inches in the drills.

Of the many beans planted only a few are put in by plowing shallow and dropping the beans in every third or fourth furrow, covering the beans by plowing and then packing and harrowing afterwards to compact the surface soil over the beans. This is not a good practice, but can sometimes be used in very small patches. Where large plantings are made, a bean planter adjusted to plant in exactly the proportion desired, should be used.

CULTIVATION

Beans of all varieties are rather shallow-rooted surface feeders. Consequently all cultivation after the crop starts should be shallow. The most important part of the cultivation should be done in the preparation of a seed bed. Immediate cultivation should commence about the time the rows can be seen in the field. Where the stand is extra good, beans may sometimes be harrowed a time or two if care is taken to do this work when the young vines are perfectly dry. If the soil

Cultivating dry land pinto beans in El Paso County is a little moist and the vines moist, the young vines will be found to be quite brittle so that harrowing will break off a large number. With the surface of the soil rather dry and the plants dry, the young plants are tough and will stand harrowing.

Some of the weeders on the market are excellent tools to use at this time.

The first cultivation with the regular cultivator should be the deepest. This first cultivation should not be over 3 to 4 inches deep. Later cultivations should be as deep or slightly shallower than the first cultivation. When the first cultivation is made, the roots have not extended very far into the space between rows. The stirring of the surface layer at that time by the cultivator makes a dry layer on top. If this is maintained the beans will root below the dry layer. Cultivation should be aimed primarily to keep down weeds and prevent the formation of a crust. Usually all cultivation should cease by the time the first pods commence to set. Sometimes the plants have grown enough so that cultivation should cease before this time. Care should be taken never to cultivate when the young bean plants are wet, as they are easily broken at such times, and when so broken are very susceptible to certain bean diseases. Under irrigated conditions cultivation should follow irrigation, as soon as the surface moisture and the plants will permit. The aim should be to prevent the loss of water by cultivation rather than to furnish water by excessive irrigation.

Irrigating Beans.—A study has been made of bean irrigation in eight Colorado counties. This study shows conclusively that it is fully as easy to over-irrigate beans as to under-irrigate them. As an average of all results obtained, two irrigations give higher yields than three or more irrigations. There was some difference as to quality of land; very open gravelly lands would stand more irrigation than sandy loams, loams and clay loams.

In irrigated districts which have a low precipitation and where crops must usually be irrigated up, it is good practice, especially on loam, clay and adobe soils, to irrigate the land before planting, thoroly watering the land at this irrigation. Just as soon as the soil can be worked after the irrigation, the soil should be harrowed, or disked and harrowed, leveled and planted. Cultivation should be depended upon to conserve the water supply. Irrigated in this way, two irrigations are more effective than three applied after the beans are planted. Cultivation should be resorted to rather than irrigation, to conserve the water supply.

In irrigated regions beans should be given water when they show a need for water, namely, when the plants show a very dark green and commence to wilt during hot periods of the day. If the plants are light green and growing vigorously, irrigation may often be delayed unless it is necessary to irrigate to get the water.

Beans in irrigated districts will usually be planted in rows around 24 or 28 inches apart. The first step in irrigation is to use a furrow opener and make furrows between the rows. Water is run down these furrows under proper control, until the soil is moistened laterally and to a depth of at least 2 feet. This figure 2 feet is a relative one. Sometimes there is moisture enough in the subsoil at less than 2 feet from the surface when the surface needs irrigation. In such cases a lighter run of water will suffice. The last irrigation should very seldom be given after the blooming period; just as the plants are coming into bloom is as late as water should be applied in ordinary seasons, and on ordinary soils. Later irrigations delay the maturity of the crop and endanger proper ripening, because of possible frost injury. Such later irrigations do not materially increase the yield of beans.

The chief consideration, either on irrigated land or dry land, is good thoro cultivation. Such cultivation should be given as soon after irrigation as possible to get onto the land, and on dry lands such cultivation should be given after rains as soon as it is safe to work the soil. Cultivation should not be given after the vines begin to run, which is about the blooming period, as previously mentioned.

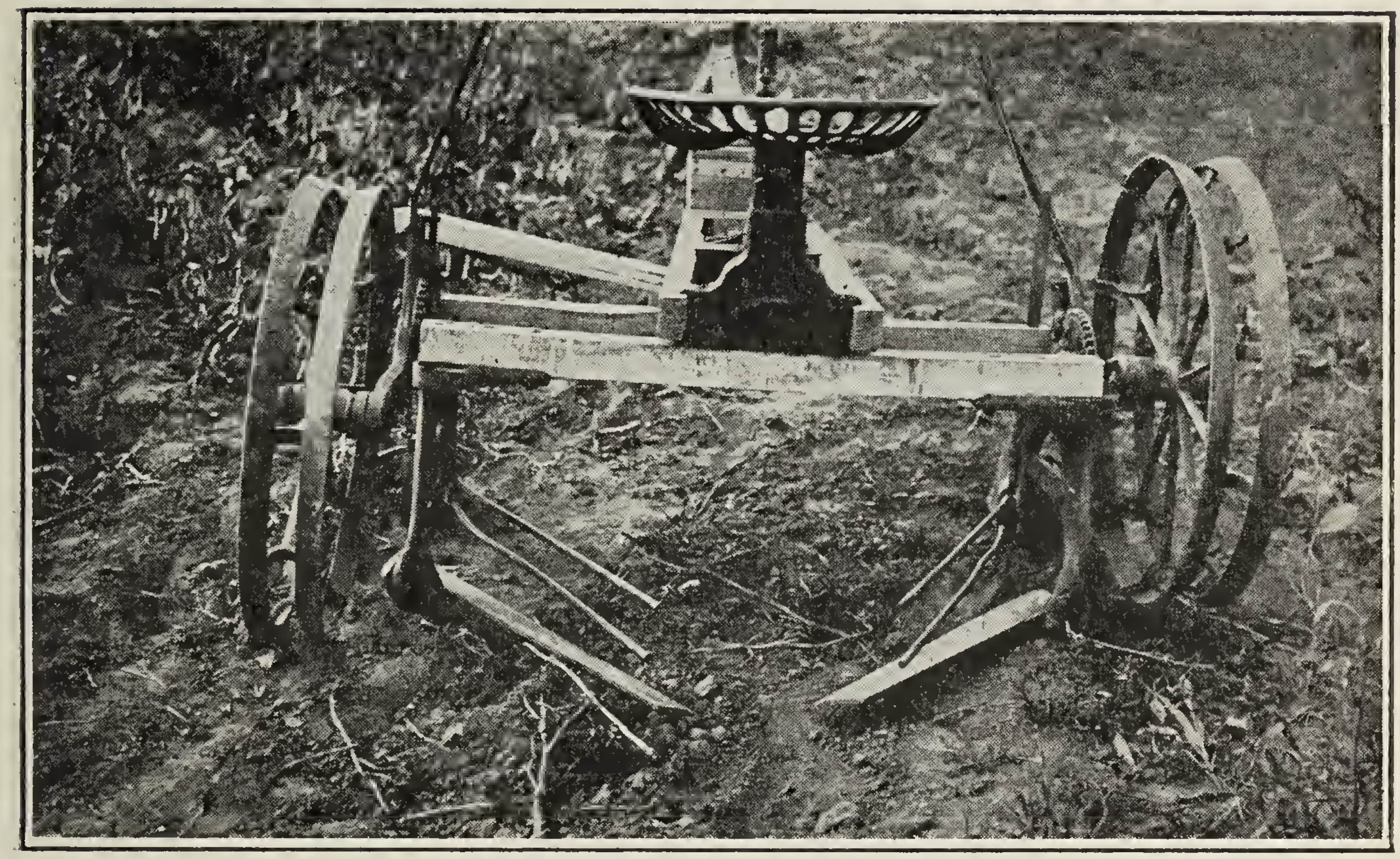
HARVESTING

All harvesting methods can be classified into hand harvesting and machine harvesting.

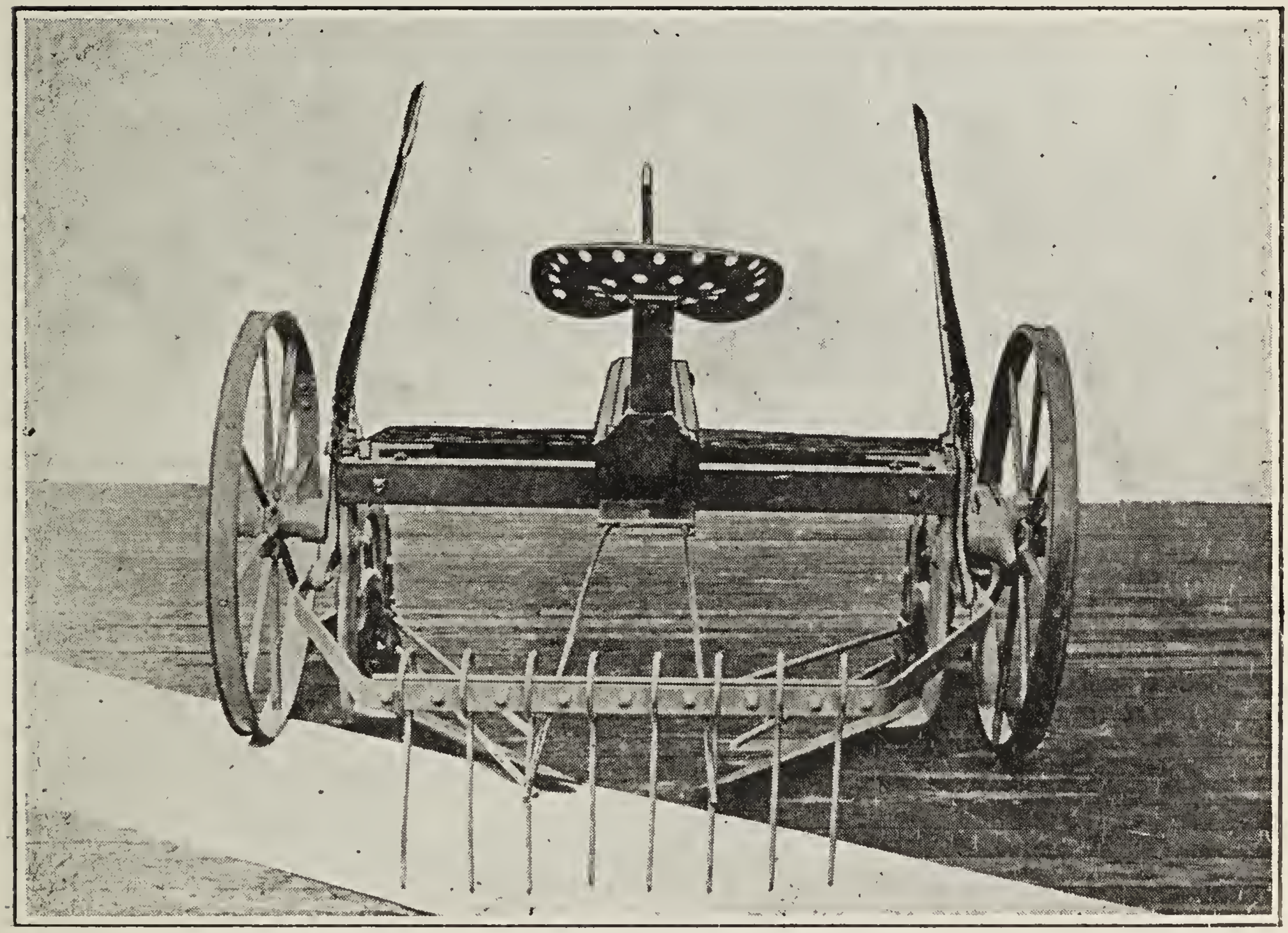
Hand harvesting is only adapted to small patches. Hand harvesting is usually done by either pulling the vines or cutting them off just under the surface of the ground with a sharp shovel. The vines thus pulled or cut off are shocked by means of pitch forks.

On sod land the ordinary type of blade bean harvester will not work on lands of such preparation. Hand harvesting has been necessary in the past. A few growers have overcome the difficulty by setting a revolving disk so as to cut off the plants below the surface of the soil. A special arm or frame has to be constructed to hold the disk at the proper angle and in the proper place. The disk, on account of its rolling motion, will not clog up with trash and chunks of unrotted sod.

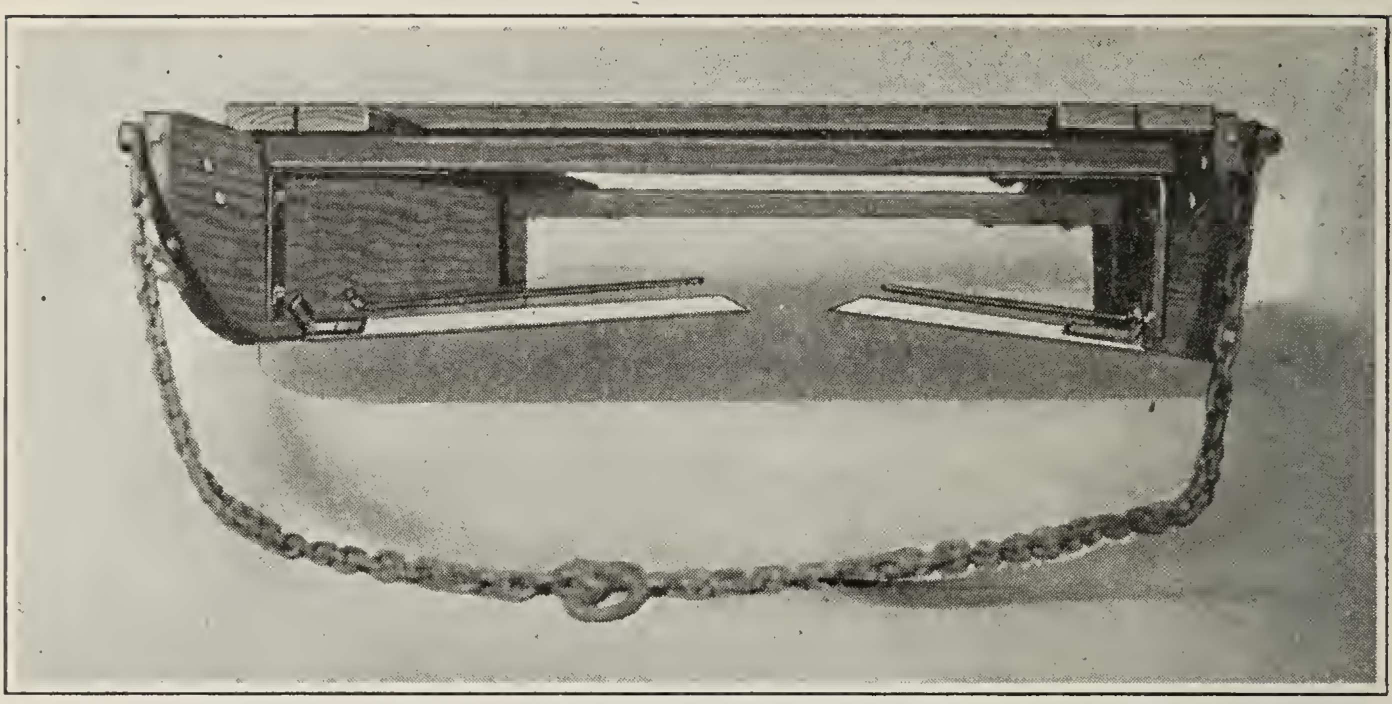
The best machines for harvesting beans are the regular bean harvesters. These machines cut the bean plants off just below the surface of the ground and by means of fingers push two rows together into one harvested row. The most up-to-date machines have bunching devices on the machine which bunch the cut vines into small, neat bunches. These bunches can be dressed up a little by a man with a pitch fork, for curing. Many of the machines, however, have no bunching device. In this case the bunching must be done by hand.



A common type of bean harvester



One of the newer bean harvesters with bunching attachment

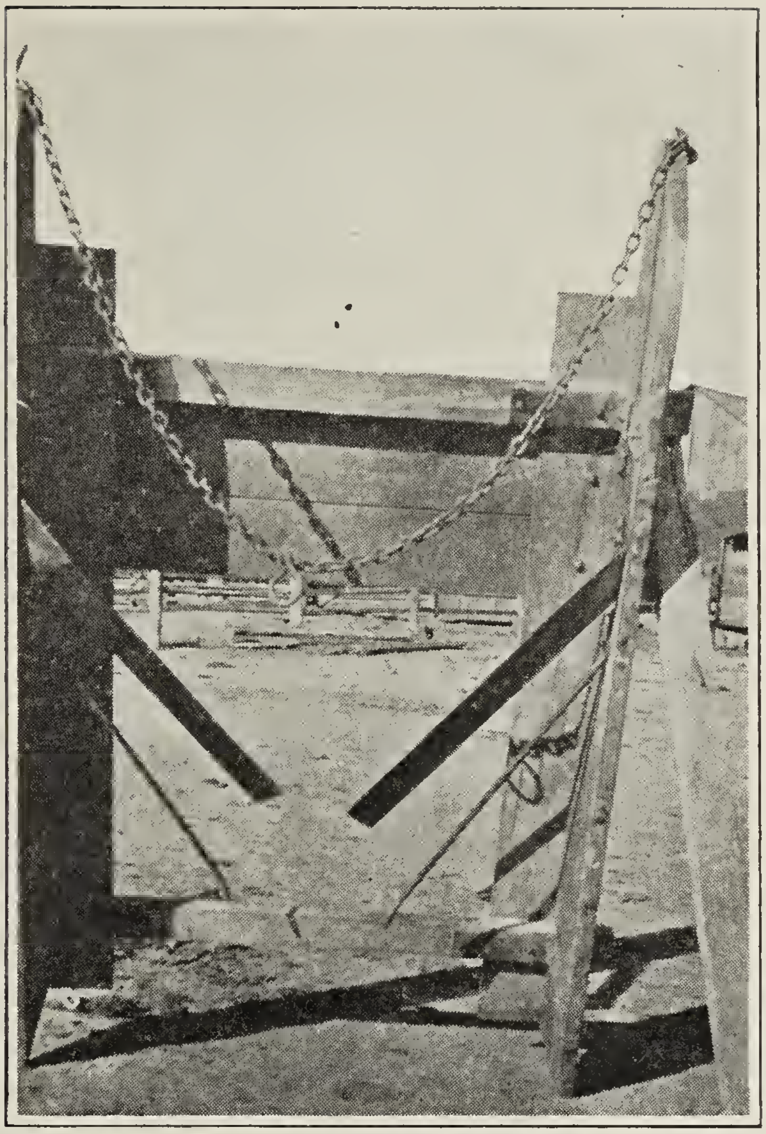


Home-made bean harvester (Photo by W. H. Lauck)

Men follow the machine with pitch forks putting the cut beans into neat shocks. Under Colorado conditions in practice the machines with the bunching attachment have not proved as successful as it was hoped. Some growers have found that if cut while the vines and pods are sufficiently moist, they can bunch the vines with a horse rake. This practice has only one disadvantage, namely, the bunches are usually too large for the proper curing and drying out of the vines and pods. A better practice is to collect the vines in small, rather flat bunches which can be easily turned over with the pitch fork in the hands of a single man. Such bunches cure readily and, if wet, can be inverted for drying. It has been found by experiment that a much higher quality of bean can be obtained by this method of bunching.

While a regular bean harvester is desirable and should always be used if there is any considerable acreage of beans grown, they may be harvested by using a breaking plow of the rod type, or by using a common sod plow with the mold board removed. Such expedients are much better than hand work on patches an acre or more in size, but should only be used on small patches where the size of the patch is not large enough to justify the purchase of a regular harvester.

Harvesting Period.—Opinions differ as to the proper time of harvesting. But experience and experimental work both show that if the beans are allowed to become completely ripe on the vine, heavy loss occurs from shattering. A good rule to follow is to harvest when the pods are turning yellow but have not yet dried out; at this stage there will usually be about half of the pods yellow ripe and a few still showing some green, providing the beans are ripening uniformly. When cut at this yellow-ripe stage, the beans will ripen up in the shock during the curing process and the loss in weight by drying out



Another view of home-made bean harvester (Photo by W. H. Lauck)

is very much less than the loss in weight thru shattering if the beans are allowed to become too ripe.

Experience shows in the case of pinto beans that they may be cut while the pods are still green if the bean is plump and well formed, that is, completely developed but green in appearance.

Care of Harvested Beans.—The beans thus cut with the harvester should be made into small shocks. Experience has shown that a small flat shock, just large enough so that it can be completely inverted or turned over with the pitch fork in the hands of a single man, will be blown about less by winds and enables the beans to be cured up in a much more perfect condition than larger shocks. These small flat shocks are not injured so much by wet weather as they can be dried out easily and cheaply by turning the bunches. They are close to the ground and do not blow badly. Being small and thin, shocks of this character dry out very rapidly in the curing process. Consequently they can be stacked and thrashed in a much shorter period than if larger shocks are used. If it is impossible to thrash them when cured, it would be far better to stack them in neat stacks so as to prevent loss by blowing, discoloration from weather conditions and also to leave the land free for cultivation. If the beans have been properly shocked, there will be very little shattering in stacking as the stacking can be done early in the day, or loss may be prevented by covering the hay rack or bean rack with canvas. In building a stack a bottom should be made with straw and the stack should be topped out with straw and weighted. If straw or millet is not at hand to be used for this purpose, a stack cover of canvas or corrugated iron will be advisable if any considerable time is to elapse before thrashing.

The harvesting process, together with summer cultivation, leaves the land in excellent shape for fall planted crops such as wheat, or even for spring planted crops as plowing is not necessary after the tillage given the beans.

THRASHING

Beans split very easily unless handled with care. Split beans are docked on the market. Consequently, tools should be used which split the minimum of beans. It is for this reason that the regular bean hullers or bean thrashers should be used for thrashing the crop.

There are a number of manufacturers having bean hullers on the market. It is possible by using some of the modern attachments to thrash beans with the regular grain separator. This should not be done unless a bean huller is so expensive, acreage considered, as to make it inadvisable. Where the grain separator is used to thrash beans, special attachments are put in and the cylinder is run at a very slow speed. Usually all the concave teeth with the exception of one row are removed.

Where a grower has only one-half an acre, or one acre, it is sometimes easiest and cheapest to thrash out his beans with a flail. Fifteen to eighteen hundred pounds a day can be thrashed out in this way by a single man.

Very few of the thrashing machines on the market will properly clean beans for the market. Consequently, machines called bean cleaners have been devised to clean up the beans ready for marketing. If any considerable acreage is grown, it would pay to have a bean cleaner to clean the thrashed beans before they are put on the market. Where only small acreages are grown, neighbors might well co-operate in the purchase of a cleaner, as one cleaner would do the work for several small growers.

YIELD

The Colorado pinto is the great market bean for Colorado. As has already been said, it is grown on more acres than all other kinds of beans combined. The average yield of pintos per acre on the dry lands in 1914 and 1915 was close to 800 pounds. In 1916 the average varied from 300 to 600 pounds per acre, with total failures in some neighborhoods. The season of 1916 was one of the driest in the history of the Colorado plains. The average yield of Colorado pintos on irrigated lands in 1914 and 1915 was 1,400 pounds per acre. In 1916 the average pinto yield under irrigation was close to 1,600 pounds per acre. Yields as high as 2,000 pounds per acre have been produced on the dry lands and as high as 3,200 pounds have been produced on irrigated lands. These higher yields are by no means average, but they show the possibilities of the crop when all conditions are made favorable. 1917 was a very unfavorable bean season. The spring was late, cold and wet which delayed planting. On the dry lands many sections received no rain for a three months period thereafter. Irrigated beans produced average yields better than ordinary but dry-land beans did not average over 200 pounds of beans per acre and

A good set of pinto beans; after a light frost

very few yields higher than 600 pounds per acre were reported. Some fields returned yields of over 300 pounds per acre without receiving any rain during their period of growth. Where these yields were obtained, the land had been plowed previous to the rainy spring. Where plowing was done after the rainy spring, low yields were uniformly obtained.

MARKETING

One of the most important problems in the marketing of beans is to have a clean, high-grade, uniform product. Mixed beans, with discolored, broken beans, seriously dock the price. Since the pinto outyields most other beans in practically all the Colorado bean-growing sections, it should constitute the chief market bean.

Machine-cleaned pintos will usually sell on the market within a cent of the price asked for hand-picked navies. The actual net return on pintos will usually be higher than for navies, because the cost of cleaning is not so great and the rejections under good market conditions are a great deal less.

In abnormal years, like 1916, buyers will take almost any kind of a bean, but even in 1916 buyers were paying a premium for uniform lots of clean, well-graded pintos. In some localities pintos are handled in bulk. Where this is true a uniform grade and cleanness should prevail in the bulk delivered. Many bean markets, however, require that the beans be bagged for shipment. Where such is the case, the beans should be thoroly cleaned and graded. Uniform, standard quality should be bagged in bags of uniform size and marking . The marking suggested is "100 Pounds Colorado Pintos". The remaining marking can specify the grower and address when so desired.

Growers will be able to receive much better prices where a uniform product is produced and where the entire neighborhood is growing one kind of bean. This is due to the fact that the marketing costs are lower under such conditions.

With the exception of one season, Colorado pintos have netted the growers around 4 to 4½ cents for the past eight or ten years. In 1916, prices much higher than this prevailed. But 1916 prices were as abnormally high as 1912 prices were abnormally low. At 4c a pound to the grower, pintos constitute a reliable cash crop which will return good acre net profits to the grower.

The red Mexicans, the spotted Indian beans and teparies do not have a standard market in this section. They are grown extensively in the Southwest. In fact, the pink bean in southern California, Arizona and New Mexico is quite generally grown and is perhaps the most common bean on the market, but for those sections to which Colorado normally ships, namely, the South and East, pintos and navies are the types known. Navy beans may be successfully grown under Colorado conditions, but they require much more hand work and care. Consequently, they are much more expensive to produce. While they bring higher prices on the market, the spread between navies and pintos is usually not over one cent. This spread will be more than obliterated by the increased cost of preparing navies for market. Besides, there will be a very much lower rejection in grading and cleaning from pintos than from navies, so that a greater proportion of the crop will actually reach the market.

Market grades have been established for the pinto beans. These grades have been adopted by the bean buyers' associations. It is quite probable that the Bureau of Markets may standardize grades for this crop. When such is done, it will be much easier for growers to prepare a standard product for the market. A standard product can be marketed to a better advantage than an unstandardized product, because very much less inspection is required to determine the quality of the product offered, where beans are so standardized and graded as to permit them to be sold on grade and sample without the necessity of sampling each individual bag.

Communities could do much in helping out their market problem by growing uniform quality and following market demands as to package and cleaning.

COST OF PRODUCING BEANS

It is impossible to give exact figures which will really represent the cost of producing beans, as so many factors enter into the cost of production on different farms. On dry land it was found that beans could be raised with as little labor as corn. The average amount of labor, therefore, required to produce an acre, would be equivalent to about 15 man hours per each acre of beans per year, and about 42 horse hours. While the number of horse and man hours necessary to produce an acre of beans will vary greatly with the season and type of soil, the amount of labor put in is fairly constant with a given set of conditions. The price of everything going into production, however, is increasing. Feed is higher. Horse and man labor and machinery are more expensive. In 1915 and 1916 the labor cost of producing a bean crop on dry land was probably between a minimum of $5.00 and a maximum of $11.00 per acre. The same amount of labor applied in 1917 would be a minimum value of around $12.00 per acre and a maximum of around $25.00 per acre for dry land conditions. To this labor cost it is necessary to add interest and depreciation on machinery and equipment and interest on the land or land rentals.

The cost of producing beans under irrigation will give a labor cost somewhat higher with additional expense for machinery, land rentals, watering expense and other incidental items.

For the years 1914 and 1915 studies were made on the dry lands. These studies showed that at that time the cost of field operations for the production of beans varied from a minimum of about $2.25 per acre to a maximum of about $8.00 per acre. Under the same conditions of operation these costs would have been more than doubled in 1917. Under present (1918) conditions it is impossible to make very accurate estimates as to cost of production because of the uncertainty of labor and machinery prices.

USE OF BEAN STRAW

The bean straw and hulls after the beans have been thrashed out will yield from one-half to three-quarters of a ton per acre on dry lands and somewhat heavier yields will be received from irrigated lands. This bean straw is capable of utilization. Especially on the dry lands every bit of bean straw should be saved and fed. Enough experience has already been obtained to indicate that on the dry lands if bean straw is fed with silage that it will return a food value nearly as great as alfalfa. If the bean straw is fed with other dry feeds, it is not as valuable as alfalfa. In fact, it appears to return about one-half the feeding value if fed with dry feeds, and almost as much as alfalfa when fed with succulent feeds. The utilization of bean straw, therefore, constitutes a very material addition to the feed supply under dry land conditions. It will pay growers having any considerable acreage to purchase hand cleaners and clean their beans at home, thus saving the culls, splits, etc. for use as feed upon the farm. Good split beans have a market at about half the price of first grade, first quality products. Splits may even be utilized for sale if properly handled where there is not sufficient stock to utilize them as feed.

BEANS IN ROTATION

Under irrigated conditions, beans furnish an opportunity for a cultivated cash crop, which is their chief value in irrigated rotations. Some types of weed pests can only be cleaned up where a cultivated crop can be introduced. Beans furnish such a crop, which may not only be cultivated, but hoed. On the dry lands, however, beans have a still greater value, because they furnish a cash cultivated crop well adapted for dry lands and capable of returning very good money values, dry-land possibilities considered. It has been found by experience that wheat, after a bean crop which has been well cultivated, will yield as well as after summer tillage or a summer fallow. Since they will usually pay well for growing, beans may be produced on lands which in many cases would be without a crop.

On the dry lands beans have a tendency to build up the soil. If the bean straw is fed to livestock and the manure properly applied to the land, the beans will be a decided, positive asset. If bean growing is a part of the regular farming system, the beans themselves should be grown in rotation. There are many bean diseases which tend to not only reduce the yield of beans, but to reduce their salability. One of the best methods of fighting these diseases is to plant beans in rotation, that is, never plant beans two years in succession upon the same land. At least two or three years should intervene in order that the land may not become inoculated with the diseases which affect the bean crop.

IMPROVEMENT OF PINTO BEANS BY SELECTION

The greater proportion of the planting of pinto beans has been done with little or no seed selection. Sufficient experimental work has been done to show that as much progress may be made from selection with pinto beans as is sometimes done with corn in the corn belt. The bean plants are mostly self-fertilized, thus, if a good strain is once obtained, no further selection within the strain is necessary, because the strain is a pure line and breeds true. Every pinto bean grower who is making a business of bean production should start a seed patch. The start should be made by selecting plants in the field. In making selection, the following points should be watched for:

A desirable type of plant—dry land Pinto Bean

1. High individual plant yield

2. Early maturity

3. Uniform ripening of pods on the plant

4. Freedom from disease

To make a seed plat, the seed of each of these selected bean plants should be planted by itself in a row. These rows are really comparative tests of the value of the selections. The high-yielding rows which are produced represent the mother plants which it is desirable to keep. All the seed from high-yielding rows having other desirable characteristics should be saved. If one strain should prove to be very much better than all others, this should be saved for seed and increased to the fullest extent possible. In this way the entire bean acreage will soon be planted from this high-yielding, early-maturing, even-ripening, disease-free strain.

Preliminary work with bean selection shows that it is easily possible to increase the yield 25 per cent by selection alone. To increase the yield this much would pay for all of the extra work of starting a seed patch and testing out in comparative tests the various selections, thus enabling the grower to pick out the highest yielding strain of his crop from which he may eventually plant his entire crop. It will pay to hand select seed to get seed of uniform marking, uniform size and freedom from disease, even if time and conditions do not permit the better work of the selection of pure, high-yielding strains.

A good field of dry-land pinto beans ready for harvest

DISEASES OF BEANS

By WALTER G. SACKETT

As mentioned elsewhere. the growing of beans in Colorado for seed purposes is one phase of the industry which has developed at a remarkably rapid rate, considering the length of time that the crop has been raised with this in view. In all probability, one reason for this has been the desire on the part of the seedsmen to obtain seed grown under conditions which normally tend to reduce the percentage of diseased seed. Such conditions obtain to a greater or less extent in both the dry land and the irrigated sections of the State. The absence of moisture in the form of rain, which tends to spread disease over the plants and from plant to plant, together with abundant sunshine are both valuable assets to the localities where beans are being grown.

Another consideration which made Colorado a desirable place for raising seed beans was the fact that until two years ago the disease question was practically negligible. There was plenty of disease-free land, new so far as bean culture was concerned, on which there was good reason to believe that no difficulty would be experienced for years to come in the line of plant diseases. But the inevitable has happened, and in the remarkably short space of two years.

Someone innocently planted diseased seed from which unhealthy plants developed, and from these as a starting point, it has been a relatively simple matter for the infection to spread from vine to vine, plant to soil, and field to field.

Where irrigation is practiced, the irrigating water, flowing as it does thru infected fields, carrying more or less trash and diseased soil with it, cannot be lost sight of as a means of disseminating the various ailments to which the bean is heir.

Our severe and prolonged winds which may assume the form of sand storms, transport quantities of soil, irrespective of whether it is diseased or not, from one locality to another. The mechanical injury to the pods and beans which results from this incessant pounding by the sand grains, not only weakens the plant, but also opens up the way for subsequent infection with germ-laden soil particles.

Some growers have failed to use beans in a rotation and have planted beans after beans on the same land, having lost sight of the fact that, aside from this being poor farm practice, the dangers from disease are increased very greatly by such a procedure.

Little if any attention has been given either to the planting or the selecting of disease-free seed, with the result that we have built up a big seed business in a phenomenally short time, but a business which is destined to fail, as has been the history elsewhere, unless we can establish a reputation for our seed with respect to quality, purity and freedom from disease.

Now is the time to do this, before our fields become generally infected, and while the prevalence of disease is so slight that it can be controlled for the most part by the means that we have at our disposal.

For the present consideration, we shall confine the discussion of bean diseases to those which have been observed to occur in the State during the last two years, and which, if neglected, may prove a serious menace to the industry.

Fig. 1.—Bean pods affected with Bacteriosis or Bacterial Spot

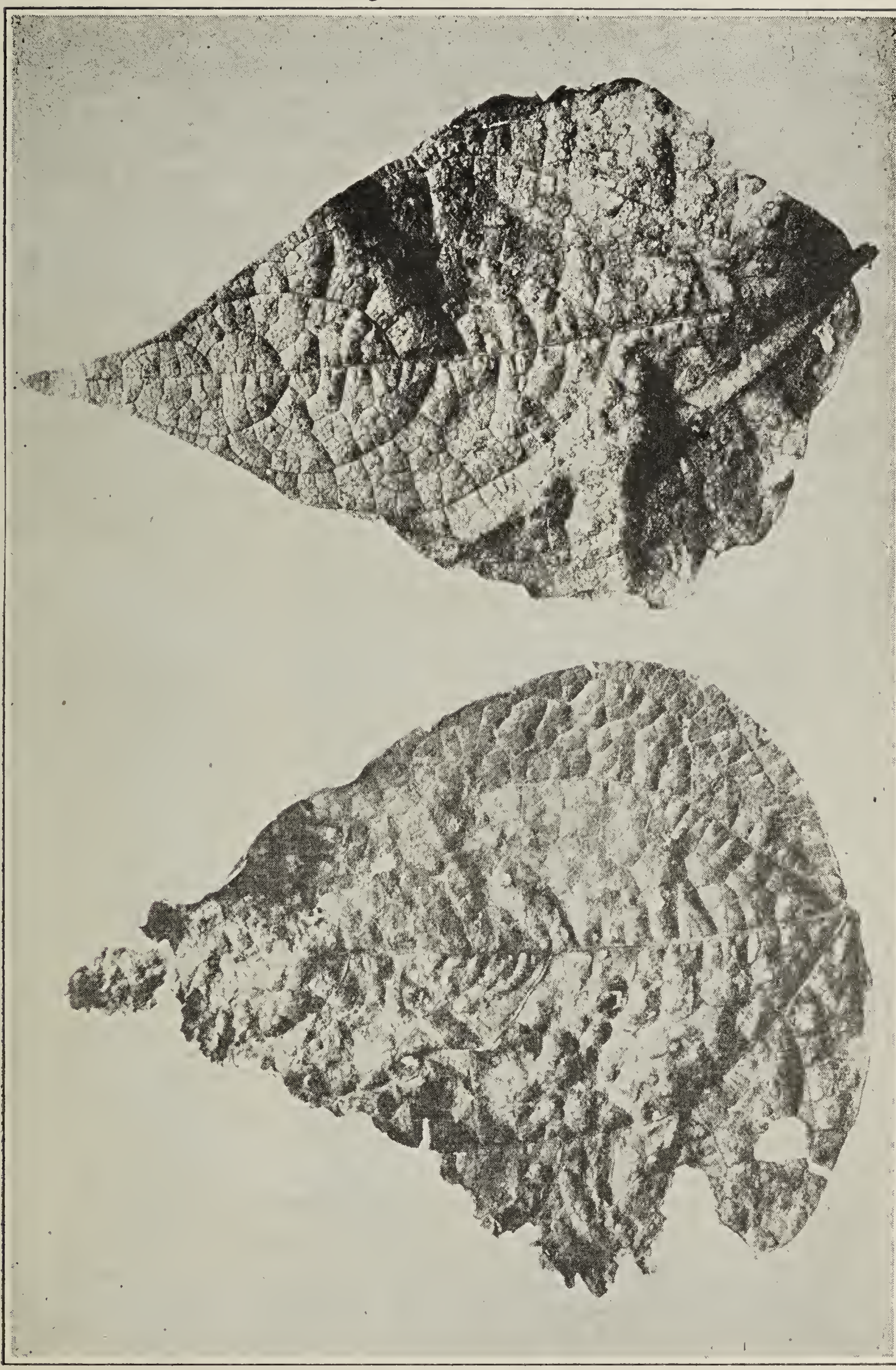


Fig. II.—Bean leaves affected with Bacteriosis or Bacterial Spot

DESCRIPTION OF DISEASES

Bacteriosis or Bacterial Blight

Without doubt, the greatest damage to our bean crop during 1916 resulted from an attack of the bacterial blight. This is caused by a germ, *Pseudomonas pheseoli*, which enters the plants thru the breathing pores or stomata and thru wounds produced by mechanical injury.

The disease is common upon field, garden and lima beans and attacks leaves, pods, stems and seed. It is very conspicuous upon the pods and leaves and can be recognized most easily, perhaps, upon the former, particularly in the wax varieties. Here we find watery spots ranging in size from tiny specks to areas three-eighths of an inch and more in diameter. They are usually irregular in outline and roughly circular in shape. On the wax varieties, the spots are translucent or watery, amber-yellow in color and frequently have a rosy-red margin. Their appearance, on the whole, is not unlike an ordinary blister, except that they are neither raised nor sunken. In the more advanced stages, they may be coated over with a thin, pale yellow or amber-colored crust which is composed largely of the bacteria which produce the disease. Ulcers in all stages of development can usually be found on a single pod. (See Fig. I.) When the lesions are numerous, they frequently coalesce, or run together, so that the whole side of the pod presents one continuous canker.

The injury to the leaves is very marked. In the early stages, irregular, watery spots can be found scattered over the surface which soon turn yellow and in a short time become frosty-brown in color. If the spots are numerous they will often coalesce and give the dry, brown leaf a peculiar blistered appearance. (See Fig. II.) The tissue in this condition is extremely brittle and is easily torn and broken, which accounts for the ragged condition of blighted leaves. The stems are affected in much the same way as the foliage.

Badly diseased plants lose their leaves early and fail to mature their seed. Spotted pods are unfit for the market as green beans, and seed from them is very apt to be diseased as the infection is communicated to the seed from the pod.

Pod-Spot or Anthracnose

Pod-spot or Anthrocnose has been of relatively little importance thus far in Colorado bean fields, but because of its ravages in other localities, it seems advisable to become acquainted with its symptoms in order that it may be recognized should it become serious.

The disease makes its first appearance on the seed-leaves and stems of the seedling plants. It manifests its presence there by brown, discolored, sunken spots or ulcers, indicating rather clearly that the causal fungus, *Colletotrichum lindemuthianum*, has been carried over winter in the seed.

In due course of time, spores, by means of which the disease is spread, are produced in these early spots. Eventually they are blown, or otherwise carried, to the growing stems, leaves and pods, where they soon become established and begin their destruction.

Fig. III.—Bean pods affected with Anthracnose or Pod Spot (After Whetzel, Bulletin 255, Cornell Experiment Station)

On the leaves we find reddish or blackened areas developing along the large veins on the under surface. The veins may be eaten thru by the fungus and destroyed, while the blade shows numerous cracks or holes with shriveled, blackened margins. Leaves in this condition are practically worthless as food-building organs, and as a result the nutrition of the plant is greatly impaired; either the yield of seed is reduced appreciably or the seed fails to mature.

Previous to the time of blossoming, the attack has been concentrated against the leaves, and by the time the young pods make their appearance the fungus has become well established and is amply supplied with spores. These soon find their way to the young, tender pods where they produce rusty-brown or black sunken spots with reddish or yellowish margins. (See Fig. III.) These vary in size, much as the bacterial spots previously described. The spores of the fungus are produced in the center of the black ulcers and form little pink masses visible to the naked eye. They are glued together with a mucilaginous material which sticks them securely to the spot. However, as soon as a drop of moisture touches them, the mucilage is dissolved and the spores are set free in the water. At this time any disturbance of the plant is apt to scatter the spores in the flying drop of water, and for this reason beans affected with anthracnose should never be cultivated while the dew is on them or while they are wet from a shower.

From the affected pods, the disease finds its way to the seed where it produces the familiar rusty-red or brown spots. In severe cases, the whole seed may be involved, altho ordinarily only a slight discoloration is produced on one side.

Bean Rust

Bean rust was observed in several fields last year, but it came so late in the season that little if any damage resulted. The causal fungus, *Uromyces appendiculatus,* attacks the leaves, stems and pods. The rust, as the name implies, can be recognized in its summer stage by the small, raised, rusty-brown powdery specks on the under side of the leaf which rub off easily with the fingers as a rusty-brown powder.

In the winter stage, the specks are black in color and occur on both surfaces of the leaf. When found on the upper side, they are usually surrounded by a light border, apparently where the green leaf tissue has been killed. (See Fig. IV.) While the rust is not uncommon, it has rarely been of sufficient economic importance to cause any considerable alarm. Of course, if the attack should come early in the season and be very general, the crop would suffer in proportion as

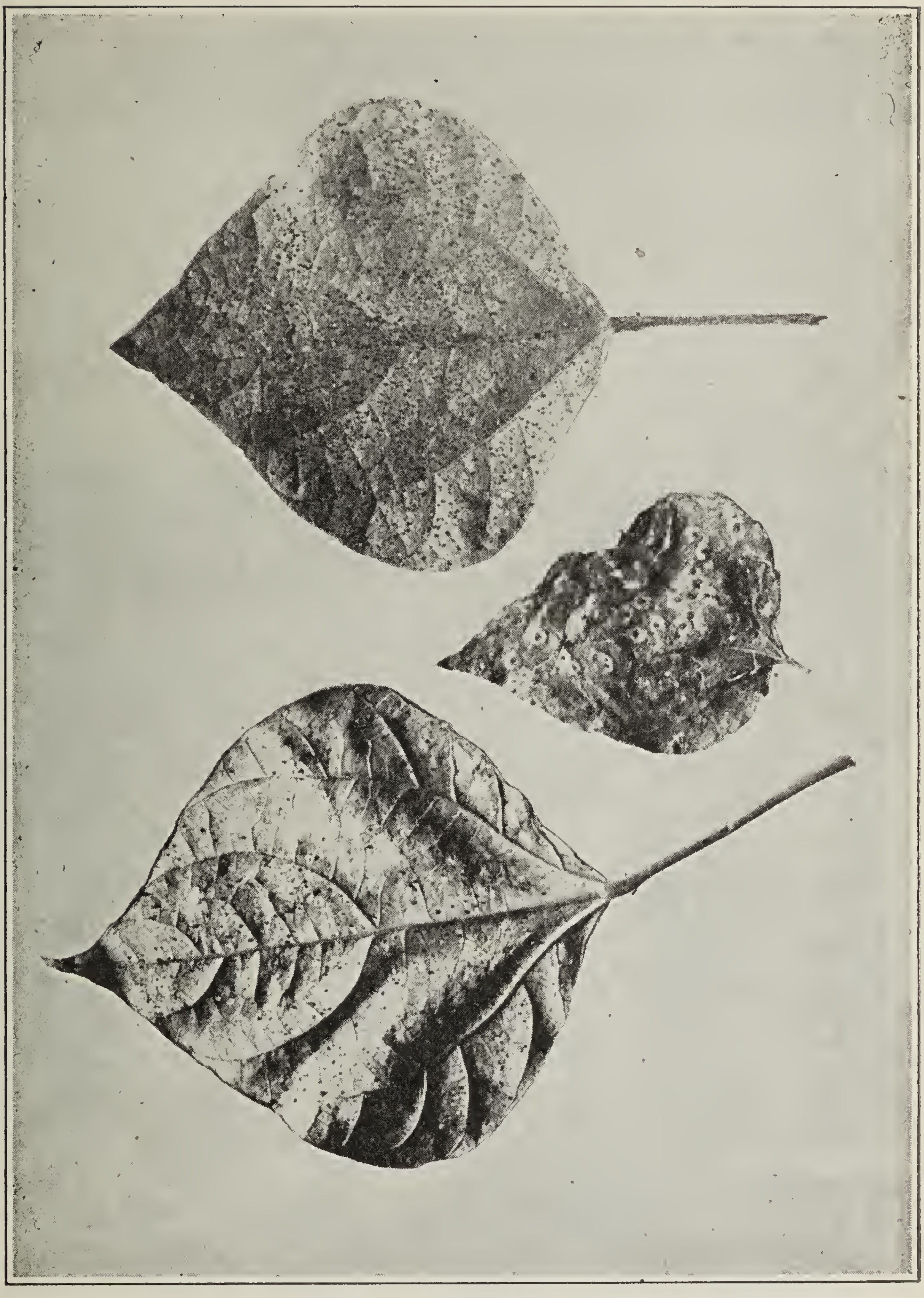


Fig. IV.—Bean leaves affected with Rust

the vitality of the plant was affected. As the disease winters over on the leaves, the destruction of these by burning offers the best means of eradication.

Bean "Streak"

For want of a better name, the term "Streak" is used here to designate what appears to be a new and undescribed disease of beans, which was observed in Colorado for the first time during the summer of 1916. Whether this is in reality something new, or merely a different manifestation of an old trouble, remains to be seen. It attacks stems, leaves and pods, the symptoms on the first two of these being much the same as with the bacterial blight. On the pods there appear peculiar rusty or orange-brown discolorations in the form of irregular splotches, just as if a brown stain had been spattered on them, and had run down in lines or streaks. (See Fig. V.) The side of the pod next to the plant is practically free from the discoloration, while the outer side may be more or less affected over its entire sur-

Fig. V.—Bean pods affected with "Streak"

face. The leaves are destroyed and the plants become defoliated before the crop matures.

It is our purpose to make a study of this disease during the coming summer and to determine, if possible, its cause and control.

Fig. VI.—Bean plant affected with "Streak". (By courtesy of Dr. H. G. McMillan.)

MEASURES OF CONTROL

The measures of control which can be recommended for any one of the diseases described, apply equally well to all. Accordingly, this phase of the question has not been taken up in connection with the individual diseases, but has been reserved for consideration as a whole.

1. Plant beans on the same land not oftener than once in three or four years, particularly if disease has been prevalent. Soils which once become thoroly infected as a result of continuous cropping are seldom safe to use for the same or closely related crops for years to come.

2. Wherever practical, destroy all diseased vines and trash by burning.

3. If the bean straw from diseased vines is to be fed, do not use the manure on a field that is to be planted to beans.

4. As far as possible, avoid cultivating the beans early in the morning when there is dew on them, or when they are wet with rain.

5. Hand pick disease-free pods, or if possible, select disease-free plants, for seed. Use these to plant a seed plat on land which has never raised beans and which is removed some distance from the main crop.

Remember that hand picking of seed as it comes from the flail or thrasher for the purpose of controlling disease is of no value, since it is impossible to detect even a small percentage of diseased seed.

6. Seed treatment for beans is of no practical value since any chemical that would penetrate the seed deeply enough to destroy the disease-producing organism would likewise be apt to kill the seed.

7. Spraying with Bordeaux mixture, 5-4-50 formula, even when done thoroly by competent persons, is at best unsatisfactory, unprofitable and only partially successful. However, if one desires to try this, the first application should be made when the plants have their first set of true leaves, repeated ten days later, and again just after blossoming. Remember that if any real benefit is to be derived, the stems, leaves and pods must be kept covered with the spray material.

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RECLAIMING NITRE SOIL IN THE GRAND VALLEY

By

E. P. SANDSTEN

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Fig. 1. Method of reclaiming nitre land by flooding

Fig. 2. Furrow method of reclaiming nitre land

RECLAIMING NITRE SOIL IN THE GRAND VALLEY

By E. P. SANDSTEN

The experimental work of Dr. Headden and Professor Sackett* of this Station has proven conclusively that the origin of nitre, often called black alkali, so abundant in many of our Colorado soils, is due to the activity of the nitre-forming organisms. The nitre is not confined to any particular section of the State, but occurs in almost every district and in all types of soil.

A study of soil management, especially in the orchard areas of the Grand Valley, has led the writer to conclude that the excessive accumulation of nitre is greatly increased by clean cultivation, as extensively practiced by the fruit growers.

It is a well-known fact that in most semi-arid soils there is little or no fermentation of organic materials, due to the action of prolonged sunshine, light rainfall and dry atmosphere. This, coupled with the presence of a high percentage of alkaline salts, forms ideal conditions for the activities of the nitre-forming organisms. The additional fact that nitre rarely occurs in injurious quantities in soils on which alfalfa is grown continuously for a long series of years, would indicate that land kept constantly in clean culture furnishes the best conditions for the nitre-forming organisms.

The orchard survey of Grand Valley, made by the Horticultural Department, reveals the fact that more than one thousand acres of bearing orchards, and orchards just coming into bearing, have been destroyed by nitre during the last few years, and, in addition, a considerable portion of the remaining orchards in the Valley are showing signs of nitre poisoning.

These observations led the writer to undertake some work in Grand Valley to reclaim land that had become barren because of excessive nitre, and also to check the process of nitre-formation in orchards that were still healthy and productive, but which showed signs of nitre poisoning.

The presence of excessive nitre in the soil is readily distinguished by the characteristic reddish-brown discoloration, and the mealy or powdery texture which always accompanies this trouble.

In the orchards, the presence of nitre is also readily distinguished by the appearance of the foliage of the trees, especially the foliage on tender growing shoots. The margins of the leaves

*See Bulletins Nos. 155, 160, 178, 179, 184, 186, 193.

turn reddish-brown, while the central portion assumes a pale yellow, greenish color. When the nitre is present in large quantities, the whole leaf turns reddish brown, and, in severe cases, the nitre may even attack the branches and the whole tree. In many instances, only a portion of the tree is affected. This is due to the fact that nitre may be present only in small spots, and the roots, feeding in these, become poisoned, and the branches which receive food from the roots in these areas show the presence of the poison. Often, a half tree will die, while the remainder of the tree appears to be perfectly healthy.

Several thousand acres of land in Grand Valley that have been made unproductive by nitre poisoning, could have been saved, and could yet be saved if the growers practiced rational methods of soil management.

The object of this investigation was to determine the quickest and most economical method of correcting and reclaiming nitre land in the Grand Valley. Particular attention was paid to land occupied by fruit trees, or lands that had been occupied by fruit trees which had been killed by excessive nitre in the soil.

The work was started in June, 1914, and has been carried on for the last three seasons on a farm west of Grand Junction.

Arrangements were made to take over two acres of land on which an apple orchard had been killed and the trees removed several years previous. This piece of land, at the beginning of the experiment, was entirely barren of vegetation. Even the hardiest and most resistant weeds failed to grow on it. Samples of the soil analyzed by Dr. Headden, Station Chemist, showed excessive amounts of nitrates. The condition of barrenness had existed for several years without any apparent change in the character of the soil, so far as sustaining plant life was concerned. The water table of this plat of land during the irrigating season came to about four feet of the surface and in no way interfered with the growth or ripening of the ordinary farm crops. The land is nearly level, but with a slight fall toward the south. The soil is heavy and does not permit the water to percolate freely.

METHODS EMPLOYED

The land was well plowed, harrowed and prepared in the usual manner for seeding grain crops. A portion of the land, about one-fourth acre, running the whole length of the field, was enclosed with an embankment of earth, and water was led into this enclosure so that the whole strip was covered to the depth of several inches. The land was kept covered for ten days, permitting the water to gradually work its way thru the soil and drain off slowly. After the water had been taken off and the embankment leveled down, the strip was seeded to oats. A fine stand of oats was obtained without any further work on the land. (See Fig. 1.)

This strip has now borne full crops for the last three seasons, and shows no indication of returning to its former condition. No crop has been taken off the land, but each has been plowed under.

The balance of the land was seeded to oats, rye, rape, sorghum and winter vetch. After seeding, the land was corrugated, the furrows were placed close together to obtain the maximum of exposure, and then water was permitted to run in these furrows for thirty-six hours. (See Fig. 2.) The seed started to grow along the edges of the water, especially the oats and rye, but the ridges remained barren. The irrigation was continued at intervals of several days during the first season. The results obtained showed that a certain amount of the nitrates had been washed out by irrigation. However, the ridges remained barren and showed the characteristic brown color and powdery texture. At the end of the season the field was almost as barren as before. The rape, sorghum and winter vetch made a poorer showing than the oats and the rye, and were discarded as unsuited for the work.

The corrugating method of washing the soil was continued during the last two summers, with the oats and rye as crops, and the field is now practically reclaimed, tho there are isolated spots which are still more or less barren. The crops on the reclaimed portions were very rank and dark green in color and showed that a large amount of nitrates was still present in the soil. (See Fig. 3.)

Fig. 3. A crop of rye on reclaimed land

FLOODING GIVES QUICKEST RESULTS

There are two conclusions which we can draw from this work. First, that the quickest way of reclaiming nitre land is by flooding. Second, that the corrugating method, while beneficial, is too slow, and, in the long run, more expensive than the flooding method. Lands that are in the first stages of nitre poisoning may be restored by using the corrugating system of irrigation, but on land made unproductive by excessive nitre, and especially if the character of the soil and the lay of the land are such as to permit of rapid drainage, and where rapid, complete reclamation is desired, the flooding method is recommended.

COVER CROPS HELP CHECK NITRE IN BEARING ORCHARDS

At the same time that the work of reclaiming this particular piece of land was undertaken, experiments were carried on to correct the nitre condition of soils in bearing orchards, by the use of cover crops. This method of soil treatment is particularly applicable to orchards, and since most of the orchard land is deficient in vegetable matter, due principally to clean cultivation, the plowing under of cover crops is the cheapest and most effective means of supplying this deficiency, and at the same time checking the tendency to form nitre.

Two orchards in the first stages of nitre trouble were selected and were seeded to hairy vetch. The seeding was done early in September, and the plants made a rather poor showing during the fall. The poor stand was due to three causes: First, the lack of water; second, to the dense shade caused by the apple trees; and, third, to the tramping of the land in harvesting the fruit.

In spite of these drawbacks, the vetch showed up well the following spring, particularly in one of the orchards, where it completely covered the ground and attained a height of over 5 feet. (See Fig. 4.)

The vetch was plowed under during the second week in June, when it was in full bloom. Both of these orchards were in the first stages of nitre trouble, and to all appearances, the trouble was checked.

In plowing under large green crops in the orchard, there is some danger of too rapid fermentation and heating which may cause injury to the trees. This generally happens if the plowing under is delayed until the latter part of June, or until July. For this reason, the plowing under of large green crops should be done as early as possible.

Fig 4. A cover crop of hairy vetch in a Grand Valley orchard

CLEAN CULTIVATION RESPONSIBLE FOR PRESENCE OF NITRE

As indicated above, the presence of excessive nitre in so many of the orchards in Grand Valley, is in the main, due to the prevailing system of soil culture. It has been a universal custom in the Valley, up to within a few years ago, to practice clean cultivation in the orchards, and this practice seems to have given the best results. The clean culture method is advisable only so long as the soil conditions remain favorable to tree growth and fruit production, and when these show signs of decline, corrective measures must be taken. The corrective remedy lies in the use of cover crops, alternating with clean culture. The use of cover crops is now more extensively practiced in the Grand Valley orchards, and with its more extended use, we shall look for less nitre poisoning.

DRAINAGE IMPORTANT

In connection with the reclamation of nitre land, it should be borne in mind that drainage is of vital importance. If irrigating waters percolating thru the soil have a means of escaping readily, the nitre salts will be carried off by them, as they are very soluble. Lack of proper drainage makes evaporation the only source by which water is eliminated from the land, and this is sure to cause trouble, as the salts remain in the soil after the water has evaporated. If proper drainage is provided, the salts, to a large extent, will be carried off in the waters thru the subsoil and into the drainage.

The nitre trouble is only one of the problems which confront the land owners; another and equally important one is seepage. Cheap and abundant irrigation water have led to over-irrigation. This, togeher with the natural seepage from canals and laterals has filled up the subsoil with water and brought the alkaline salts to the surface. In many instances the water table is within 4 feet of the surface, and on some of the lower land the water reaches the surface. Where these conditions exist, drainage is the only remedy. The occurrence of nitre in the soils of the Grand Valley and other sections of the State, has little or no relation to drainage but is a distinct and separate problem.

While the apple tree roots, in most cases, do not extend deeper than 4 or 5 feet, (practically all the feeding roots are confined to the upper 3 feet of soil), capillary action carries the water too close to the feeding roots and interferes with the proper drainage and aeration of the soil in the feeding zone. Further, the high water table usually occurs during the growing season, and thus directly affects the growth of the trees. A high water table is less harmful during the winter months when the trees are dormant.

The importance of good drainage and the use of cover crops in connection with orchard operations should be known by every fruit grower in the Valley.

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THE DANDELION IN COLORADO

By B. O. LONGYEAR

Fig. 1. May is the month of profuse bloom

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THE DANDELION IN COLORADO

By B. O. LONGYEAR

Dandelions everywhere! They spring up along ditch banks, crowd into open places in alfalfa fields, or luxuriate in gardens and flower-beds. They swarm over vacant city lots, troop along the sidewalks, and encroach upon lawns to the very door-stone of rich and poor alike.

The common dandelion (*Taraxacum officinale Weber*) is generally recognized in our state as about the worst weed pest in lawns. A native of Europe, this plant was early introduced into North America, where it has overrun nearly all parts of the country except those of an arid or semi-arid character, and into these it has found its way wherever the land is brought under irrigation. Within our own range the dandelion seems to have found the conditions peculiarly favorable and entirely to its liking. Here we find it thriving, not only in lawns and gardens, but it is encroaching more and more upon the alfalfa fields of the irrigated plains and the meadows and pastures of our mountain parks.*

The moisture requirements of this plant determine in large measure its local distribution, and for this reason it seems unable to gain or maintain a root-hold upon the native prairie without irrigation. This same factor of soil moisture has been found to determine in some measure the distribution of the weed in lawns, the best watered portions being especially favorable for its growth. When once well established, however, the larger dandelion plants can often endure a temporary period of drought severe enough to kill out the lawn grass.

In its light relations, the common dandelion shows a wide range of adaptability. It is found growing vigorously in full sunlight as well as in the diffused light within the shadow of trees and buildings.

In its altitudinal range, the common dandelion may reach an elevation of 11,000 feet, where it can be found associating with one or more subalpine and alpine native species of less economic im-

* The red-seeded dandelion (Taraxacum erythrospermum) has been recently found by the writer in a lawn at Fort Collins. This plant closely resembles the common dandelion except that it is usually smaller. The leaves are more deely cut-lobed, the flower heads are fewer in number and smaller and the seeds are bright reddish brown instead of dull greenish brown in color.

portance. (Rydburg's Flora of Colo., Exp. Sta. Bul. 100, records it as reaching 7,000 feet. Prof. Ellsworth Bethel has found it occurring above 11,000 feet on the slopes of Arapahoe Peak and flourishing with unusual vigor at Arrow, 9,500 feet elevation.)

LIFE HISTORY OF THE DANDELION PLANT

The common dandelion may be described as an apparently stemless, herbaceous plant with a long, fleshy, perennial tap-root. Every part of the plant is permeated by a system of minute channels containing a milky juice (latex) which readily oozes out wherever a wound is made. The plant spreads readily by means of its numerous little seed-like fruits, each one being attached to a small parachute of downy hairs which enables the seed to drift

Fig. 2. This picture shows that the larger dandelion plants can survive a temporary dry spell in summer which will kill the lawn grass

before the wind often for considerable distances. The seeds germinate readily wherever there is sufficient moisture. During its first season of growth, the seedling dandelion plant produces merely a tuft of leaves at the top of its deep-growing tap-root. Early in the spring of the second season, and each season of its lifetime thereafter, the crown of the root sends up a new whorl of leaves in the center of which several flower-buds soon appear.

The Root.—The dandelion possesses a most remarkable root system. In plants two years old, it often extends to a depth of two feet or more into the earth, and while commonly in the form of a single tap-root, it occasionally possesses several main branches. One of the unusual features of the root is its ability to produce buds and shoots wherever it is cut off. This property is possessed by all parts of the root, so that even a small piece left in the soil may give rise to a new plant in a few weeks' time. In one experiment, tried by the writer, roots were dug from frozen soil in midwinter, cut into inch lengths, and planted in moist sand kept at living room temperature. In about three weeks' time every one of these pieces had produced a number of small sprouts at the upper end. In another case a root nearly 18 inches long was cut into inch lengths, which were planted in moist sand. The results of this experiment are shown in Fig. 3.

It is for this reason that the dandelion is so difficult to eradicate merely by cutting it off, even to a depth of two or three inches underground. When cut off below the crown, the root usually sends up a number of shoots so that a cluster of new plants will be formed by this process.

The writer has found, moreover, that the dandelion will eventually form clumps or clusters of plants by a natural process of root division when left to itself. This process begins during the second year following the blooming period, toward the close of the season. As the blossom stems come from the center of the crown of the plant, this part of the root dies and becomes hollow. A number of buds which had formed earlier in the season around the margin of this hollow root crown have now given rise to short branches, each with its own crown of leaves at the top, but all united below to the common root. The crowding of these plants tends to further split the old root apart into separate strands until it eventually appears when dug as a bundle of distinct plants somewhat loosely united by the lower part of the old root. These new plants may also go through the same process of division so that in time an old plant may give rise to a large clump of densely crowded plants which have all arisen from one individual seedling.

During the growing season, and especially toward its close, the dandelion root tends to shorten somewhat, a process which produces a wrinkling of the surface and which draws the crown of the plant a little deeper into the soil, where it is better protected from adverse conditions.

The Leaves.—The dandelion foliage consists of a whorl of leaves borne upon a very short stem at the crown of the root. These leaves vary a good deal in number and size, depending upon the vigor of the plant, but are so familiar to most persons as to need no description here. During the colder parts of the growing season and in dry situations, the leaves usually spread out as flat against the surface of the ground as possible and form what is called a rosette, but in warmer weather, especially if the plants are crowded by other taller vegetation, they stand in more or less erect tufts. This difference in habit of growth also corresponds in a large degree to the age of the plant. Thus during the first year from seed the rosette habit is characteristic, while in old plants which have a branched root crown the leaves are forced into erect clumps by mutual crowding. The leaves of plants growing

Fig. 3. One-inch lengths of a dandelion root sprouting after being in moist sand for 18 days. The smallest piece was 18 inches below the surface of the ground when the plant was dug up.

in shady places are thinner and more tender than those in full sunlight.

The surface of the dandelion leaf is covered with a thin epidermis which is readily wet by water and other liquids. This is one of the vulnerable points in the dandelion plant, as it makes possible the use of certain spray mixtures which readily destroy its foliage, while other plants, like the grasses, may escape with but little injury.

The Blossom.—Blossoming of the dandelion may begin sometimes as early as the middle of March, where plants are growing in sunny, protected spots. General blooming, however, is not usually well under way until the latter part of April, while May is the month of profuse bloom. This is followed by a partial resting period of decreased blooming, although blossoms may be found at any time during the summer and until severe freezing occurs in late fall. The number of blossom heads produced by one dandelion varies a good deal, depending upon the size and vigor of the plant. Small, stunted plants growing in dry parts of the lawn may produce only a single head at one time, while the large, thrifty clumps along roadsides and in the edges of gardens and fields may produce fifty or more at once.

Fig. 4. Thrifty growth of new rootlets and five sprouts from a one-inch length of dandelion root grown in a flower pot of sand.

The behavior of the flower heads from the time when they first open until the seeds are mature is interesting. The heads are borne upon hollow stalks which are from two to six inches or more in length. During cold or dry weather, these stalks bend down as close to the earth as the surrounding vegetation will allow, so that the flowers appear to rest upon the ground, but in warm weather, and especially in moist, shady places, they may stand erect. When through blooming, and after the flower head has closed for the ripening of the seeds the stem bends downward so as to bring the head close to the ground, where it remains for several days. In this position these closed flower heads are better protected from injury than if they stood on erect stems, and it is difficult to cut them off with the lawn-mower during this time.

When the seeds are nearly mature, the flower stem begins to straighten up and at the same time elongates, thus lifting the ripened seeds into a better position for the wind to get at them.

In some cases, this seed-bearing stalk lengthens to a remarkable extent. Thus, the writer found one plant growing in partial shade and among taller vegetation, which had a seed stalk 29 inches tall.

Careful examination of the dandelion bloom will show that it consists of many very minute flowers crowded into a dense cluster at the upper end of the flower stalk and surrounded by two sets of narrow green bracts. The number of these little flowers in one blossom head varies greatly according to the size and vigor of the plant which bears them. Thus, the lowest number, 30, was counted in a blossom head from a small, stunted plant, while one of ordinary size was found to contain more than two hundred of the minute flowers, each capable of producing a single seed. The bracts of the outer or lower set turn downward, while those of the inner set form a close covering for the little flowers when not in bloom.

When about to bloom, these covering bracts spread apart and expose the crowded mass of tiny yellow flowers inside. Toward night the bracts close together but open again the next morning. In this manner the flower heads open during two or three successive days, after which they remain closed until the seeds are mature. From the first day of blossoming until the seeds ripen and the bracts open for them to escape, nine or ten days usually elapse.

Pollination of the Flower.—This consists in the transfer of the yellow powder (pollen) from the stamens of the flower to the stigma or tips of the pistil which produces the seed. Without this transfer of pollen no seeds would be produced. In the minute flowers of the dandelion head this process of pollination may take place in two ways. First, the powder-like pollen grains are pushed out of each little flower by the lengthening of the pistil during the process of blossoming. The two stigmas of each flower during this stage are closed in such a way that none of the pollen is apt to adhere to them from the stamens of their own flower. The crowded condition of the little flowers, however, almost insures the contact of the two stigmas, as they uncoil, with pollen from other flowers that are just opening.

The second method of pollination is by means of insects which visit the flowers and in crawling over them bring the pollen powder in contact with the stigmas that are ready to receive it. The common honey bee is prominent among such insects, while certain flower-visiting flies are capable of performing the same office.

The Seed.—Each minute flower of the blossom head produces one small, seed-like fruit, about one-eighth of an inch long. The top end is prolonged into a slender stalk nearly one-half an inch in length, with a tuft of spreading hairs at the apex. This little parachute not only enables the wind to readily scatter the seed, but it also causes the seed to drop end downward among the blades of grass. When thoroughly wet, these hairs readily mat

Fig. 5. Sprouts on dandelion roots cut at different depths. The left hand root was cut below the crown. All were taken from a lawn where the dandelions had been dug out seven weeks before.

together and cling to whatever object they are in contact with, thus permitting the seed to be at rest while germination takes place.

Germination of the Seed.—The seeds are ready to germinate almost as soon as they begin to leave the plant. Fifty seeds, just matured, were gathered June 22 and were put in moist filter paper on the following day. On June 28, twelve seeds had germinated, and by July 6 forty in all had sprouted. Fifteen days later seven more seeds germinated at one time, giving a total germination of 94 per cent. In this case there appear to have been two germinaation periods, the first covering 13 days and the last culminating at the end of 28 days.

In another experiment, made to determine how late in the season the plants can produce viable seed, 470 seeds were taken at random from several different plants on November 29. At this time the ground was frozen quite hard, although open, dry weather prevailed. Some of the blossom heads were not fully matured, which probably accounts for the low percentage of germination, 16 per cent at this time. It is evident, however, that some good seeds are being formed as late in the season as it is possible for blossoming to occur, and although these seeds are too late for germination at once, they will be on hand for early sprouting the next spring.

Fig. 6. How the dandelion root divides as it grows older. Left hand root one year old, right hand root three or more years old

In order to find out how soon after blossoming the flower heads were able to mature seed capable of germination when removed from the plant, the following experiment was carried on:

Eighteen flower heads, just opening for the first time, were picked and allowed to lie on the ground until wilted, after which they were taken indoors and allowed to become dry. Examination later showed that in no case had any seeds matured, although some of them had that appearance.

Thirty-six flower heads were marked with numbered slips of paper and careful records of them were kept during ten days.

Beginning with the fourth day, following the first opening of the blossoms, a few of the heads were picked each day during the remaining six days, at the end of which time all that were left had come to maturity. After being allowed to dry, seeds were taken from each head and examined carefully or submitted to a germination test.

RESULT OF GERMINATION TEST

Number of days after beginning of bloom when heads were picked	4	5	6	7	8	9
Number of heads examined	3	5	5	5	6	3
Highest percentage of germination from one head	0	0.7	0	5.0	16.6	25.0
Lowest percentage of germination from one head	0	0	0	0	0	8.3
Average percentage of germination	0	0.14	0	1.6	10.0	14.0

From this experiment it appears that at least seven days must elapse, after the first opening of the flower heads, before any but a negligible number of seeds mature sufficiently to germinate. This fact has an important bearing upon the control of the dandelion in lawns for the rapid increase of the plant is due largely to the seeds which are allowed to mature upon the premises. Most of these seeds drop upon the ground near the parent plants, especially during the quiet days, and when the lawn is being watered by the hose they are washed down in contact with the soil where the conditions for germination are most favorable. If all blossom heads, including those that have closed to ripen the seeds, are picked or cut off once a week, the seed crop will be practically prevented even though the blossom heads are left on the lawn.

NATURAL ENEMIES OF THE DANDELION

The dandelion, like most weeds, has no serious natural enemies capable of appreciably reducing its numbers or of holding it in check. Among insects are certain plant lice which sometimes infest the plants and cause them to appear unhealthy or may occasionally be so abundant as to kill the plants outright.

Fungous diseases of the dandelion, while not uncommon, seldom inflict serious damage to this host plant. One of the most common diseases of the dandelion is caused by a species of rust fungus (*Puccinia Taraxaci*) which produces numerous minute pustules of a dark brown color on affected leaves.

A species of mildew (*Sphaerotheca*) is also not uncommon upon the foliage of this plant, but the damage caused is slight. Another fungus (*Synchtyrium*) produces tiny swellings or galls upon the leaves of the dandelion which results in a partial stunting of the foliage without killing it.

Apparently the most important natural enemies of the dandelion are found among the seed-eating birds. Thus it is common to see quite large flocks of siskins, small, sparrow-like birds, feeding upon the maturing seeds of the dandelion, especially dur-

Fig. 7. A flower head photographed at different stages in its development. (a) The day before blooming. (b) Just opening for the first time. (c) In full bloom on the second day of opening and insect pollination being effected. (d) Closed at end of third day. (e) Closed and bent down while ripening the seed. Compare the shape in this condition with that of the bud stage (a). (f) Straightened up and fruiting on the ninth day after first blooming. (g) Tenth day; the "seeds" all gone.

ing the season of freest blooming. These little birds usually attack the closed heads, in which the seeds are nearly mature, by removing some of the bracts from one side, after which they pick out the seeds and devour them in large numbers. The common house finch and the goldfinch consume a great many dandelion seeds in the same manner, while even the despised English sparrow has been occasionally observed at the same good work.

EXPERIMENTS IN THE ERADICATION AND CONTROL OF DANDELIONS IN LAWNS

During several years experiments have been carried on by the writer at the State Agricultural College for the purpose of learning the most effective and cheapest methods of eradicating and controlling the dandelion in lawns. These experiments have included the means commonly employed for this purpose, such as digging and the use of gasoline, while particular attention has been given to the matter of spraying with iron sulphate.

The following records give the methods employed and the results of this series of experiments to the present time:

Experiments in 1909

A piece of old lawn, in which the dandelions were uniform and so thick as to nearly hide the soil, was selected on the College grounds. This was laid off into small plats of equal size and treated as follows, using commercial sulphate of iron, or "copperas", dissolved in water and applied with a bucket spray pump so as to thoroughly wet the foliage of every plant:

Plat No.	Strength of Solution	Date of Application	Result October 1
I....	20%	August 6, August 31, September 23	No dandelions to be found
II....	10%	August 6, August 31, September 23	Less than 1% of dandelions present
III....	5%	August 6, September 23	About 20% of dandelions present
IV....	2.5%	August 6, September 23	Dandelions injured to some extent

The first spray on Plats I and II caused the dandelion leaves to turn black and die, but new leaves were pushed out from the strongest and oldest plants in a few days. The grass was also somewhat blackened at first and throughout the experiment the color was a darker green than that on untreated areas. By the first of October all dandelions had completely disappeared from Plat I, while only two or three were to be found on Plat II. It is evident that a 15 per cent solution should be practically as effective as the 20 per cent for this purpose, and that three applications, the first as soon as the plants are in full leaf in spring, the second in about three weeks and the last in midsummer, should prove effective in controlling this pest. Although the grass was very thin on the areas treated, it soon began to thicken, and by October 1 formed a fairly close sod. Nearly all of the white clover was killed by the two strongest solutions.

The contrast between the treated and untreated areas was especially marked during the period of active blooming the next spring, the clear sod of the treated plats being surrounded by a thickly scattered growth of dandelions in flower. This effect was noticeable during at least three seasons following the application of the spray.

Experiments in 1910

In the spring of this year three plats, each 10x20 feet, were laid off on the College campus and treated as follows: Plat I sprayed four times, using a 10-percent solution of iron sulphate; Plat II sprayed four times, using a 15-percent solution of iron sulphate, Plat III, check plat, unsprayed. The sprayings were applied April 25, May 5, May 17, and May 27, about one gallon of the solution being used for each 150 square feet of lawn at each application. The live plants on all three plats were counted the following spring, May 10, 1911, with the following results:

Number of Plat	I	II	III
Treatment	10% iron sulphate, 4 sprayings	15% iron sulphate, 4 sprayings	Check, untreated
Number of plants alive after one year	200	209	1,574
Percentage of live plants in terms of Plat III	6.32	6.60	100

According to the above, the weaker solution gave slightly better results than the stronger. This may be accounted for in part perhaps by the fact that the plants were apparently somewhat more numerous on Plats II and III than on I at the beginning of the experiment. The good effects of the sprayings on Plats I and II were apparent during at least three following seasons.

Experiments in 1915

During this year more varied experiments in the control of dandelions were conducted than before with special attention to the use of iron sulphate. A lawn of uniform character in which the dandelions had gained a considerable foothold was found and laid off into plats of 100 square feet each, the corners being marked by small wooden stakes driven into the ground, level with the surface. A chalk line was tightly stretched along the boundaries of the plats and the dandelions within each area were carefully counted, including all sizes. The following table gives the treatment accorded each plat, together with the results in percentage of plants killed:

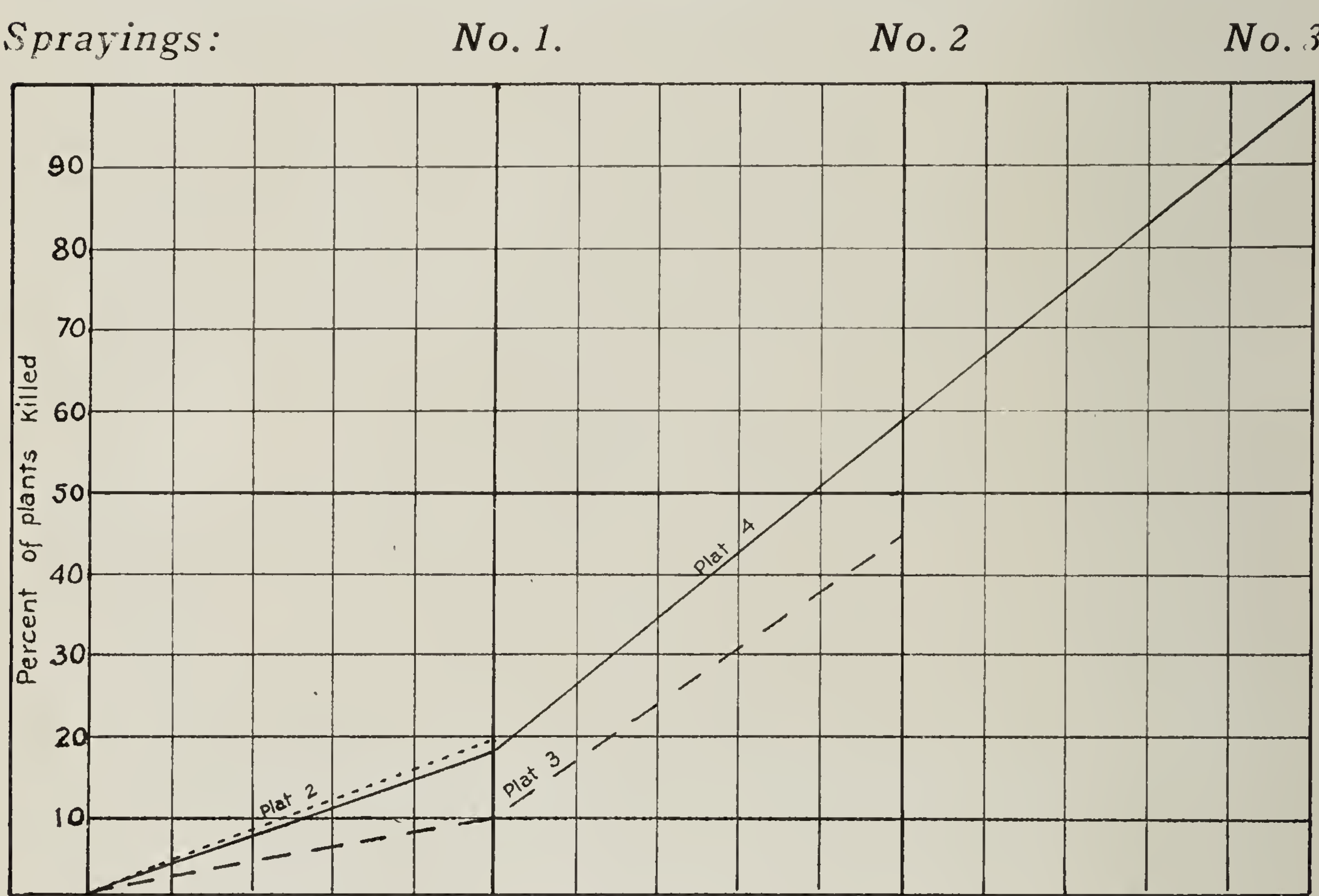
METHODS USED AND RESULTS OBTAINED IN 1915

Plat No.	Treatment of Plat	Dates	Number of Plants Before	Number of Plants After	Percentage of Plants Killed	Cost of Treatment	Material Used	Labor, Minutes
1	Check plat, untreated	—	659	—	—	—	—	—
2	Sprayed once with solution	July 6	859	696	19	$.04	1 gal.	4
3	Sprayed twice with solution	July 6 and 21	630	349	45	.08	2 gals.	8
4	Sprayed 3 times with solution	July 6 and 21 Aug. 5	913	10	98.9	.12	3 gals.	12
5	Check plat, untreated	—	1031	—	—	—	—	—
6	Gasoline put on each plant	July 3 and 10	634	32	95	.25	0.33 gals.	55
7	Two applications of dry iron sulphate	July 13 and 28	649	—	80 Estimated	.15	4.75 lbs.	15
8	Check plat, untreated	—	520	—	—	—	—	—
9	All plants dug out	June 30	665	235	64.7	.40	—	120
10	One late spraying with iron sulphate solution	Sept. 21	650	233	64	.04	1 gal.	4

The solution of iron sulphate used was made by dissolving 1¼ pounds of the dry granular salt in each gallon of water, thus making approximately a 15-percent solution. The pump used was an ordinary bucket spray pump with an extra length of hose attached and with a three-foot stick wired to one side near the nozzle to serve as a handle in directing the spray (Fig. 12). In most cases two men worked together, one to operate the pump while the other held the nozzle.

The costs were determined upon an estimate of 20 cents per hour for labor and 2 cents per pound for granular iron sulphate, delivered in 100-pound bags. These figures, while true at the time of starting the experiments, are possibly somewhat low at the present time. The lawn was well sodded and was well cared for during the experiment. It was not allowed to suffer by drought and was clipped about once a week during the season of active growth. The low results following the first spraying of Plats II, III, and IV, were due in part to uneven application of the spray. The original plants which survived the first two sprayings were found to be feebly sprouting and were thus easily killed by the third spraying on September 21, the original ten plants still alive on Plat IV were very feeble but were accompanied by a considerable number of new seedlings which had come in since the last spraying.

Plat III, when examined May 23, 1916, showed 112 plants capable of blooming while Plat IV had but six. Plat V, treated with gasoline, required a second application a few days after the first to kill plants missed the first time. While this treatment shows a high efficiency, it is relatively expensive, due to the cost



of gasoline, which was charged for at 25 cents a gallon. The gasoline was applied by means of an ordinary tin oil can, about one teaspoonful to a plant being used. A small spot of grass is killed out around each plant by this treatment, but in a few weeks' time this fills in again. When counted May 23, 1916, 173 plants were growing on the plat but of these only five were sufficiently large and vigorous to bloom, most of the remainder being evidently seedlings which had come in since the treatment.

In the case of Plat VI, the dry iron sulphate, in granular form, was sifted on by means of a tin can with perforated cover. The first application killed 28 per cent of the plants, while the survivors were much weakened. Some thinning out of the grass followed the two treatments of this plat.

Plat IX, when examined 28 days after digging, showed a few sprouts from dug plants, while numerous seedlings were showing, with leaves 1 to 3 inches long. The examination of May 23, 1916, showed 235 plants, which includes the seedlings that survived the winter.

Plat X was sprayed late in the year to determine what effect this might have as compared with that done early in the season. When examined May 18, 1916, the remaining plants, 233, were nearly all very small and weak, while hardly a dozen were strong enough to produce any bloom.

Fig. 8. Sectional view of dandelion head, showing the numerous little flowers (florets) of which it is composed. Those in the center have not yet opened. Twice natural size

Experiments in 1916

The experiments during this season were for the purpose of securing further data on the effects of digging and spraying the dandelion.

Plat I covered an area of 18 square feet and contained 92 plants, mostly of fair size, when dug May 13. The plants were dug to a depth of ½ to 3 inches, with the purpose of determining:

1. If plants dug in early spring will bloom during the latter part of the season.

2. The number of plants that fail to recover from the process.

None of the plants had bloomed by September 2, at which date they were counted and dug again. It was also found, at this date, that an increase of 15 plants had taken place, consisting apparently of new seedlings together with the recovery of most of those first dug out. On May 10, 1917, there were 57 plants on the plot, including the smallest, all of which were somewhat inferior in size and vigor to those outside this area. This denotes a total reduction of about 47 per cent from the two diggings.

Plat II consisted of a strip 5x38 feet in a lawn from which the dandelions had been dug during the preceding May. The plants on this area, 302 in all, were dug again on September 23.

The area, when inspected May 15, 1917, showed a decrease of 105 (36) per cent, and those left were small and weak, with about

Fig. 9. (a) Four florets in different stages of blooming, taken from the same flower head. (b) Mature "seeds" with parachute of hairs. Twice natural size.

10 per cent able to produce bloom. The results of these two experiments seem to indicate the importance of digging in late summer and autumn, in addition to that in spring. The first or early digging prevents the ripening of seeds by the plant, while the later digging weakens them by causing new growth, at the expense of reserve food, late in the season, or kills them outright.

Plat III covered 190 square feet in the same lawn as Plat II. This area was sprayed September 23 with an 8-percent solution of iron sulphate. Inspection of this plat on May 15, 1917, showed an increased number of plants amounting to nearly 19 percent, consisting, evidently, of new seedlings. From this experiment it appears that one weak spraying is of little effect in controlling the weed, even when used late in the season.

Plat IV covered an area of about 120 square feet in a different location on the same lawn as the preceding plat. This was given an application of a 12-percent iron sulphate solution on September 16, and an 8-percent solution applied October 10.

This plat, when inspected May 15, 1917, showed a decrease of 36 per cent in the number of plants at first present, while those left were weak and small with only about 10 percent able to produce a few under-sized flower heads. Apparently about 25 percent or 30 percent of young seedling plants had grown up and appeared in the last count. The results of this work compare favorably with that in 1915, Plat III, considering the weaker spray used in this case. Considerable injury to the grass resulted from the first application, which appears to have been due in part to the rather dry condition of the ground in this plat. Similar results have been noted under such conditions, in other cases. By June 1, 1917, the grass had entirely recovered on this plat.

GENERAL OBSERVATIONS

Spraying.—Weed control by means of chemicals, known as herbicides, has been practiced for a long time both in Europe and in this country. The chemicals that have been experimented with and employed for this purpose include common salt, copper sulphate or blue vitriol, iron sulphate or copperas, sodium nitrate, sodium arsenate, ammonium sulphate, potassium chloride, potassium sulphide, slaked lime, corrosive sublimate, carbolic acid, formaldehyde, coal tar creosote, gasoline and kerosene, or coal oil. While many of these are effective in killing weeds they are also destructive to other vegetation as well and are therefore unsuited for use on lawns or in fields where crops are grown.

A suitable herbicide to be used as a spray for eradicating weeds in lawns must be capable of killing the weedy plants without serious injury to the lawn grass. In the case of the dandelion, sulphate of iron or copperas has been found to be the most useful and practicable selective herbicide. Iron sulphate, unlike common salt, is not apt to produce an injurious cumulative effect upon the soil as the chemical becomes oxidized and combined with certain common constituents of our soils and is thereby rendered insoluble and inert. In fact the application of iron sulphate seems to stimulate a healthy growth of the grass, after its immediate effects are passed, so that the lawn appears of a darker green than before.

Strength of Solution.—Most of the work done elsewhere, especially in the spraying of grain fields for the control of wild mustard, has been done with a solution made by dissolving 100 pounds of the granular iron sulphate in a barrel, about 50 gallons, of water. Our own experiments seem to indicate that a somewhat weaker solution, made by dissolving the iron sulphate in water, at the rate of 1¼ pounds to a gallon, is practically as effective as this stronger solution, is less apt to injure the grass, and is a little cheaper.

Time and Frequency of Spraying.—From the experiments tried here it appears that slightly more effective results may be expected from late summer or mid-autumn treatment than earlier in the season. This is perhaps due in part to the fact that most

Fig. 10. Showing behavior of the flower heads on a plant in open lawn. The bloom is produced quite close to the ground with closed heads bent as low as possible during seed-ripening. In the fruiting stage the heads are lifted up by the straightening and lengthening of the flower stalk

of the young seedlings which start in the early summer can be killed by the later spraying and that the plants which do survive the treatment are much weakened too late in the season for complete recovery before going into the winter.

As to the number of applications, it is evident from all the tests here that at least three sprayings, properly performed, are necessary to eradicate the plant. Two thorough sprayings in autumn will greatly reduce the weed, however, and prevent a large percentage of bloom the next season. It should be the aim, however, to entirely prevent the re-seeding of the lawn each season from plants permitted to go to seed upon the premises. Where neighboring lawns are badly neglected, spraying is necessary at least every alternate year together with some digging or other treatment in order to keep the pest under control. The sprayings, to be most effective, should be repeated as soon as the dandelions have partly recovered from the first treatment, an interval of about three weeks between sprayings having been found desirable. The plants should be allowed to put out new leaves, the time for the next spraying being due a little before the new foliage is fully grown. In this way the plants are forced to use up their reserve material in the root by growing a new set of leaves which are again destroyed before they are able to do much in the manufacture of a new food supply.

Application of the Spray.—There appears to be some relation between the method of applying the spray and its effectiveness. Thus, it has been found that better results are secured by using a fine, forcible spray, which drives the solution well into the crowns of the dandelions, than by sprinkling it on with a hand sprinkler. For this reason a good spray pump should be used, capable of producing a strong, spreading mist-like spray. For the small lawn, a good bucket pump with brass cylinder and fittings is desirable. The solution of iron sulphate shauld be made and used either in wooden or graniteware vessels, as it is apt to discolor and corrode iron surfaces, even though galvanized. For larger lawns, a spray pump attached to a barrel mounted on wheels forms the most serviceable outfit, while for large areas, such as parks, a power outfit, like those used for field or orchard spraying, is the most practicable.

It is desirable to cover every part of the lawn surface as evenly as possible, in order to hit any small plants that may not show plainly at the time of spraying. Where the plants are especially numerous, however, the spray may be applied more freely than elsewhere. One of the difficulties in applying the spray evenly over the whole surface may be largely overcome by moving the spray nozzle back and forth in one direction across the lawn and then going over it again at right angles to the first, using only half the total amount each time.

Effects of the Spray.—Observations upon the effects of the iron sulphate spray on the foliage of the dandelion were not made with a view to the physiological explanation of its action. The effectiveness of common salt as an herbicide is said to be due to its power of absorbing moisture from the plant. Iron sulphate appears, in addition to this action, to produce a chemical effect upon the dandelion leaves whereby they turn black. The most pronounced effect appears to be due to the action of the chemical upon the green coloring matter (*chlorophyll*) of the leaf, whereby it is partly decomposed, a dark-colored material being left in the leaf as the result. It was noted that the application of the iron sulphate to dandelion foliage caused the milk or latex in the leaves and flower stalks to ooze out in drops, sometimes of considerable size, within half an hour. This phenomenon, while offering an interesting subject for study, has not been investigated sufficiently by the writer for an explanation. It appears to be due to the absorption of the iron salt by the cells of the leaves and flower stalks and the production of sufficient internal pressure ***(turgor)*** to rupture the cell walls and liberate the latex. It is possible, moreover, that a corrosive action upon the tissues of the leaf takes place which weakens or partly destroyes the cell walls which confine the latex of the plant. The effect is most rapid in warm weather when the spray becomes concentrated upon the surface of the plants by evaporation of the moisture and when the plants are full of the milky juice.

Fig. 11. Flower heads from which the ripening seeds have been removed and eaten by birds.

Blackening and withering of the dandelion foliage, due to applications of iron sulphate, are hastened by direct sunlight. This was shown by densely shading a portion of a treated plant for three days. At the end of 9 hours the plants exposed to direct sunshine were blackened, while the shaded ones were only slightly discolored. At the end of three days, however, there was practically no difference in the blackening of the shaded and unshaded plants.

In order to secure the maximum effects of the iron sulphate spray, it is desirable to apply it during comparatively dry weather, altho in some of our experimental work a light shower a few hours after the application did not appear to decrease its effectiveness. It is advisable, however, that no irrigation be given the lawn within less than 24 or 36 hours after the spray is applied during clear weather and during cloudy weather this time should be extended to 48 hours. Good care in the matter of irrigation and mowing the lawn should follow the spraying in order to encourage the growth of grass.

The iron sulphate spray causes a darkening of the lawn grass and may even kill a portion of the leaves in some cases. It was noted that where the ground was quite dry at the time of spraying the injury to the grass was much greater than where plenty of moisture was present. A good time to apply the spray is the day following rain or a thorough irrigation of the lawn. Under suitable conditions the grass will recover in a week or ten days and will usually show a darker green color throughout the remainder of the season than unsprayed lawns.

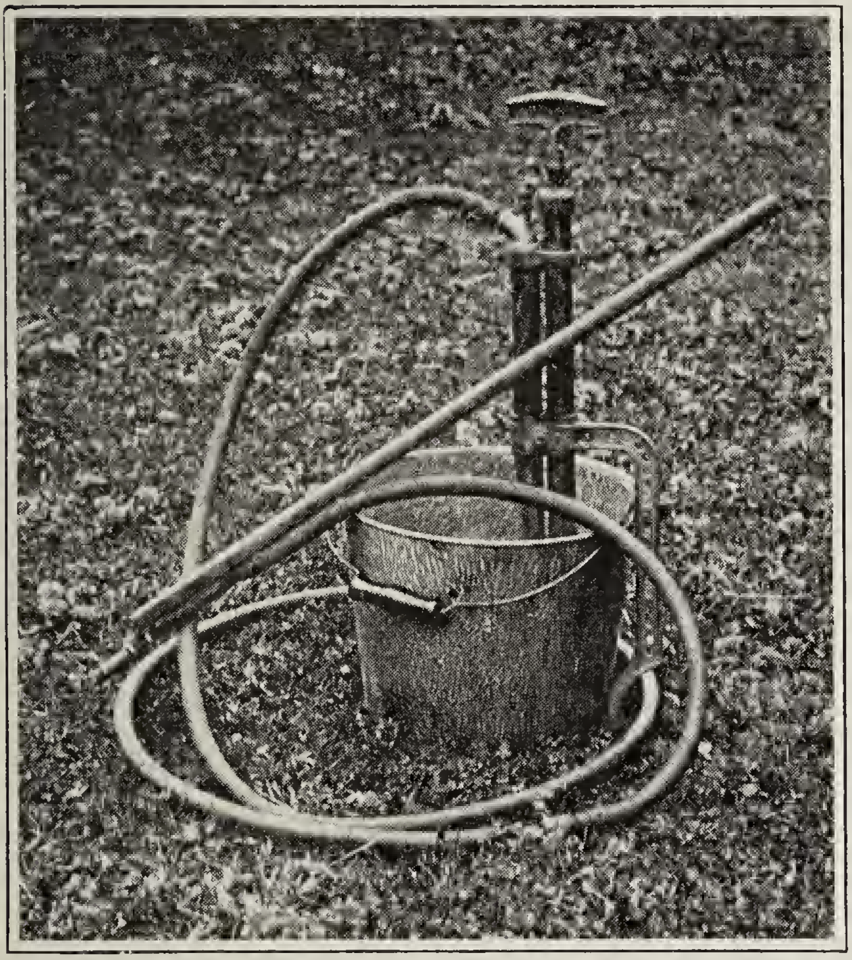


Fig. 12. A suitable outfit for spraying a small lawn.

The iron sulphate treatment may be expected to kill out most of the white clover in the lawn. In cases where the lawn consists largely of white clover it may appear that the spray has killed the grass, while in reality there may have been but little grass present at the start. Most lawns that are badly infested with dandelions are sure to have a poor stand of grass. In all such cases it is advisable to re-seed the lawn after the last spraying, using a garden rake or other tool to loosen up the surface of the soil so that the seed may germinate well.

Iron sulphate solutions will stain light-colored objects a rusty color and for this reason it should be applied carefully along sidewalks, curbings and foundation walls. It is desirable where extensive work is being done to protect such surfaces with boards, old canvas, or other covering during the application of the spray. The iron sulphate is not poisonous and no fears need be entertained in handling it, with the exception of its tendency to discolor or stain some objects, especially those that are light-colored or which contain compounds of tannin.

Amount Required.—In the experiments carried on by the writer it was found that 1 gallon of the solution of iron sulphate would cover 100 to 150 square feet of lawn surface. More of the spray was required to do a thorough job when the grass was high than after it had been recently cut, hence it is a matter of economy to mow the lawn just before each application.

Use of Dry Iron Sulphate.—This method of using the iron sulphate, while about equally effective with the spray, was found to be much more expensive than the latter, due to the larger amount required to secure equally good results. Injury to the grass is more apt to occur than with a spray. The granular iron sulphate can be readily applied by using a tin can or small covered pail with the bottom punched full of nail holes, which permits of its being used as a large shaker.

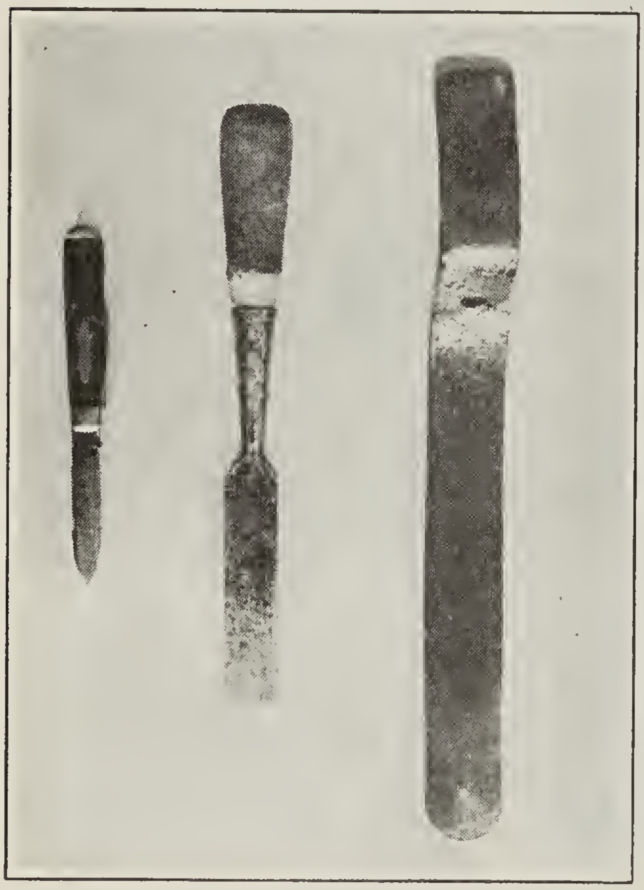


Fig. 13. Tools used by the writer in digging dandelions. The pocket-knife is employed principally as a makeshift when the other tools are not at hand. The right-hand implement, made from an old buggy spring, is the chief reliance for serious and effective work.

Gasoline, Kerosene and Creosote.—Gasoline forms a very effective herbicide for killing dandelions, but its cost is apt to be prohibitive except on small areas and where the plants are few in number. About one teaspoonful of the liquid applied in the center of the plant is usually sufficient, although large plants often require twice that amount. The treated plants soon wilt and in a day or two appear quite dead. In many cases the entire root will be found in a shriveled condition and can be pulled out of the ground.

The gasoline will also kill the grass around each treated plant, the spots often being two or three inches across. As the gasoline soon evaporates, the grass may re-occupy these spots after a few weeks' time, but where a great many plants are present, this injury becomes rather serious in the aggregate.

The cost of clearing a lawn from dandelions with this method varies greatly, being almost directly in proportion to the number of weeds present. It is a useful method to employ where the plants are comparatively few and of good size. In the case of lawns containing many small plants, it is correspondingly expensive in time and material required in addition to the injury suffered by the lawn. Kerosene has been found about as effective as gasoline, and may be used in the same way. A large sized oil can forms a convenient means for applying the liquid.

Fig. 14a. Taking out a dandelion with the right hand tool shown in Fig. 13., cutting the sod close to plant.

Coal tar creosote, such as is used in treating timber to make it last, is capable of doing good service as a herbicide. It is applied in the same manner as gasoline, but in smaller amounts, from one-fourth to one-half teaspoonful being enough for each plant of good size. Its effects appear to be most pronounced if the liquid is applied when the ground is rather dry.

Digging the Dandelion.—This is the most familiar and common method of combatting the dandelion in lawns. There are two general methods of digging. The first consists in cutting the root off and removing the severed part of the plant, while the lower portion of the root is left in the ground. This the common method of digging and varies from shallow to deep digging, the former being the prevalent practice. The second method of digging aims at the removal of the entire plant, including practically all of the root.

The chief advantages of digging are that it at once removes the offending weed from sight, it requires little or no outlay for special tools or material, and it can usually be done on a small place without other expense than the patience and time of the owner. Its disadvantages are that it fails to kill more than a small percentage of the plants, when performed in the usual way, unless repeated frequently; it is a slow and laborious task, and it cuts many small holes in the lawn. Our experiments indicate

Fig. 14b. Inserting tool.

that if dug out early in the season, by the first method, just before the plants mature seed, and again in autumn, the dandelion can be kept under excellent control, especially if the lawn does not become seeded heavily from outside areas.

Digging is useful, also, in connection with spraying in order to remove the few plants which may survive that treatment. It was found that plants cut off below the crown will sprout up again from the depth of even 4 inches. Plants thus dug, however, will not bloom again during that season, except possibly in a very few cases. This fact makes it possible to control seed production in plants on the premises, but of course does not hinder seeding from outside sources.

Fig. 14c. Prying up and pulling out plant.

Digging is commonly performed with a stiff-bladed knife, a spud, or a chisel. A cheap wood chisel with one-inch blade is a suitable tool for the work and permits of deeper cutting than a pocket knife. The writer has used the smallest leaf from an old buggy spring and has found it to be the most effective tool thus far tried for this purpose. One end was sharpened on a grindstone and the other was shortened and bent into a convenient handle in a blacksmith shop. With this tool the largest plants can be readily cut several inches below the surface and pried loose with two or three simple motions. It is not necessary to dig a hole in the sod, but the plants can usually easily be lifted out when loosened in this way. Having the lawn well watered, so that the soil is quite soft, facilitates the operation and in some cases the entire tap root will pull out of the ground, especially when they are pried up instead of being cut off underground.

Fig. 14d. The plant removed and the sod pressed back into place.

Digging by the second method, while not commonly employed on the small lawn, is entirely effective, as it permanently disposes of each plant by removal of the whole root. This is the method employed by the gardeners in charge of the Denver City Parks, where it is practiced successfully over several hundred acres of public lawns. A special tool has been devised for this purpose which closely resembles one to be found on the market except that it is straight and of equal width throughout and is less deeply notched at the end. Being also stiffer, it is better adapted to prying the plants out of the ground. The dimensions of this tool are: Blade, 1 inch wide, 1/8 inch thick, 8 inches long, outside of the handle.

The most suitable time for taking dandelions out of the lawn with this tool is while the ground is quite soft, following a rain or an irrigation. The point of the tool is pushed into the soil about 4 inches away from the plant to be removed and at an angle of about 45 degrees. No attempt is made to cut the root but instead it is pried out by pushing downward on the handle of the tool. The plant is then pulled out by grasping it just below the crown, after which the sod is pressed back into place with the foot.

In lawns where the sod is thick and tough it is often desirable to first cut it open close to the plant with the point of the tool. This causes the sod to split open, when pried up, in such a way that the plant can be easily lifted out with the fingers.

The removal of dandelions by this method requires more time than by the common way of digging, but it is the most effective means of destroying the plants in one operation without the use of herbicides.

Deep digging, which removes only the upper part of the root, while not preventing the sprouting of the part left in the ground, is nevertheless advisable as it requires a longer time for sprouts to get to the light. This means delayed blooming and reduced vigor, while some of them may entirely fail to reach the surface.

Prevention of Seed Production.—On account of the fact that the spreading of the dandelion is almost wholly dependent upon seed, it is evident that the prevention of seeding is an important matter in the control of the weed. While it is usually impossible to prevent the going-to-seed of plants outside of one's own boundaries it should be done upon the premises. As previously noted, it has been found that at least seven days, after the first day of blossoming, are required for seeds to mature sufficiently to germinate. Thus, if all flower heads were removed once a week from the lawn, there would be no danger from this source. Mowing the lawn each week, especially during the period of profuse blooming, will take care of a great many flower heads except those which lie too close to the ground to be cut off by the mower. Those which have already passed the early stages of bloom and have bent down to ripen their seeds are also apt to escape unless other means are taken to destroy them.

Hand picking is often employed and is very effective but tedious. A tool especially designed for gathering the flower heads of the dandelion, in all stages of development, has recently been put on the market. This tool consists of a rake with teeth which resemble those of a saw blade, except that they are longer, and it is used in the same manner as a rake. With this rake (Fig. ....) the young flower buds, the heads in bloom and the seed-ripening heads may all be gathered in one operation. Its thorough use over the lawn once a week should entirely prevent seed production on the premises, altho the plants are still left in the ground.

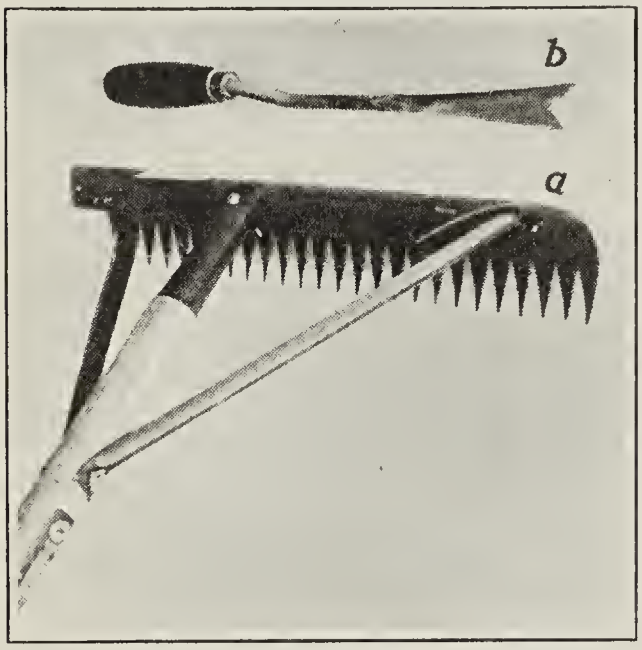


Fig. 15. (a) The Dandelian rake. It is used to remove the flower heads in the prevention of seed production. (b) A dandelion digger found on the market. Its chief defect is the thin blade, which does not permit of deep digging without bending.

Poultry versus Dandelions.—Most persons who have raised poultry are aware of the fact that chickens, ducks and geese are fond of the dandelion tops and will eat them in preference to grass. In one case under the writer's observation an area of 8 or 10 square rods of lawn is used each spring as a pasture for about forty or fifty young chickens. The grass is cut only a few times during the growing season, merely enough to keep it from going to seed. No dandelions are to be seen on this area, altho no attempt is made to destroy them. The chickens keep them and the white clover eaten down as fast as they appear, but do not seem to molest the grass, which forms a deep sod.

This suggests the feasibility of employing a light, portable yard which could be moved over the lawn during the months of April and May and would permit of utilizing the dandelions for growing chickens, ducklings or goslings. Side and back yards, which are often allowed to become badly infested with dandelions, could thus be made to yield considerable forage in raising the growing flock and at the same time be cleared of this weed for the remainder of the season.

Lawn Grass and Dandelions.—The foundation for most lawn mixtures is Kentucky Blue Grass, a plant which is capable, under favorable conditions, of competing successfully with most other plants in occupying the soil. Blue Grass does best on strong deep clay loams with good drainage, but where there is always moisture present. On light sandy soils it is difficult to maintain a dense sod without the use of ample water and the application of fertilizers and winter mulch. Many lawns are started on poorly prepared ground, which often consists of the subsoil excavated in digging the cellar for the dwelling or which has had the surface soil entirely removed in grading. Or, in some cases, the foundation upon which a lawn is to be made is built up from a varied assortment of old mortar, bricks, rock fragments, coal ashes and dump-heap rubbish mingled with some earth and covered with a thin layer of top soil. A lawn which has been started on a suitable soil after deep and thorough preparation, using plenty of the best grade of lawn grass seed obtainable, should resist the encroachment of weeds and last for a long time without reseeding.

It is a matter of common observation that the presence of thin places and bare spots of ground in a lawn serve as invitations for the entrance of weeds. In some cases good results have been secured by occasional re-seeding of the lawn, especially where the grass has died out or become thin. Sometimes the temporary lack of water for irrigation in summer or the extreme dryness which occasionally prevails in winter cause the grass to die out in certain places. These areas should be well seeded again as soon as the damage is discovered the next spring in order to keep up a full stand of grass. In one case inspected, the lawn, which at first consisted principally of dandelions, had been quite well reclaimed by seeding thickly with blue grass and white clover seed raked into the surface of the soil but without other effort at removing the weeds.

One lawn which the writer has had under observation during several seasons has actually improved to such an extent that the dandelions have been greatly decreased in numbers and vigor simply by giving regular attention in the matter of watering and clipping the lawn. This lawn was established, however, on a fertile soil capable of producing heavy crops of alfalfa, sugar beets and grain.

In many cases it is difficult to maintain a good lawn on account of the soil being filled with the roots of shrubs and trees besides being shaded to such an extent that the grass cannot successfully compete with the more adaptable dandelion. When for any reason the lawn grass has become badly depleted and the ground covered with dandelions, it will often give better results to plow or spade up the ground, preferably in autumn, remove all dandelion roots and rubbish, and re-seed it the following spring

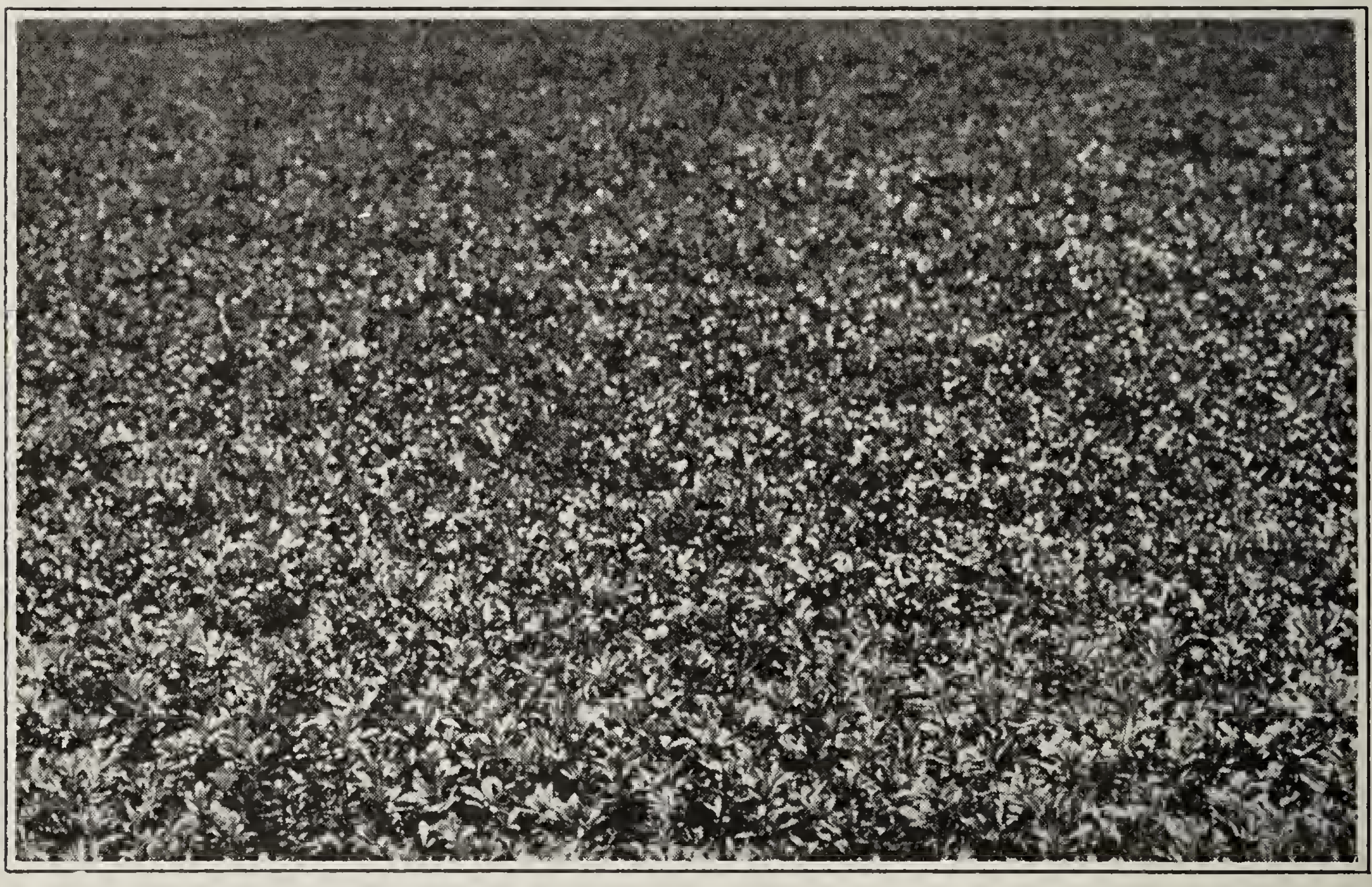


Fig. 16. Photographs of two alfalfa fields less than ten rods apart. Note the dandelions in the upper apparently crowding out the alfalfa, while in the lower none appear. The fields have been seeded about the same length of time, but the first has been injured by trampling and in other ways the alfalfa has been killed out, allowing the weeds to enter

after thorough preparation by deep tillage and fertilizing with decomposed manure.*

NO EASY, CERTAIN METHOD OF EXTERMINATION

It is evident from the foregoing that there is yet no easy, certain method known to the writer by which the dandelion may be exterminated and held in check for any considerable length of time. A beautiful area of velvety lawn, free from the cheerful golden blooms of dandelions in May, of their fluffy gray heads in June and of their ragged, mussy foliage throughout the season, tells of persistent, painstaking effort on the part of someone to keep it so. The very difficulties involved in maintaining a fine weed-free lawn will always distinguish the owner as a person of good taste and diligence, no matter what may be his financial rating.

THE DANDELION AS A FIELD WEED

Weeds are sometimes classified according to the habitat which they find best suited to their particular mode of life. Thus we have weeds of waste ground; weeds of lawns, pastures, and meadows; weeds of cultivated crops, and weeds of grain fields. The dandelion belongs to the first two classes and is not an important factor in the growing of grain and tilled crops. This is due to the fact that the dandelion is a low-growing plant which requires room to spread its foliage close to the ground and that it cannot spread laterally much underground. Furthermore, it does not produce seeds until the second year of its growth from seed and is therefore easily destroyed by cultivation before this occurs.

The dandelion has become an important field weed in some parts of Colorado, especially in native pasture lands of mountain valleys below 8,000 feet elevation. In such localities the dandelion, with its ability to grow where it is cold, often finds the soil moisture and the open spaces which it delights in and here it thrives wherever bare ground or thin spots among the native grasses occur.

When once established the dandelion is apt to remain and to take advantage of every opening that appears. In such cases there seems to be but little to recommend in combatting this weed, except to avoid over-grazing the pastures and to use the methods

* For those who desire to start a good lawn, the writer recommends the reading of an article on the subject by Samuel Parsons, Jr., in the American Cyclopedia of Horticulture.

of improving the stand of forage plants employed by the Federal Forest Service* in some regions.

These methods involve the following means: (1) Fencing and resting the land during parts of one season or for parts of several seasons, (2) rotation of pastures, (3) reducing the number of stock grazed on a given area, (4) reseeding the area with or without previous cultivation.

The seriousness of the dandelion as a weed in the alfalfa field is a matter which has elicited considerable discussion in this State. There are those who claim most emphatically that dandelions will crowd out alfalfa, while others, with equal positiveness, declare that they cannot. Alfalfa is doubtless our most persistent and dependable cultivated forage plant, and under favorable conditions it can compete successfully with almost any other plant classed as a weed. In fact, alfalfa is recommended as one of the best smother crops to be used in crowding out farm weeds.† In some cases, however, the alfalfa may not succeed well and may die out, thus opening the way for the less exacting weeds. The alfalfa may fail because of one or a combination of unfavorable factors. These may be :(1) Unfavorable climatic conditions which lead to winter killing, (2) unfavorable soil conditions, either due to chemical or physical composition or lack of proper moisture conditions, (3) improper treatment of the crop in its management on the farm, and (4) injuries caused by parasitic diseases, insect pests and rodents. The fact that alfalfa can hold its own against all weed encroachment, in many cases for long periods, is clear evidence that when weeds do appear to crowd it out there exists some one or more conditions unfavorable for its thrifty growth.

In a measure, alfalfa is capable of crowding itself out. Thus it has been found that, during the first few years, following a heavy seeding, there is a reduction in the number of plants in the stand amounting often to nearly two-thirds, without any decrease in the production of the crop. This thinning of the stand is the natural process by which the weaker plants are eliminated by the more vigorous ones, but it normally ceases when a balance has been established between the surviving plants. When, however, this thinning continues to such an extent that weeds like the dandelion

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* Bentley, H. L. "Experiments In Range Improvements in Central Texas," Bur. Plant Indus. Bul. 13, 1902.

Cotton, J. S. "The Improvement of Mountain Meadows." Bur. Plant Indus. Bul. 127, 1908.

Forbes, R. H. "Range Improvement and Administration." U. S. D. A. Experiment Station Bul. 115, pp. 85-86, 1901.

Griffiths, David. "Forage Conditions and Problems in Eastern Washington, Eastern Oregon, Northeastern California and Northwestern Nevada." Bur. Plant Indus. Bul. 38, 1903.

† See Farmers' Bulletin 660, "Weeds: How to Control Them." U. S. D. A.

appear in considerable numbers, it indicates that the conditions are in some way unfavorable. The appearance of numerous weeds in the alfalfa, which seem to be crowding it out, calls for a careful study of the soil and moisture conditions, and the presence of diseases and injurious insects and animals and the system of management, to determine what corrective measures, if any, can be employed.

SUMMARY

1. The common dandelion is our most noticeable and persistent weed in lawns in Colorado. It sometimes becomes a bad weed in meadows, pastures and in alfalfa fields where the stand is becoming thin.

2. The plant gains entrance and spreads by means of its wind-wafted seed-like fruits. Irrigation water taken from ditches along which the weed grows plentifully may also carry the "seeds" onto the land. As the plant gets older, the tap root may split up into several strands by a natural process of division and thus produce large clumps. Any part of the root, when cut off and left in the soil, may sprout and produce a new plant by means of adventitious buds.

3. The dandelion plant does not produce blossoms and fruit during the first year from seed. Its most profuse period of bloom and seed is during May and June. About nine days elapse between the first opening of the flower heads and full maturity of the seeds. Only a very small percentage of the seeds are mature enough to germinate by the seventh day following first blooming of the flower head. Flower heads picked or cut off when in bloom and left to lie on the lawn will not produce mature seed, capable of germination.

4. The dandelion has no serious natural enemies capable of keeping it under control. Certain seed-eating birds consume large numbers of the ripening seeds and thereby reduce the number scattered.

5. The dandelion can be controlled in lawns by persistently employing one or a combination of the following methods:

(a) By establishing the lawn on a carefully prepared seed bed with the ***best*** grade of lawn grass seed obtainable. A mixture containing 10 per cent of white clover seed is desirable when quicker results are wanted in securing a soil cover. Dead spots and thin places in the sod of old lawns should be re-seeded each year to maintain as dense a growth as possible and thereby discourage the entrance and growth of weeds. Early spring is the best time for this renewal seeding.

Old lawns on poor soil, where much bare ground and weeds occur, will sometimes demand plowing or spading the soil, removing roots and rubbish and fertilizing well. This is preferably done in late autumn and should be followed the next spring by thoro harrowing or raking and the sowing of the best grade of lawn grass seed.

(b) By applying about one teaspoonful of gasoline or kerosene in the crown of each plant by means of an oil can. This may be done at any time during the growing season and is especially effective in killing the older and larger plants which would sprout up if cut off. Care should be taken to apply only enough to kill each plant, as an excess will cause dead spots in the lawn grass.

(c) By digging the dandelion plants as deeply as possible at least once each season, preferably in spring just before blooming. This will kill a fair percentage of the plants and will prevent those which sprout from blooming during the season. A second digging in autumn before the end of the growing season will destroy a still larger number and greatly weaken the survivors. Digging may be done in such a way as to remove the entire plant and thus destroy it at one operation. This is the method employed in some of our large city parks where the dandelion is controlled over large areas.

(d) By prevention of seed production of plants growing on the premises. This can be accomplished by early digging, the use of gasoline on individual plants, frequent clipping of the lawn and picking the flower heads while in bloom at least once a week, and by early spraying with a suitable herbicide.

(e) By spraying badly infested lawns at least three times at intervals of about two weeks, using a solution of iron sulphate in water, 1¼ pounds to the gallon. The most effective results have generally been secured in late summer. Apply the spray in the form of a fine, forcible mist which will drive the solution down into the crowns of the plants. Cloudy, damp weather is favorable if the application is not followed by rain within 12 to 24 hours. Use a spray pump with brass fittings and do not put the solution in galvanized iron, tin or iron vessels. All utensils should be thoroly rinsed with water after using and the working parts of the pump kept well oiled. Wear old clothing and gloves while applying the spray and avoid getting any of it on walks, curbings and foundations or other objects where a rusty stain would be objectionable.

(f) According to our experiments, the cheapest and most effective method of eradicating the dandelion from a lawn, when labor costs are considerered, is by spraying with the iron sulphate solution.

(g) The dandelion cannot crowd out alfalfa where the latter is growing under favorable conditions, and under proper management, as shown by fields which successfully resist the encroachments of this weed. Where this appears to be the case, a careful study of conditions should be made in order to find out, if possible, the limiting cause. In most cases a proper system of crop rotation should be employed, which involves a period of cultivation.

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THE PROPERTIES OF COLORADO WHEAT

By W. P. HEADDEN

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FORT COLLINS, COLORADO
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THE PROPERTIES OF COLORADO WHEAT

By
W. P. HEADDEN

This station has published four bulletins* as the result of its study of Colorado wheat. These bulletins have been written for the student of this subject rather than for the farmer of Colorado. In presenting this subject to students it was necessary to give a mass of details of so good as no interest to others than such as are not satisfied with the statement of general results. This bulletin is not written for that class of readers. All such readers are referred to the previous bulletins wherein they will find a great many details of the investigation.

GENERALLY BELIEVED THAT COLORADO WHEAT MAKES INFERIOR FLOUR

It has been a generally accepted statement among us that wheat grown in Colorado is "soft" and does not make as good flour as the wheat grown in many of the Northwestern States. The question why, has usually been answered by the statement that our wheat does not contain as much gluten as the harder wheats. It has been the belief of both bakers and housewives that Colorado flour yields less bread than Kansas or Minnesota flour, because, as has generally been accepted, the flour will not take up as much water in making a dough, which is a result of there being less gluten in it. These are the reasons that I have heard stated for the preference given to Minnesota and Kansas flours over our Colorado flour and for their very general use by bakers and our housewives in bread-making. The Colorado flour is credited with making an attractive, white, well-flavored loaf, but smaller and lacking, in some important respects, those superior qualities for which the Minnesota and Kansas flours are justly prized.

We assumed all of these statements, made concerning our wheat, to be correct; for instance, we assumed that the statement that a hard seed from Kansas or North Dakota produced a soft wheat when planted in Colorado and that this soft wheat produced a less desirable flour than the parent wheat. We proposed to inquire into the facts and, if we should find these statements

*Bulletins Nos.: 205, 208, 217, and 219.

correct, of which we had no doubt at the time, for we have a great deal of confidence in the common judgment of a community, we proposed to try to find out the reasons for them.

The subject itself pertaining to the causes for differences in the properties and composition of wheats is really an old one, and has been studied by so many very able men that our proposal to take up this question as it applies to Colorado wheat provoked a smile, but permission to undertake it was given, and the following pages present our endeavor to make our views and result known to the Colorado wheat grower.

CLIMATE AND SOIL IMPORTANT FACTORS

There are two big groups of factors concerned in the production of a crop of wheat. This much is very evident and agreed to by all parties. The first group comprises the climatic factors; the second the soil factors. In the first group we have all of those factors which we often express as weather, such as temperature, rainfall and winds. In the second group we have the actual content of the soil in plant food and the ratios in which these foods exist in the soil and the forms in which they may be present, i. e., whether the plant can take them up easily enough to produce the best results or not. We also have the mechanical and physical properties of the soil, its deportment toward moisture, whether it is retentive of it, whether it puddles, bakes and cracks or not. These are all things that the farmer knows when he comes to think of them.

OTHER FACTORS

There are still other things that he knows, one of which, for instance, is that a few, only three or four, wet, muggy, warm days, just before the wheat ripens, will practically spoil his crop. Many of us have seen heavy dews, or a few hours of fogginess, produce the same result, and we rightly believe that it was not the wet, nor the heat, nor the cloudiness in themselves that did the damage, but it was because rust developed under these conditions. The farmer knows that when the rust comes on his wheat that the grains of wheat will be shrunken and will not sell so well, in fact, will be inferior. This is an indirect result of unfavorable weather. If there were no rust plants growing in the country, and consequently no rust spores, ready to germinate, the warm muggy weather would probably do very little, or no harm at all. The weather in an indirect way may mean more than it does by its direct action, for the wheat plant itself, as well as the rust plant, will not grow if the weather be unfavorable. A hot, dry wind may kill the wheat plant as quickly as a warm muggy spell, or the lack of ventilation in lodged grain may start an unwelcomed development of the rust fungus. The rust fungus is not the only hostile form of plant life whose development may depend upon the weather, but whose presence we are unable to observe under ordinary conditions. On the other hand, the soil may also contain beneficial organisms, whose development may be made more easy or more difficult by the weather conditions, and the good or bad influence of these factors upon the crop must be considered as an indirect effect of the climate.

These plants are not so unlike the wheat plants themselves, for they are not wholly independent of either the climate or the soil. The rust fungus happens to be an injurious parasite on the wheat plant, and its development seemingly depends, in an extreme measure, upon the weather and the condition of the wheat plant for its development in an injurious degree. On the other hand, our soil conditions may be unfavorable; for instance, in the case of peas, etc., they may be such that the little wart-like growths which are ordinarily present, on the roots of our peas, red clover and alfalfa may not appear and these plants will not do so well and will not yield satisfactory crops.

ALL FACTORS MUST BE CONSIDERED

So, if we separate soil and climate from one another or leave out these other factors, we make a mistake which will quite surely defeat us in trying to explain the facts with which we meet.

The climatic factors are not, as a rule, under our control. We cannot regulate the temperature nor control the winds, clouds and rains. If there is no rainfall, we can apply water, even in field culture, which of course is the only culture that we have in view. Practically all writers on this subject have attributed the greatest importance in determining the properties of the wheat to the supply of water. One writer on this subject points out that in Hungary they have, in the regions of light rainfall, small-grained, hard wheat which grows softer and larger in the grain as they go up into the hill and mountain countries, where the rainfall is greater, further, that in France, England, Holland, Denmark, and the Scandinavian countries, where they have a coastal climate with a heavy rainfall, the wheat is soft, with large plump grains. English writers in discussing the character of their wheats, attribute deficiencies, in this respect, to an excess of rainfall, rather than to a deficiency in the mean temperature of their country. These writers point out that the supply of plant food is usually sufficient. Our own writers almost without exception have attributed the greatest influence in determining the character of a wheat crop to the climate.

The two features of climate referred to mostly in this connection, are the temperature and moisture supply. The English writers referred to above express it in terms of rainfall and mean temperature. A German writer referring specifically to Colorado says:

"We shall have to remind the reader that the climate of the Colorado section is characterized by an extraordinary degree of dryness of the atmosphere and great daily variations of temperature. The advantages of the Colorado climate consist in the clearness of the sky, intense sunshine, and a light atmosphere favorable to evaporation."

The same author again says:

" I have referred previously to the fact that the cultivation of wheat in this zone is only possible under irrigation, but which, under the other favorable climatic conditions, yields extraordinary results, as it can be applied at exactly the opportune time. The high yield and weight per kernel is explicable only by this."

An American writer expresses himself in almost identical words, to-wit:

"Where irrigation is practiced in Colorado * * * ideal conditions for plant growth prevail, for there the sky is clear, the sunshine intense, the air dry. Therefore, if water can be supplied when the crops are in need of it, assimilation will go on at its best, and the production of organic substance will be all the more favored. The result will be a large crop of large-sized grain."

These statements represent very fairly the general views held in regard to the part played by the climate, more particularly, by water. If there be any doubt that this is the principal feature had in mind, the following sentences from the English authors remove it.

"Thus, the plant, which luxuriates in a comparatively dry soil and climate passed its whole existence under exactly opposite conditions; and the result was only what was to be expected."

In another place they say:

"It has, of course, long been known that an excess of wet is injurious to the wheat crop."

In passing we may add, that yellow-berry, a condition very frequently observed in Colorado wheat, has been held to be a result of our practice of irrigation, or is also an effect of water. The European writers also virtually maintain this; for instance, they attribute the character of the French, English, and Danish wheats to their moist climate, and the characteristics of these wheats are that the grains of the wheat are big, plump and mealy and are not small, hard, flinty and dark-colored.

RELATION OF WATER SUPPLY TO YIELD

This brings up possibly the most important practical question that we have to deal with in wheat growing, namely: What is the relation of the water supply to the yield and character of our wheat? The answer to this question is somewhat difficult to present, but for the sake of having a definite presentation of our answer we will assume that water has two sharply distinguishable effects, direct and indirect, and that these may vary with the manner of application. If we should have a long continued rainfall which actually changed the chemical composition of the whole plant and its product, the seed, we would consider it a direct effect. Such an effect is possible, but if the rain or moist spell chanced to come during a period of hot weather, with little wind, and the rust developed, as we know it will in Colorado, we would consider this an indirect effect of the wet and warm weather.

IRRIGATION AFTER WHEAT IS IN HEAD DOES NO GOOD

These different effects are actually produced and we cannot control these conditions. So far as the growers of wheat in Colorado are concerned, it would be a good thing if we had no rain at all from the time the wheat comes into head till after it is threshed, for water, applied after the wheat comes into full head, does no good and may be very dangerous, especially in the form of frequent light rains accompanied by warm, cloudy weather.

It is perfectly well understood that plants must have water in order to grow, and while some plants may thrive in a comparatively dry soil and climate, as the wheat plant is said to do, there is a period during which an amply sufficient supply is necessary for its best development and no abundance of supply, at some other time, will make up for a lack during this period; for this reason this is often spoken of as the critical period.

We did not attempt in our work to establish the limits of this period. Every man who has cultivated plants has learned that it is a general rule that plants which have been stunted, whatever the cause, will not produce as good plants as those that have been kept continuously in good growing condition, even though the cause of stunting may be wholly removed, as in the breaking of droughty conditions; a few varieties of plants may recover from such stunting, but most plants will not. The wheat plant needs an abundant, i.e., an amply sufficient, supply of moisture to keep it growing vigorously till it is well advanced in boot. If there should be any signs of a want of moisture previous to this time, it should be irrigated. If, however, there is no lack of moisture up to this time, and the wheat is coming into head, some of it, perhaps, already in head, it should then receive a liberal irrigation, enough water to wet the land thoroughly. The quantity of water and the time necessary to get over the land will depend upon the moisture in the soil and its texture. But whether it takes little or much, the crop should be irrigated thoroughly at this time. The application of water much later than this is worse than labor lost, for it involves the risk of lodging and the accompanying dangers without compensating advantages.

We have the results of four series of experiments on this point in which 1, 2 and 3 feet of water were applied. The application of 1 foot of water in our series when the wheat was well up in the boot, produced as much wheat and straw as the application of 1 foot at this time and a second foot four weeks later. The second application produced no effect whatever upon the quantity or quality of the crop. This was true of the growing plants as well as of the matured crop. In the two other series the water applied, was 1, 2 and 3 feet, applications being made through the season at intervals of from 12 to 26 days. In this case there were slight differences in the crop in favor of the larger applications of water, but no differences in the character and composition of the wheat. So far as the application of irrigating water to wheat is concerned, no commensurate good is done if it is made materially later than the period of heading, at which time it must have an ample supply. It should have water previous to this if it shows distress. On the other hand, the application of water to the land up to within 15 days of ripening, exercises no influence upon the character and composition of the wheat.

IRRIGATION AND RAINFALL HAVE DIFFERENT EFFECTS

This appears to be in direct opposition to the view held, almost without exception, by writers on this subject previously referred to. Their statements, at least the most of them, are based upon the observed effects of a wet climate, a continued excessive supply in the form of rain, in which case the plants are kept wet nearly all of the time, either by the rain or the dews which accompany these conditions. Our statements pertain to the application of the water to the land while the plants themselves are dry, and the weather usually clear, with a strong, bright sunlight. This makes a big difference. We have never collected the dew from our wheat plants to see how much such water had dissolved out of the plant, but we have analyzed plants grown in a season of almost no rainfall and in one of very frequent rainfall and very heavy dews. The plants during these two seasons received in the aggregate, the same amount of water, so that any differences in the effects can be attributed only to the differences in the manner of application. One might think that the condition of the plant at the time the water was applied had determined the effects observed. This does not seem to be the case, for the application of 5 inches of irrigating water every 8 or 10 days had no effect upon the composition of the wheat grown. While very much less water in the form of rainfall caused the production of plants with less nitrogen and less ash constituents and the wheat produced was of inferior quality which may have been mostly due to rust which developed very strongly under the conditions of that year. The rain water, without doubt, simply washes the substance out of the plants. We made an experiment to see whether water would actually wash out nitrogenous substances from the plants by simply putting cut-up plants in water, and it did. We already knew that water will wash out the ash constituents of both the plants and the ripe wheat grains. So, after all, it is no great wonder that a season of well distributed and high rainfall should produce results different from those produced by the same, or even a much larger amount of irrigating water applied to the soil.

These statements are true of all the varieties with which we have experimented. These include Dicklow Spring, Marquis, Defiance, Red Fife, Kubanka and Turkey Red. The number of experiments made to show the effect of the amount of irrigating water applied was 32.

These are the principal facts that our observations on the effect of the amount of irrigating water and the time of its application have shown, namely, that the last application of irrigating water should be made when the wheat is well in boot or early head. Whether an earlier application should be made will depend upon the season and can be judged by the condition of the plants. Water applied much later than this will do no good and may do harm.

The land may be kept wet up to within 15 days of ripening without affecting the composition of the wheat, but if the plant is kept wet by frequent rains, the composition of the grain will be affected, and if rust is induced, which will be while the plant is somewhat green, both the yield and the quality will be affected.

OBJECT OF INVESTIGATION TO DETERMINE WHY WHEAT IS SOFT

The object of our investigation has already been stated, namely, to discover, if possible, why our wheat is soft. The writers who have discussed the causes for the differences in the quality of wheats have agreed that the weather prevailing during the season, is the big factor in the problem, wet weather producing inferior wheat. We have just seen that there are reasons for this conclusion, but they do not hold good in our case, for our wheat has been considered as soft wheat though the seasons are dry. We have sections in which the farmers grow soft wheat where the average annual rainfall is less than 12 inches, and the amount that falls during the life of a crop of spring wheat, say from 108 to 130 days, is insufficient to grow the crop, even if it should fall at the very best time in the case of each individual field, which is, of course, not possible.

Some have claimed that irrigation produces soft wheat. If this were true, it would explain why our wheat has gotten the reputation of being soft, and would take the place of climate. We did not quite believe this in the beginning and have told in the preceding pages some of the facts that we have found in studying the effects of irrigation on the composition of the wheat plant and the grain produced.

METHODS OF DETERMINING WHETHER WHEAT IS HARD OR SOFT

We have repeated the assertion that our wheat is soft and that the flour made from it is not so good as flour made from harder wheat. It is a difficult matter to tell just what is meant by hard wheat and soft wheat. The people of the Kansas Experiment Station have suggested that we determine, by means of a proper machine, what weight it will take to crush an average grain of the wheat. If it takes less than a certain weight, they suggested that it be classed as soft; if it requires a greater weight than this, but less than another certain weight, they suggested that it be classed as medium; and the wheat requiring a still greater weight to crush it, should be classed as hard. This gives us a definite standard by which to judge, but it is a difficult matter to get the average grain of wheat. As a matter of fact we all apply this principle in a rough way when we crack grains of wheat between our teeth; if they crush with difficulty we say that the wheat is hard, if not, that it is soft and the judgment formed is about right.

There is another way that we judge whether a wheat is soft or hard. If the wheat is dark-colored, glassy, and more or less translucent, we say that it is hard; it looks flinty. If, on the other hand, it has a yellowish white, chalky or mealy appearance, we say that it is soft. Of the former, we say that it is rich in gluten, of the latter that it is poor in gluten; it is starchy. This is about as near as one can arrive at a definition of hard and soft wheat, but the distinction is really of a great deal of importance, for the flour yielded by hard wheat is more desirable for bread-making than that made from soft wheat.

There are differences in varieties in this respect; for instance, our Colorado Defiance is, at the very best, a soft wheat compared with Kubanka, a durum wheat, or with Turkey Red. This, however, is not the softness of which we set out to find the cause. It must be remembered that some grains of Defiance wheat are harder than other grains and the same is true of other varieties. Some grains of Kubanka are flinty and very hard, while others are mealy and much softer. Now it sometimes happens that all the grains are mealy and soft when they ought to be flinty and hard, and it is the cause of this that we have been trying to find out, and not why one variety is harder than another.

A few years ago spring wheat was grown almost exclusively and Defiance, a soft wheat, was our popular variety. Of late years we have been growing other varieties and more winter wheat, so that the wheat milled now may be harder than that previously milled, and the flour produced better. I make this statement in this connection, for I think that the reader should bear in mind the fact that the practices of the country have changed in regard to wheat growing of late years, whereas, the reputation of our wheat has not changed and what may have been true of our flour some years ago, may not be true now. The low estimate so generally put upon our flour some years ago may have been just, but may not be just at this time, and still that reputation will be passed along and be kept alive for a long time to come.

AMOUNT OF IRRIGATING WATER DID NOT AFFECT QUALITY

Let us return to the question why some grains of wheat, or a whole crop, may be yellow and soft and others amber-colored, flinty and hard. The amount of irrigating water applied not only did not produce such results, but did not seem to influence them either one way or the other in the experiments that we made, and the effect of rain was not to produce this peculiar condition. The reader will observe that this is stated as a matter of fact, that the application of 3 acre-feet of water in the experiments given did not appear to have any influence upon this condition that 1 acre-foot did not have. I have seen this condition present to just as great an extent in the so-called dry-land wheat as in irrigated wheat.

THE EFFECTS OF PLANT FOOD

We endeavored to find out what the effects of the individual plant foods, usually considered necessary for the growth of crops, are. It is well established that the plant foods of first importance are only three in number and if these be present in the soil in sufficient quantities, the other necessary elements of plant food can be considered as also present in sufficient quantities. We know that this is true of practically all of our Colorado soils. The three important elements are potassium, phosphorus and nitrogen. Our soils are not excessively rich in phosphorus and total nitrogen. I say total nitrogen because there are two kinds of nitrogen, organic and inorganic, and we get these together in our ordinary analysis. So far as our present problem is concerned, we can consider the organic nitrogen as of no use to the wheat plant. The total nitrogen present in our soils is usually very moderate. Still our crops do not show by their color or the manner of their growth that there is any shortage of nitrogen. As our soil already contains enough plant food to grow good crops, the only way that we could study the effect of these foods on the plants and their seed, on the field scale, was to apply enough to exaggerate the effects of each one, and compare the results with a check plot, which received no fertilizer. In this manner we obtained a most definite answer to the question which we have stated, i. e., why some of our wheat is yellow and soft. This condition is quite frequently designated by the specific name yellow-berry.

INCREASE IN NITROGEN PRODUCES HARD WHEAT

We applied the nitrogen in the form of sodic nitrate, chile-saltpetre, and found that with the application of 250 pounds of this salt to the acre, put on at the time of planting, we changed the character of the wheat produced to a small-grained, flinty, hard wheat, with a decided increase in the amount of gluten over that grown without it. This was the answer to one side of our question, namely, how to produce hard wheat. The answer to the other part of the question, What makes the wheat yellow, mealy and soft? was just as plain, for the potash increased the yellow-berry very greatly in each of 45 different experiments.

EXCESS OF POTASH CAUSES YELLOW-BERRY

So here was the whole problem worked out in land sufficiently well supplied with inorganic nitrates, which furnish the nitrogen to the wheat plant, to grow big crops of mixed hard and soft wheat. If the potash be in excess, then we have yellow-berry. By this we mean that some grains of the wheat will be yellow, others will be partly yellow, while some may be wholly flinty and hard. This is the case with a great deal of the wheat grown in different parts of the State.

We increased the nitrates and obtained hard wheat. We applied more saltpetre than was necessary to produce a satisfactory result on our ground, but how much more than was needed to correct the excess of potash we have not determined, and it would do no one any good if we had determined this point, because the reader's land might need more or less than ours. The big thing for us was to find out the facts as to what makes the wheat yellow and soft, and what to put on the land to make it hard.

FALLOW CULTIVATION INCREASES NITROGEN

There are other ways to increase the inorganic nitrogen in the soil besides buying Chile-saltpetre at a high price. The best way in Colorado is to cultivate the land fallow. This both improves the condition of the soil and adds nitrogen to it, which is finally changed into the form in which the wheat plant can use it.

MANURE DOES NOT AFFECT COMPOSITION

In one series of experiments which we have recorded 16 loads of well rotted manure was applied to the acre but it had no perceptible effect upon the number of yellow grains in the wheat. The reason for this was that the nitrogen in the manure was present as organic nitrogen and the soil agencies were not able to convert this organic nitrogen into a usable form fast enough to affect the character of the wheat produced. The effect of this manure, 16 loads, upon the size of the crop, was to increase it by about 7 bushels of wheat and 600 pounds of straw to the acre; it did not affect the composition of the wheat at all. The biggest increase that we obtained from the application of Chile-saltpetre was about 4 bushels of wheat, but the composition of the wheat was changed, that is, the gluten was increased. Evidently our soil contained enough nitrates to produce about its maximum crop, so there was no great increase in crop, as is often observed as a result of the application of saltpetre.

The recorded observations of different experiments on the effects of farmyard manure are contradictory, some saying that it does and others saying that it does not affect the composition of the wheat. Our record is that it does not change the composition of the wheat produced, and further, that the increase in the crop was very moderate indeed. The crops ranged from 17 to 30 bushels to the acre, so this was not due to the production of a great big crop on the unmanured plots that was hard to make any bigger.

The fact is that two experiments made in exactly the same manner on two different, perhaps very different pieces of land, may give very different results, and this is the explanation for the contradictory results in this case; besides, farmyard manure may be young or old, of one kind or another. We believe that the wheat plant can use practically only one form of nitrogen in building its tissues and this form is nitric acid which is present in the soil as nitrates. If this be true, then all of the organic nitrogen present in the manure must be changed into this form before it is of any use to the wheat plant. This change is called nitrification, and the ability of soils to bring this about varies greatly, and the effects of nitrogen applied to wheat land in the form of farmyard manure will vary just as this power of the land varies. This is why experiments with farmyard manure on wheat on different lands have given such different results.

With us the practice of cultivating fallow gives excellent results for two reasons: First, because the amount of nitrogen in the soil actualy increases by amounts as great as are involved in the different characters of the crops, and second, by the change of this organic nitrogen into a usable form for the wheat.

EXAMPLES OF RESULTS OF FALLOWING

When we have no bad weather or other accidents to interfer with the development of the wheat, it is perfectly proper to compare the gluten in two wheats as the measure of their quality, and likewise, as a measure of the nitrogen used by the plant, so if we compare the amount of the gluten in two samples of the same variety of wheat grown under equally favorable conditions of soil and climate, the one having the more liberal supply of usable nitrogen will contain the larger amount of gluten. The best illustration that I have of this is presented by two samples of Red Fife wheat grown on pieces of land separated by a roadway 16 feet wide. The land on the west side had been cultivated fallow, that on the east side had been cropped to oats the preceding year. These plots were planted to Red Fife wheat. That grown on the fallowed land was flinty and contained 17.14 percent of protein, while that grown on the cropped land was affected by yellow-berry and carried 12.93 percent protein. I also have a pair of samples of Marquis wheat, but they are not so thoroughly comparable as the preceding pair given, still the samples grown on fallowed land contained 14.09 and that grown on cropped land 10.42 percent of protein, or, in general terms, gluten. With us, then, to cultivate the land fallow the year before it is planted to wheat helps wonderfully in increasing the hardness of our wheats. I have given the reason as being due to the accumulation of nitrogen, and its conversion into the form best suited for use by the wheat plant. If we had from 40 to 60 inches of rainfall, as they have in some states, the nitrogen might be washed out if no precautions were taken to prevent it, but with a rainfall of less than 15 inches per year, this does not make much difference.

When the potash does not produce yellow, spotted and mealy berries, it produces a distinctly lighter color in the wheat grains, which is easily recognized, also a marked plumpness, and the grains really crush easier than the flinty or dark colored grains grown in the same field. The yellow-berry grains crush more easily than the flinty grains picked out of the same sample. In the case of the Defiance, we found that it took 8 pounds more to crush the flinty grains than it took to crush the yellow-berry grains; in the case of the Kubanka it took 10 pounds more to crush the flinty than the yellow-berry grains. As the potash produces the yellow-berry and the light-colored wheat which is soft, we conclude that the presence of too large a proportion of this element is present in the soil. Of course, we may state it the other way, that as the addition of nitric acid or nitrates makes the grains flinty, there is too small a proportion of this element present in the soil to produce hard wheat. It makes no difference how we state it, the fact remains the same, i. e., to increase the nitric nitrogen in our soil tends to harden our wheat, without materially increasing the crop, and to increase the potash tends to soften it.

NITROGEN MAY BE WASHED FROM LAND BY EXCESSIVE RAINFALL OR IRRIGATION

The statement made about the possibility of the nitrates being washed out of the land by excessive rainfall was emphasized by English writers more than 30 years ago as the following sentences makes very plain:

"It has, of course, long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently, that one, at least, of the material causes of the adverse influence has been made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."

This is another manner, in addition to that already mentioned, in which rain may be bad for a wheat crop. Too heavy and too frequent irrigations might produce the same effect.

The application of 1 acre-foot of water on 12 June was not sufficient to perceptibly modify the effects of 40 pounds of nitrogen applied in the form of Chile-saltpetre at the time of planting, and, as this amount of water is, under our usual conditions, sufficient to mature our wheat in the very best manner, there is no reason at all why such a thing as the washing out of the nitrates, due to water applied, should happen. I think that usually 1 acre-foot applied when the wheat is in boot or early head is about the maximum that will be found necessary.

Some writers have stated that wheat is softened by irrigating it. The statements just made show how this might be the case, but I think that it seldom happens in our practice that wheat is softened by over irrigation. It is, however, worth bearing in mind, that while water is indispensable, we can do harm by using too much of it.

CHIEF CAUSE OF SOFTENING IS EXCESS OF POTASH OVER NITROGEN

The only cause for the softening of our wheat, unless it be where subirrigation is practiced, is, I think, due to the large excess of potash over the nitric nitrogen present in our soil. This nitric nitrogen, then, is something that we should cultivate and preserve in our soils if we wish to grow good wheat. I have said "cultivate" for this is one of the things that we do when we cultivate our land fallow.

COLORADO WHEAT VARIES GREATLY IN COMPOSITION

Our wheat varies greatly in respect to its hardness. I have samples from some sections of the State that are as good wheat as we could possibly desire, and I have others that are as soft as wheat can be. The Defiance is a very popular spring wheat, but it is often an extremely soft wheat, though the grains are large and the yield is satisfactory. This latter statement has not been exemplified in my own experience. Red Fife and Kubanka have each yielded better than it for the 5 years that I have grown them side by side. Defiance wheat has not only failed to give me the yield, it has not had the quality of these others. The Kubanka is a durum wheat and it may be that I should not compare the Defiance with it, but this is not the case with the Red Fife. I have seen some samples of winter wheat which were very soft but the most of it is very good, hard wheat, and, as I believe, worth just as much as wheat grown anywhere. This lack of uniformity in the quality of our wheat is unfortunate, for it seems to be true that the soft wheat is not so desirable as the hard wheat, but it is all Colorado wheat and the flour made is all Colorado flour, but it is not all equally good, very far from it.

I call to mind two samples of Turkey Red wheat grown on neighboring farms, in one all of the grains were narrow, glassy, and hard, in the other they were mostly yellow or partly yellow. The manager of the local mill went with me to see these wheats in the hope that I could tell him what made the difference in them. He said that he would willingly buy the hard wheat for he knew that he could make good flour out of it, but that he did not want to buy the yellow wheat because, if he mixed it with good wheat, he could not be sure that the flour would be up to the best standard. Now this wheat was grown from the same lot of seed and on two neighboring farms, and yet the crops produced were, in the judgment of this mill-manager, of very different quality, and he was entirely right in putting different values upon them.

ALL COLORADO FARMERS SHOULD BE GROWING BETTER WHEAT

While some of our wheat is very good it is not all good; on the other hand, while some of our wheat is very soft, a very great deal of it is hard. The hard wheat is richer in nitrogen, which is practically the same as saying richer in gluten, than the soft wheat and yields a better bread-making flour. In the first place it takes more water to make a bread-dough and consequently makes more pounds of dough. It may take 20 or 25 pounds more water to 100 pounds of flour. If we were making bread, even for a big family, we would appreciate this and we can not blame the baker for wanting this kind of flour. Many of our farmers are growing wheat that produces this kind of flour, and everybody ought to try to grow it and then they ought to get pay for this quality of wheat, but they are not all growing it. I understand that a difference of about 5 cents a hundred is sometimes made in favor of the hard wheat, and this is just.

Very many of the bakers, if not nearly all of them, in the larger towns of Colorado, claim to use, and I believe actually do use, Kansas flour for bread-making; at least they mix it with the better grades of Colorado flour. Some families that do their own baking use Kansas flour and think that they save money by doing it, because it makes more bread. I have heard this story now for thirty odd years and it must be true, at least they believe that it is true. I went to the largest bread-making establishment in Colorado and asked them what flour they used in bread-making. They said "Kansas flour"; but for other purposes they used Colorado flour. I asked them why they did not use Colorado flour for bread-making. The reason given was definite, i. e., because it made less bread to the barrel of flour by from 30 to 40 loaves. Now these people were using a great many carloads of flour every month for making bread and this was a commercial fact, concerning which they were certainly not deceiving themselves. The difference in these flours corresponds to the wheats from which they were made. The hard wheats of Kansas produce good bread-making flours while the softer wheats of Colorado yield less desirable ones. This is not only true in respect to the amount of bread made, it is also true in regard to the quality of the bread itself.

COLORADO CAN PRODUCE FIRST-CLASS WHEAT

These statements may be, and I believe are, true of some Colorado flours but they certainly are not true of all Colorado flours. The best of our flours may not be as good as the very best Minnesota or Kansas flours, but of some of them it is true that they rank in real merit just as close to these very best samples as the other Minnesota or Kansas flours do. By the choosing of good varieties and proper care in the cultivation and care of the grain, Colorado can produce first-class wheat and flour so that the baker will have no excuse for using Kansas flour nor the miller for claiming that the wheat is low in gluten.

QUALITY OF COLORADO WHEAT SHOWN BY PROTEIN CONTENT

The relation between the composition of the wheat and the flour produced is quite intimate, so intimate that it is quite permissible in this presentation to speak of the wheat only, and assume that the statements made apply to the flour. This is true to such an extent that the amount of crude protein is justly taken as the measure of the quality of the wheat. The crude protein is estimated by multiplying the nitrogen found in the wheat by the factor 5.7. The factor 6.25 has been used in estimating the amount of crude protein in many of the older analyses of wheat. It is necessary to remember these factors in comparing the statements of the protein content of wheat. We could avoid this confusion by giving the total nitrogen instead of crude protein, but we wish to give the amount of protein as nearly as possible, for this is the substance in the wheat that contains the nitrogen, and corresponds nearly to the gluten present, which everyone associated with the quality of the flour.

Someone may wonder why we have two different factors for the same thing and if they can both be right. They are probably neither exactly right, but one is more nearly so than the other.

The explanation for the use of two factors in this case is simple. The average nitrogen content of proteid substances is 16.00 percent, so if we find the nitrogen in a substance that contains no other than proteid nitrogen, this is equal to 16/100 of this substance present, so we multiply the nitrogen found by 6.25. It has been found, however, by extended investigations that the proteids of wheat are richer in nitrogen than the average proteid; they contain about 17.5 percent instead of 16.0 per cent; so the factor is 5.7 instead of 6.25. This factor of course gives a lower figure for the proteids in wheat; for instance, the protein content of the average American wheat is given as 12.23 percent. This statement was made, using the old factor 6.25, and becomes 11.16 percent, using the smaller and more recent factor. These two statements are for the same wheat. The importance of this point is this; if the reader should chance to compare the proteid content of Minnesota, Kansas or Hungarian wheat with that of a Colorado wheat given in this bulletin and find 18.75 given for the percentage of protein in the Hungarian wheat and 17.10 for that in the Colorado wheat, he would feel satisfied that the foreign wheat, be it Minnesota, or Hungarian, was more than 1.5 percent richer in protein than the Colorado wheat, whereas they are supposed to have exactly the same amount of nitrigen, 3.0 per cent, and to be wheats of the same quality.

The average composition of whole wheat is given as follows:

	Domestic Wheat Percent	Foreign Wheat Percent
Moisture	10.62	11.47
Protein	11.16	11.02
Fat	1.77	1.78
Fibre	2.36	2.28
Ash	1.82	1.73
Carbohydrates (Diff)	72.27	71.72
Wet Gluten	26.46	25.36
Dry Gluten	10.31	9.82
Weight of 100 grains	3.866 grams	4.076 grams

The one substance in this analysis that is of the greatest interest to the general reader is the protein, for this is the substance that yields the gluten which shows the bread-making qualities of the wheat. The wet gluten and dry gluten simply show the following; the former how much this wheat-proteid weighs when it is combined with water, and the latter how much of the crude protein is recovered in this form. In the two analyses just given, 10/11 of all the protein in the wheat was recovered from the wheat by washing out the starch and other constituents. The two analyses given are average analyses, one of domestic and the other of foreign wheat. Of course many wheats contain more protein than is given in these analyses and all of those that contain more than 11 percent belong to the higher grades of wheat. This is the principal thing that an analysis of wheat shows, so far as the farmer is concerned. This, however, is just what, in the next place, we want to show the Colorado farmer about our wheats, and to show him further how he can grow better wheat, and wheat which is more uniform in quality than we are growing.

First, however, we shall give him some idea of how our wheats vary in quality, and, as we have shown why we use the amount of crude protein in wheat as the measure of its quality and that the other details of the composition of wheat are not material for the farmer's understanding of the question with which he has to deal, we shall give only the crude protein, wet and dry gluten. While the ash and other constituents may be important from certain points of consideration, they do not play any big part in the questions interesting the wheat grower, and, besides, they will largely take care of themselves under our Colorado conditions. The only object in giving wet gluten and dry gluten is to show how much water the wheat proteids take up. Gluten washed out, as these glutens were, always contains some starch and other things, but we will not go further into these details.

GENERAL SAMPLES OF COLORADO WHEATS, TAKEN IN 1913-1914

SPRING WHEATS

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Defiance	Ft. Collins	13.46	30.66	11.74
Defiance	LaJara	8.29	14.33	6.10
Defiance	Del Norte	8.05	13.73	5.44
Defiance	Ft. Collins	13.93	35.33	13.41
Defiance	Grand Junction	13.92	29.73	10.90
Defiance	Clifton	14.44	28.74	11.68
Defiance	Eckert	11.25	28.37	12.49
Defiance	Ft. Collins	14.92	23.30	12.89
Defiance	Ft. Collins	12.04	32.00	12.99
Marquis	Ft. Collins	16.00	38.63	15.06
Marquis	Ft. Collins	14.06	40.40	16.40
Red Fife	Ft. Collins	15.20	38.00	14.83
Red Fife	Ft. Collins	17.14	40.67	15.58
Red Fife	Ft. Collins	14.79	43.20	16.90
Kubanka	Limon	12.99	30.00	12.49
Kubanka	Ft. Collins	12.77	25.40	10.79

WINTER WHEAT

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Turkey Red	Wellington	10.99	28.50	10.34
Turkey Red	Wray	10.14	20.53	7.87
Turkey Red	LaJara	8.22	16.07	6.42
Turkey Red	Las Animas	11.44	24.63	9.85
Turkey Red	Fruita	13.31	28.00	10.98
Turkey Red	Clifton	13.03	32.67	12.52
Turkey Red	Fruita	9.65	24.37	10.06
Turkey Red	Fruita	10.05	26.66	10.67

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Turkey Red	Fruita	13.21	37.60	15.49
Kharkov	Ft. Collins	11.98	25.40	9.72
Kharkov	Ft. Collins	15.30	38.67	14.00
Jaroslov	Ft. Collins	15.97	40.73	15.04
Jaroslov	Ft. Collins	14.99	48.83	18.15
Red Cross	Fruita	14.15	28.30	11.13
Red Chaff	Eckert	10.05	21.53	8.57
Red Chaff	Eckert	8.04	17.63	7.20
Fultz Mediterranean	Ft. Collins	14.00	42.00	16.00
Fultz	Ft. Collins	16.33	42.23	14.96
Big Frame	Ft. Collins	16.25	42.50	14.63

These samples show that our wheat, whether spring or winter, varies in quality very greatly indeed even for the same variety. In collecting these samples we were surprised and disappointed in finding that the average miller, and the farmer too, took no interest in this matter and occasionally we found a man who demanded pay for the few pounds of wheat making a sample. A greater difficulty was to obtain reliable information concerning the conditions under which the samples were grown. The reasons for this were many; it was seldom possible for the millers to give them and the farmers were but little better able to do so, because they do not understand the things that we want to know about the soil, the weather, the irrigation, the crop grown on the land the previous year, and the treatment that they had given the land and crop. The great importance attaching to these data, made it evident that, so far as the problems that we were studying were concerned, general samples would not serve any good purpose, so we made no attempt to collect such after the first year.

The samples given, however, serve to show that the same variety of wheat grown on different land in the same general section of the State, Turkey Red for instance grown near Fruita, varied from 9.65 to 13.21 percent of crude protein. These samples were grown the same season and it is only from my personal knowledge of certain conditions which existed in these cases that it is possible to account for the difference in the amount of protein in the wheat. The difference was that there was more nitric nitrogen in one piece of land than in the other. These wheats were irrigated, probably once each. When we consider the Defiance we see that this may be a very good wheat or a very poor one when grown in different sections of the State; for instance, the Del Norte sample contained only 8.05 percent crude protein while a sample grown the same year at Fort Collins contained 14.92 percent, or almost twice as much; the dry gluten is twice as much and a little more. The season of 1913 was a good one for wheat in all sections of the State and yet we have these great differences which are mostly due to the land on which the wheat was grown.

They further show that there are still greater differences between varieties. The highest protein percentage for the Defiance is 14.92, for Marquis 16.00 and for Red Fife 17.14. Of course these are all excellent samples, but the Red Fife is much better than the Defiance. The Kubanka, which is a maccaroni wheat, is not so rich in crude protein as one would expect; with us it is not an especially high protein wheat though it is a hard wheat.

We see the same variations in the amounts of protein in the winter wheats and these variations are largely due to the same causes, the principal one of which is the variation in the amount of nitric nitrogen in the soil.

SPRING WHEATS USED IN EXPERIMENT

It is the province of the agronomist to point out whether it is better to grow spring or winter wheat, and to determine the best varieties of these to be grown, but we chose spring wheats with which to experiment. We made this choice for the following reasons: First, The time from planting till harvest is short; second, The growing period is continuous; third, The spring wheats are known to be of excellent quality; fourth, Because, up to within a very few years, spring wheat was the principal wheat grown in the State.

The first fact enabled us to follow the effects of our fertilizers quite easily, the second removed the uncertainty of changes in both the soil and plants during the winter or resting months and the third feature promised us a bigger range of effects of fertilizers, or weather, on the amount of protein present in the grain. We chose three varieties, our Colorado Defiance because it has been our most popular wheat and I do not know but that it still is, the Red Fife because it is a dark-colored wheat of the very best repute in the northwest, and the Kubanka because it is probably the best of the durum wheats.

The reader already knows that the object of the investigation was to find out the reason for the softening of wheats in Colorado. We assumed that the general opinion held on this subject and in regard to the quality of our flour was correct on the principle that what is generally believed has its foundation in facts and is not prejudice created by a continued effort to depress the selling price of the grain. The general samples given, both those of spring and winter wheats, show that there are enough samples of poor wheat to give color to very bad stories about our wheat. There must be some cause for these poor wheats which probably have given rise to this generally prevailing bad impression of our wheats and flours. The three varieties of spring wheat chosen for our experiments represent two of the hardest and our own Defiance, not only a soft wheat, but one which was originated here and has been grown in this section for 30 or more years and represents perfectly a Colorado product which from the beginning was adapted to Colorado conditions.

We were very fortunate the first year of our experiments, 1913, in having an ideal season, so that no unfavorable seasonal influence interfered with the quality of the crop. This was not the case in the succeeding three seasons, 1914, 1915 and 1916. So far as our 1916 experiments are concerned, we simply abandoned the large plots. The seasons of 1914 and 1915 favored a strong development of rust which made a big difference in the quality of the grain.

In 1913, as I have just said, the season was as nearly ideal for our experiments as we can ever expect a season to be. We had two hard wheats and one soft wheat. Our experiment could work both ways, to soften the two hard wheats or to harden the soft wheat.

The softening of wheat under Colorado conditions seemed to me to show that the usual explanations for this condition could not be true. I believed that it must be due to something in the soil or possibly to irrigation as some claimed, though I did not belive this latter, for I knew that our dry-land wheat, and dry land here means really dry land, not a country of 19 or more inches of rainfall, fairly well distributed, is often quite soft, or shows yellow-berry badly. For reasons which it will be well to leave out in this place, I thought that the key to the matter lay in the food supply furnished the plant. I could, in a measure, control this and the amount of water, but in regard to the weather, I had to take my chances. Concerning the irrigating water and its effects, I have already said that it may determine the size of the crop but not its quality, as our problem has to do with the quality alone, the question of water is wholly set aside.

There are only three plant foods, aside from water, which it is deemed in any case necessary to add to the soil. These are potash, phosphorus and nitrogen. I have stated on previous pages that nitrogen must be present as nitric nitrogen, i. e., in the form of some nitrate, in order to be taken up by the wheat plant. The land that was placed at my disposal, fortunately, did not need the addition of anything to produce the biggest crop for the season. So the addition of these plant foods would simply show the effects of the food or fertilizer applied upon the quality of the grain by exaggerating the particular quality affected by it, and, as we planted both hard and soft wheat, we had two ways to observe these effects, namely, by the hardening of the soft wheat and the softening of the hard wheat. The results were all that we could have expected and as we repeated each experiment nine times that year, we might have taken the results as conclusive, but we did not. We have repeated them now for five years with the same results each year. In the bad years these effects were less satisfactory because so many things had a part in fixing the quality of the wheat. So we shall say nothing about any other than the 1913 crop. While I shall give the general composition of the three varieties, I shall not discuss them separately.

PRODUCED HARD AND SOFT WHEAT UNDER SAME SOIL AND MOISTURE CONDITIONS

In order to save labor and avoid confusion, I shall speak of "nitrogen," "phosphorus," and "potash" wheats to show which plant food was applied, and "check" wheat to show that nothing was added. When we threshed these different parcels, we could easily see that there were very great differences in the color of the wheats, also in the size of the grains, but we obtained no differences in the yields which were worth mentioning. I think that any farmer will agree with me that almost any two acres in a 20-acre field of wheat may differ in yield by 3 or 4 bushels, and unless the yields on 1/10-acre plots showed more of a difference than this, they would not be sure that it was the fertilizer applied that made the difference, unless this difference was made in the yield of every plot to which the fertilizer or plant food was applied. This was not true in our case, and even if the favorable differences found had been produced by the fertilizer, it cost so much to produce it that a man would be much better off without it. As I have said, the color of the wheat from the different plots varied just as the grains in some lots of wheat vary, some were darker, more glassy and harder than others. Here was the very thing that we were looking for; here was hard wheat and soft wheat grown during the same season on the same piece of land, which we had divided into 1/10 acre plots, and to which we had applied the same amounts of irrigating water. Our nitrate wheats were all harder, and potash wheats were all softer than the check wheats, while the phosphorus wheats were just like the check wheats.

There were no regular differences in the yields in favor of one or the other of the fertilizers and the yield from the check plots often had the advantage. All of our results showed in the quality of the wheat. The nitrogen had hardened the wheat; the potash had softened it. We have found this to be the case every time in upwards of 90 experiments, which proves that the cause of our yellow-berry, which is an extreme case of softening, is due to the presence of potash in excess of nitric nitrogen in our soil.

The following analyses represent our own wheats grown in these experiments and show, I think, the real quality of Colorado spring wheats grown under favorable weather conditions. Each analysis given is the average of nine analyses made of different samples of the particular kind of wheat.

WHEATS GROWN WITHOUT THE APPLICATION OF NITRATES

Variety	Crude protein Percent	Wet gluten Percent	Dry gluten Percent
Defiance	11.66	23.79	9.77
Red Fife	12.63	27.78	11.25
Kubanka	12.53	25.91	10.68

WHEATS GROWN WITH THE APPLICATION OF NITRATES

Variety	Crude protein Percent	Wet gluten Percent	Dry gluten Percent
Defiance	13.94	30.43	12.15
Red Fife	14.86	32.78	12.98
Kubanka	14.18	31.24	12.56

These analyses present the clearest and best statement that I know of in regard to the quality of our spring wheats. All of the wheats produced without the application of the nitrates were soft to a greater or less degree and those produced with the application of the potash were affected to the greatest extent by yellow-berry, and in the cases of the Red Fife and Kubanka, showed lower crushing strengths. On the other hand, all of the wheats grown with the application of nitrates were free from yellow-berry. The grains were smaller, glassy, semi-translucent and sometimes more or less shrunken. They would be graded as hard wheats.

These analyses show that wheats grown with the application of nitric nitrogen are richer in crude protein, by about 2.0 percent, than the same variety grown under the same conditions of season and soil but without the application of nitrates. Further they show that both the wet and dry gluten are very materially higher than in the same varieties grown without the application of nitrates.

If these analyses be compared with the average given for the composition of whole wheat, it will be seen that our Defiance grown without the application of nitrates is just about an average wheat so far as the crude protein contained is concerned, but a trifle below the average in both the wet and dry gluten. The Red Fife and the Kubanka grown without the application of nitrates are fully up to the average for domestic wheat, which is higher than the average for foreign wheat. All three of the varieties grown with the application of nitrates are well above the average, in fact, are very good indeed. If the reader will turn back to the table of general samples of winter wheat he will observe that only three of the 19 samples are much below the average for domestic wheats, while nine are much above it.

COMPARISON OF COLORADO AND MINNESOTA WHEATS

Of course the question which has been at the basis of all of this work is simply, What makes this difference? The general impression is that all of our wheat, when compared with Minnesota wheat for instance, is inferior in composition, that is, contains less gluten. This is not true, a great deal of our wheat is just as good and even better than Minnesota wheat. In 16 analyses of Minnesota wheats which I find in one of their bulletins the crude protein varies from 11.63 to 16.02 percent, and in 28 analyses that I find in another bulletin the crude protein in the wheat, which is about 1 percent more than is found in the flour, ranges from 11.17 to 15.75 percent. In some samples that I obtained from Minneapolis as samples of wheat which was on that market, marked Minnesota Spring No. 1, 2 and 3, I found:

	Crude protein	Wet gluten	Dry gluten
No. 1	12.81	24.67	9.88
No. 2	12.61	26.27	10.29
No. 3	12.20	24.73	9.62

Hard Winter Wheat from the same market gave,

	Crude protein	Wet gluten	Dry gluten
No. 2	11.22	21.73	8.64
No. 3	10.76	21.87	8.99

These samples were not as fine looking wheats as our own products and the analyses are just about average.

One thing to notice in these results is that they are more uniform than ours but the number of samples is smaller. We have some very low ones, our Red Chaff from Eckert carried only 8.04 percent crude protein and the Defiance sample from Del Norte 8.05 percent, whereas the Fultz from Fort Collins carried 16.33, and another sample of Red Fife 17.14 percent crude protein. These differences are very big though these samples were grown in good seasons, so that we cannot blame the weather, nor can we blame much of the difference to the variety, for while the Defiance is a soft wheat it is not always a poor wheat. This difference in the value of samples cannot but hurt the reputation and perhaps the market price of our whole crop. We can obviate this in so far as it is due to the land. We can, in the first place, plant varieties with a high protein content. The Marquis, for instance is, with us, richer in protein than the Defiance. So is the Red Fife, and the latter, though it is a bearded wheat with an apparently much smaller head than the Defiance, is a much surer cropper, because, it is earlier, stiffer in the straw and withstands rust better. I have not grown the Marquis and this is the reason that I say nothing about it. With us the thing that we have to dread most of all in connection with the quality of our wheat is rust. Continued wet weather, which would keep all parts of the plant wet most of the time would without doubt give us poorer wheat than clear weather. It is not the amount of water that does the damage but the fact that the plants are wet almost all of the time, which either washes out material that should be stored in the plant and later in the grain, or prevents the plant from taking this material up from the soil. The fact is that plants kept wet most of the time while they are growing are poorer in those substances that make good grain than plants not kept wet. We may keep the ground wet and not make the grain poor, but if we keep the plants wet, that is another thing. The difference made by the water alone is not so very big though it is big enough to be a matter of regret. The biggest danger to which our crops are exposed is an attack of rust. When this is prevalent, the crop is very poor in quality, even if it is not badly shrunken. When the rust develops abundantly on our wheat, the nitrogen which makes the protein in the wheat, and with it the other constituents also, seems to be very largely stopped from going into the grain. When this happens just when the grains ought to fill out, they don't fill and we have shrunken wheat. The Defiance is late in ripening and is susceptible to rust. My own experience with it has been very unsatisfactory on this account. The season of 1913 was a very favorable one. That of 1915 was wetter, but the promise of a crop was good till within 15 days or so of harvest, when, due to rain, lodging of the wheat and high temperature, rust developed very abundantly.

The yield and the analyses of the wheat from the same plots treated in the same manner in the two years follow. The only difference in the two seasons was the development of the rust. The promise in 1915 up to this point was good.

The statement of the results shows for itself the differences.

DEFIANCE SECTION 1800, SEASON OF 1913

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	38.83	13.79	31.33	12.32
Phosphorus	39.50	12.01	24.50	9.85
Potassium	41.66	12.33	24.50	10.08
None	40.58	12.14	25.07	10.22

DEFIANCE SECTION 1800, SEASON OF 1915

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	10.83	10.72	27.17	10.71
Phosphorus	22.50	8.76	18.50	7.47
Potassium	25.33	8.44	20.00	7.99
None	19.50	9.00	18.70	7.37

These two crops were grown with the same amount of water. In 1913 we had 7 inches of rainfall during the life of the wheat and we applied 12 inches of water; in 1915 we applied 6 inches of water and had 13 inches of rainfall. In 1913 we had very little, we may say no rust; in 1915 our wheat was very badly rusted. The yield for the Defiance in 1915 was not quite one-half of that of 1913 and the quality was no good at all.

I have stated one of the objections to the Defiance to be its late ripening. A comparison of the above data with similar ones for the Red Fife may be instructive.

RED FIFE, SECTION 1800, SEASON OF 1913

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	39.91	14.91	32.20	12.84
Phosphorus	34.90	13.24	27.00	11.04
Potassium	33.90	13.81	27.20	11.07
None	33.16	14.43	28.83	11.55

RED FIFE, SECTION 1800, SEASON OF 1915

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	23.66	10.07	24.70	9.28
Phosphorus	33.00	8.01	18.00	7.27
Potassium	33.16	8.82	22.17	8.99
None	33.66	8.38	19.40	7.73

This variety matures about 10 days earlier than the Defiance. We find that the 1915 crop is only a little less in volume than that of 1913 but the quality is extremely poor, just about the same as that of the Defiance. The Kubanka showed the same effects as the Red Fife, but in a much less degree in regard to the wet and dry gluten. We had two bad conditions in the season of 1915. The plants were kept wet most of the time by a succession of light rains and by heavy dews, and rust developed very badly. Of course the rust would not have developed except for the moisture, but how bad things would have been had the rust not developed we cannot say. Judging, however, from results obtained through our observation of the movement of nitrogen in the plant, the more injurious condition was the rust.

The differences in the composition of the crops of 1913 and 1915 are no greater than the differences in the milling results. The crop of 1913 yielded much more flour and less bran. The Defiance yielded about 72.0 percent flour and 21 to 27 percent bran in 1913, and from 64.0 to 66.0 per cent of flour and from 34.0 to 36.0 percent bran in 1915. The quality of the flour yielded by the 1913 crop was better than that of the 1915 crop.

COLORADO FLOUR COMPARED WITH OTHER FLOUR

Tests made on our flours in comparison with other flours bought in our market show our local flours to require from 57.06 to 68.0 percent of water to make a good bread-dough, Kansas flours 59. to 63., Minnesota flour 56. The size of the loaf produced compared favorably with the other flours, though it was a little smaller than the best Kansas that we tried. The flavor of the bread made from local flour is good and the color depends upon whether the flour is bleached or not.

To repeat some of the points of most interest.

BETTER COLORADO WHEATS ABOVE AVERAGE

The better wheats grown in Colorado, whether spring or winter, are very good wheats, far above the average in composition.

Some of our wheats grown in seasons producing in general a high quality of grain are poor in quality, due to lack of nitric nitrogen in the soil, which can be avoided. Other years we may have lower quality in our grain due to unfavorable weather and the prevalence of rust. The variety planted may be of much importance in this respect as a long-growing variety susceptible to the attack of this fungus, makes the loss more certain and serious.

BEST QUALITY OF WHEAT CAN BE PRODUCED IN COLORADO

There seems to be no reason why we should not produce more uniform wheat and of the very best quality. The flour made from our best wheats is as good as any flour and will make just as many and as big loaves of good bread as most other flours. The general impression seems to hold among us that wheat is wheat and it is all good so long as the miller buys it. If the flour is not good it is the miller's fault. This is not altogether true; the miller might spoil good wheat by his treatment of it, but when wheat is of poor quality when it goes into his bins he can not make it good. The grower should see to it that he grows good varieties on properly-cared-for land and that his good wheat is not injured by the weather in so far as he can avoid it.

Some of us think that it does not hurt wheat to lie on the ground in sheaf or to be wet in the shock; this is not true.

POOR REPUTATION OF COLORADO WHEAT UNDESERVED

Colorado wheat has among our bakers and people a rather indifferent reputation. This is wrong, for much of our wheat is A1 in every respect. Great improvement could be made by the exercise of a little more intelligent attention to these points: The variety planted, the condition of the land and the care of the crop after harvesting. These points are in the control of the farmer. The miller too, has his share in producing good flour but the Colorado farmer can produce a very good wheat if he has the will to do it.

RECAPITULATION

Some of the most important conclusions are as follows:

The better grades of Colorado wheat rank well with the wheats grown in Kansas and the Northwest.

When Colorado wheat is low in gluten, soft, it is due to its growing in a soil relatively low in available nitrogen—a condition that the farmer can remedy if he will.

A poor quality of grain sometimes results from an attack of rust, but not more frequently than in other states.

The Defiance is very susceptible to this disease and is late in maturing, increasing the chance of an attack. The growing period of the Red Fife is from 8 to 10 days shorter than that of the Defiance, has a stiffer straw and has proven less susceptible.

Flour made from the better grades of Colorado wheat, grown on ground rich in available nitrogen is as good as Minnesota or Kansas flour for bread-making. It produces as many loaves and the quality is as good.

The quality of the wheat varies a good deal with the variety. We find the Defiance the poorest of the varieties used in our experiments.

We have found that the available nitrogen can be greatly increased in our soil by cultivating it fallow the preceding season. This is brought about by the activity of micro-organisms. Early fall plowing is also very helpful.

The available nitrogen necessary to produce hard wheat may be added to the soil by growing alfalfa or clover and turning under the stubble.

The effects of subirrigation on the quality of wheat are small.

Wheat should be well supplied with moisture till in early head, when it should have its last irrigation.

Water applied later than this does but little or no good and may do harm.

If the plants are kept wet by frequent rains and heavy dews the quality of the wheat is lowered.

Rust is the most dangerous enemy of high quality in wheat that we have.

Wheat should not be exposed to the weather after harvesting; the sheaves should not be left lying on the ground till threshed.

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The Agricultural Experiment Station
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CLEANED, TREATED AND TESTED SEED FOR COLORADO

W. W. ROBBINS, H. E. VASEY
and G. E. EGGINTON

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CLEANED, TREATED AND TESTED SEED FOR COLORADO

W. W. ROBBINS, H. E. VASEY and G. E. EGGINTON

I. CLEAN, PURE, VIABLE SEED—ITS NEED.

The main object of this Bulletin is to point out the great need of having all seed cleaned, treated and tested before it is planted. It urges the placing of clean, treated and tested seed in the soil.

This year there is going to be a scarcity of some kinds of seed. Therefore, it is all the more urgent that the seed we do plant be in the best condition possible when sown. We are not placing special emphasis here upon the planting of more seed so much as we are the use of seed of high quality. There being a seed scarcity, every effort should be made to raise the quality of the seed we have on hand. This can be done by extra care in cleaning and treating. By testing, we hope to find out and eliminate seeds of low quality, be in a position to advise recleaning when found necessary, and give data which will guide the planter of seed as to how much to sow per acre.

We must get the most out of the seed we have, the most out of the acreage we have, and the most out of the labor we expend. We must not have crop failures nor low yields this year through any negligence of our own—through any negligence to make the conditions of which we have control the very best. Weather is beyond our control, but we can see to it that the seed we place in the ground is of the very best quality obtainable, that the soil in which it is sown is in the very best condition for germination, and that the plants are properly cared for from youth to maturity, and harvested at the proper time, and in the correct manner.

It is disheartening to the farmer to prepare his field with the greatest care for sowing, expending much labor and valuable time of man and beast, and subjecting his machinery to wear and tear, to find that the seed sown does not germinate well, or that the crop is accompanied with a vigorous growth of weeds, which growth increases the labor expended in caring for the crop, decreases the yield, causes the farmer to suffer an unnecessary dockage at the mill, and contaminates his seed and soil for the following crop season. The acreage in such a year does not live up to its productive capacity.

Pure, Live Seed Helps to Make Big Crops.—Even the most fertile soil, the best seed bed and the most careful cultivation will be useless unless pure, live seeds are planted. It is safe to say that with the same acreage and with the same cultural methods, and with the same care in harvesting, the yields of the crops in Colorado can be increased 10% to 15% by simply giving *unusual attention to the use of pure, clean, sound and vigorous seed.* Poor seed is often the only cause of crop failure. Poor seed is largely responsible for weedy farms. Weed control will be useless unless more attention is given to the use of pure seed.

Is the seed purchased alive? Will it germinate vigorously? Is the seed purchased filled with dirt, chaff and the seeds of such noxious weeds as wild oats, dodder, bindweed, poverty weed, cheat, sow thistle, wild barley and others? These are questions which give the farmer much concern.

The grades of seed for seed purposes and the cost of the same should be largely determined by the percentage of live seeds they contain and by their percentage of purity.

Clearly, there is but one way to find out the true value of a lot of seeds, and that is to give it a thorough test and analysis. It is usually impossible to judge of the quality of seed even by careful examination of handful after handful. The outward appearance of the seed will give one little idea of the vitality of the germ inside. Moreover, there are a number of weed seeds which are often associated with and may be easily mistaken for certain field seeds. For example, the seeds of alfalfa, yellow trefoil, white and yellow sweet clover and dodder have very much the same appearance and may be very easily confused.

That good seed is one of the most important factors in crop production no one can deny. How to secure pure seed and how to make it possible to know whether the seed is reasonably pure or not is another question.

It should be unnecessary to emphasize the need of pure seed. Everyone knows, or should know, that poor seed is the worst of economy; that low-priced seed is often the poorest economy. One lot of poor seeds carrying noxious weeds has made many a farmer years of work in eradicating them. It is recognized that the heaviest tax on a farm is its weeds. We have probably seen cases where a single carload of seed infested with noxious weeds has wrought havoc in a whole community.

When seed is tested, one gains reliable knowledge of one more factor in crop production. The farmer is in search of knowledge of as many of these factors as possible. Every farmer should know how his seed tests before he places it in the soil. The amount to plant per acre depends largely upon the result of this test. In the case of an extremely bad lot of seed, it would prevent a complete failure and the loss of labor and land.

A farmer several years ago planted twelve acres presumably to rape. His stand was a heavy, luxurious crop of wild mustard, one of our most noxious weeds. An analysis of the seed would have saved his labor and land and loss of the crop for that year.

High-priced seed is usually the cheapest seed. Someone has gone to the trouble to clean the seed, to remove from it various impurities such as dirt, stones, chaff, broken seeds and noxious weed seeds, and consequently a better price must be asked for such seed. However, we have seen low-priced seed with a quality as high as that of high-priced seed. *Testing determines the actual quality of the seed exposed for sale or intended for planting.*

Actual Planting Value of Seed.—The quantity of seed to plant per acre varies widely and is determined by a large number of different conditions. In this Bulletin emphasis will be placed upon the relation between quality of seed and the proper amount to plant per acre. This brings us to the consideration of the *actual value* of a lot of seed.

There are two chief factors in considering the quality of seed. *First, purity.* That is, its degree of freedom from sticks, stones, chaff, dirt, weed seed and other seeds. *Second, vitality.* That is, its power to germinate readily and produce vigorous sprouts. If both purity and vitality are high, the amount of seeds necessary to plant per acre in order to secure a heavy stand will be less than if either the purity or vitality, or both, are low.

The *actual planting value* of a lot of seed is secured by multiplying the percentage of purity by the percentage of germination of pure seed.

Let us illustrate with specific cases: Wheat of standard purity has a purity percentage of 99. Standard germination of wheat is 90% to 95%. Let us assume that the seed wheat is up to standard, with a germination of 93%. The actual planting value of this standard wheat will be 99 times 93, or approximately 92%. That is, on the basis of seed that contains no impurities and with every grain viable, we may expect to get 92% value from the seed. In other words, for every 100 pounds of seed sown, one would sow but 92 pounds of good seed.

Let us take a case now in which the germination is down to 90% and the purity down to 90%. This seed would not be considered hopelessly bad, but its actual planting value is only 81% as compared with 92% for seed giving a test considered standard. Let us take a case in which the yield from planting standard seed wheat is 40 bushels per acre. This year the value of an acre of $2.20 wheat would be $88.00. If we planted the seed with an 81% planting value at the same rate per acre as we did that of the 92% value, the yield per acre would be 35.2 bushels. The value of this acre of wheat would be $77.44, a loss of $10.56 per acre. With 80 acres of wheat, this loss would amount to $844.80. But this does not represent the entire loss. By the use of seed low in purity, carrying weed seeds, weeds have been introduced into the field, which make cultivation more difficult, rob the crop plants of soil nutriment, possibly harbor insect and fungous pests, furnish a crop of seeds which infests the soil for another year and infests as well the crop seeds taken from that field.

Let us compare the planting value of high grade and low grade alfalfa seed. Alfalfa with a germination of 87% and purity of 98% may be considered standard quality. The actual planting value of this seed is (87x98) 87.2%. Let us suppose that it takes 10 pounds per acre of this seed at 22 cents per pound. The cost of the seed necessary to plant an acre will be $2.20. Seed with the same germination, but with a purity of 90% will have a planting value of (87 times 90) 78.3%. If 10 pounds of standard quality seed were used per acre, how much of the inferior quality of seed should be used in order to scatter on each square rod the same number of seeds per acre? It will require 10.9 pounds per acre which, if sold at the same price per pound as the high quality seed, would give an acre cost of $2.40. Upon the same basis, alfalfa seed with a germination of 60% and a purity of 90%, which is not unusual, will have a planting value of (60 times 90) 54% and will need to be seeded at the rate of 16 pounds per acre, which will give an acre-cost of $3.52.

These illustrations are taken to show the great necessity of using the best of seed; moreover, the great need of having seed tested before planting in order to have a guide as to how much seed to plant per acre. If the actual planting value is low, more seed will necessarily have to be planted per acre to secure a good stand than when a standard, high quality of seed is used.

Every farmer should make it a rule to test for himself, or have tested for him, all seed before it is planted. The farmer in the case above lost $844.80 on his 80 acres of wheat; most of this might have been avoided by using better quality of seed or by planting greater amounts per acre of the lower grade of wheat.

More emphasis should be placed upon the actual planting value of seed. This value is secured by multiplying the percentage of germination by the percentage of purity. It is only by making a test of the seed that we can know of its planting value.

It is far better to use some seed as feed rather than seed. If a germination test shows the seed to be of low viability, or if it is heavily infested with noxious weeds which are difficult of removal, surely such seed should be used for some other purpose than seeding.

Character of Impurities in Seed.—We should know more than the purity percentage of seed, however. Two lots of seed may both have a purity of 98%; in the one case the 2% of impurities may be largely dodder, a most pernicious and destructive weed; in the other case the 2% impurities may be made up of harmless inert matter such as broken sticks, gravel, etc. Again, a lot of seed with a purity of only 90% may be superior to one with 98%, having the same germinability, if the purity in the first case is of harmless material and that in the second is of noxious weed seeds. The purity reports as issued by the Colorado Seed Laboratory give, not only the percentage of purity, but the percentage of noxious weeds, the percentage of other seeds, the percentage of inert matter and the number per pound of each kind of noxious weed seeds. This is information that should be in the hands of every seller and purchaser of seed.

Seed True to Variety.—Care should be used to plant seed true to variety. Mixed seed results in a crop that is not uniform. The stand is uneven. The plants of the different varieties mature at different times. Consequently, there may be considerable loss from shattering or from immaturity.

If seed of a given kind (wheat, for example) from a number of growers is dumped into a bin elevator, it is sometimes the case that such a lot represents a mixture of varieties. There are many farmers in Colorado who are buying such mixtures of seed wheat. And, the rather prevalent practice of mixing strains of cereals is resulting in a positive loss to the State.

Extravagant Claims of Seed Promoters.—We need to be cautious of extravagant claims of seed promoters. From time to time varieties of wheat have been introduced on the market which are said to give yields of enormous crops, much above the ordinary. For other varieties it is claimed that but small amounts of seed need be planted per acre, and this claim is made to justify the exorbitant price for such seed. As a general proposition, it is advisable to use home grown seed that has been tried and found to give satisfactory yields when its purity and viability are high and when proper cultural methods are used, and the seed is acclimated.

Cleaning Seed.—The fanning mill should be made greater use of by farmers. There are a number of excellent kinds of fanning mills on the market, some of which are of such a price as to be within reach of individual growers. Many farmers are equipped with such mills. Occasionally, several farmers of a neighborhood join in the purchase of a fanning mill. With the small cereals the fanning mill will remove chaff, wild oats, light and shriveled seed, smut "balls" and many weed seeds, and thus secure a much larger percentage of plump, vigorous seeds.

It has been demonstrated that running seed grain once through the fanning mill will often result in an increase of from 2 to 5 bushels per acre.

The cleaning of seed can be done during the winter days when there is a let-up in farm work, and before the rush of spring work begins.

The Germination of the Seed.—The seed contains the germ or young plant, often surrounded by stored food material. This stored material will be used to nourish the young plant until it secures a foothold in the ground and is able to absorb water and has sent out leaves which enable it to make its own food.

Certain conditions are necessary for the germination of all seeds. These are as follows: (1) Water, (2) moderately high temperature, and (3) air (oxygen). If any one of these is lacking, the seeds will not germinate.

Hard Seeds.—Most grains have seed coats which permit the ready intake of water. It very often happens that the seeds of alfalfa, sweet clover and other legumes have seed coats which are almost impermeable to water. Such seeds are called "hard seeds." They will not grow readily when placed under perfect conditions for germination. Hard seeds are not necessarily poor seeds. Some of them will germinate in several weeks; some will remain in the ground for an indefinite period without germinating. It has been determined experimentally that on the average about one-third of the hard seeds will germinate in a reasonable time. Unhulled sweet clover seed may often have as much as 85% hard seed. Hulled sweet clover has a lower percentage of hard seed than the unhulled. Alfalfa seed will often have 20% to 25% hard seed.

It is claimed that a larger percentage of hard seeds is produced in dry climates or when ripening takes place under dry seasonal conditions than in moist climates or moist seasons.

The permeability of leguminous seeds can be increased by "scarifying"; that is, passing them through a machine that scratches the surface. The ordinary alfalfa huller is effective for this purpose, as is shown by the experiments of Harrington, who found that alfalfa grown under a variety of soil and climatic conditions had about 90% of hard seeds if hulled by hand, and only about 20% if hulled by machine.

Scarifying machines are on the market. One machine, known as the Ames Hulling and Scarifying Machine, which may be operated with a one-horse power motor, or a two-horse power gasoline engine, has a capacity of from 18 to 25 bushels of alfalfa or sweet clover seed an hour. Scarifying, or abrasion of the seed surface, is accomplished by blowing the seed over garnet paper. The Ohio Agricultural Experiment Station gives the following results from using this machine, with sweet clover seed:

Seed not scarified	30% germination
Seed scarified	87.6% germination

It is unwise to plant leguminous seeds with a high percentage of hard seed.

Temperature and Germination.—The temperature which is the most favorable to germination is not the same for the different kinds of seeds. Moreover, the highest temperature and the lowest temperature at which seeds germinate vary. For example, it is quite well known that cucumbers and melons require a higher temperature to germinate properly than wheat and barley and some other small cereals.

Cool season crops, such as peas, lettuce, radish, small cereals, etc., will germinate readily at 50° to 60° F., while corn, pumpkin, cucumber, egg plant, and other warm season crops require a temperature of 70° to 80° F., to give fairly rapid germination.

Oxygen and Germination.—All seeds require air (oxygen) in order to germinate. Seeds will not germinate when the soil is deprived of air. If seeds are planted too deep in heavy clay soil, or in a soil that is too wet, they are quite likely to have a poor supply of air and to germinate slowly.

Light and Germination.—A number of seeds germinate better in the light than in the darkness. The best known example of such a seed is Kentucky bluegrass.

Conditions Affecting the Vitality of Seed.—It is a common observation that when a lot of seeds is placed under the most favorable conditions for germination a number of them fail to germinate. Some seeds are quick to germinate and form strong, vigorous seedlings. Others sprout but slowly and the young plants are weak and sickly. The farmer wants seeds which have a power to germinate readily and produce vigirous sprouts. In other words, he wants seeds of high vitality.

There are many conditions which affect the vitality of seeds:

1. *Maturity.* Although seeds will often germinate when they are not fully ripe, the plants from such are usually weak and cannot withstand unfavorable conditions. Moreover, the yield from immature seeds is always lower than from properly matured seeds. Lack of maturity or low vitality in corn is usually indicated by soft ears, by any discoloration of the grain, especially at the tips, and by blisters on the skin. Immature corn quickly loses its germinating power.

2. *Age.* All seeds gradually lose their viability with the lapse of time. The rate at which they lose their viability depends upon the kind of seeds and upon the condition of storage. As a rule, seeds retain their viability longest under low and equable temperature and moisture conditions. Ordinary crop seeds lose their vitality rather quickly when stored under high temperatures and where the atmosphere is moist.

Seeds containing oil, such as corn and flax, lose their vitality much earlier than starch-bearing seeds. The seeds of legumes are noted for their great longevity. Some have been known to retain their viability for 150 to 250 years.

The seeds of many plants have a rest period. That is, they will germinate better after a period of rest than they will when first mature. This dormancy is more common among wild plants than among domesticated ones. For example, wild oat experiences a delay in its germination, seldom germinating the same year that it is formed; on the other hand, the seeds of cultivated oats will germinate the same year in which they are formed. The seeds of a number of weeds will lie in the ground for years in a dormant state. It has been shown that some seeds are still viable after thirty years burial in the soil. Among such are the seeds of pigweed, black mustard, shepherd's purse, common dock, green foxtail and evening primrose.

There is an old saying that one year of seeds means seven years of weeds. A crop of seeds is borne; some of them may germinate immediately if the conditions are favorable; others may remain dormant for a year or two, and still others may remain dormant for five or six or seven years. In cultivation the seeds may be buried to such a depth that they do not get enough oxygen to germinate. Consequently, they lie dormant in the soil. Later, perchance, they may be turned to the surface in plowing and brought under conditions favorable to their germination.

3. *Freezing.* Corn often suffers from freezing before the grain is thoroughly dry. The tissue of the grain is broken down by the freezing of the water in it. If the grain becomes thoroughly dried, it will withstand very low temperatures. Corn containing 13% moisture may be stored with safety in bins exposed to very low temperature.

Corn raised along its upper altitudinal limits in Colorado may quite frequently suffer from an early frost; and although the grain may have the appearance of being healthy in every respect, many of the germs may be killed or their vitality considerably reduced as a result of the freeze, although slight. Consequently, it is very essential that Colorado-grown corn be given a careful test for germination before planting. Where frost was known to have injured part of a crop, or there is any doubt about the viability of the seed, it is the safest plan to have germination tests made. If the test is low, and better seed is not obtainable, the deficiency can be made up by increasing the rate of planting. All seed corn, no matter what its source, should be carefully tested this year for germination.

Corn grown in Colorado in 1917, that has been tested to date at the Colorado Seed Laboratory, shows extremely wide variations in the percentage of germination, from almost zero to 95%.

4. *The low vitality of seed may be due to the unfavorable conditions which prevail at the time the seeds are maturing. Most seeds mature best under dry atmospheric conditions.*

5. *The vitality of seeds depends largely upon the manner of curing.*

6. *Storage conditions affect in a very marked degree the vitality of seeds.*

The following table gives the length of time seeds may be expected to retain their vitality under average storage conditions:

TABLE I.—AGE AND VITALITY OF SEED

Seed	Years	Seed	Years
Alfalfa	6–8	Mustard	4
Alsike clover	2	Okra	5
Asparagus	5	Onions	2–5
Beans	3	Orchard grass	2-3
Beets	6	Parsley	3
Brome grass	5	Parsnip	2
Cabbage	5	Peas	3
Carrots	4	Pumpkin	5
Cauliflower	5	Pepper	4
Celery	8	Radish	5
Corn, field	2	Red clover	6–8
Corn, sweet	2	Red top	6
Cress	5	Rhubarb	3
Crimson clover	1–2	Salsify	2
Cucumbers	10	Spinach	5
Egg plant	6	Squash	5
Endive	10	Timothy	6
Kale	5	Tomato	4
Kentucky bluegrass	1–2	Turnip	5
Kohlrabi	5	Vetches	3
Leeks	3	Watermelon	5
Lettuce	5	Wheat, oats, barley, rye, and other small grains	1-2
Millet	6	White clover	2
Muskmelon	5		

Under the dry climatic conditions of Colorado and other western states, many seeds may retain their vitality much longer than given in the above table.

From the above discussion it will be seen that there are many factors which affect the vitality of seed. In the first place, the vigor and longevity of seeds are specific, varietal characters, determined by heredity; and in the second place, the vigor and longevity of seeds are influenced markedly by the environmental conditions prevailing during the growth of the plant, particularly during the period of maturing, and to conditions which obtain while they are in storage.

These facts simply emphasize the urgent necessity of testing seeds before placing them in the soil.

Standards of Purity and Germination.—The following table shows the standards of purity and germination of a number of common garden and field seeds; it is taken from the Yearbook of the U. S. Department of Agriculture, 1896. These standards have no legal status; the Colorado Pure Seed Law sets no standard. The table is included to give one some idea of what is considered good seed, so that he may have a basis of comparison by which to judge of the quality of any lot of seed:

TABLE II.—STANDARDS OF PURITY AND GERMINATION

Seed	Purity %	Germination %
Alfalfa	98	85–90
Asparagus	99	80–85
Barley	99	90–95
Beans	99	90–95
Beet	99	150 sprouts from 100 balls
Bluegrass, Canada	90	45–50
Bluegrass, Kentucky	90	45–50
Brome grass	90	75–80
Buckwheat	99	90–95
Cabbage	99	90–95
Carrot	95	80–85
Cauliflower	99	80–85
Celery	98	60–65
Clover, alsike	95	75–80
Clover, crimson	98	85–90
Clover, red	98	85–90
Clover, white	95	75–80
Collard	99	90–95
Corn, field	99	90–95
Corn, sweet	99	85–90
Cotton	99	85–90
Cowpea	99	85–90
Cress	99	85–90
Cucumber	99	85–90
Egg plant	99	75–80
Fescue, meadow	95	85–90
Lettuce	99	85–90
Kafir corn	98	85–90
Melon, musk	99	85–90
Melon, water	99	85–90
Millet, common	99	85–90
Millet, hog (*Setaria italica*)	99	85–90
Millet, pearl (*Panicum miliaceum*)	99	85–90
Mustard	99	90–95
Oats	99	90–95
Okra	99	80–85
Onion	99	80–85
Parsley	99	70–75
Parsnip	95	70–75
Peas	99	93–98
Pumpkin	99	85–90
Radish	99	90–95
Rape	99	90–95
Rye	99	90–95
Salsify	98	75–80
Sorghum	98	85–90
Spinach	99	80–85
Spurry	99	85–90
Squash	99	85–90
Timothy	98	85–90
Tomato	98	85–90
Turnip	99	90–95
Tobacco	98	75–80
Wheat	99	90–95

II. HOME METHODS OF SEED TESTING.

The Purity Test.—Purity tests are beneficial and advisable from the standpoint of better yields made possible by definite knowledge of the quality and constituents of the lot of seed to be sown. Casual inspection of a lot of seed will reveal very few of the weed seeds present, especially when the lot under examination has been milled and the chaff, sticks, and smaller weed seeds removed. A carefully conducted purity test will, because of its thoroughness, result in the detection of all adulterants as well as unmilled weed seeds and inert matter. Take, for example, alfalfa containing a small amount of large-seeded alfalfa dodder. Not one buyer in ten will detect this undesirable seed because of its close resemblance in size and color to the alfalfa seed.

Each farmer before planting should know just what his lot of seed contains of weed seeds and inert matter such as broken seed, chaff and dirt.

When seed is home-grown there is no particular hurry about having a purity test made, and there is ample time to have tests of such seeds made at the Colorado Seed Laboratory, which is specially equipped to make very accurate analyses. When it is necessary to purchase seed from a seed company it may be advisable to make a purity test at home, for a home test means immediate returns and the farmer is able to take advantage of a choice lot of seed when it appears on the market, whereas a delay of several days in securing results from the state laboratory would mean loss of opportunity in securing the best seed before the stock has been entirely exhausted. The prospective buyer should ask for a representative sample of the seed offered for sale and satisfy himself as to the quality before purchasing. The large and reputable seed companies conduct a "buy on sample" business, and a purity test is therefore entirely possible.

FIG. 1.—Seed trier which may be used in taking samples of the smaller seeds from sacks without opening the sacks.

Samples from home-threshed seed should be taken in such a way as to secure a representative sample. The ordinary metal seed sampler (Fig. 1) is very commonly used for sampling small seeds such as alfalfa, red clover and timothy in bags. The use of this sampler does away with opening each bag. When only one bag is to be sampled, small amounts should be taken from the top, middle and bottom of the sack. If more than five bags, samples should be taken from every fifth bag. The composite sample of one lot in any case should be thoroughly mixed in a receptacle so that there may be even distribution of weeds and dirt throughout the sample. The sample so mixed is known as the test or trial sample. Of course, samples may be taken by hand from open bags, bins, etc.

FIG. 2.—The seed to be tested as to purity is spread out on a sheet of paper. A knife and simple tripod lens are all the apparatus necessary to separate the seed into pure seed, weed seed and other crop seeds, and inert matter.

The first step in making a purity test is to spread the trial sample on a flat white surface, preferably cardboard over wood (Fig. 2). The necessary apparatus consists of tripod lens* and a knife or forceps for separating weeds, broken seed and inert matter from the seed. If the trial sample is too large, it may be divided and re-divided (Fig. 3) until the desired amount is obtained.

TABLE III.—THE APPROXIMATE AMOUNTS OF SEEDS TO TAKE FOR PURITY TESTS

Alfalfa, red clover, sweet clover	1-6 oz.	(5 grams)
Timothy, alsike clover, white clover	1-16 oz.	(2 grams)
Wheat, oats, barley, rye, buckwheat	1 oz.	(28 grams)
Brome grass	1-10 oz.	(3 grams)
Bluegrass, red top, Bermuda grass	1-28 oz.	(1 gram)

Accurate scales or balances are seldom accessible to the farmer and for the majority it will be necessary to roughly estimate the percentage of foreign material. (In U. S. D. A. Farmer's Bulletin No. 428, T. H. Hillman has described a simple weighing device which should give fairly accurate results.)

In making a home purity test some knowledge of weed seeds is necessary. For the purpose of determining the unknown weed seeds,

*Tripod, lens and forceps are obtainable at any drug store.

the Colorado Seed Laboratory has prepared a collection of the most common weed seeds* (Fig. 4). By means of this collection the farmer can easily distinguish seeds of the common weeds.

After the separation or purity test is complete the resulting divisions will consist of pure seed in one pile, dirt, chaff and broken seed or other inert matter in the second pile, and weed seeds or other seeds in the third. The percentage of purity can be accurately determined when scales are available or roughly estimated if there are no scales to be had. Unknown seeds which do not occur in the authentic collection may be sent to the Colorado Seed Laboratory for identification.

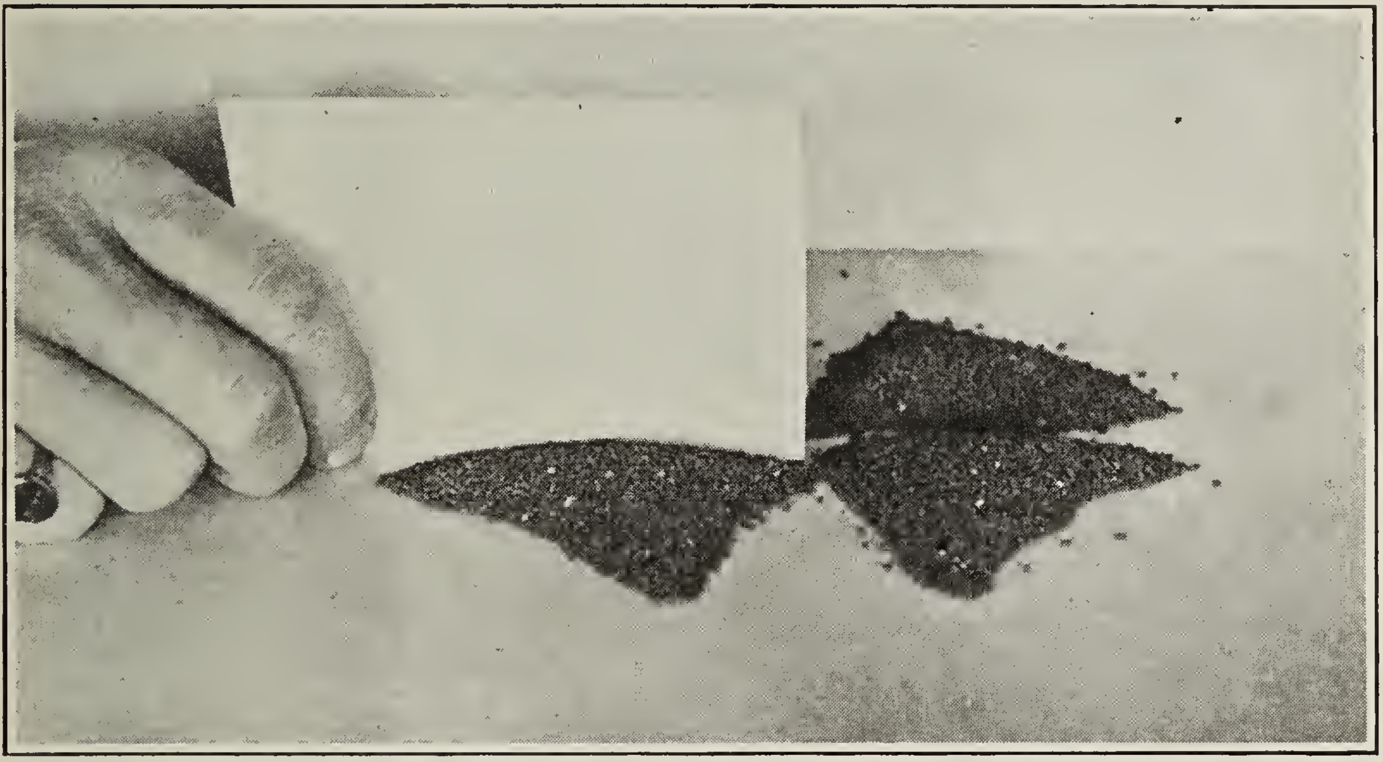

FIG. 3.—Showing method of dividing original purity sample in order to obtain the proper amount for purity analysis. This method of dividing eliminates any tendency of the individual to select either good or bad seed for analysis.

Much has been written regarding home purity tests, but there is still much doubt as to the accuracy of such tests even when good scales are obtainable. There is oftentimes marked variation in purity tests made by experts using highly specialized apparatus, so it is obvious that a *rough* estimate or the use of even an ordinary scale would mean wide variation—far greater than the usual 2% allowed in the seed laws of the several states. Emphasis should be placed upon the ability of the Seed Laboratory to give the farmer that which he cannot afford to obtain for himself—the knowledge of highly trained experts and the use of specialized apparatus, which make for accuracy

Germination Tests.—Germination tests can be made by anyone, if the correct method is followed and care is exercised. For germination, all seeds require heat, air and moisture.

It has been found after many years of experiment that different crop seeds require different seed bed conditions for the most accurate

*Each collection case contains 24 different weed seeds and may be purchased from the Seed Laboratory at the cost of preparing—75c.

results in germination. The seed beds most commonly used are blotters, strips of Canton flannel, sand, soil and sawdust. The last three named are used in either flats or pots. The kind of seed bed to use depends upon the size of seed and variety. The large seeds require more moisture than the smaller seeds, and blotting paper would not supply a sufficient amount, whereas Canton flannel would hold too

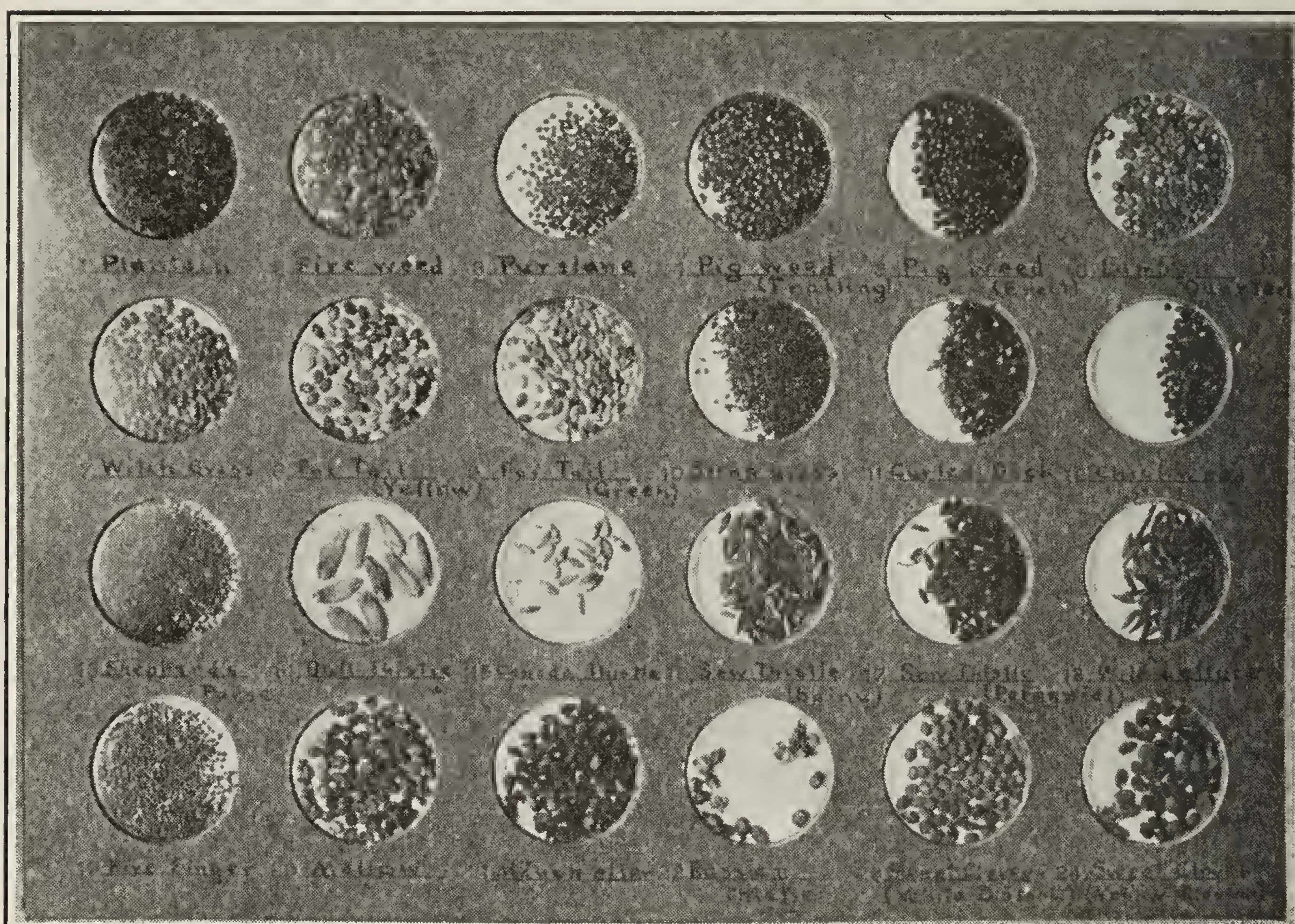

FIG. 4.—Weed seed set: This collection of 24 different common weed seeds may be purchased from The Colorado Seed Laboratory at cost price of 75 cents.

great a supply for the smaller seeds. In making germination tests care should be taken to keep the blotters and cloths moist, but not *saturated* or *dripping*.

The following table will serve as a guide in reference to seed beds, temperature, and duration of test:

TABLE IV.—SEED BED, TEMPERATURE AND DURATION OF TESTS.—
(See Note)

Kind of Seed	Seed Bed	Temperature Fahrenheit	Day for Making Germination Report	
			Preliminary	Final
Field Crops:				
Barley	B	68	3	5
Beans	C	68-75	3	6
Beets b–c	B	68–75	5	10
Buckwheat	B	68–75	3	5
Corn*	C	68–75	3	5
Flax	TB	68–75	2	5
Hemp	B	68–75	3	5
Oats	B	68	3	5
Peas*	C	68–75	4	8
Rye	B	68	3	5
Turnips	B	68	3	5
Wheat	B	68	3	5
Grasses, Clovers Forage Plants:				
Alfalfa	B	68	3	5
Bermuda grass *	BJ	68–75	10	21
Blue grass	BJ	68–75	14	28
Brome grass	B	68–75	5	10
Clover, alsike	BT	68	3	5
Clover, crimson	B	68	2	4
Clover, mammoth red	B	68	3	5
Clover, common red	B	68	3	5
Clover, white	TB	68	3	5
Cow peas*	C	68–75	4	10
Johnson grass	B	68–75	6	10
Meadow fescue	B	68–75	5	10
Millet	B	68–75	3	5
Orchard grass	B	68–75	6	14
Rape	B	68	3	5
Red top	TB	68–75	5	10
Sorghum	B	68–75	3	5
Sudan grass	B	68–75	3	5
Timothy	TB	68–75	5	8
Turnips	B	68	3	5
Vetch	C	68–75	4	14
Vegetables:				
Asparagus	C	68–75	6	14
Beans*	C	68–75	3	6
Beets b–c	B	68–75	4	10
Cabbages	B	68	3	5
Cauliflower	B	68	3	5
Carrots	B	68–75	6	14
Celery	TB	68–75	10	21
Cucumbers x	B	68–75	3	5
Egg plant	B	68–75	8	14
Lettuce b	B	68	2	4
Muskmelons x	B	68–75	3	5
Onions	B	68–75	4	7
Parsley	B	68–75	14	28
Parsnips	B	68–75	6	21
Peas	C	68–75	3	6

Kind of Seed	Seed Bed	Temperature Fahrenheit	Day for Making Germination Report	
			Preliminary	Final
Peppers	B	68–75	4	10
Pumpkins x	C	68–75	3	6
Radishes	B	68	3	5
Salsify	C	68–75	5	10
Spinach	B	68	5	10
Squashes x	C	68–75	3	6
Sweet corn	C	68–75	3	5
Tomatoes	B	68–75	4	10
Turnips	B	68	3	5
Watermelon x	B	68–75	4	6

NOTE:

B—Between blotting paper.

TB—On top of blotting paper.

BJ—Bell jar (these seeds may also be germinated in daylight germinator).

C—Between folds of cloth.

b—Soak six hours in water at room temperature before testing for garmination.

c—It is recommended that the germinaton of beet seed be confined to determining the percentage of balls which give sprouts.

*—Germinate in soil when possible.

x—Germinate in sand when possible.

To make the germination test, first prepare the seed bed. If blotters are to be used, select blue or white blotting paper in strips about 6 inches by 12 inches and fold lengthwise once. When Canton flannel is used, for large seeds, the strips should be about 8 inches by 32 inches and folded lengthwise twice.

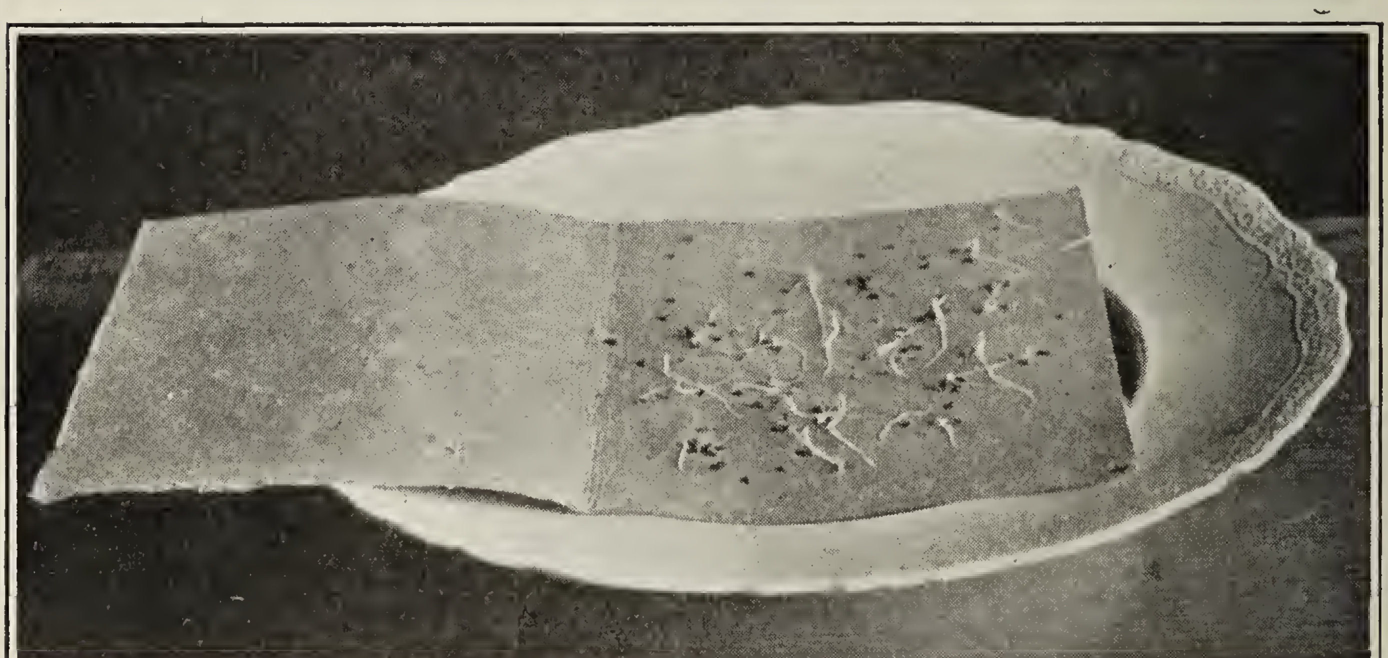

FIG. 5.—Use of dinner plate in making germination test. The blotter is dipped into water, laid on the plate, the seeds spread evenly over surface of blotter, and another dinner plate inverted over them, thus making a moist chamber.

Next, immerse the blotters or cloths in water and after draining, place on an ordinary dinner plate (Figs. 5 and 6). It is advisable to run two tests of each lot. Count two lots of 100 seeds each, taking the seeds as they come without discrimination and including shriveled as well as plump seeds. Selection of plump seeds only would fail to give a representative test. Scatter 100 seeds on each blotter or cloth

FIG. 6.—Germinating corn between the folds of Canton flannel. Use two dinner plates, one inverted over the other.

so that no two seeds touch each other. If the seeds are to be germinated between blotters or cloths, the end of the strip should be folded over the seeds before the top plate is adjusted. Then cover with a plate of glass or another dinner plate, thus making a moist chamber.

Do not place the plates on a window sill or over the stove. Keep the tests in that part of the house where the temperature is most uniform. The seed bed should be kept moist during the test. Count the sprouts according to the length of time designated in Table IV.

Attention is called to seeds of legumes (alfalfa, red clover, alsike clover, etc.) which remain hard at the end of the given period for test. These are known as hard seeds, which usually grow quickly when the seed coats are scratched or broken. One-third of the number of hard seeds may be considered as sprouts and added to the percentage of germination.

A few varieties of garden seed germinate best in sand. (Table IV.) These seeds can be sown in pots or small wooden flats (Fig. 7) with a light covering of sand. The pots or flats should be shaded, as direct sunlight causes rapid evaporation. The sand should be moistened lightly every day.

Corn should be germinated in soil when possible (Fig. 7). Germination tests may be made in flats or pots, whichever is convenient. Sprouts in soil can be counted as they appear. It is advisable to allow three or four days additional when tests are made in soil, because it requires more time for the sprout to break through the soil than to make the same growth between folds of Canton flannel.

Canton flannel over sawdust is the most popular method of making individual ear tests of corn. The ordinary soil flat (Fig. 7) is filled with well moistened sawdust to about three-fourths its depth.

After marking off the Canton flannel in 2-inch squares with ink or indelible pencil it should be well moistened and placed over the wet sawdust. The squares may be numbered to correspond with the numbers on the ears being tested. Kernels from different parts of the ear, usually six to ten in number, are placed in each square, and the whole is then covered with a second layer of Canton flannel. The final count in this case will come after six days.

In making a germination test there are, in brief, several items of importance: (1) Count out the seeds accurately; (2) keep blotters

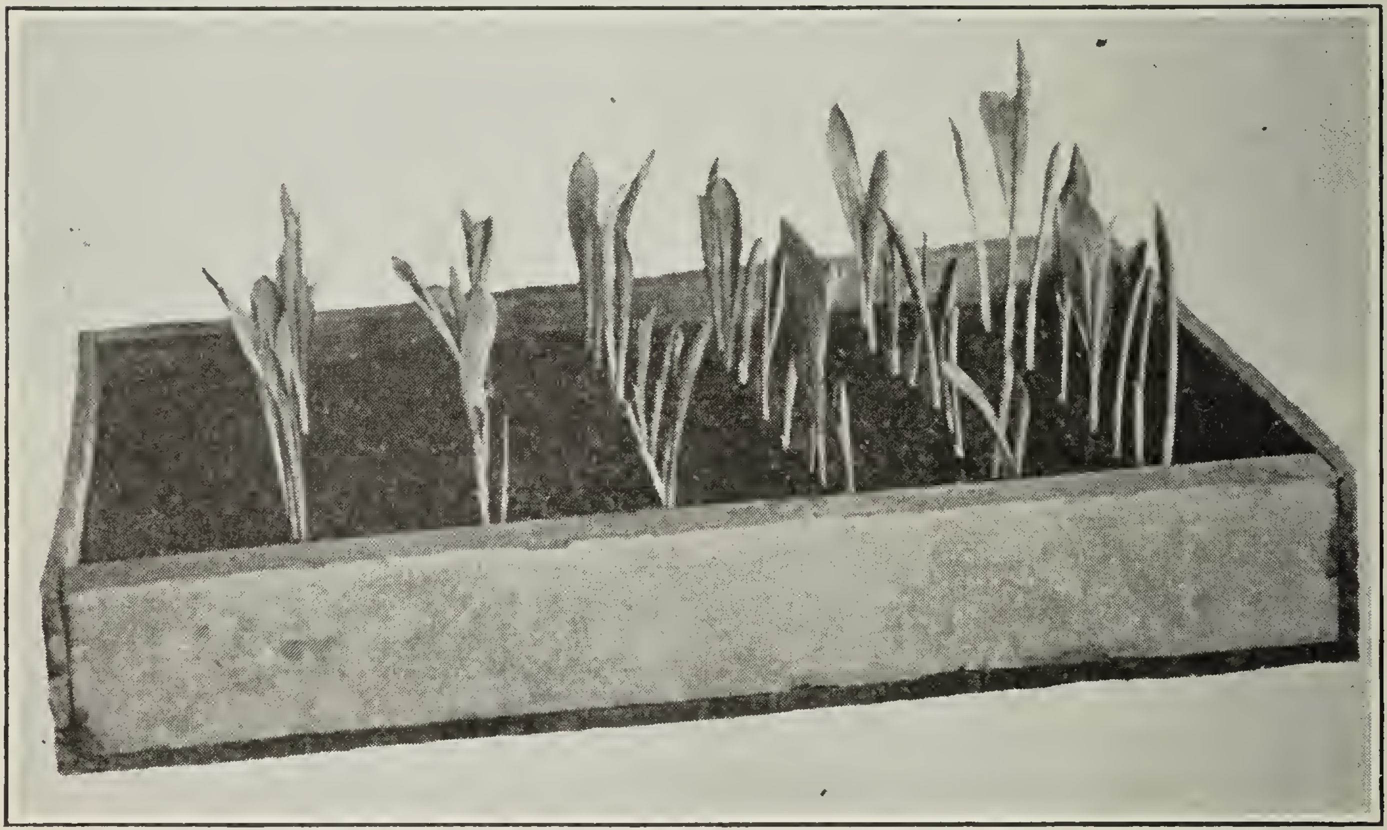

FIG. 7.—The soil flat, especially recommended for testing germination of corn, beans, peas, and other large seeds.

and cloths moist, but not *saturated;* (3) keep at a uniform temperature, and (4) count the sprouts at periods stated in the table.

The ease with which germination tests can be made, from the standpoint of apparatus and labor, means that home germination tests will rapidly become popular among farmers. To them it represents a guarantee not only of their own seed but all seed that is being offered on the market, and the consequent lessening of risk of great losses.

III. METHODS OF SEED TREATMENT FOR THE PREVENTION OF DISEASES IN CERTAIN FARM CROPS.

One of the chief reasons why so little attention is given to the sowing of healthy seed is that the damage resulting from various plant diseases is invariably underestimated by the crop grower. In a goodly number of instances the purity and germinative power of seed have been carefully determined, but the failure to go one step farther and make sure that it is wholly free from disease has brought quite unnecessary losses in the crop and caused no end of worry to the farmer himself. We should not forget to add to the slogan "Pure seed, and viable seed," the third important essential, "clean seed," because it is only through healthy seed that we may ever expect to harvest healthy crops and to insure maximum profits. Passing notice might well be given to the value of seed disinfection as it affects only such diseases as the smuts. Below is a table showing in dollars and cents the possibilities in confronting smut in wheat, barley and oats alone:

TABLE V.—LOSS FROM WHEAT, BARLEY AND OATS SMUT IN COLORADO

Kind of Grain	Year	Total yield based on average	Average % of smut in crop	Average losses bushels	Average loss for 1 year, dollars
Wheat	1909	7,224,057	6	433,443.42	910,230.30
Barley	1909	1,889,342	5	94,446.10	113,363.00
Oats	1909	7,642,855	5	382,142.75	247,142.00

Total, $1,270,735.00

Seeds As Carriers of Disease.—Some of the diseases most dreaded in farm crops are among those carried over on agricultural seeds. Together with the handling of clean seed comes the problem of clean soil. The latter is greatly influenced by the quality of seed sown. It has been shown that, at least for some sections of the United States, the use of bad seed and infested soil associated with constant cropping brings about soil-sickness for such crops as wheat, rye and barley, and perhaps many others. There is no doubt that poor yields in many cases are entirely the result of noxious diseases introduced to the soil and crop by means of infested seed. Bolley of the North Dakota Experiment Station, contends that many disease organisms attack the roots, leaves and stems of wheat and cause material damage to the crop. He believes they are the chief cause of failure of wheat to properly stool. Parasitic diseases introduced into a soil are apt to persist year after year and do considerable damage, the amount of which depends upon the kinds of soil and atmospheric conditions. In contact with the seed, these diseases are readily distributed from crop to crop and from season to season. In fact, they may be so well protected within the shallow parts of the seed or within the seed coats themselves as to effect distribution over long distances as from Europe to America, or *vice versa.* Disease germs thus concealed upon the seed may escape the most careful observer, so that the proof of bad seed appears first in the crop. Poor yields should arouse suspicion regarding the health of the seed; missing plants, shriveled grain, unusual yellowing of leaves, and dwarfing, all may easily be the result of fungi which gained foothold by the route of uncleaned seed.

Clean seed, however, cannot insure a normal healthy crop when put into infected soils. We should not forget the soil problem in looking after that of the seed, and it is essential, therefore, that the condition of the soil in regard to the presence of disease should have consideration in determining the scheme of crop rotation.

On the other hand, while one is using every effort to keep the soil clean by crop rotation, he should be just as *careful that diseased seed does not undo all his work of preparing the soil.*

Advisability of Disinfecting Diseased Seed.—There is hardly a group of plant diseases known which can be more readily and completely controlled than those carried on the outside of seeds. Considering the cost of treatment, which seldom exceeds two cents per bushel, the farmer can ill-afford to use anything but clean seed. Whenever any noticeable number of diseased plants is seen in a field, there always occurs a material loss of the crop, hence prompt means of eradication should always be taken, depending upon the disease present. Not all diseases can be controlled by treatment of the seed as, for instance, wheat rust, mildews or blights, or even corn smut, but on the other hand, such diseases as the cereal smuts, certain anthracnoses and various vegetable diseases are best controlled by seed disinfection.

It is not always an easy matter to determine whether or not fungi are attached to seeds wanted for seeding purposes, but it is very unwise to use seed known to have come from diseased fields, even in small amounts.

Seed treatment is very simple and can be performed with a very small outlay of materials and a minimum of trouble. The principle of seed treatment is to kill fungous spores lodged on the surface of the seed by the application of a disinfectant solution. The solution must be strong enough to destroy the spores, but effect no injury to the grain. For this purpose formalin and corrosive sublimate are most in use. Formalin is a solution of formaldehyde gas in water. When purchased for seed treatment, it should possess 40% concentration. All druggists have this strength in stock (and it is sold at 50 to 70 cents per pound). Corrosive sublimate is a severe poison and when employed for seed disinfection, the seed should not be fed to livestock. It is diluted in the proportion of 1 part to 1,000 parts of water. Corrosive sublimate is sold in the form of a powder and readily dissolves in lukewarm water.

Diseases for Which Seed Treatment Should Be Used.

Bean.

Bean Anthracnose. This disease affects all above ground parts of the plant. The greatest injury occurs on the pods usually, where the appearance of the disease is marked. It is manifested by spots that are round to oval in shape, discolored, dark and sometimes pinkish and surrounded by a reddish zone or margin. On the leaves the spots are similar in appearance to those on the pods; they occur on the large veins, generally on the under surface. In advance stages, the leaves may be eaten through by the fungus. Frequently the seeds themselves show marked discoloration as a result of serious attacks on the pods, and as a general rule the seeds carry the disease over the winter to next season's crop.

Control:

1. Wherever possible, destroy all diseased vines by burning.

2. Do not plant beans on land a second year after it has produced the disease; wait about three years.

3. Avoid cultivation of diseased plants while rain or dew is on them.

4. Seed selection is the best and safest means of control. Hand-picked seed pods should be used; the picking should always be done when seed is to be taken from diseased fields.

5. In cases of seriously affected seed, if such must be used, it is important to sterilize the seed, although sterilization may not render it absolutely healthy, due to the presence of the disease-producing organism within the seed. Disinfect the seed by soaking 18 minutes in a solution of 1 part of water to 1,000 parts of corrosive sublimate. It is advisable to plant the seed soon after drying.

Bacterial Blight. This occurs as spots upon the pod, leaf, stem and seed of field, garden and lima beans. The leaves are usually the first to be attacked. The spots are irregular in outline and water-soaked when young. Later these spots dry up and become papery and brittle. Sometimes whole leaves are affected and sometimes all leaves on a plant are killed. Spots on the pods later become reddish in color, although not sunken. As a rule, they may be separated from anthracnose spots by the absence of black color and definite smooth margins which are frequently rose red in color. The disease is carried over on infected seed. It is spread in the field by insects.

Control: The measures of control recommended for anthracnose apply equally well to blight.

Cabbage.

Black Rot of Cabbage. This is a bacterial disease characterized by the occurrence of black streaks on the woody portions of the stem and leaf stalks. Diseased leaves pulled from the stem show blackened spots in the leaf stalk. Badly diseased plants are dwarfed, often one-sided, and are devoid of the lower leaves at maturity. Sometimes the entire head fails to develop, or the plant dies in mid-season. The disease germ may enter at the leaf margins, through the roots or at the base of he leaf close to the stem. A very disagreeable odor nearly always accompanies the disease.

Control:

1. Soak the seeds before planting for 15 minutes in either: (1) corrosive sublimate solution of 1 ounce to 1,000 ounces of water, or (2) in formalin solution of 1 part formalin to 240 parts of water.

2. Change the crop for two or three years, although do not plant vegetables related to cabbage.

3. Burn refuse from diseased plants.

4. Do not allow animals to roam over infested fields, for they carry the organisms to non-infested fields.

Celery.

Blight. There are two distinct blights of celery, the early blight and the late blight. Remedial measures for the two are similar.

Early Blight. This blight makes its appearance in the early stages of the plant's growth. The outer leaves are attacked first, the disease is manifested by grayish-green spots, almost circular in outline and with slightly raised borders. Later the spots may coalesce and exhibit an ashen gray color. Finally the entire leaf withers and dies. Spores produced from these spots are readily blown to other plants and set up the disease anew.

Late Blight. In general, this blight resembles the early blight of celery. It may follow early blight in the same field. As compared with the early blight, the spots are less regular in outline and with yellow interiors instead of ashen gray. As in the early blight, the disease begins on the older, outer leaves, passes to the inner leaves, until no salable part is free from the injury. Severe attacks mean worthless celery, since the bunches will not keep in the market or storage. Even slight attacks on the leaves are undesirable and the price is usually cut by market buyers. The disease organism lives over winter on trash of diseased plants. The seeds from diseased fields practically always carry the fungus. Wet weather makes the late blight severe by facilitating spore dissemination.

Control:

1. Disinfect the seed before planting, by first soaking it for ½ hour in warm water, but not in hot water. Then soak for ½ hour in a solution of corrosive sublimate, 1 part to 1,000 parts of water. This solution can usually be purchased from druggists already prepared. Corrosive sublimate is very poisonous.

2. Seed that is two or three years old, if of good germinative power, may best be used for seeding purposes, since the disease organisms on the seed are usually dead after that length of time.

3. Do not set plants from the seed bed that are the least spotted. Burn diseased plants and rubbish from the field in the fall.

CEREALS.

Wheat.

Stinking Smut. This is the most common and most destructive smut of wheat. It is exclusively a disease of the grain. At harvest the contents of the grain are completely replaced by black powdery masses of spores having a disagreeable odor. The affected grains are enclosed by the chaff and appear darker than healthy kernels. On threshing, the smutted berries are broken open and the powdery spores scattered. They lodge on healthy grains where they remain. The spores are sown with the grain and the young wheat plant becomes infected in a very early stage. The smut does much damage, not only in reducing the yield, but badly smutted wheat loses grade on the market and is docked because it cannot be used for milling purposes. Stinking smut affects both fall and spring wheats, but fortunately cannot affect any other cereal.

Control: The smut can best be exterminated by disinfecting the seed, the principle being to kill the spores adhering to the grain without injuring the seed itself. If the seed is badly smutted, it is advisable to run it first through a fanning mill and then treat it.

Solution required: One pound of formalin of guaranteed 40% strength. Mix this with 40 to 45 gallons of water.

Application to grain: Two methods may be used—*steeping method* or *sprinkling method.*

Steeping Method:

1. Secure a wooden barrel or tank of convenient size and put in enough of the above-mentioned solution to allow the immersion of a sack of grain.

2. The solution must completely cover the sack of grain.

3. Lift the sack several times up and down in the solution until the bubbles of air stop coming to the surface.

4. Allow the grain to remain in the solution for exactly 10 minutes, but not for a longer or shorter period.

5. Remove the sack and allow to drain back into the barrel.

6. Set away in wet sacks for 2 hours, or empty in a heap and cover with canvas or wet sacks.

7. At the end of two hours, dry the seed by spreading it out on a clean floor.

8. The solution should be replenished as often as needed. The dipping may be facilitated by using block and tackle to hoist the sacks.

Sprinkle Method: (Fig. 8)

1. Use a clean floor or wagon bed or canvas in the open. A few bushels of grain should be spread a few inches deep upon the floor and sprinkled with the above mentioned formalin solution.

2. Sprinkle the solution over the grain with ordinary garden sprinkling can. Use about one gallon of solution to each bushel of grain. By all means use enough to thoroughly wet the kernels.

3. Then the grain should be well shoveled. A thorough mixing while the solution is being applied will insure contact of the solution with the grain which is necessary to make the treatment

entirely successful. One person can handle the mixer while another thoroughly mixes the grain.

4. Shovel treated grain into pile and cover with canvas or gunny sack that has previously been dipped into formalin solution. Leave covered about six hours, but not more than twelve hours.

5. Spread grain out not more than 2 inches deep and allow to dry.

6. The grain should be put into clean sacks or stored in a clean bin so as to prevent spores from coming in contact with it. In no case should it be returned to the bin from which it was taken unless the bin has been cleaned with formalin solution. Sweeping in the granary before the treated grain has been removed should never be done, since large quantities of smut spores which settle on the floor and walls may find their way back again to the grain.

FIG. 8.—The sprinkle method of treating grain for smut: One man sprinkles the grain with the formalin solution, while the other thoroughly mixes the grain and solution by shovelling over and over.

By the use of this sprinkle method, two men can treat large quantities of seed in a short time, and it is preferred for treatment of any considerable amount of grain. Either method is entirely satisfactory and efficient.

Recommendations:

1. All utensils, such as sacks, seeders, etc., if likely to be contaminated, should be cleaned with formalin before being used.

2. Grain must not be left covered for more than 12 hours, while 6 hours is desirable; the grain must be dried thoroughly if it is to be stored any length of time.

3. The formalin solution does not lose strength with age, but rather increases in strength; the water evaporates before the gas.

4. Wetted grain should not be exposed to frost, because it injures seriously the germination.

5. The formalin purchased must be of guaranteed 40 per cent. strength. Make the solution according to directions. Thoroughly mix the grain and solution.

6. Grain treated with formalin solution may be fed to stock; the formalin leaves no poisonous substance upon evaporation.

7. Treated grain may be kept indefinitely so long as protected from further contamination.

8. It is urgently recommended that farmers treat enough grain to furnish clean seed for the following year, if they are not in a position to treat seed for the whole of their acreage. When this is done, treated seed should always be sown by itself to give the best results, and no other grain should be mixed with it in harvesting.

Loose Smut. This smut is caused by a fungus distinct from the one just described. It is not present in large amounts in Colorado wheat. It is earlier than stinking smut and differs in the total disappearance of the smutted berries and chaff. At harvest time only barren stalks of smutted plants remain, the spores having been disseminated before maturity. The spores come in contact with other heads of grain while they are flowering and infection of the seed is the result. From such an infected seed a smutted plant will develop the following year, although from all external evidence of the seed no one could tell that it bears the smut fungus embedded in the seed. Loose smut is therefore carried over within the seed, not on the outside as in the case of stinking smut.

Control: The object of seed treatment is to kill the smut fungus within the grain, but produce no injury to the grain itself. The formalin treatment is of no account here as it does not reach the interior of the grain. A method of cold and hot water treatment may be used to destroy the smut fungus within the seed However, it is advisable, in view of the relatively small amounts of loose smut in Colorado wheats, to purchase seed known to be free from the disease. If this cannot be done, then the use of the hot water method is imperative. This method is as follows:

Hot Water Treatment for Loose Smut of Wheat:

1. Secure a reliable thermometer and large wooden barrel or any kind of metal tank or vat.

2. Use good strong gunny sacks that allow water to pass through to the grain.

3. It is well to have some kind of stove or fireplace to heat the water, as it must be kept at nearly constant temperature.

4. The seed is to be soaked 4 or 5 hours in water at a temperature of 68° F., to 86° F., and then followed by hot water treatment with the temperature at 124° to 125° F., for ten minutes. The temperature should never be below 122° F., or above 129° F.

5. It is well to have two barrels for water of the two temperatures, together with hot and cold water close at hand.

6. Fill grain sack one-half to three-quarters full with grain to be treated and allow plenty of room in each sack for grain to move back and forth. Immerse in barrel with water at 86° F., for four hours; add hot water as needed to maintain this temperature.

7. Into a second barrel pour hot water and bring it to a temperature of 112° F., then remove the grain to this barrel, leaving there 15 or 20 minutes.

8. Meanwhile, prepare a third barrel with water at 129° F Place the grain in this barrel and carefully watch the temperature, as it will become lower a few degrees, but should not be permitted to go below 122° F. It is best if kept at 125° F., but should never be lower than 122° nor higher than 129° F. The former fails to destroy the fungus, while the latter very seriously injures the germination of the grain. Keep in this barrel for 10 minutes.

9. Especial care must be taken to thoroughly dry the grain after treatment; this is one of the greatest drawbacks of the whole treatment. If possible, use sunshine, air currents and shoveling to get it well dried.

Oats.

Loose and Closed Smut. The common smut of oats is loose and is very similar to stinking smut of wheat. It appears at heading time and is conspicuous by the darkened smutted grains and chaff. Smut spores are easily blown away, leaving the oat plant bare. The spores lodge on healthy grains and are carried over winter clinging to the outside of the seed.

Control:

The formalin method described for stinking smut of wheat is to be used for the prevention of oat smuts. Either the steeping or sprinkle method may be used.

Barley.

Closed Smut. At maturity the smut masses are enclosed by a thin covering which gives a dark color to affected heads. Spore masses are broken up in threshing and healthy seed becomes contaminated. As a result, the crop grown from such seed will contain smut unless the seed is sterilized.

Control: Use the formalin sprinkle or steeping methods given under stinking smut of wheat.

Loose Smut. In this the smut masses are not enclosed for any length of time by the scales or chaff. Soon after heading the smutted stalks become bare, owing to the disappearance of all smutted parts. It appears earlier than the closed smut and differs further in that the grain becomes diseased in the field, the smut fungus entering the germ of the grain exactly as in the case of loose smut of wheat.

Control: Follow the same method given for the control of loose smut of wheat.

Corn.

Corn Smut. The appearance of corn smut is so well known that the description here is unnecessary. Seed treatment cannot control this disease in corn, because the seed does not carry the fungus. Corn smut is mentioned here because of a somewhat prevailing opinion that smut can be exterminated from this crop by means of seed disinfection. Infection of the corn plant comes originally from the soil, from smut boils that live over winter.

Control: Instead of seed disinfection, the most profitable and practical control is to change the crop for two or three years. On a small scale the smutted parts may be removed from the field and burned, although this is not practical in fields badly smutted.

Millet.

Millet Smuts. The foxtail and grain millets are attacked by two smuts which recently have become important in different sections of the United States. Smut in the foxtail varieties is recognized in the field by early yellowing of the heads which at harvest appear darker than healthy heads. In the grain millets, such as red hog or proso varieties, the smutted head is enclosed by a whitish membrane forming a smut boil. Spores of the disease are spread to healthy grain in threshing and these produce infection of the millet seedling in a very early state of its growth.

Control: Use formalin solution made of one pound of formalin, 40 per cent. strength to 40 gallons of water. The sprinkle method may be used as recommended for wheat or the grain may be immersed in this solution for one hour. The grain should be thoroughly dried.

Flax.

Wilt. The cause of flax wilt is a fungus which grows on the inside of the plant. It is found that the roots of diseased plants are chiefly affected. Flax wilt may live over in the soil from year to year. Plants of all ages may be attacked, wilting and dying in response to deficient water supply. The disease organism is carried by the seed and it is therefore important to disinfect the seed, particularly as is known to be unhealthy.

Control:

1. Use formalin solution made at the rate of 1 pound of formalin 40 per cent. strength to 40 gallons of water.

2. Use the sprinkle method described under stinking smut of wheat.

3. The solution should be thoroughly mixed with the seed, using about ½ gallon of solution to 1 bushel of seed.

4. Allow the seed to stand 5 or 6 hours covered by a canvas or wet sacks and then dry by stirring it around.

5. Fanning before treatment will remove many light weight affected seeds.

6. Rotate crops on infected soil. It is well to remove or burn diseased flax straw or stubble.

7. Do not use fresh or undecayed manure made from infected flax straw. Well-decayed manure will contain no spores capable of germination.

Rye.

Smut. This disease is known as stalk smut, stem smut and stripe smut. All above ground parts are attacked. The first appearance of the smut is marked by elongated narrow stripes grayish in color. Later the affected tissue appears brownish or black, due to the exposure of the black smut spores from beneath the epidermal layer. The disease is first noticed usually at heading time. At this time the leaves may show rifts or splits lengthwise, and the stems are often misshapened and stunted. The heads are almost always destroyed and often do not develop.

The smut spores are spread in threshing or are blown by wind to healthy grain. Infection may come either from infected seed or from diseased soil.

Control:

1. Two things are essential in controlling this disease—crop rotation and seed treatment. Stakeman and Levine recommend the following method (Bul. 160, Minn. Agr. Exp. Sta.):

2. Use formalin 1 pint to 40 gallons of water for seed treatment.

3. Dip the sack of grain into the solution in such a way as to wet all the grain, lift it out, drain for a moment, dip again and repeat until it is certain all the grain is wet.

4. Then either keep the grain in the sacks or pile it and cover with wet sacks for 4 to 12 hours.

5. It may then be dried and sown.

6. The sprinkle method may also be used if preferred. Use one pint of formalin to 40 gallons of water and follow directions given for stinking smut of wheat.

Timothy.

Leaf Smut. This disease affects mainly the leaves and stems, although the heads are also attacked. Stunting or dwarfing is characteristic of affected plants. The disease appears first in the form of elongated narrow stripes on the leaves and later on the stems. The general appearance of affected plants is quite similar to that of rye smut. The stripes or spots at first are grayish in color, but later are black, owing to the exposure of the black spore masses. Affected leaves become very much torn and shredded, especially those at the top of the plant. No marked discoloration is visable from a distance except in extreme attacks.

Affected plants do not usually produce heads. However, when they do appear they are found to be diseased. In severe attacks all parts of the head are destroyed, even including the bristles. Osner has shown that the timothy smut fungus may pass the winter in three different ways:

1. In the green tissues of the plants.

2. In the embryo of the seed.

3. In bulbs and rootstocks of perennial plants.

The greater percentage of infection, no doubt, occurs at the time the plants are flowing, hence the seed when mature contains the smut fungus in the embryo. In respect to infection, therefore, timothy smut is quite similar to loose smut of wheat and barley.

Control:

1. Hot water treatment of the seed offers the best known control measures.

2. The method recommended under loose smut of wheat may be used for timothy, except for modifications as follows:

3. Soak the seed in cold water 6 to 8 hours. Then transfer it to water at about 118° to 120° F., and leave for one minute. From this transfer the grain to water at 125° F., and keep it there for 10 minutes. The temperature should not be allowed to exceed 126° F., or serious injury may result to the germination power of the seed.

4. Keep down all wild grasses adjacent to the field which became smutted. Timothy smut occurs on red top, orchard grass, Kentucky blue grass and many others.

Tomato.

Tomato Wilt, Blight. Affected plants show a gradual wilting beginning with the lower leaves. Wilting is usually accompanied by a yellowing and a dying of the lower leaves. The water-conducting vessels become blackened, as can be seen by cutting through the stem or leaf stalks. The disease may progress slowly or within a week the whole plant may die, depending upon weather conditions and severity of the attack. Frequently the fruit of affected plants remains attached, but ripens earlier than normal. The disease organism once introduced into the field will remain in the soil for several years. The most common way of spreading the disease is probably by means of plants taken from diseased seed beds. Young plants are usually attacked, but the effects are not noticeable until maturity.

Control:

1. Plant clean seed in new soil if at all possible.

2. Rotate the crops so that tomatoes will not be planted in the same field more often than once in 3 years.

3. Remove and burn affected plants as soon as they appear in the field.

4. Disinfect the seed by soaking in corrosive sublimate 1 part to 1,000 parts of water for 3 minutes.

5. As soon as seed is treated, it should be washed in water and then dried.

6. Seed treatment may not be necessary if conditions of sanitation are carefully regarded and uninfected seed is used.

IV. THE COLORADO PURE SEED LAW.

The Twenty-first General Assembly of Colorado passed an act "to regulate the sale, the offering or exposing for sale, and the importing of field and garden seed; to provide for the testing of such seeds; to make an appropriation for carrying out the provisions of this act; to provide a penalty for its violation, and to repeal all acts or parts of acts in conflict with this act."

In passing this measure, Colorado has taken a step forward looking toward the improvement of its agriculture. The Colorado Seed Act aims to prevent the introduction and spread of noxious weeds; to protect the farmer from unknowingly purchasing seed which runs high in noxious weed seeds and adulterants, or low in percentage of germination; and to protect the careful and conscientious seedsman against the carelessness or wilful designs of the unscrupulous seedsman. The act does not require a farmer to purchase seed of any particular quality. He is at liberty to buy low-priced, inferior seed, if he wants to. But now, that all agricultural seed must be labeled, the farmer may know what he is buying. The effect of the Seed Act will be the more general use, in Colorado, of seed of high purity and high germination. Nothing but the best of seed will be shipped into the State. No reliable retail or wholesale merchant or other seller of seed will offer for sale seed that is not up to standard. Farmers generally will become more and more particular about the seed they purchase. As a result, our fields will be freer of noxious weeds, our crop stands more uniform, and yields increased.

QUESTIONS AND ANSWERS RELATING TO SEED LAW.

1. **When did the Act become effective?** The Act was approved April 10, 1917, and the labeling requirements under it took effect October 1, 1917.

2. **What are "field seeds" as used in the Act?** Field seeds are defined as the seeds used by farmers, and which include the seeds of red clover, sweet clover, white clover, alsike clover, alfalfa, Kentucky blue grass, Canada blue rass, timothy, brome grass, orchard grass, red top, meadow fescue, oat grass, rye grass and other grasses and forage plants, corn, flax, rape, wheat, oats, barley, rye, buckwheat and other cereals, field peas, grain sorghums and forage sorghums.

3. **What is the main feature of the Law?** It requires the labeling of all field seeds sold or offered or exposed for sale within this State for seeding purposes in this State, either in bulk, packages or other containers of five pounds or more. The Law is primarily a labeling law.

4. **Where shall the labels be placed?** The main intent of the Act is to place the label in such a position that the purchaser of the seed may readily see that label. If it is a sack of seed, on the outside of the sack; if a bin, small or large, on the outside of the bin.

5. **Is any particular form of label or tag required?** No.

6. **In what language shall the label be?** English language.

7. **Must the statements on labels be written or printed?** Either written or printed.

8. **What shall the label contain?** The label shall contain (1) the commonly accepted name of the field seeds; (2) the name and full address of the person selling or offering for sale such seeds; (3) the approximate percentage of purity, which shall be within 2%; (4) the name and approximate number per pound of each kind of seed designated as noxious weed seed which is present in excess of 90 seeds to a pound; (5) the percentage of germination, which shall be within 10%; (6) the date when such germination test was made; (7) the state or foreign country where the seed was grown and, if in Colorado, the locality, or plainly marked "unknown."

9. **Must the label give both the name of the kind of seed and the variety of seed? For example, can wheat be sold under the label "Wheat" without giving the variety name, such as Marquis, Defiance, etc.?** Seeds may be labelled as to kind only; that is, wheat may be sold under the name

"Wheat" without designating the particular variety, if the purchaser is willing to buy wheat under such label. However, it will usually be the case that a purchaser of seed will want to know the variety as well as the kind. If seed is labeled as to variety, that variety name must be the correct one. If the variety is requested and is unknown, the label should have the statement, "variety unknown."

We are suggesting the following as a suitable form of label to use:

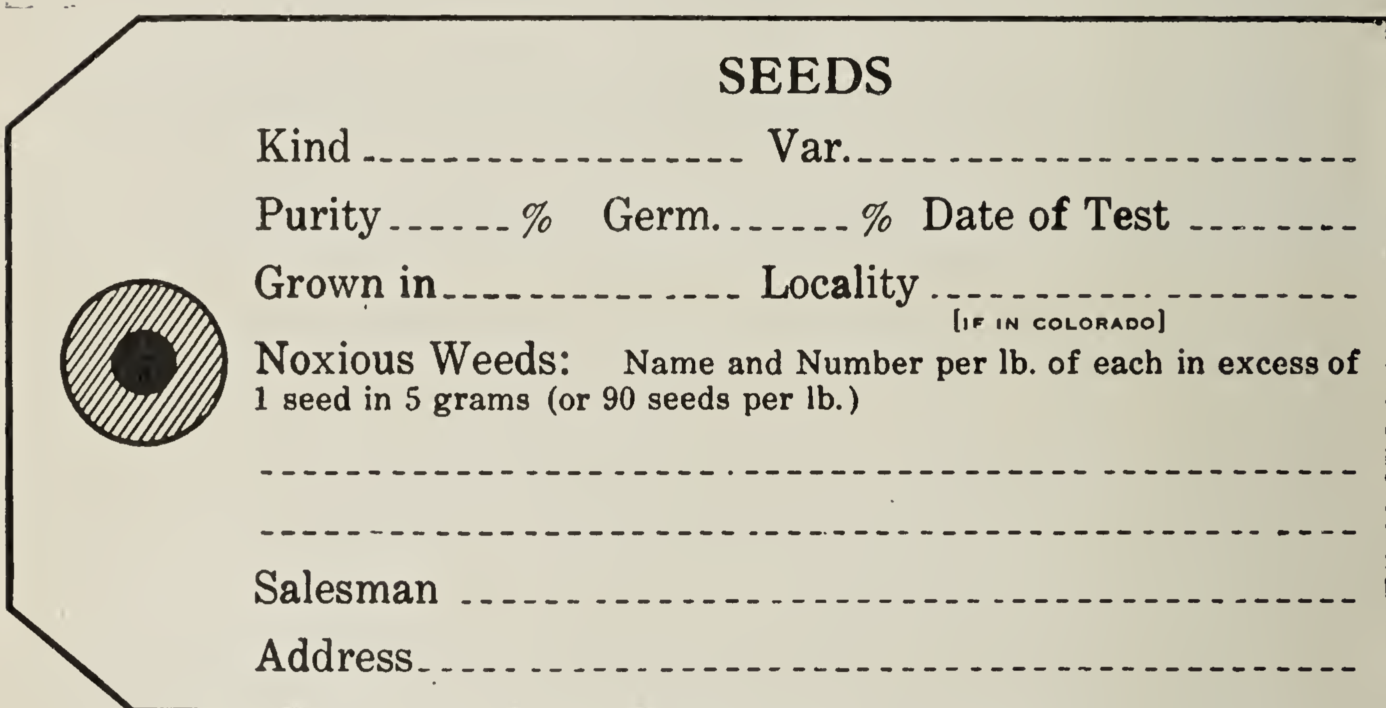

FIG. 9.—A form of label recommended. The label may be of any shape, but the material on this label is that prescribed by The Colorado Seed Act. Tags or labels may be made at home or purchased.

10. **Can a seedsman sell mixed seed?** He can, if he labels it "seed mixture."

11. **Can an elevator sell seed wheat from a bin containing two or more varieties from a number of different farmers?** It can, providing it labels such bin of seed wheat, "seed mixture," or "variety mixture," and also gives the other requirements of the label. Of course, if a bin of seed, even though from a number of farmers, is of the same variety, the variety name may be given.

12. **What is meant by "percentage of purity?"** The freedom of seed from foreign matter or from other seeds distinguishable by their appearance, expressed in percentage.

13. **Must the percentage of purity of seeds be exactly that indicated on the labels?** The percentage of purity as indicated on the label must be within 2% by weight.

14. **What weeds are designated an noxious in the Law?** Any variety of wild mustards, any variety of clover and alfalfa dodder, wild oats, any variety of the plantain, bindweed, or wild morning glory, any variety of the poverty weed, crab grass, cheat, Canada thistle, cockle, sow thistle, wild barley or squirrel tail grass, and hop clover.

15. **Does the Seed Act require that a seedsman must sell seed of any particular quality?** No. A seedsman may sell seed of any quality, good or

bad, providing he labels that seed correctly. The label must be accessible to every purchaser of seed and the purchaser of seed, knowing what the seed is from the label, buys on his own responsibility.

16. **Is one required to buy seed of any particular quality?** No. One may buy seed of any quality desired. He may buy poor seed or good seed. He may pay a low price or a high price.

17. **May a sample containing noxious weed seed in any quantity, no matter how large, be offered for sale?** Yes, providing the label states the fact.

18. **May a sample with a low germination test be offered for sale?** Yes, providing the label states the fact.

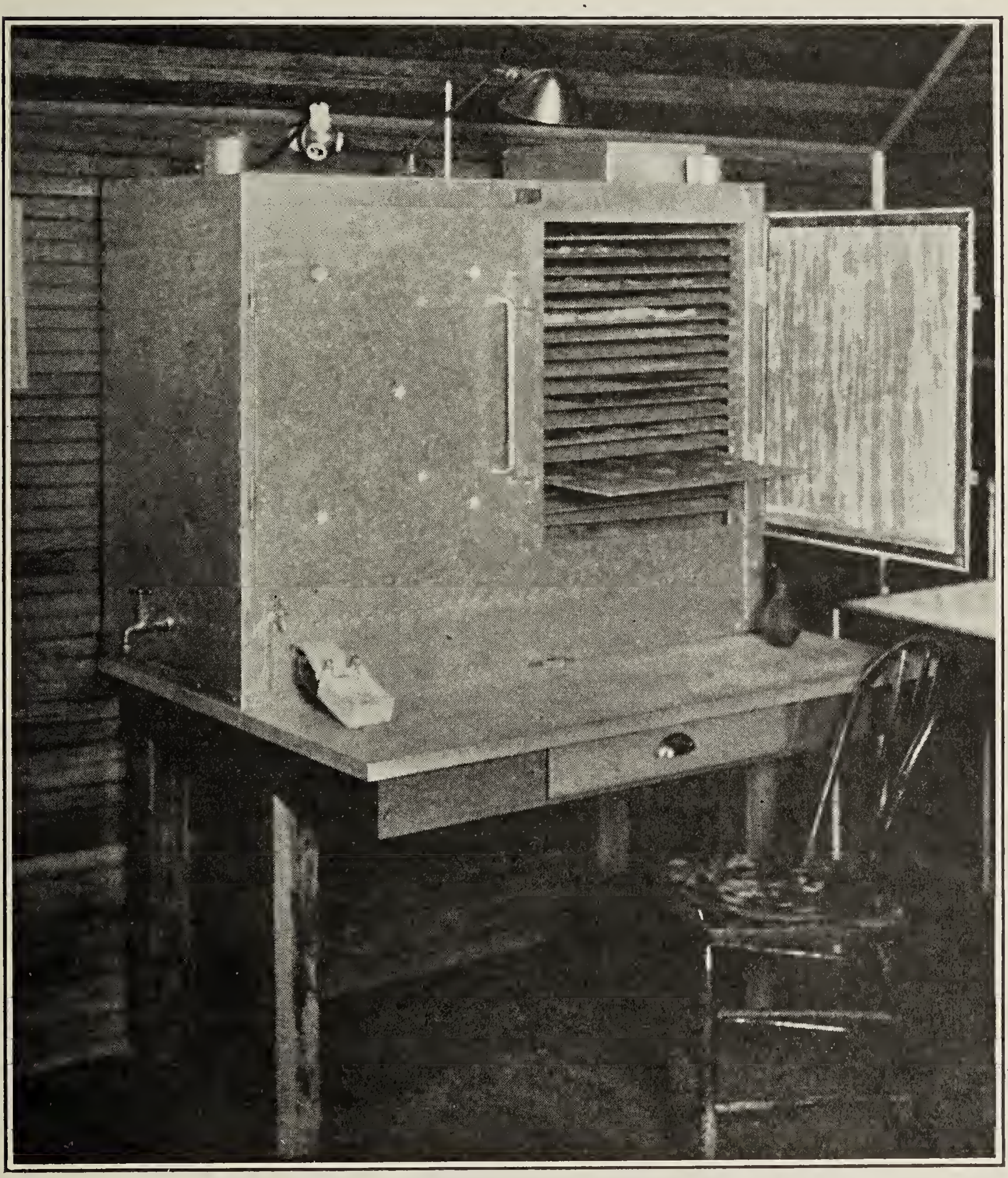

Fig. 10.—A corner of The Colorado Seed Laboratory showing the electrically heated and controlled seed germinator, with a capacity of about 500 samples.

19. **Does the Colorado Pure Seed Law set any standard of purity or of germination?** No.

20. **If a shipment of seeds from the wholesale dealer or farmer is divided by the retailer into separate packages or lots of five pounds or more and offered or exposed for sale, is it necessary to label each separate package or lot?** It is. In such case the information on the wholesaler's label or farmer's label may be used or a sample of seed may be sent to the Seed Laboratory where a test will be made and reported upon free of charge. If the wholesaler's label or the farmer's label is used on these smaller lots, the retailer assumes the responsibility for the correctness of the same.

22. **Can an elevator sell so-called "commercial wheat" for seeding purposes?** Yes. Such seed, of course, must be labeled according to the provisions of the Act.

23. **Where may seed be sent for test?** Any citizen of this State or person shipping seed into Colorado for seeding purposes in the State has the privilege of submitting to the Colorado Seed Laboratory samples of field or garden seeds for tests and analyses, subject to such rules and regulations as may be adopted by said Laboratory.

24. **May a seedsman or any other seller of seed test his own seed and use such data on the label?** Yes, but he must stand back of his tests and, if they are not correct within the limits prescribed by law, he is subject to prosecution. His tests are subject to retests by the Colorado Seed Laboratory.

25. **What charges are made for tests and analyses of seeds by the Seed Laboratory?** The Seed Laboratory has ruled that tests and analyses will be made free of charge until further notice. However, it probably cannot make more than 25 purity tests and 50 germination tests a month for any one person or firm.

26. **What are the directions for sending samples to the Laboratory for tests?** Place name and address of sender on each package, give commonly accepted name of seed, variety if known; if seed is home-grown, so state, indicating the season harvested; if the seed was purchased, give the name of person or firm from whom purchased; state whether a purity or germination test is wanted, or both; if both are requested, indicate whether or not a purity report is desired before the germination report. Unless otherwise directed, both purity and germination tests will be made and both reported at the same time. All transportation charges on seeds sent to the Laboratory must be prepaid. Address all samples and correspondence to The Colorado Seed Laboratory, Fort Collins, Colorado.

27. **What sized sample should be sent for test and analysis?** The minimum weight of seed forwarded for test should be: (a) one ounce of grass seed of any kind, or of white and alsike clovers; (b) two ounces of red and crimson clover, alfalfa, millet, flax, or seed of like size; (c) one-half pound of wheat, oats and other cereals, or seed of like size.

28. **What information will the Seed Laboratory give on the reports issued?** Two reports will be issued for each sample, a purity report and a

germination report. The purity report will give the percentage of pure seed, the percentage of noxious weed seeds, the percentage of other seeds distinguishable by their appearance and the percentage of inert matter. It will also give the number per pound of each kind of noxious weed seeds, indicate the presence of other seeds and give the character of the inert matter. The germination report represents the average of duplicate tests. It gives the germination of the seed at the end of a short period of time and also the final germination, and, in the case of leguminous seeds, the percentage of hard seeds.

29. **How shall dealers and others use the information on these reports?** This information must not be used for advertising purposes. The reports are upon the samples submitted and are no guarantee that the information in them is representative of the whole lot of seed from which the sample is taken, unless such sample has been taken in regular form by the seed inspector. The one who receives a report may copy the data from the reports issued from the Laboratory on to a label. If he does this he is guaranteeing that his sample is representative of the lot from which it was taken.

30. **How snall seeds mixed for special purposes, such as lawn mixture and pasture mixture, be labeled?** Mixtures of field seeds prepared for special purposes must be so labeled. They must be labeled "seed mixture" or "lawn grass mixture" or "pasture mixture," etc. In addition, the label of each seed lot must contain the name and address of the person selling or offering for sale such seed; also the percentage of purity, the percentage of germination and the name and approximate number per pound of the noxious weed seeds and the foreign country in which the seed was grown and, if in Colorado, the locality, or plainly marked "unknown."

31. **Does the law provide for seed inspection?** Yes, the Colorado Agricultural Experiment Station at Fort Collins, through its regularly appointed agent, The Colorado Seed Laboratory, will inspect, "examine and make analyses of and test seeds sold, offered or exposed for sale in the State at such time and places and at such expense as it may deem necessary. The inspector will have free access at all reasonable hours upon any premises to make examination of any seed, whether such seeds are upon the premises of the owner of such seeds or on other premises or in the possession of any warehouse, elevator or railway company, and upon entering payment therefor at the current price may take any sample or samples of such seed." Samples will be taken according to rules recommended by the Association of Official Seed Analysts of North America. These methods insure a fair and representative sample. Duplicate samples are taken. One is left with the owner of the seed, the other taken by the inspector for analysis. Both samples are sealed. The owner of the seed is at liberty to accompany the inspector when the sampling is done and the samples are sealed. Samples are drawn so that they will represent as accurately as possible the bulk lot from which they were taken. Failure to secure representative samples is one of the most common causes of variation in tests of seed.

32. **What methods of sampling are advised?** Samples from sacks or bags should be made up of portions taken from near the top, middle and bottom, approximately one-third from each level. If there are a number of

sacks of the same lot of seed, samples from different sacks should be taken. Samples should be drawn from each bag when there are not more than five bags; but never from less than five bags. These samples may be kept separate and given a designation mark, such as a, b, c, or may be combined into one sample.

Seed "triers" or "samplers" (Fig. 1) may be purchased, enabling one to sample seed without opening the sack. Loose seeds in boxes, barrels, bins, or other receptacles may be sampled by taking approximately equal parts from three different places, and mixing.

33. **Suppose the seedsman finds it necessary to replenish his stock during the seeding season and has not the time to wait for a germination test, must he use the regular label?** Seed sold or exposed for sale during the then seeding season from such an emergency shipment will be exempt from the requirements to label as to germination when labeled "emergency." Moreover, The Colorado Seed Laboratory must be notified of the date when such shipment was received and furnished with a copy of the bill of lading.

34. **How shall seed be labeled that passes directly from farmer or grower to seed merchant?** The regular label does not need to be used in this case, but it must be labeled, giving the commonly accepted name and the state or foreign country where the seed was grown and, if in Colorado, the locality, or plainly marked "unknown."

35. **Is it necessary to label field seed being shipped or hauled to a general market to be cleaned or graded before being offered for sale?** No.

36. **Must field seed being held in storage be labeled?** No.

37. **Can the regular label be dispensed with if it is labeled "not clean seed?"** Yes, if held for sale outside of the State only.

38. **Can the regular label be dispensed with if seed is labeled "not tested seed?"** Yes, if held for sale outside of the State only.

39. **Does the Law control the importation of uulabeled seed?** It does. "No seed in quantities of five pounds or more shall be shipped or brought into Colorado from outside the State by any person to be used by himself for seeding purposes unless such seed shall have been tested and the containers of such seed shall have affixed thereto in a conspicuous place on the exterior of the container of such field seeds a plainly written tag or label giving the information and tests required by the regular label and bear an official certificate of inspection for purity and viability issued by the state from which shipment is made or by the Colorado Agricultural Experiment Station or by U. S. officers or board. In case such importer shall receive such seed and it has not been tested or tagged or labeled as required by this Act, the importer of such seed shall immediately notify The Colorado Seed Laboratory and send the Director of this Laboratory a fair and proper sample of the imported seed for inspection and shall hold such seed until the test required by this Act shall have been made."

40. **Is it unlawful for any transportation company to import field seed that is not tested and labeled?** Yes, "it shall be unlawful for any transportation company to bring into the State of Colorado, except as hereinafter

provided, any field seed as defined in this Act for seeding purposes, unless such seed has been tested as to purity, which test shall be established by the official certificate issued by the state from which such shipment is made or by the Colorado Agricultural Experiment Station or by United States officers or board, and a duplicate of such certificate shall be attached to the bill of lading, and unless the containers of such seed are labeled or tagged, giving the information as required on the regular label. Where such certificate has not been obtained or where the containers of such shipments have not been labeled or tagged, the transportation company may bring the seed into the State, but shall notify The Colorado Seed Laboratory and shall hold such seed for inspection, such inspection to be made at the expense of the owner of the seed."

41. **What constitutes a misdemeanor under the Act?** "Whoever sells, offers or exposes for sale within the State any field seed as defined above without complying with the requirements of labeling, or whoever shall prevent the representatives of the Colorado Agricultural Experiment Station from inspecting said seed and collecing samples, or any transportation company or person who shall ship or bring field seed into this State without complying with the requirements above shall be guilty of a misdemeanor."

FIG. 11.—Making purity analyses in The Colorado Seed Laboratory. Samples submitted by you for analysis are given the most painstaking attention, and care is taken to give you accurate information as to the percentage of pure seed, the percentage of noxious weed seeds, the percentage of other seeds, the percentage of inert matter, and to identify and designate on the report to you each kind of weed seed found in your sample.

42. **What is the penalty for one guilty of a misdemeanor?** Upon conviction, one found guilty of a misdemeanor shall be fined not more than $100.

43. **How are prosecutions instituted?** When the Colorado Agricultural Experiment Station, through its regularly appointed agent, The Colorado Seed Laboratory, "believes or has reason to believe that any person has violated any of the provisions of this Act, it shall cause notice of such fact, together with full specifications of the Act or omission constituting the violation, to be given to such person, who, either in person or by agent or attorney, shall have the right under reasonable rules and regulations as may be prescribed by The Colorado Seed Laboratory to appear before the Laboratory and introduce evidence. If, after such said hearing or without hearing, in case said person fails or refuses to appear, said Colorado Seed Laboratory shall decide or decree that any or all of said specifications have been proven to its satisfaction it may, in its discretion, so certify to the proper prosecuting attorney and request him to prosecute said person according to law for the violation of this Act, transmitting with said certificate a copy of the specifications and such other evidence as it shall deem necessary and proper. Whereupon said prosecuting attorney shall prosecute such person according to law."

44. **Who may submit samples for tests and analyses?** The Act provides that any citizens of Colorado or any persons shipping seed into Colorado for seeding purposes in the State may send samples to the Seed Laboratory of the Agricultural Experiment Station for test and analysis, subject to such rules and regulations as may be adopted by the Seed Laboratory.

45. **What publications will be issued by The Colorado Seed Laboratory?** It "shall make an annual report to the State Board of Agriculture, a copy of which shall be transmitted to the Governor of the State of Colorado, upon the work done under this Act, which report shall show the results of inspection, examination, analyses or tests of field seeds, together with dates of said inspection, examination, analyses or tests, and may include names of persons, firms or corporations having had seed under such inspection, examination, analysis or test."

46. **What other publications may be issued at the discretion of the Seed Laboratory?** It may "publish bulletins or press reports setting forth results of inspections, examinations, analyses and tests, which bulletins or reports may include the names of the persons, firms or corporations having had seeds under inspection, examination, analyses or tests. It may also at its discretion publish bulletins or press reports setting forth information on field seeds, which bulletins may be distributed free to the citizens of this State."

47. **What appropriations have been provided for equipment?** The General Assembly appropriated from the State Treasury $1,500 for the equipment of a seed testing laboratory at the Colorado Agricultural Experiment Station.

48. **What appropriations are made for carrying out the provisions of this Act?** There is an annual appropriation of $4,000, beginning with the fiscal year 1917, for carrying out the provisions of this Act.

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The Agricultural Experiment Station
OF THE
Colorado Agricultural College

ALKALIS IN COLORADO
(INCLUDING NITRATES)

By W. P. HEADDEN

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Colorado Agricultural College

FORT COLLINS, COLORADO

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ALKALIS IN COLORADO

(Including Nitrates)

By W. P. HEADDEN

One of the things often spoken of as characteristic of the western plains is the occurrence of alkali. I think that this used to find more frequent mention than it does now. This is perhaps easily explicable in that travelers do not now have to depend upon surface waters for drinking purposes, nor plod their way slowly through an unfamiliar country subjected to all the inconveniences of the early day travel. On the contrary, the stranger now enjoys all the comforts of modern travel, mostly through succeeding reaches of well settled and cultivated country. For all of this the question of alkali is often presented to the agriculturist as one of serious import and still unsettled.

I recall an incident that happened some years ago which illustrates how striking the appearance of our alkali-covered areas may be to those unaccustomed to them. The Colorado and Southern train was approaching the town of Loveland and such an area suddenly came into view. One of the children in an eastern family that had never been west before cried out, "Oh papa! See the snow!" This was in spite of a prevailing high temperature and of the fact that we had passed field after field of grain ready for harvest or already in shock. The impression may be largely one of surprise but the reasoning is that a thing so unusual as this must be injurious. This in the past has been not only the reasoning of the individual, but it very generally has been declared to be a fact that alkalis are injurious.

This opinion is in both the public mind and in the scientific views on this subject. I have in the outset no thesis to prove. When I began the study of the subject I participated in the prevailing public opinion on the injurious nature of these salts.

ALKALI GENERAL IN COLORADO SOILS

The occurrence of alkali in Colorado soils is practically universal The differences in the amounts in different places may be considerable, but generally it is a question of visibility and absolute quantity and not of its presence. There are not many places where one can collect samples of soil that can be truthfully said to be free from alkali and in saying this I do not mean to use any fine distinction in regard to the amount of soluble salts remaining from those formed by the decomposition of the minerals forming the big mass of the soil. I do not even have in mind any minimum amount of soluble salts that must be present before we shall consider the soil as carrying alkalis. In the case of most of our soils the alkali will show if a sample of wet soil be allowed to dry slowly, when perhaps the whole surface, or possibly certain prominences, will become white. This is a sufficient amount to justify one in considering the soil as carrying alkali. It is evident that this applies to "white alkali" alone; "black alkali" will betray its presence in other ways, the principal of which is the tendency of the soil to become very hard and to turn black where any drops of water may ooze out of it.

The salts present in these alkalis are the sulfate of soda, (Glauber's salt), the sulfate of lime (gypsum), and sulfate of magnesia (Epsom salts), sodic chlorid (common kitchen salt), sodic carbonate (ordinary washing soda), and possibly, also, sodic bicarbonate (baking soda). Sometimes we have still other salts, calcic, magnesic, and sodic nitrates, also calcic chlorid, etc. In some alkalis we find small amounts of potassic salts and phosphoric acid. These, together with substances that occur rarely or always in small quantities, we may neglect.

The origin of the sulfates, chlorids and carbonates can be traced directly to the minerals in the soil. So far as the sulfates are concerned we have an abundant supply of them in the minerals themselves. For instance, felspar contains sulfuric acid, chlorin and phosphoric acid enough to supply a very great quantity of sulfates in the form of gypsum or of sodic sulfate. We do not need this source for we have a great supply of sulfate in the gypsum which is very common in Colorado, and which is very often present in the marl or hard pan that has formed in nearly all of our lands. In some places the sulfid of iron, marcasite, and pyrites may form by their oxidation sulfuric acid and sulfates which eventually give rise to the sulfates of soda, lime or magnesia.

SULFATES AND CHLORIDS CONSIDERED "WHITE ALKALI", SODIC CARBONATE "BLACK ALKALI"

Of these salts usually found in the alkalis the sulfates with the chlorids are considered as "white alkali". The salts are themselves white and the water in and on the land where they occur is only slightly if at all colored. Sodic carbonate is called "black alkali", not because the salt is black, for washing soda and baking soda are white salts, but the solutions of washing soda in the soil where there is a lot of half decomposed plant or vegetable matter dissolves this half decomposed stuff to a black solution. This salt, or its solution is, moreover, so caustic that, if it be kept, especially strong solutions of it, in contact with the stems of plants, it will eat them, that is, destroy their tissues and kill them. The vegetable matter and the solution of the salts at the same time becoming black. In this way it has come to be called "black alkali".

TERM "ALKALI" USED IN COLLOQUIAL SENSE

The term "alkali" is used in its colloquial senes whenever reference is made to such a mixture of salts as has been described. The sulfates of lime and magnesia are not alkalis in a proper sense and it is a question, how far we should consider calcic sulfate an alkali, even in this colloquial sense. The reasons why we consider its use doubtful are: First, it is in no case injurious to general crops, on the contrary it is often applied to land as a manure, something to do the land good. Second, it constitutes such a large percentage of a few soils which are often quite productive that we are justified in neglecting it among the alkalis which we consider accidental soil constituents peculiar to semi-arid regions, remaining in the soil because there has not been a sufficient rainfall to wash them into the rivers. The sulfate of lime, however, that fairly forms a zone along the eastern flank of the Rocky Mountains has not so simple a history and could not readily be removed by any conceivable rainfall. On the other hand, this salt actually forms a part of the mass of efflorescent salts to which the popular name "alkali" is applied and makes up a large percentage of these salts, sometimes almost the whole of the efflorescence. We cannot well reject such efflorescences from the group of our popularly designated alkalis. This difficulty does not attach itself to the sulfate of magnesia though, chemically, it has a close family relation to the calcic sulfate.

These salts, singly and in sufficient quantities, are injurious to vegetation. Many apple orchards in Colorado have unwisely been planted on land under-laid by gypsum (often shortened to gyp.), at shallow depths. Such orchards grow for a few years and then turn yellow, because unthrifty, and perhaps die. This is an experience altogether too common in Colorado. The yellow, unthrifty condition of such orchards, and in some cases the death of the trees, is attributed to the action of the gypsum. If this view be correct, then the calcic sulfate should be included among the injurious salts. Though this view seems well sustained by observable facts it is not so simple, for the gypsum, which is of frequent occurrence almost as a hard-pan quite near the surface in many sections, is not pure gypsum. I have found much of it quite rich in arsenic, which may in part or even wholly account for the unhealthiness of the trees.

It has been often observed that apple trees planted on gypsum lands bleed from wounds, especially during the second year after trimming. This bleeding causes the deposition of a light brown deposit, often forming pendant masses several inches long. These deposits are rich in lime and arsenic. This bleeding, with its resultant deposits is abnormal and such quantities of lime and the arsenic are not proper constituents of the sap of the apple tree. It looks as though the gypsum, with its arsenic, were the source of this trouble. This does not make out so strong a case against lime as it appears to, for trees do well and live to an old age in limestone countries; so this effect is either peculiar to gypsum or to the arsenic which is frequently present in it.

There are difficulties introduced by retaining the calcic sulfate as a component of our alkalis, but I have consistently retained it, and that for the reasons indicated. It is seldom, however, outside of cases like the apple trees that questions of the possibly poisonous character of the calcic sulfate are raised. Sometimes shallowness of soil over a gypsiferous layer, or the impermeability of this layer may give rise to mechanical troubles which are entirely distinct from the effects alluded to above, which may also be present at the same time. I recall a very bad case of an orchard in which this was the case and both difficulties had to be contended with. But I would in no way consider myself justified in considering the case as an instance of alkali trouble.

The question regarding magnesic sulfate is not wholly unlike that of the calcic sulfate but is somewhat turned around. Experiments have shown that magnesic sulfate is quite poisonous but its presence in alkali in the soil does not actually prove so detrimental as our experiments would lead us to expect it to be. I have only made sprouting experiments in sand to which this salt had been added in as large quantities (2.5 percent of the dry sand) as we are likely to meet with in any of our soils. The germination was delayed but not prevented and the little plants grew well for the few days that we observed them. I do not think that anyone has questioned the propriety of including magnesic sulfate among the alkalis.

ORIGIN OF THE ALKALIS

There is unanimity in regard to the origin of the alkalis; briefly stated it is explained as follows: The earthy mass that we term soil is, from a mineralogical standpoint, a mass of small rock fragment in which a very large variety of minerals are represented. Among these minerals two greatly predominate, quartz and felspars. The quartz is so good as wholly unattacked by water. It is a simple chemical compound, and if it were dissolved by water it would not give rise to the kind of new bodies that we find in the alkalis. The felspar are comparatively complex minerals and water acts on them quite vigorously breaking them up and forming new compounds. For the present purposes we may consider the plagioclase felspars only; these consist of alumina, lime, soda and silica, and are very abundant in our rocks. These felspars yield readily to the action of the natural waters, all of which contain greater or less quantities of carbonic acid taken up from both air and soil, and yield sodic carbonate, calcic carbonate, soluble silicates and free silicic acid, and leave as the end product, a hydrated silicate of alumina. This is insoluble in water while the other products are soluble. This presents the main features of this alteration process. If there be only a moderate amount of water, the decomposition may go on and the products formed remain in the soil or be only partially removed. This is the case in our semi-arid areas. These products of the alteration of the rocks remain in the soil or are removed only a little way from where they were formed only to be left, by the evaporation of the water, in some other nearby place, where they become so abundant as to form white incrustations. While this is true, it is very far from presenting all that we know about these changes, in fact, we are compelled to go further in the explanation of the facts as we find them. According to what we have said, these incrustations should be composed of sodic carbonate, calcic carbonate, some silicates and silicic acid. It is only occasionally that we find these deposits to be made up of carbonate; as a rule, we find them to be sulfates, and while the sulfates of soda and lime make up by far the larger part of our alkalis, the sulfate of magnesia and sodic chlorid are so good as always present in varying quantities. That some carbonate should be present would seem to be inevitable, for the solutions furnished by the decomposition of the felspars are in the first place carbonates and the changes that are made in these solutions may not always be quite complete; besides, the felspars are actually everywhere in our rocks and soils and are all the time being acted on by carbonated water. The calcic and sodic carbonates are partially or wholly changed into sulfates. These salts contain a different acid from the carbonates, which got their acid from the water which effected the decomposition of the minerals. The gypsum in the soil is the agent that most commonly brings about this change. We have also added magnesia to the list.

If we take fresh felspar, grind it up very finely, treat it with water containing carbonic acid, say for three weeks, and examine this water, we will not only find that it contains the carbonates of lime and soda with some silica, but also both sulfates and chlorids, not so much as carbonates, but enough to show that these minerals themselves contain some sulfates and chlorids. If every rock mass of our mountains contains some chlorids and some sulfates ready formed we need scarcely puzzle ourselves in looking for the source of the chlorids and sulfates that we find so generally distributed. It won't help us any to go further back in the history of these chlorids, for our purposes, it suffices that they are present in the rocks of our mountains and in the waters that flow from them to the plains. The same is true of the sulfates, and why should we look further? Here is a source sufficient to supply as much chlorin, for instance, as we may be called on to account for. If we need more sulfuric acid, there is a source near at hand. Concerning this easily available sulfur we need ask no questions as to where it came from, it suffices that there are large quantities of sulfides almost everywhere in our shales, especially if they have contained organic matter. The sulfides of iron, known as marcasite and pyrite, yield upon exposure to air, oxids of iron and sulfuric acid which may combine with lime and water to form gypsum or with soda to form sodic sulfate. This, under some conditions, is the easiest explanation for the presence of sodic sulfate in large quantities and it is, at least in part, the correct explanation. The occurrence of gypsum crystals in many of our shales owe their formation, in all probability, to the action of the sulfuric acid formed by the oxidation of these sulfids of iron on lime compounds. There are immense quantities of gypsum along our foothills extending both north and south of us, and under the plains. As to the source of this sulfate of lime, it suffices in this case to acknowledge that it is there in very great quantities.

Our knowledge of the source of the magnesium sulfate is not so clear. Lime is very frequently accompanied by magnesia, be it more or less in quantity. The felspars, which furnish lime and soda by their decomposition, also furnish a little magnesia and other minerals present in the rocks, also in the soil, contain magnesia, so there is no need of looking very far to find a source of this substance. Some of our limestones are strongly magnesian. The sulfate of magnesia is very easily soluble, as is also the chlorid, so we would not expect to meet with these salts in our rocks. These salts do occur in extraordinarily large quantities in Stassfurt and elsewhere in Germany but the magnesian salts that occur in our alkalis have not the history that these Stassfurt salts have. Our salts have probably only started on their course to the ocean, while the Stassfurt salts have run this portion of their course and witnessed the passing of the ocean itself. The magnesian salts that we meet with in our rocks and minerals are silicates and carbonates; in our waters and alkalis they are the sulfates and chlorids. These salts are unquestionably formed in the soils by the interaction of the magnesian minerals and the sulfates and chlorids derived from the felspars through the action of carbonated water. The case of some deep-seated springs in the old metamorphic rocks may be different, but, the ground-water occurring sometimes within two feet of the surface, many of our shallow springs and even artesian waters met within or above the Dakota sandstones will come under the statement made.

In regard to the chlorids in general, I believe that I shall have to avail myself of an explanation that I recall having read somewhere which referred their formation to the primordial chemistry of our globe. The incompetency of this statement to explain anything is its commendation. We find chlorids in the old metamorphic rocks when we look for them, at least we find chlorin, in small amounts it is true, but the mass of our mountains is tremendous and that of the still undecomposed fragments of these rocks and minerals in the soil is beyond our conception. So, without appealing to the sea water and salt deposits occurring in various parts of the world, the aggregate supply of chlorids is not only exceedingly great but their distribution or occurrence is universal, our great bodies of fresh water are not free from them and the beds of our ancient fresh-water lakes contain them. The flow of the waters from the land to the sea is carrying a constantly renewed burden of these salts, especially the sodic and magnesic chlorids and the magnesic sulfate, to the sea. The reason that we have such quantities of sodic sulfate, sodic carbonate, magnesic sulfate, calcic sulfate, and the chlorids in our soils is not that they have produced more of these salts than other soils but because the water supply has not been big enough to carry away the products of its own action. The insufficiency of water is fully indicated in our term "semi-arid climate".

Enormous Quantities Contributed By Rivers

The reader for whom this bulletin is really written possibly has never thought of the different kinds of work, or the amount of it, that the streams of our mountain-sides are doing. He knows that the gaps in our hog-backs of today are places through which streams may flow, sometimes only during heavy rains or continued wet spells. He is familiar with the canyons of perhaps a score of little streams in the mountains. He may sometimes wonder how the deep gashes through the solid rocks may have been cut, but he probably never thinks of the burden of material carried by the clear, cool water that he drinks with great pleasure.

The Cache la Poudre

The Cache la Poudre River, which flows through the mountains of Northern Coloardo, is a comparatively small stream. Its flow averages about 600 second feet. The average fall of the river for the first 50 miles of its course, is 80 feet to the mile. In many places it is a mass of foaming water just as some other mountain streams are. This impresses us with its ability to wear the rocks which are already worn smooth and the rock walls bear witness, by their polished faces, to the action of this process in the past. We do not wonder that the boulders are worn and that the fine sand has in so large a degree been carried away. But that this same limpid water carries an unseen burden and is doing a continued work in changing the very substance of the rocks and carrying them away does not impress itself on the mind of many of us, and yet this little river with an average flow of 600 second feet, whose waters carry approximately 3 grains of total solids to the imperial gallon, is carrying more than 50 tons of matter through its canyon every day. This mass of material, mostly carbonates of lime and soda with small quantities of sodic chlorid and some magnesia, has been dissolved out of the rocks and means the breaking down of hundreds of cubic feet of solid rock every day. Estimated roughly the amount of material mentioned here is about equal to 650 cubic feet of rock which is 2½ times heavier than water. To make still plainer the magnitude of this action of water, we will take another example. We have stated that sodic carbonate constitutes what we call "black alkali", and also that this carbonate is one of the products of the action of water on plagioclase, a felspar, which occurs in schists and granites as well as in igneous rocks. The watershed from which the water drains into some of our mountain valleys is several thousands of square miles in area, and even though the rainfall may be only 15 or 20 inches per annum the water that flows into the valley may be millions of acre-feet. In a concrete example that I have recently had occasion to study, the amount of water removed by evaporation was 1,500,000 acre-feet. This water was supplied by the mountain streams flowing into the valley, and, on the supposition that each 10 pounds of water carried 2½ grains of sodic carbonate, which is about what the water actually carried, the amount of this salt brought into the valley every year amounted to 145,500,000 pounds. This has been going on for many centuries and, if none of it has been washed out of the valley, the amount present at this time must be so great that we can form no adequate notion of it, and such are the facts, so far as we can make them out. These processes by which these alkalis are formed are not peculiar to our soils or our mountains. They are active everywhere but, in regions of heavier rainfall, the salts that remain in our soils and are known to us under the name of "alkalis" are washed out and carried, eventually, to the ocean, possibly not in the form in which they were dissolved out of the rocks, for they may change when they come in contact with other salts.

I have not mentioned these sources of our alkalis as necessarily the immediate source of every patch of them, but in some cases it seems to be true as in the case of the carbonate cited in our last example.

NITRATES FORMED IN THE SOIL AN IMPORTANT FACTOR

There are other salts found in our alkalis which are not always understood as being included under our term "alkalis". I refer to the nitrates and in some instances excessive quantities of calcic chlorid. The nitrates are being formed now just as the other alkali salts are being produced, by the decomposition of the minerals in the soil, but by different agents. Nitrates in very small quantities are often present in well-waters, seldom present in river-waters and are not components of ordinary minerals. They have long been known to be present in small quantities in the surface portions of rocks and have been considered as factors in their weathering or the changes taking place in them. They have also been found in caves, but wherever they have been found they have been considered as the products of living organisms. It is only within recent years that these salts have been noticed in the soil in sufficient quantities to become detrimental. Their presence in some California alkalis was noticed by Hilgard and their origin attributed to the oxidation of the nitrogen found in organic matter. This is without doubt correct, but Prof. Hilgard did not account for the organic matter. I do not recall his making any definite statement concerning the organic matter from which these nitrates are supposed to have been formed. The nearest to a definite statement pertaining to this subject is made on Page 68 of "Soil", where he states: "In the plains of the San Joaquin Valley, spots strongly impregnated with niter are found, especially under the shadows of isolated oak trees, where cattle have been in the habit of congregating for a long time".

The conversion of organic nitrogen, such as exists in the excreta or in the bodies of animals and in the tissues of plants, into nitric acid or nitrates is well established and has been accepted for about 30 years. I think that Prof. Hilgard considers such to be the source of the nitric nitrogen referred to in a preceding sentence, in which he states that the nitrates form at times as much as one-fifth and even more, of the entire mass of alkali salts. "In one case the total amount in the soil has been found to reach two tons per acre with an average of twelve hundred pounds over ten acres". This, though it is a large quantity, is not big compared with the quantities of these salts that we have found in some of our Colorado soils. This is enough to say on this phase of the subject in this place.

The nitrates found may be either the nitrate of lime, of magnesia or of soda. It is a matter of accident, apparently, which one of the three occurs. There is a question whether these belong to the alkalis. I think that they should be included. They constitute an important part of the soluble salts in many of our lands, and more than this, we can trace very serious damage to them. Considered from the standpoint of their source, including them with the alkalis seems scarcely justifiable, on the other hand their presence in very notable quantities, their solubility and their deleterious action on vegetation are in my opinion sufficient reasons for considering them in this connection.

Calcic chlorid is occasionally met with in large quantities and is probably formed by the interaction of other "alkali" salts.

Injure Vegetation If Present In Large Quantities

These salts, included under the general term "alkali" are all injurious to vegetation when present in large enough quantities, which of course, vary for different plants and for the different salts. Our information relative to the amount of these indiivdual salts which may be required to do damage to the crops is not very satisfactory and this is not surprising, as we cannot imitate, or even determine, all of the conditions which may be met with in our fields. I think that it can be safely stated that the most dangerous salts that we have mentioned are the nitrates. I do not know that there is any distinction to be made between the different nitrates that we have mentioned, calcic, magnesic, and sodic nitrates. They are all very soluble and all poisonous when present in large quantities. How they act upon the plant I do not know, but the results that they produce are very marked and they cause the death of the plants very quickly. The plants that I experimented with were 4-year-old apple trees. I know how much nitrate of soda I put on the ground and to how large an area I applied it, but I don't know how strong the solution was that reached the feeding roots nor do I know what proportion of the feeding roots of the trees were reachel. My object in the experiment was to see what the effects of the nitrates were upon apple trees and not to determine the points that have just been mentioned. Further, I don't know how the effects were produced, whether by absorption, the prevention of osmosis, or whether the solution to all intents and purposes simply killed the root hairs. This much I do know, i.e., the leaves burned and the trees died, or were badly injured. One of these trees was dead in four days after the application of the nitrate. It was left standing for two years but it never recovered. I have seen old trees with perfect foliage and a full crop of half-grown fruit burn and die in a few days and I have never seen an instance of recovery in trees injured in this way. Sometimes only a part of a tree may be injured and this injured part dies. I have dug up such trees and followed the roots for as much as 27 feet from the trunk in an endeavor to find how the nitrates killed the tree. I have never been able to determine this. In the four-year-old trees experimented with I was unable to find any nitric-nitrogen in the leaves in more than traces although I had firmly expected to find it. Some plants, heliotropes, from the greenhouse treated with saltpetre were placed at my disposal; in these cases there was no trouble in finding nitrates in the leaves, for the nitrate crystalized out on their surfaces. We are not sure that the two cases are parallel but the important end results were the same—the plants were killed. I am inclined to think that the action of the nitrate in these two cases was different in character. In the case of the apple trees I think that the burning of the leaves was due to drying out caused by the cutting off of the water furnished by the root hairs. This view is further strengthened by the deportment of vigorously growing trees located in ground rich in nitrates. I have seen the foliage wilt and the trees die without tip burning. I took this to be caused by the sudden cutting off of the water supply. The solution in this case contained large amounts of nitrates. May a sufficiently strong solution of other salts possibly act in a similar manner? I tried this with ordinary kitchen salt of which I put 25 pounds around a four-year-old apple tree and threw up a little dike around the area and turned in the ditch water. No injury resulted. This experiment served its purpose very well, but in this connection it only shows that 25 pounds of salt did not furnish a sufficiently strong solution to do any damage.

SODIC CARBONATE ESPECIALLY HARMFUL

The next most injurious compound in these alkalis is sodic carbonate. When this salt is present and is brought into solution it acts like caustic soda or a weak solution of lye. It attacks the tissues of the little plants and sometimes big ones and kills them. Another thing it does is to cause the soil to become hard, so hard indeed that one may be surprised that plants can grow at all. I recall such a crust, from 4 to 6 inches thick, so hard that we used a mattock to cut through it. Under this crust the soil was open, even sandy. The presence of this compound is very general, as we would expect it to be, for it is one of the first products of the breaking down of the felspars which occur in every fragment of granite, schist, or igneous rock and also in many sandstones. It is from such rocks that our soils have been derived, at least in far the greater part, and these felspars occur practically everywhere, so we have good reason to expect more or less of this carbonate everywhere and we find it very generally in drain-water and in our alkalis in small quantity.

The magnesic sulfate and chlorid in pure solutions are more detrimental to vegetation than the carbonate of soda, but they don't occur in the form of pure solutions, nor are they bottled up in separate corners of the soil. Even the soil itself very often has a great deal to do in determining what the compounds will do.

The most abundant constituent of our alkalis is the sulfate of soda, commonly known as Glauber's salt. This salt is fortunately not very injurious, even in pure solutions. It is scarcely corrosive at all, as many ranchmen in Colorado have had ample opportunity to observe, for the white coatings that in many places covers the surface of the land, in some sections for many square miles in one continuous body, consist very largely of this substance.

Sodic chlorid, ordinary kitchen salt, does not occur in any large quantities in our alkalis. The areas in which I have found much salt are both few and small. Large quantities of this salt, or brine, of course will kill most kinds of vegetation. These big quantities which would make it a serious thing for us are not found in our alkalis. I recall one place where it is very abundant in what we would designate alkalis, but to insist on considering this would be foolish, because it is only in a comparatively small area and its source is evidently from a salt spring at the head of the stream along which this salt is found. In early days they boiled salt at this point. While it does not occur in injurious quantities, it occurs everywhere.

Calcic sulfate is very abundant in our soils and, as it is soluble in water, it comes to the surface with the other salts in solution and crystallizes out, forming a part of our alkalis. Sometimes it forms a very large part of them. This compound in very large quantities is dangerous as I have pointed out in the case of apple trees, but ordinarily it can be neglected unless it forms a hard-pan, when it is very objectionable, both because it forms a hard-pan and because it may become injurious.

As I may not come back to this point, I shall digress to state that the most regrettable results that I have seen in this connection are its effects on orchards. The trees may do quite well for eight or ten years, but at about this period several difficulties show themselves. The trees cease to grow and often turn yellow. In such cases it will generally be found that the root system has been prevented from developing and is inadequate to properly nourish the trees and the food that these roots furnish to the growing parts of the trees may be and probably is an improper food, i.e., is poisonous, not necessarily in a virulent degree but so much so that the trees become unthrifty.

Calcic chlorid is not very injurious and does not often occur in our alkalis in any considerable proportion. There are a few places, however, where it may be said to be very abundant. These occurrences have no significance from an agricultural standpoint, for the places where I have found it most abundant would be unproductive if it were absent, due to other conditions. I have no idea at all how much of this substance it would require to make a soil unfriendly to vegetation. I recall an orchard in fairly good condition in which the soil contained enough of this substance to keep the surface wet enough to make it so dark in color that one could easily pick out these spots. I do not know what effect this condition had upon the orchard. At the time I visited it there was no marked difference in the size and vigor of the trees in these spots and in the condition of those growing outside them. As the condition of the whole orchard was only fair and I made no further study of it than the examination of a single set of samples of soil that I took on this visit, I cannot state that this calcic chlorid had done no harm whatever. I only wish to state that the trees in these spots where there was enough of it present to keep the surface so moist that it was actually darker in color than the rest of the surface, were neither better nor worse than the rest of the orchard.

HOW SALTS AFFECT PLANTS

I have tried to make the preceding statements clear, but there are some things that badly need explanation and even then will remain unsatisfactory. A solution may enter the plant and travel through every part of it and kill it. Just how this is done is for the plant physiologist to tell us but we know that, if we allow a solution of sodic arsenite to come in contact with the feeding roots of one side of an apple tree for instance, this sodic arsenite travels very quickly even to the ends of the branches, and wherever it goes, it kills. We can follow this sodic arsenite up the roots, through the trunk of the three and into the individual branches, and we find dead tissues wherever it goes and live tissue wherever it did not go. We can also recover arsenic from this dead tissue. The solution need not be very strong. It enters the tree with the water that the roots take up. A similar solution of sodic chlorid (kitchen salt) would have been taken up too, perhaps. A very much stronger solution was taken up in a case in which I put 25 pounds of salt about a four-year-old tree, but it did not kill the tree. The sodic arsenite is a poison and it kills every living cell that it meets in its course up the roots, trunk and limbs of the tree. This is one way in which a poison may act.

Destroy Root Hairs

We are thinking of a poison as anything that will kill the plant. If we could take all of the little hairs off of the roots of a tree so that it could not get water to keep it fresh and moist it would dry up and die. We can cause it to do this by bringing strong solutions of certain salts into contact with these little hairs, when they will refuse to take up any water. The result is that the sun, the wind and the dry air take the moisture out of the leaves and none can take its place because these hairs on the roots which have been supplying the water to the leaves and limbs have stopped functioning, the leaves burn, and the plants may even die. Salts which will not ordinarily kill the plants, like the sodic arsenite, may be made into solutions strong enough to kill in this way and then you may not find them in the leaves or in the trunks for the root hairs refused to take them up. I do not know how strong a solution of any salt may have to be before it will do this, but I believe that nitrates do act in this way, in many instances, and I think that ordinary alkali salts, may act in this way too. In this case it amounts to killing the root hairs which is worse for the tree than killing the leaves, for if the leaves alone are killed the tree may put out others and go on living, if we don't take off the leaves too often, but if we kill or injure the root hairs so that the tree cannot get either food or water enough its leaves burn, perhaps wilt if the action on the root hairs is sudden enough and it dies. I have seen the leaves burn on very many trees, thousands in this case is no figure of speech, and I have also seen the still green, full-sized leaves just wilt and hang limp. These trees all died. There are difficulties in making the different things that we have learned about these matters agree or consistently apply, but it may be that a nitrate solution of a certain strength may kill the root hair by poisoning just as the sodic arsenite killed the leaves and the living part of the limbs, trunk and root, whereas it did not act on the root hairs in such a way as to prevent its being taken up. If a nitrate solution will act in such a manner as to stop the taking up of water, whether it acts by poisoning or purely in a physical manner, the result is the same.

ONE SALT MAY MODIFY ACTION OF ANOTHER

The different salts act differently, some may under no conditions act as a direct, poison but simply in a physical manner by their osmotic pressure. Further, the presence of one may modify the action of another. Magnesic sulfate, for instance, in pure solutions, has been found to be very poisonous, pretty nearly the most poisonous salt, but this don't seem to hold in the field. Experiment shows that seedling roots can just live in a solution containing 7 parts of magnesic sulfate in 100,000 parts of water, but I found the roots of four-year-old alfalfa plants which were more than 12 feet long and extended 1 foot below the level of the ground-water, which was bitter to the taste and carried 852.5 parts of mineral matter in each 100,000 parts of the water. One-tenth, or 85 parts of this mineral matter was magnesic sulfate. We have in this ground-water twelve times as much of this salt in 100,000 parts as the experiments given showed to be the limit that plants could tolerate and yet these roots were living and the plants were thrifty. This field yielded between 4 and 5 tons of hay per acre the year that this sample of water was taken, and continued to do so for years afterward. This difference between the results of laboratory experiments and the facts of the field is well known and the explanation offered is that pure solutions of these salts act differently from solutions of mixtures. In the case of the ground-water just mentioned carrying twelve times more magnesic sulfate than would be necessary in a solution of this salt alone to limit growth, there were also other salts making up nine-tenths of the whole and the presence of these other salts, sodic sulfate, calcic sulfate, calcic carbonate, magnesic chlorid and carbonate, kept the strong solution of magnesic sulfate from doing any harm. In solutions containing only magnesic sulfate, this salt is the most poisonous of all the compounds that we usually speak of as alkalis. In the field it seems to be harmless in the quantities that are present in our soils. It may be true of other salts as well as of magnesic sulfate, that their action on vegetation is modified by the presence of other salts, perhaps even by the soil particles, but we must not attempt to carry this principle too far; for instance, I do not think that we can argue from the manner in which this mixture of alkalis effects the action of magnesic sulfate what its effect would be on the action of sodic nitrate. In this case both parts of these salts are different and the two salts named have no part in common, but I do not think that this makes any difference in the statement made. I think that I can say of magnesic nitrate, just what I have said of sodic nitrate. There is, too, another side to the influence of other salts upon the action of a given salt. In the case of magnesic sulfate, the presence of calcic sulfate and other salts has the effect of lessening the action of the magnesic sulfate. There may be other combinations which might make it greater. We know a great many instances in which even a small amount of salt may greatly intensify the action which may be going on. The reader will recall the statement that the presence of calcic sulfate, sodic sulfate, etc., lessens the action of magnesic sulfate. This is mentioned to explain a contradiction between the results produced in the laboratory and in the field. One experiment is made in glass and the other in the soil. This is a difference, but the bigger difference is that in the one case only magnesic sulfate was present and in the other case a great mass of other salts was present to which we attribute the lessening of the bad effects of the magnesic sulfate. The reader must not think too little of this conclusion because we have chosen the more plausible of two possible causes for the difference; further, he must not find fault with the explanation, because we have not even attempted to tell him that this action is due to this or that individual salt. Our statement represents soil conditions as giving different results from our laboratory experiments and all of these salts are in the soil.

Sodic sulfate is by far the most abundant of our alkalis. Even in pure solutions, it is far less poisonous than the magnesium sulfate and its poisonous action is lessened by the presence of other salts, even calcic carbonate which we might expect to increase its poisonous action actually makes it less by four-fifths, so that it is only one-fifth as bad in the presence of calcic carbonate as in its absence. Calcic carbonate is usually, so far as I know is always, abundant in our soils, so that we would expect to find in our field observations that the presence of sodic sulfate in our soils, in the quantities in which we find it, is scarcely objectionable at all.

Sodic chlorid is much less injurious than sodic sulfate and its action is lessened by the presence of other salts, notably so by calcic carbonate. The presence of calcic carbonate reduces the action of sodic chlorid to one-third of the action it shows when calcic carbonate is absent.

NITRATES AND CARBONATE OF SODA DO GREATEST DAMAGE

The two salts that we meet with in the alkalis in Colorado which have done us serious damage are the nitrates (calcic, magnesic, and sodic) and the carbonate of soda.

EFFECTS OF SODIC CARBONATE

It is difficult to tell which of these two classes, the nitrates or the soluble carbonate, especially sodic carbonate, has done us the greater damage, but probably the nitrates, for these have a very wide distribution and are very poisonous even in comparatively small quantities, but how small these quantities may be I do not know. The sodic carbonate is likewise injurious in quite small quantities but in this case we have a pretty definite idea of how much may be present in the soil before it becomes dangerous to the plants. The amount in the soil that will injure wheat plants amounts to 0.04 percent of the soil, while beet plants will endure it up to 0.05 percent. It is, however, doubtful whether beet plants will live and produce beets with so much as 0.05 percent of sodic carbonate or "black alkali", in the soil. These two figures probably represent the largest amounts that may be be present without injury to the plants. These percentages mean, when put into pounds, for instance, that 100,000 pounds of soil may contain from 40 to 50, or 1,000,000 pounds of soil may contain from 400 to 500 pounds of sodic carbonate before it will actually kill the plants. A smaller quantity may cause the ground to bake very badly and in this way interfere with the growing of a crop. The figures given above amount to from 1,600 to 2,000 pounds of sodic carbonate to the acre-foot of soil, but a much smaller quantity than 1,600 pounds to the acre-foot may be sufficient to do damage if it be concentrated in the upper part of the soil. I suppose that, as a rule, we plant our small seed, wheat for instance, from 2 to 2½ inches deep. If the sodic carbonate in the top 3 inches of the soil, or at any point in the top 3 inches of this soil, equals or exceeds 0.04 percent of the soil, it is apt to kill the young plant. This statement leaves out the danger of the baking of the soil which may be caused by a much smaller amount of this salt. I don't know how small an amount of sodic carbonate it takes to cause the soil to bake on drying, but a sample of a sandy soil which I gathered for the purpose of determining the sodic carbonate in it had become so firm a mass by the time it reached the laboratory that one could not break it, with one's fingers. No seedling plant could possibly have broken its way through such a mass. The sodic carbonate contained in this sample was 0.017 percent, or 680 pounds to the acre-foot. We do not, at the present time, know of any other cause why this soil becomes so hard.

The reader probably recalls the statement previously made that sodic carbonate is one of the first products of the decomposition of rocks by the action of water. This is why the waters in our mountain streams all contain some sodic carbonate. He may further ask, Why, then, is not this salt everywhere? The answer is that it is practically everywhere in Colorado but not in injurious quantities, for the simple reason that this salt, when it comes in contact with solutions of other salts in the soil, calcic or magnesic sulfate, for instance, it makes a trade with them, exchanging its carbonate acid for their sulfuric acid, and the sodic carbonate becomes sodic sulfate and the calcic or magnesic sulfate becomes calcic or magnesic carbonate. In this manner the very poisonous sodic carbonate is transformed into the slightly poisonous sodic sulfate and at the same time forms calcic carbonate, which makes the sodic sulfate still less poisonous. There is usually a little sodic carbonate left; besides, there is a little being formed all the time in the soil. The conditions are such in some places that the sodic carbonate is not changed and has already become so abundant, and is so nearly the only salt present, that it has become injurious, and there are great stores of it in the water beneath the land. The conditions in most parts of Colorado do not permit of the concentration of this sodic carbonate, even where these mountain waters are used for irrigating the land, for they are largely changed into the sulfate and the small remnant is carried off in the drainage water, for the soil particles seem to have less power to hold this salt back than any other, unless it be the nitrate, which facts we infer from the readiness with which these two salts pass into drain-waters. So, if there be any drain-waters, they tend to wash it out of the soil. There are really two carbonates of soda which are not quite alike, the one is more poisonous than the other. The more poisonous one is our washing soda and the less poisonous one is our baking soda. I have said nothing about the latter salt and will satisfy myself with the statement that the one is more poisonous than the other.

ORIGIN AND EFFECT OF THE NITRATES

We have seen where the carbonates, one of our really troublesome alkalis, come from, but we have not yet attempted to tell where the nitrates come from. Rocks, except near the surface, do not contain these salts, and when they occur in well- or river-water, except in very small quantities, we consider the water polluted. It is said that natural waters can obtain from sources other than animal matter only from one-tenth to two-tenths of a grain per imperial gallon, which is 10 pounds. Taking the higher figure, this would be a little less than 50 pounds of sodic nitrate in an acre-foot of water. This amount is so good as without influence, but it must come from somewhere. It is not stated where it does come from, but it seems to be taken for granted that it is formed from the vegetable matter that is decomposed on the surface or near the surface of the rocks and soil. If there are any more nitrates than this, students of the subject consider that the nitrogen in the nitrates originally came from animal excrements. Water from deep wells contains at the very most 30 parts per million of nitrates and nitrite together. This would make 81 pounds to an acre-foot. This amount would do good and not harm to any crop to which it might be applied if it had any effect at all. We have never found in any sample of irrigating water more than one-tenth of this amount and the largest amount that we have found in return waters was in one taken from the Arkansas river at Rocky Ford which was one-fifth of the amount here given for deep wells. In the case of these deep wells, the nitrates are supposed to have their origin near the surface. Nitrates in general are supposed to come from one of three sources: They may be washed out of the atmosphere where they are formed by electric discharges, or they may be formed as the end product of the decomposition of vegetable or animal matter containing nitrogen. The very big quantities of sodic nitrate found in Chile and Peru are thought by some to have been formed by the decomposition of immense masses of sea weeds, which would give them a vegetable origin; others have claimed that they were formed by the decomposition of dung. This, of course, would give them an animal origin. These are the principal suggestions that have been made to account for their formation.

NITRATES NECESSARY TO GROWTH OF PLANTS

These nitrates constitute the most expensive fertilizers that we have and are necessary to the growth of most plants. It is possible that plants that grow in stagnant water, for instance, may take up their nitrogen in the form of ammonia compounds, but most plants get their nitrogen from the nitrates of the soil. While nitrogen is an absolute necessity to the growth of plants without any exception, and these nitrates are the most important source of their nitrogen, too much of these nitrates will kill the plants. Ordinarily the amount of these nitrates in the soil is very small, less than 48 parts per million, or less than 200 pounds in the top acre-foot at any one time. The crop, as it grows, uses this up, but it is being constantly replaced, not so fast, however, as the crop uses it, so that at harvest time the amount of nitrates in a wheat or oat field may be very small indeed—one-fifth or even one-eighth of the amount just given. The important question in this connection is, Where does the nitrogen in the nitrates come from. If we have the nitrogen given in decaying nitrogenous matter the processes by which it may be changed into this form, the one best fitted for the use of the plant, are known. The students of this subject have to deal with very small quantities compared with the mass of the soil or in comparison with the quantities in which some of the other important constituent are usually present. In a cropped field, for instance, it is not uncommon for us to find so little as 24 pounds, or even less, in an acre-foot of soil, and the plants, too, deal with very small quantities of these nitrates. I added 250 pounds of nitrate of soda to the acre and injured my wheat crop. These 250 pounds of nitrate of soda contained only about 40 pounds of nitrogen. Perhaps the average reader will appreciate this more fully if we state this another way, i. e., that I spoiled my crop by adding 10 pounds of nitrogen for each 1,000,000 pounds in the top foot of soil. The quantities of nitrogen, then, that we have to deal with are not big like the quanties of sulfate or carbonate of soda, and still smaller in comparison with the water-soluble portion of the soil. The soil of my wheat field contained a little over 3,800 pounds of soluble salts in each million pounds of soil and yet the addition of only 10 pounds of nitrogen as sodic nitrate injured my crop. It did not kill the plants, but they fell down and did not ripen as they should and the crop was short. I have done this now some fifty times, always with the same result.

Too Much Nitrate Is Injurious

These results show us that while the nitrates are necessary for the plant's growth and fruiting, it is easy to get too much for the production of good, strong, healthy and productive plants, in fact, it is easy to get enough to kill the plants outright.

Nitrates Cause of "Brown Spots"

It is a fact, on the other hand, that we find areas, some of them very small and others very large, where these nitrates are very abundant, equivalent in some extreme cases to 56,820 pounds in a million pounds of the soil. Some of these areas are very sharply defined with only two things to show them to be different from the rest of the land. These two things are; First the fact that there is nothing growing on them, and second that they are almost always brown. They sometimes look as though they were wet and have a slight crust on the top. Under this crust they are often mealy and if there is no crust the surface may be so mealy that it is puffed up.

We find two very striking things in regard to the nitrogen in these areas. The first is that there is much more of it than in the land just outside of the area; the second one is that a very large percentage of it is in the form of nitrates. Further, it sometimes happens that the difference between the total nitrogen and that present in the nitrates is bigger than the amount found in the soil just outside of the area. I have examined vertical sections of such areas and have found but one instance in which the second or third foot of soil contained more nitrates than the first foot; in all other cases the top foot contained much more nitrate than any succeeding foot. The top 3 inches of the soil contains much more nitrogen and also much more as nitrates than the succeeding portions. The top 3 inches usually contains more than the succeeding 2 feet and sometimes more than the succeeding 5 feet. This is especially apt to be the case if there is much nitric nitrogen in the surface sample.

We thought that the nitrates might come from the waters below the surface and in this way come from some other place, but we could not prove this. On the contrary, we found a piece of land on which nitrates were so abundant in spots that the owner failed to get anything to grow on them. This piece of land lay between some seeped land which was badly alkalied, and the river. The water that flowed from this seeped land to the river had to flow under this nitrate land. I examined four different samples of this water, three taken from the seeped ground and one from an under-drain at the north edge of the land in question, i. e., farthest from the river. Three of these waters contained no nitrates and the other contained only one-tenth part per million. The alkalis on this bad land also contained no nitrates, consequently the nitrates found in the lower land along the river could not have come from this source, for they were not present in either the alkalis, the soil or the water which flowed from under it. A further fact in this case was that the owner had previously tried to wash this soil in order to get things to grow, but it did no permanent good. As all nitrates are very easily soluble in water, and are perhaps the very easiest to wash out of the soil, it was remarkable how they persisted in these spots. Their ready solubility in water should prevent their accumulating in any spot and especially on the surface, if there were water enough to wash them down, and if they were in the rocks, the water coming out of these rocks ought to hold them in solution. Of course, if there be nitrates in the soil or in the rock through which the water runs, we will find them in the water. For this reason we do find them present in some waters which flow over the surface of some of our lands or run down through the soil of some of our mesas and seep out along their edges. But the water that comes from the rocks themselves does not contain nitrates. The following case will make plain the meaning and force of this statement. There is a piece of land near Canon City which had been planted to fruit, apples, plums, currants, etc., but after growing well for about 13 years, a very large portion of the trees and bushes died in a single season. The cause of this trouble was attributed to excessive water. We could not well hold to this explanation for, after study and a great deal of work, we came to the conviction that the surface waters collected at a depth of about 6 feet. The surface of the ground was everywhere very rich in nitrates and in places changed from its ordinary color, for the most part that of a reddish loam, to a dark brown. A slight moistening brought about this change in a remarkable manner. This soil was, when not wet, soft and mealy. This land passed into the hands of another party, who was convinced that the main trouble was too much water. This man had an extensive system of drains put in. I saw upwards of 7,000 feet of trenches open at one time to a depth of 3½ or 4 feet and they were not gathering enough water to yield a flow. I saw many hundreds of feet that did not draw any water at all. There was water at about 6 feet below the surface. This was very bad water and rich in nitrates. In this case we had nitrates on the surface of the land in large quantities and nitrates in the water in the ground. Had the nitrates from the water below come to the top or had they gone down from the top with the water? I wanted to know the answer to this question and that very badly, for, if they were coming from below, it would have an important bearing on our investigations. There was no question about their being in the water at a depth of 6 feet but this was very bad water; it held from 14,250 to 17,500 parts of mineral matter in a million parts; of this mineral matter, from 425 to nearly 800 parts were nitrates. We knew from conditions found in digging a cellar and in making other excavations that this water was probably only surface water that had been applied in irrigating, so a well was bored at my request to ascertain more fully what the facts really were. In boring this well we found that there was no water after we got a little below 6 feet till we got down to 19 feet, when we struck permanent water. This proved to be even richer in dissolved minerals than that we struck at 6 feet; it carried 22,100 parts of total solids to the million of water, but it carried no nitrates. The bottom of this well was several feet in the shales which underlie this section. As this water from the 19-foot well contained no nitrates it could not furnish any to the water or the surface of the land above it and as it came right out of the shales, the shales themselves certainly contained no nitrates. This is not the only instance of this kind with which I have met. A few years ago a man came to see me about some of his cattle that had died, seventeen of them within a few days. He wanted to know whether I thought the water from a new well that he had just dug might have killed them. On learning how the animals had acted, I suspected that nitrates in the water might have been the cause of their dying. The owner had brought in some of the water and it responded strongly to a test for the presence of nitrates just as he had taken it from the well. This man said: "I have to drive my cattle several miles to water and I want a home supply", and asked what I thought about driving a well. I had tested deep-well waters from this section and knew that they were unfit for any household use unless one were absolutely forced to use them, but I did not think that they would kill cattle. He put down a well 280 feet and obtained water. It was just such water as I had received from other wells and his cattle got along all right, but it physicked the men who drank it. Later he came to see me again and as the locality was a new one for the occurrence of these nitrates, I went to see the place. My assistant who went with me remarked before we got within three-quarters of a mile of the place that the whole country looked to him like an area in which we should find nitrates in great abundance. Anyone could recognize the characteristics. We found the well which had killed his cattle. It was in the middle of his corral and so shallow that I would not do any work on such water. We returned on another occasion prepared to obtain a sample of water to represent this well. We did not get it out of the corral nor very near to it. The water in the old well in the corral had risen to within 3 feet or so of the surface. We dug a hole in the edge of a beet field, perhaps 250 yards south of this well, and the water came into this hole at a point about 3 feet from the surface. Below this there was but little or no water to the depth that we dug, about 5 feet. We waited till about 10 gallons of water had run in, which required about an hour. The well that he drilled was just outside of his corral and was 280 feet deep, most of the way in shales. This well is cased. We took a sample of this water, for here we had as fair conditions as we could possibly get to show us whether these nitrates might come up from the shales below. The results were that the water from the 5-foot hole contained some 3,000 parts of nitrates and 6,900 parts of other salts to a million parts of the water, while the water that came from the shales 280 feet from the surface contained no nitrates, though it carried 5,328 parts of other salts for each million of water. The surface soil at this place, taken to a depth of 4 inches, contained 7.46 percent water-soluble salts of which 54.5 percent, or more than half, were nitrates. This means that 4.0 percent of this surface soil was nitrates, or 40,000 pounds per acre in the top three inches of this area where I took the sample. This condition was scattered over at least a square mile. Other portions of it were quite as bad as this, so this does not represent just a little, sought-out spot to give us a high result. We have these facts: The surface soil is extremely rich in nitrates; the ground-water is also very rich, while the water from the shales carries none at all. The shales then cannot be the source of the nitrates that we find on the surface of the land, nor in the ground-waters. Evidently the nitrates in the ground-waters came from the surface soil.

We have the following facts to help us answer the question Where do the nitrates come from? The mass of the mountains does not contain them, they are not brought to the lands by irrigating waters; they do not come out of the shales even when these are present. In this connection I will call attention to the fact, that, in discussing this point in Bulletin No. 155, the first one this station published on the occurrence of nitrates in soils in injurious quantities, and I believe the first one ever published on this subject, I said: "This, (Referring to a suggestion that I had previously made to the effect that these nitrates might, in some cases at least, be derived from the shales), can all be answered very easily by stating the following facts: The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken; second, that nitre spots occur in entirely different geological formations where these shales do not occur, in alluvial deposits and under ordinary prairie conditions, in other words, the shales, considered as a source of the nitre, would not be adequate for the explanation of the greater number of occurrences and, independent of any other reason, than their insufficiency, we must seek for a more general source, or a cause sufficient to account for all of the occurrences, assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes."

The nitrogen in these nitrates never forms a component of the rocks in the sense that soda or potash or phosphorus does and there is no great store of this nitrogen laid up anywhere to be changed into these nitrates. The only stored-up nitrogen that we have is in coal, a vegetable residue, or in these nitrates themselves, which are final products in the oxidation of organic or ammonic nitrogen. On the other hand, we find nitrogen and nitrates in all soils. This nitrogen is of vegetable or animal origin, we think mostly of vegetable origin, and the nitrates are found in the soil mostly at the surface. If we find them below the surface, say at 3 or 4 or perhaps 9 feet, they have been washed down there, in all probability, by downward moving water, for they are easily soluble and the soil particles do not hold the nitrates back as they do some other salts. These brown spots contain nitrogen and nitrates too in much larger amounts than the soil just outside of them. These spots are sometimes only a foot or two across and as round as a circle. Inside this circle there is more nitrogen and more nitrates than outside of it. These spots are not always small; they may cover a whole section of land or several sections. In such cases the nitrates are, of course, not evenly distributed forming one continuous bed of nitrates, still last year, 1916, I saw a section of land that had been planted to peas in which the nitrates were abundant enough to kill practically all of them. As said in the quotation given above, from our Bulletin No. 155, these spots and larger areas are not confined to one particular geological formation, nor so related to any given one that we can say that the formation has anything to do with them. Shales occur in great quantities within our State and some of our valleys are both bordered and underlaid by them, so it is quite proper to speak of shales in this connection, but I have met with these nitre spots, both above and below the shales and where there are no shales at all, so we could not, without leaving out part of the facts, say that they come from the shales, even if we had some good reason for believing that they really are present in the shales. I pointed out in Bulletin No. 155 that some shales carry nitrates and explained how these nitrates could have got there; in fact, they ought to be there, and we would have to explain how it happened if they were not. These nitrates occur in the surface portions of some sandstones, also of limestones and volcanic rocks. Some ammonic compounds have been found in the gases which accompany volcanic eruptions and these may later be converted into nitrates by certain living organisms, but the properties of these nitrates forbid their being an original part of a molten rock, especially if the rock is acid or contains quartz. If we find nitrates in such rocks, as well as in sandstones or in limestones, they do not belong to the rock proper and they are not in the deeper portions of the rock, but only in the surface portions.

We know that the small amounts of nitrates found in soils are formed there. It has been worked out that if we put animal matter, fish, or dried blood, for instance, containing nitrogen, on the soil, the nitrogen contained in it is broken out, converted into new forms and, while some of it may go off into the atmosphere as nitrogen gas, most of it is oxidized or burned to nitric acid. If we added enough fish or blood or other nitrogen-carrying matter, and kept our soil conditions favorable, we could make the soil carry several percent of nitrates.

The question is not how the nitrates may be formed in the soil but Where does the nitrogen contained in them come from? This is the question that bothers us.

I have stated in the preceding some reasons why I do not believe that the nitrates come from the rocks or from the waters. In fact, it would be pretty hard to explain how the nitrates, if they came from any such source, could collect in a spot, perhaps not more than 2 feet in diameter, in the middle of a field, or right at the edge of a river bank. I have stated that the nitrogen is present in the spots in greater quantities than in the soil just outside of them, also that the water that flows under them from outside land does not contain them.

Micro-organisms Fix Atmosphere Nitrogen

After I had studied a great many spots and tried to find some source for this nitrogen and could find none, the atmosphere forced itself on me as the only source from which the nitrogen could come. In short, it is well known that there are micro-organisms that in growing, take their nitrogen directly from the air and do not have to have some other plant to help them grow. The organisms that make the warty bunches on the roots of pea-vines, tubercles, in some way make the atmospheric nitrogen available to the pea, but these organisms cannot grow without the pea and the pea cannot use the atmospheric nitrogen without the organisms; nevertheless, they are said to fix the nitrogen, though they have to have help. There are other organisms, really plants, so small that we have to magnify them a great many times before we can see them, which can use the nitrogen of the air to build up their bodies. If we grow these in a soil fitted for them, these organisms add nitrogen to it even when there is no nitrogen in it to begin with, because in growing they take nitrogen from the air. We say that they fix it and call the process fixation. This process is going on in our arid soils much more freely than in most soils and in these "brown spots" these organisms have been very active and gathered a great deal of nitrogen.

These organisms die like other plants and, when dead, their nitrogen travels the same way that all other organic nitrogen travels. It is made the prey of changes that result in the formation of nitrates and when these nitrates get strong enough they kill out the nitrogen-fixing organisms themselves. We have found these organisms very abundant in some spots and have grown them and had them fix nitrogen rapidly, and in others we found them nearly all dead, at least, we judged them to be dead for they would not fix nitrogen, while their living neighbors from the outside of the spot fixed it very vigorously. We may say, then, that the nitrates are formed in these spots where we find them. The only really new thing in this explanation is the claim that these organisms carry on these processes on a big enough scale to produce these conditions that we find. We have shown that they can fix, under favorable conditions, enough nitrogen in 1 acre foot of soil to form 16½ tons of sodic nitrate if it were all converted into this form. This result is far beyond anything that we have found in our fields, so these organisms, *Azotobacter,* are not called upon to maintain this record all of the time in order to account for the conditions that we find. This explains how the spots grow and also why they become brown. Prof. Sackett has found that these organisms grow without producing any color when there is no nitrate present; at least, if they are grown for a few generations without any nitrates, they cease to produce any color, but if a certain amount of nitrate be added, they produce a dark-brown color. This is what happens in these "brown spots" and explains why we find the brown-colored spots rich in nitrates. The brown color tells us beforehand that there is an excess of nitrates present. These organisms taken directly from the soil may produce this brown color for a few generations without the addition of nitrates.

"BROWN SPOTS" FREQUENTLY CONFUSED WITH "BLACK ALKALI"

These "brown spots" have been confused with "black alkali" sodium carbonate, but the two things are entirely different in their nature and also differ in their color; the "black alkali" produces a dark almost black color on the surface of the soil. The hue of this is entirely different from that of the brown of the nitre spots. Of course, we meet with many brown places which do not owe their color to the brown coloring matter of these organisms, or yet to "black alkali". We have no more reason to say that every brown spot owes its color to *Azotobacter* pigments than we have to say that all men are white. These *Azotobacter* may be present without producing this color. They make this color most readily when the nitrates have accumulated somewhat. The "black alkali" makes no color unless there are organic substances, particularly humus, present for it to dissolve. "Black alkali" may be present in injurious, perhaps fatal quantities, without being black at all. This is sometimes the case in Colorado because there is not humus enough present to show this characteristic of "black alkali". Humus or humus-like substances may cause the soil to be dark, or even black, or go into solution and make the water brown. These are all well known facts. We even have a name for these humus-like substances *mattiere noire*, or black matter, but this does not look like the brown spots, or the black of "black alkali". These distinctions are easily recognized in the field, more so than in the books. The presence of calcic chlorid in a soil may also make dark spots in the soil, but these do not necessarily have anything to do with either the "brown spots", "black alkali" or the humus; these spots are just what they look like, wet spots, for the calcic chlorid takes up so much water that it becomes wet, even goes into solution, of its own accord.

The "black alkali" in the soil up to quantities ten times greater than is necessary to kill ordinary crops will not prevent the formation of these nitrates; on the contrary, up to this amount, it favors the development of these nitrogen-fixing organisms, so these two may be, and often are, found in the same soil. They are independent of one another in their origin and are not always associated.

We have given the views held in regard to the poisonous properties of the important members of our alkalis and it has been fairly stated that the results of laboratory experiments made with solutions of these salts do not agree with the results found by observations made in the field, also that the explanation offered is that this difference is made by the presence of other salts in the soil solutions or in the soil which modify the action of these salts. It is an important fact that these alkalis are really much less harmful in the soil than we would expect, judging from their action taken singly in laboratory experiments.

While some investigators have spent much time and effort to ascertain the amount of these alkalis at different depths in the soil, it is agreed that only that alkali that gathers at or near the surface ever does any harm. As these alkalis get to the surface largely by being brought up from the lower portions of the soil, investigators have examined the soils to a depth of 4 feet, which is a fair height for water to be lifted through the soil, and it is also a fair depth for the plant roots even of apple trees, for instance, to go down.

TWO DISTINCT GROUPS OF ALKALIS

It is necessary to separate the alkalis into two groups, one which does but little injury, and the other which does more, even great injury.

To the less injurious group belong the calcic magnesic and sodic sulfates, and the chlorids of these elements. To the decidedly injurious group belong sodic carbonate and the nitrates. Fortunately for us the less injurious alkalis constitute practically all of our ordinarily visible alkalis.

"WHITE ALKALIS" NOT INJURIOUS

These alkalis, "white alkalis" as we designate them, which form so striking a feature of some sections of our State, especially in the spring-time after a light snow or rain, are very gentle indeed in their action. So gentle that I have not seen any bad effects which were clearly attributable to these salts. If, by chance, I have seen instances in which these salts really damaged plants I have failed to recognize them. I have seen, on the other hand, so many instances of their presence, in such quantities that one would expect them to kill the plants, and they apparently did no harm, that I feel justified in making the general statement that in Colorado these alkalis constitute only an unimportant factor in our agriculture. I recall a case in illustration of my last statement. There was a piece of land planted to corn. It was, of course, deeply creased and was watered profusely. The sides of the creases just above the water had a band of white efflorescent salts, alkalis, between 2 and 3 inches wide, while the crowns between the creases showed an abundance of these salts. The corn was good. I wondered why the corn was alive. I took a sample of the surface soil at a spot where the corn was not as thrifty as most of it was. This sample of soil carried more than 4.5 percent of salts which were soluble in water. These salts consisted, for the most part, of calcic, magnesic and sodic sulfates with more sodic chlorid than usual, but no carbonates. Practically 70.0 percent of this soluble portion was made up of these sulfates, with only a moedrate amount of calcic sulfate, 16.6 percent of the total soluble matter. I mention this in particular because this calcic sulfate is very common in our soils and alkalis, often making up a big part of the white coating on the ground, further, because it is not very poisonous, but the lime salts do seem to be poisonous under some conditions. This case was even more interesting than the statements so far made suggest. The land was not only at that time full of alkali, a little more than 4.5 percent of the soil being soluble in water, but the owner was irrigating it freeley with seepage water, that carried 16,414 pounds of salts in each acre-foot of water. A good, open, loamy soil will take an acre-foot if it is dry enough to really need irrigation, and the soil is able to hold back a great many salts when such water sinks through it; besides, from 20 to 30 inches of water will evaporate from the surface of the soil and leave the salts that it held in solution. I do not know how much corn the man got to the acre, but it promised to give a fair crop. This land was planted to wheat the next season and again irrigated with this seepage water. I saw it just before harvest and it was far above the average. I subsequently learned that the yield was about 60 bushels to the acre.

In another instance, a beet field, I measured the incrustation between the rows, practically beneath the leaves, for they almost covered the ground. This incrustation was three-sixteenths of an inch thick. This case was much worse than the preceding for the land had been irrigated with seepage water and the ground-water was within 18 inches of the surface. The incrustation as gathered contained 51 percent of water-soluble material which was made up of magnesic and sodic sulfates, together 80.0 percent with 10.0 percent of sodic chlorid. There was very little calcic sulfate in this incrustation. The water-soluble in the upper portion of the soil, but not including the incrustation, was 3.6 percent; 44 percent of which was calcic sulfate, 21 percent magnesic sulfate and 20.5 percent sodic sulfate. There were less than 1.0 percent of carbonates and 4.2 percent of sodic chlorid. There was, in the top 6 inches of this soil, after scraping off the incrustation, 70,000 pounds of soluble salts to the acre. This land was in a river bottom and parts of it are sometimes flooded to such an extent as to drown out the crops. This land was planted to beets three years in succession. I got the record of the production for the second and third years. It was 9 and 10 tons respectively with a sugar content of 16.0

and 16.5 percent. Subsequent inquiry regarding the production and quality of beets grown on other portions of this piece of land showed that they were even better than those grown on the part where I took the samples that I have mentioned. The water used to irrigate this land was seepage and carried 10,930 pounds of solid matter in solution in an acre-foot. The statement of the man who was renting this place was that he could raise all manner of garden truck in abundance.

Another instance is that of a truck garden owned by an Italian. This garden was located at the base of the first bench back from the river. The north end of the piece of land was covered with water and was not more than 3 feet lower than the highest portion of the land. The portion of this land which was not cultivated was used as a cow pasture and I have seen crystals of sodic sulfate in the cow-tracks 1½ inches long by 1 inch wide. The Italian manured the ground heavily and cultivated all kinds of truck successfully. He and his numerous family were well clothed and evidently well fed and the living was made off this 5-acre garden tract. I dug a hole in a part of this garden planted to carrots and found the ground-water at a depth of 22 inches. The surface was exceedingly rich in alkali, so rich that every bit of straw or dead weed that stuck up out of the ground became covered with a mass of sulfate of soda crystals. The ground-water carried 484 grains to the imperial gallon, or 14,300 pounds of salts in the acre-foot of water. The analysis of this water residue showed 23.3 percent of calcic sulfate, 27.2 percent of magnesic sulfate, 27.0 percent of sodic sulfate, 4.7 percent sodic carbonate and 11.2 percent of sodic chlorid. The alkali gathered from the surface of the wet land carried 94.0 percent of sodic sulfate.

Such observations, combined with my own experience in growing sugar beets on land the top 4 inches of which carried 3.16 percent of water-soluble, one-half of which was made up of magnesic and sodic sulfate with only small amounts of sodic chlorid and carbonate, leads me to the conclusion that the ordinary "white alkali" as it occurs in our Colorado soils, does not do us much if any damage. If the few examples cited were the only instance of successful cultivation of strongly alkalied soils that I have seen, I would not feel willing to unhesitatingly make the assertion that I have just made. This fact, however, can be observed in large sections where the alkali, is everywhere very abundant, and in many places, we would judge, in excessive quantities.

I can see no object in giving a number of analyses all showing the same thing, i.e., that our "white alkalis", especially the effloresced masses which whiten the sulface of the land by the square mile in some sections of the state, are made up essentially of the sulfates of soda, magnesia, and lime mixed with some sodic carbonate and some sodic chlorid. In a few cases it is practically all sodic sulfate, in a few others it is largely magnesic sulfate; in one I received from New Mexico it was wholly magnesic sulfate, but the rule is that these salts are mixed.

In three of the instances that I have cited the water plane was high, in the fourth it was not high. In all of the cases the crops were good, both in quantity and quality. In the case of my own sugar beets, the best crop I gathered from the very strongly alkalied ground was 19 tons of beets to the acre with 18 percent, of sugar, an unusually good crop. L

I have explained so fully the primary origin of our alkalis that no reader ought to be surprised at the presence of some sodic carbonate in almost every sample of alkali and also of the ground-water. The same is true of sodic chlorid. The sodic carbonate is "black alkali", it is true, but the presence of a little sodic carbonate does not change "white" into "black" alkali. While it is true that we may be mistaken about the carbonate present being sodic carbonate, I do not believe that we are, and think, that the carbonate in solution is really sodic carbonate. The presence of soluble carbonates probably indicates that the process of alkali formation is now going on just as it has been ever since there have been rocks and moisture to act upon them. So the almost universal presence of more or less sodic carbonate in "white alkali" should not cause any surprise, for it is perfectly natural that some of it should be present, but it is highly injurious if too much of it be present. Under the conditions that we find in most parts of this state there is no danger of its accummulating, for it will be changed more or less quickly into the sulfate by the abundance of calcic sulfate in our soils, or it will pass into the drainage of the country, where there is any drainage. There is no doubt but that this "white alkali" is being formed in all parts of the State. There may be one considerable exception to this statement and reservation should be made on this account.

ALKALIS CONSTANTLY BEING FORMED

While some of our alkalis may be comparatively old, geologically speaking, others of them, exactly the same salts, occurring very abundantly too, may be comparatively young. It is, further, by no means necessary that, in dealing with two different samples of alkali, exactly the same in character, we are dealing with products from the same immediate source. Mr. Geo. Eldridge called attention to the fact some 30 years ago that the Cretaceous shales in this section of Colorado, particularly about Boulder, seem to be heavily impregnated with alkali. Sixteen years ago the following statements were published in Bulletin No. 65 of this station: "The alkalis are not so easily traced. The explanation offered for the presence of alkalis in the soils of arid regions is as true here as elsewhere, but these general facts are not applicable in the explanation of the particular cases with which we meet in agriculture. It is a well known fact, one long since recognized, that the shales of several of the Cretaceous groups contain a remarkable amount of these salts, designated by the general term "alkali", including sodium, calcium and magnesium as sulfates, carbonates, and chlorids.

"Analyses of incrustations from various parts of the State, and of waters from both ordinary and artesian wells, show the very general distribution of these salts. They also corroborate the observation of their presence in the shales and other rocks which, whatever may have been the origin of the salts, serve at the present time to furnish the alkalis to the waters percolating through them.

"The following figures, representing the general composition of the alkali, will serve to illustrate the general application of the assertion. An incrustation from the college farm showed:

Calcic sulfate	25.451 percent
Magnesic sulfate	19.798 percent
Sodic sulfate	41.748 percent

The ground water from about 5 feet below the surface yielded an abundant residue, composed of

Calcic sulfate	35.648 percent
Magnesic sulfate	28.754 percent
Sodic sulfate	11.393 percent

A surface well 28 feet deep yielded a large residue of which these salts formed 74 percent, as follows:

Calcic sulfate	15.206 percent
Magnesic sulfate	29.059 percent
Sodic sulfate	29.865 percent

An artesian well, supposed to tap a water bearing Dakota sandstone and having a depth of 845 feet, furnished a water carrying 79 grains of total solids in each imperial gallon, of which 83 percent consisted of these salts as follows:

Calcic sulfate	12.036 percent
Magnesic sulfate	10.473 percent
Sodic sulfate	60.758 percent

It is evident, not only from observation, but as is also indicated by such figures as these, that it is not at all necessary for the agriculturist to question in regard to the primary source of the salts included under the general term "alkali". They are so abundantly present in the rocks and water, even in waters from considerable depths, that there is no need to seek further the source. The questions relative to another more remote origin and how it happens that the shales and even the sandstones are impregnated with these salts can be left to the geologist without serious inconvenience in studying the questions with which our agriculture has to deal. They are here, and in cases where the drainage of any larger area accumulates in a small basin, alkali salts will be brought together and, under proper conditions, will appear as an incrustation. This does not take place unless the water plane is at less distance from the surface than that through which capillarity can raise the water in the particular soil".

This is all true, but does not preclude the continuance of the formation of these salts at the present time at a sufficiently rapid rate to produce all of the salt with which we have to deal. It is simply a question of judging from the conditions which is the more probable source of these particular alkalis. If we have a heavily irrigated, high country, such as many of our mesas, underlaid by shales rich in alkali, and we find the lower-lying adjacent land wet and strongly alkalied, we are justified in speaking of the shale as the source of the alkali without reference to the manner, place, or time of its original formation. The facts that we find, rightly interpreted, indicate that alkali is of recent origin. The wet land, with its abundance of alkali, shows that the shales let the water run through them and carry out the alkali. In short, it is washing them out. The long time and the water necessary to cut these mesas into their present shape would have done just what the irrigating waters are now doing. It is just as possible that the artesian water mentioned above carried the sodic sulfate into the sandstone with it as that it dissolved it out of the sandstone. If we had no districts abounding in alkali, except within the Cretaceous shales, we might be justified in leaving the impression that our alkali questions are intimately connected with the occurrence of these shales and that otherwise we have no alkali questions. This is not true, for these shales have nothing to do with our most serious alkali questions, for the very simple reason that there are none of these shales in the country where these questions arise, and yet we have square miles of this country whitened by these alkalis. Furthermore, we know the character of the water that is discharged into this country and it does not contain these alkalis. The alkalis that I refer to as whitening the country for many square miles at some seasons of the year are not confined to cultivated land; the most of it has never been irrigated since it was laid down. These alkalis are identical in every way with those referred to as coming from the shales. They consist of the same sulfates and other compounds and have without doubt been formed where we find them. While there has been moisture enough to bring about their formation there has not been enough to wash them out of the soil, not even to wash them so deep into the soil as to remove them permanently from the surface, but they are at times washed into the soil only to come to the surface again. This is the accepted explanation, and what I have said regarding the shales does not in any way contradict it. In the region referred to we are dealing with a primary source and in the case of the shales with a mediate or secondary source. The salts present in the shales may have been in part formed within the shales and in part found their way from the surface into them. In order to have alkalis present in our soils it is not necessary to have a Cretaceous or any other shale formation present. We have them without these.

It is true that a very large percentage of irrigated Colorado land lies within the Cretaceous formation but there is land of Pleistocene age completely separated from the Cretaceous areas and we have an abundance of alkalis in such lands. These alkalis are not all of the same character, but, so far as the "white alkalis" are concerned, they are composed of the same salts that we find in the Cretaceous areas. I repeat what I have already said that there is no ratio between the amounts of these salts, but they may range from pure sodic sulfate to pure calcic or magnesic sulfiate. In "white alkali" the sodic carbonate and sodic chlorid never become predominant. We have conditions under which sodic carbonate is predominant and present in injurious quantities. The geological evidence in this case is strongly in favor of a very recent origin, in fact of its production at the present time.

"WHITE" AND "BLACK" ALKALIS ON ADJACENT TRACTS

A very interesting fact in this case is that we have the "white" and "black" alkalis in adjacent territories. While it is beyond the scope that I set for this bulletin, it may be permissible to give some details in this connection. Even though I am not able to designate a section line as the dividing one between the two areas, The actual division between them, however, is very sharp, considered from the standpoint of productiveness. In the area of "white alkalis" we have such mixtures as the following:

	Percent
Calcic sulfate	0.874
Magnesic sulfate	0.033
Potassic sulfate	3.217
Sodic sulfate	79.557
Sodic chlorid	7.373
Sodic carbonate	3.472
Sodic silicate	0.748
Ferris Aluminic oxids	0.130
Excessive Silicic acid	0.684
Ignition	3.912

The water-soluble in this sample as collected was 80 percent. Another alkali collected from the surface of this land consisted of calcic sulfate 10.0 percent and sodic sulfate, including a little magnesic and potassic sulfates, 84 percent. This sample contained no carbonates. Still another sample contained 90.6 percent sodic sulfate, and another 80 percent of sulfates with 14 percent sodic chlorid. Of those having 80 percent of sulfates, 60 percent was sodic sulfate, and still another from the same ranch carried 78 percent mixed sulfates, 64 percent of which was sodic sulfate. This last sample carried 15 percent sodic chlorid. These represent the soluble portions of efflorescences as they were removed from the surface of the soil.

The soil and subsoil were sampled at the point where the first alkali sample was taken and analyzed with the following results:

ANALYSES OF SOILS NOS. 580 AND 581

	No. 581 Surface Soil Percent	No. 580 Subsoil Percent
Sand	56.271	51.285
Silica	17.531	11.662
Sulfuric Acid	0.255	0.128
Chlorin	0.462	0.184
Carbonic Acid	3.956	10.207
Phosphoric Acid	0.651	0.019
Lime	6.900	14.318
Magnesia	1.619	1.444
Sodic oxid	1.464	0.679
Potassic oxid	1.047	1.183
Aluminic oxid	3.383	2.868
Ferric oxid	4.420	3.567
Manganic oxid (br)	0.192	0.161
Ignition	1.867	3.085
Sum	100.017	100.790
Oxygen equal to chlorin	0.104	0.042
Total	99.913	100.748

This was virgin soil and about 400 feet from a large drainage ditch. The ground-water at this time was 5 feet from the surface in a stratum of sand, beneath which was a yellow, marly clay. The presence of marl in the subsoil was apparent by its color and manner of distribution. Its presence shows plainly in the analysis, being indicated by the 10.2 percent of carbonic acid against 3.9 for the soil, and 14.3 percent of lime against 6.9 in the soil.

The mineral constituents of this soil indicate the neighboring mountains as the source from which they came. The geological formation is designated as the Alamosa and consists of an alternation of sands and clays. The sands are very uniform in their mineralogical components, being those of the schists, granites, and igneous rocks which everywhere flank the valley. This alternation continues to a depth of more than 1,000 feet. I am informed that there is no change in this respect as far as any of the borings have penetrated, which I understand is 1,800 feet, of this figure I am, however, not certain.

An analysis of the ground-water from this stratum of sand is added to complete the record of our examination of this particular place. The water carried 98.9 grains of total solids in the imperial gallon. Loss on ignition 16.9 grains.

ANALYSIS OF GROUND-WATER NO. 490

	Percent
Calcic sulfate	55.647
Calcic carbonate	15.081
Magnesic carbonate	0.577
Magnesic chlorid	11.809
Magnesic silicate	3.233
Potassic silicate	0.377
Sodic silicate	8.441
Aluminic and ferric oxids	0.075
Ignition	(4.760)
Total	100.00

We have a number of other analyses of alkalis from this section and they are all of this type with few exceptions. These exceptions belong to the chlorid type. But to undertake to discuss types of alkalis in this place would lead us away from our purpose and tend to confusion rather than to clarity. The reader should remember, however, that the particular form of alkali with which he has to deal may be produced in his particular district by the interaction of the common salts occurring in the soil of the section. Sometimes these sections or areas are quite small.

SODIC SULFATE PREVAILING ALKALI IN ONE AREA OF 1,000 SQUARE MILES

The statements made in the preceding apply to an area of probably more than 1,000 square miles of which it is perfectly safe to state that the prevailing alkali is sodic sulfate associated with more or less calcic and magnesic sulfate. I have a number of analyses of alkalis from this section that contain from 90 to 96 percent of sodic sulfate. This type of alkali does not contain much sodic chlorid. I think I have given about the highest that we have found, i.e., 15 percent of the soluble salts.

ARTESIAN WATERS IDENTICAL WITH THOSE OF STREAMS

The deeper waters of this section are of the very finest quality. The artesian and spring-waters that I have examined carry from 5 to 16 grains of total solids to the imperial gallon, from 20 to 50 percent of which is silicic acid. The principal salt in these waters is sodic carbonate. This is essentially the composition of the waters of the mountain streams, almost without any change. This is what we would expect, provided our theory of artesian waters is correct. I have stated that the sands through which these artesian waters must flow are mineralogically identical with the rocks of the mountains. These artesian waters are not so far below the surface as to absolutely preclude their having an influence upon the character of the alkalis, as they actually came to the surface, in the form of permanent springs. One, of which I have knowledge, has a flow of 20 second feet. Flowing wells are also struck at depths so shallow as 65 to 75 feet. The character of these waters, even if they carried many times as much matter in solution as they do, preclude them as the primary source of such alkalis as we have been describing.

Without any change in the geological formation or surrounding conditions, we pass to an area in which the alkali relations are entirely different, and here we find a coincidence in the character of the salts in the water contained in the strata, the salts in the soil, and the alkalis, which, on the surface, are becoming more and more serious, in that they seem to be changing in their character, i.e., becoming richer in carbonates.

The waters of the artesian wells probably present these facts more plainly and simply than do the alkalis themselves though the differences show very plainly in these. It is useless in this connection to multiply examples, so I will choose only two waters, and some alkalis. The two waters that I shall give are about 6 miles apart, located on a north and south line. There is less than 20 feet difference in level between the two places and they are in the same geological formation, while the whole area is surrounded by high mountains of metamorphic and igneous rocks.

The well at the southern end of this line yields a flow of 1 cubic foot per second of good water, carrying 15.9 grains of total solids in the imperial gallon, of which 50 percent is silicic acid and 34 percent is sodic carbonates. The well at the north end of the six-mile line carried 103.6 grains of total solids, of which only 3/10 of 1 percent was silicic acid and 89 percent was sodic carbonate. The former well is 923 feet deep, while the latter was 500 feet deep, but it has been closed for a number of years. Deeper wells still further north of this point, are even richer in total solids and carbonates, though the increase is not great. There are only very small amounts of either sulfates or chlorids in either of these waters. To state the differences of these waters in other words, the one contains only a small amount of material in solution and the other contains seven times as much; the one contains relatively much silicic acid, the other very little. The total solids from the one at the southern end of the line contain 34 percent. those from the one at the northern end, 90 percent of sodic carbonate. There are only small quantities of sulfates and chlorids present in either water.

I have said enough about the alkalis of the southern section; namely, that they are essentially sodic sulfate, containing quite frequently upwards of 90 percent of this salt and, excepting a few in which chlorids are very abundant, always consisting of sodic, calcic, and magnesic sulfates. The ground-waters are very similar.

In the northern section the effloresced salts contain some carbonates varying from a very little up to 40 percent. We have in this section some deposits of pure sodic carbonate. The soil extracts contain 25 percent sodic carbonate, and upwards, while the ground-waters are even richer in carbonate than the corresponding soil extracts. We would expect this, as the soil retains the sodic carbonate but feebly, or not at all, and consequently permits it to pass into the ground-water, also into the drain-waters. It is for this reason, too, that the nitrates, when present in the soil, are easily washed out by water that runs through it.

An alkali gathered from uncultivated soil contained 8 percent of sodic carbonate. The aqueous extract from the soil below this contained more than 25 percent, and a ground-water taken in the same neighborhood gave a residue on being evaporated to dryness that contained 29 percent of soluble carbonates. These results represent a large area which has now become practically unproductive. Two efflorescences gathered about 17 miles southeast of this contained 20 and 40 percent of sodic carbonate respectively. The well-waters in this whole section, about 800 square miles in area, are alkaline. Shallow wells dug for household purposes contain, according to their depth, from 22 grains of total solids upward, 75 or more percent of which is sodic carbonate. The water from a large drainage ditch which runs through this section from west to east is essentially the same in character as the water from shallow wells. The deeper the wells after they attain a depth of 200 feet, the richer is the water in total solids and the more sodic carbonate they contain. The total solids from the deep wells contain about 90 percent of sodic carbonate.

These conditions are different from those described for the southern section, where we had calcic, magnesic, and sodic sulfates in the effloresced alkalis and essentially the same in the ground- and drain-waters, while the artesian water and that of the big springs in the southeastern portion of the section, contain only small amounts of total solids and these are poor in sulfates and chlorids but are fairly rich in carbonates, and are characterized by the presence of much silicic acid. In this northern part we have sodic sulfate as the principal salt in the effloresced alkalis with some carbonate. The ground-waters contained less sulfates and more carbonates, while shallow wells contain much carbonate and very little sulfates. The amount of salts and the percentage of carbonates increase with depth. They also increase in a line from west to east across this section; for instance, at the west side of the area, where conditions are still good, the first flow of artesian water contains 10.6 grains of total solids to the imperial gallon with 2.2 grains of sodic carbonate; 16 miles east of this the first flow, presumably the same as the preceding, contains 29 grains to the gallon and 9.3 grains of sodic carbonate, whereas at 750 feet the water in the eastern part of this area carries 104.3 grains, of which 99 grains or 94 percent is sodic carbonate. The calcic and magnesic sulfates are almost wanting in the effloresced alkalis of this section, and also in the soils. I do not recall a single section of soil in which I have found the usual layer of marl consisting of a mixture of calcic carbonate and sulfate. If we find any, it is the carbonate. The analysis of the soil made by extracting it with strong hydrochloric acid, shows that there can be but little sulfate of lime even if all the sulfuric acid present were combined with lime. It is improbable that any of it is so combined, owing to the presence of sodic carbonate. An analysis of one of these soils, taken in a very strongly alkalied section, shows only 0.363 percent of sulfuric acid, which would form but enough calcic sulfate to make a scant 0.6 percent of the soil. The analysis shows that there is carbonic acid enough present to combine with more than three-fourths of all the lime present, leaving 15 percent of soluble silicic acid to satisfy about 13 percent of bases which the hydrochloric acid took into solution. At the same time we are quite certain that some of these bases were present in still other forms, ferric hydrate, for instance.

Judging from the above sample of soil taken from as strongly an alkalied area as there is in the section, the total amount of calcic sulfate which may possibly have existed in an acre-foot of this soil is about 12 tons, but which we do not think was there at all, is not large compared with the amount existing as gypsum, which we can see in the soils from other parts of Colorado. There are some sections where we find layers of calcic sulfate 3 or more inches thick. A sample of subsoil from another part of the State taken to represent 2 feet of the subsoil, carried 120 tons of calcic sulfate to the acre-foot.

The composition of the alkalis varies locally but it is usually quite persistent in its character, for instance, in some sections the calcic and magnesic sulfates make up as much as 50 percent of the effloresced mass while sodic sulfate, chlorid, and carbonate make up the rest, of these the sodic sulfate usually predominates sometimes, however, the chlorid predominates, but this occurs rarely with us.

This whole section of approximately 5,000 square miles is characterized by the absence of calcic and magnesic sulfates in the efflorescences found on the surface of the soil, the predominant salt being sodic sulfate. This statement also applies to the 800 square miles of the northern section of which we have spoken in the preceding paragraph. In this section the sulfate is associated with the carbonate, which is not only present with it but even becomes abundant enough to be injurious. The following analysis of an effloresced alkali taken in an uncultivated section of this area, may be permitted in illustration of this statement even though a previous statement that we found 40 percent of sodic carbonate in an alkali taken from a desert claim has been made.

ANALYSIS OF AN EFFLORESCED ALKALI, UNCULTIVATED LAND

Calcic sulfate	0.710
Magnesic sulfate	0.710
Potassic sulfate	2.539
Sodic sulfate	21.929
Sodic carbonate	54.162
Sodic chlorid	16.959
Sodic phosphate	1.368
Sodic silicate	0.314
Ferric oxid	0.001
Aluminic oxid	0.161
Maganic oxid (br)	0.222
Silicic acid uncombined	1.057
Total	100.000

We have followed the same order in calculating this analysis as we have in all of this work. The sodic carbonate is evidently very abundant. This efflorescence contained, as I gathered it, 36.95 percent of material soluble in water.

This sodic carbonate is present throughout this section and its occurrence is independent of the sulfate.

ALKALIS ORIGINATE FROM FELSPARS

I have elsewhere called attention to the fact that the felspar common in our granites contains both sulfates and chlorids and these are consequently present in our mountain waters. These waters may have run their cycle of changes from rain-water to rain-water again many times but we are interested in only a short portion of their course, i.e., that they fall on our mountains as rain or snow and flow off as mountain streams upon whose waters we look as pure, but which, as in the case of the Poudre, carry their burden of rock constituents from the mountains to the plains. This burden sums up a surprisingly large amount, even in a single 24 hours of their average flow. The Poudre, with its average flow of 600 second-feet through its canyon is carrying material in solution equal to 650 cubic-feet of rock material to its lower levels every 24 hours. These materials consist of calcic, magnesic, sodic, and some potassic carbonate with sulfates and chlorids. The sulfuric acid and chlorin forming the sulfates and chlorids may be combined with calcium or magnesium, but it is more probable that they are combined with sodium and form sodic sulfate and chlorid.

This is the solution that I believe we should start with in accounting for the origin of our alkalis, for this is the solution formed by the action of rain- and snow-water upon the surface rocks of the drainage areas of the water courses coming down from the mountains, also of all soft waters on the felspars, especially the plagioclase felspars, present in the soil. In our case these felspars are very abundant, as this soil is composed of a mixture of sands derived from granites, schists, and quite a range of igneous rocks. In the neighborhood of Fort Collins and very generally eastward from this place the soil owes its origin largely to the rocks of the Front Range. There are some soils derived from the shales and sandstones, but the latter contain much felspathic sand. In the San Luis Valley there are no shales and the soil is derived from the rocks of the surrounding mountains. Among these rocks is included a variety of igneous rocks. The sands brought up in sinking artesian wells are of the same general character as those near the surface. This statement is true for a depth of at least 800 feet. Through this extended region we have the action of water on these felspars and these are practically our soda-yielding minerals. They may also yield lime and magnesia but there are other minerals that might yield these elements so their presence is not such direct evidence that the felspars are the source of our alkalis as are the sodic salts. It is, however, easily susceptible of demonstration that both calcic and magnesic salts are actually derived from these felspars. This process of alkali formation is actually going on everywhere at the present time just as has been explained by writers on the characteristics of arid soils and they are present due to the fact that there has not been water enough to wash away the compounds built up by the action of water and carbonic acid. This process is not confined to the rocky watersheds of the mountain streams but is going on perhaps even more vigorously within the mass of the soil itself. While these changes may go on within the soil in the same measure as on the mountain slopes, we have not the same opportunity to study them, as they are certainly modified by more complex conditions. Our mountains are not thickly covered by an old accumulation of any sort, in fact they are only thinly covered by the fragments of rocks of the same kind or perhaps not covered at all and the products of the changes which they are suffering are constantly being carried away in the waters of the streams flowing out of them. For these reasons these mountain waters present the simplest and best conditions for the study of these changes.

A STUDY OF MOUNTAIN WATERS

It may now be interesting to see what we find in these mountain waters and to inquire whether the waters and the alkalis that we have tried to present bear any evident and natural relation to them. I am, of course, convinced that they do and that we have, in this area where we find the carbonates in the soil and waters even to the depth of approximately 800 feet, the simplest case for study that we have yet found and we shall see that the case may be quite easily explained.

That the waters of our mountain streams are as pure natural waters as can be obtained, spring waters which may come from deep-seated sources or may issue from an open, shallow mineralized veins are not included in this statement. The waters, for instance, of a stream in South Park whose very head is a brine that in early times was boiled as a source of salt, could not be included, even though these waters, later in their flow, appear as mountain waters, nor a spring which was struck in the bed of Clear Creek, Gilpin County, which was rich in the sulfates of iron, manganese, and zinc associated with calcic sulfate. Such springs may discharge their waters into mountain streams, and if their volume is sufficiently big, may modify the character of the water of that stream in a lower part of its course. It really seems unnecessary to state such evident exceptions as these but they are of actual occurrence, and there are many such within the State. I know of a small spring which is discharging an almost pure solution of aluminic sulfate into one of our rivers. This spring is at an altitude of approximately 5,000 feet, but we would scarcely consider the river at this point a mountain stream, though it is a branch of the Gunnison River. Such a water would of course be changed quickly on mingling with any ordinary water.

By mountain waters is meant such as run off of the mountain areas or issue from springs fed by such waters which have been in contact with metamorphic or igneous rock in which felspathic constituents are abundant. The presence of carbonic acid is assumed, as it is present in the atmosphere, in all surface waters, and in the soil.

I will give the analysis of a residue obtained by evaporating about 40 gallons of water to dryness. This water was taken from the Poudre River above the mouth of the North Fork before it receives any other than mountain water.

ANALYSIS OF POUDRE RIVER WATER

	Percent
Calcic sulfate	11.782
Calcic carbonate	24.781
Magnesic carbonate	9.063
Potassic carbonate	4.325
Sodic carbonate	9.146
Sodic Chlorid	5.899
Sodic silicate	8.772
Iron and aluminic oxids	0.388
Manganic oxid (br)	0.063
Silicic acid uncombined	16.546
Ignition	(9.235)
	100.000

SANITARY ANALYSIS

	Parts per Million
Total solids	41.4286
Chlorin	1.9804
Nitrogen as nitrates	Trace
Nitrogen as nitrites	None
Saline ammonia	0.0350
Albuminoidal ammonia	0.0900
Oxygen consumed	2.5500

The waters of our mountain streams, as they flow in their mountain sections, are quite similar in composition and carry the following salts in solution: Some sulfate, usually calculated as calcic sulfate; calcic, magnesic, potassic, and sodic carbonates; some chlorid, usually calculated as sodic chlorid, and a relatively large amount of silicic acid.

The amount of sodic silicate present in such a residue will undoubtedly depend upon the amount of aeration to which the water may be subjected. If the fall of the stream is heavy and the water has to flow over falls and large boulders we will find sodic carbonate instead of sodic silicate and the silicic acid will be free or absent, as it may have been deposited. If, on the other hand, the water flows over a more even bed and the aeration is slight, the sodic silicate may not be broken up. We find this to be largely the case in the Rio Grande waters, which flow for many miles with an almost unbroken surface over material of essentially the same character as the naked rocks of the mountains themselves.

The following analysis will make the difference plain:

ANALYSIS OF RIO GRANDE WATER

	Percent
Carbon	1.661
Calcic sulfate	10.203
Calcic carbonate	27.620
Magnesic chlorid	1.218
Magnesic carbonate	2.730
Magnesic phosphate	0.351
Magnesic silicate	5.220
Potassic silicate	4.705
Sodic silicate	10.000
Ferric oxid	0.645
Manganic oxid	0.609
Silicic acid uncombined	35.037
Total	100.000

SANITARY ANALYSIS

	Parts per Million
Total solids	77.00000
Chlorin	0.00014
Nitrogen as nitrates	None
Nitrogen as nitrites	0.000070
Saline ammonia	0.000001
Albuminoidal ammonia	0.000002

This residue was obtained by evaporating the necessary amount of water in the field and this is the reason why there is no determination of the dissolved carbonic acid. The appearance of carbon in the analysis is due to the fact that we had to destroy some organic matter and we preferred to heat no higher than was necessary to accomplish this purpose as we knew that there was an excess of silicic acid present sufficient to expel all of the other acids.

When such waters as these pass into the soil which differs from the rocks and sands with which they previously have been in contact, changes take place which vary with the character of the soil. In the case of the Poudre water these changes, in their rougher features, are that the silicic acid is almost completely removed, and the calcic, magnesic and sodic carbonates are exchanged for sulfates, the sodic carbonate less completely than the others. Potassic salts are, as a rule, completely removed. Other changes may also take place and give rise to special forms or types of alkalis. These changes are often complex and their course not self evident.

The waters previously referred to are collected from the same general watershed as those of the Rio Grande, though they do not find their way into it but are delivered into the valley by other smaller streams. I have stated that the strata, even the soil of the valley, are made up of the same minerals that form the rock masses surrounding the valley. The principal differences between its condition as the water of mountain streams and when spread out in the strata of the valley is the change from a flowing mass to a resting one spread over many times the area, with changing conditions of pressure and concentration. The effect of these differences is to permit the calcic and magnesic compounds to be removed probably as carbonates and the silicic acid also either as such or as newly formed silicates, leaving in solution the sodic salts as sulfates, chlorid and carbonate. If a solution containing these salts, sulfate, chlorid and carbonate, be allowed to run through the soil, the carbonate is permitted to pass most readily while the sulfate and chlorid are retained to a very much larger degree. The evaporation of the water and consequent concentration of the salts held in solution is a matter of fact and of great importance. I hold that this, in a rough way, is the manner in which we have to account for the difference in the character of the alkalis in the two sections which I have presented. The process of formation of the alkalis in the two sections is essentially the same and the source of the alkalis is the same. The fundamental cause of the difference is that the one section has always enjoyed drainage enough to keep the underground, the artesian water constantly removed from the surface, and evaporation has played a very minor part. Whereas in the other section the supply of fresh mountain water has, in fact, been less abundant and there has been no drainage, or one wholly insufficient to cause the renewal of the water frequently enough to prevent accumulation of the sodic carbonate. In this case the discharge of water into the area is not enough to replace more than one-half of the water that would evaporate from a free water surface and scarcely more than enough to replace that which evaporates annually from the land surface, if it be kept ordinarily moist. Under these conditions the silicic acid, calcic and magnesic salts pass out of solution, leaving the sodic salts. Any calcic sulfate that may be formed, together with the sodic sulfate, will be retained near the surface and will be brought up and deposited as efflorescences or disappear into the soil again, according to the supply of surface-water or the weather, while the sodic carbonate in excess of what may be necessary to form calcic and magnesic carbonates will remain in solution and in effect be concentrated therein by each annual increment. This may seem too simple an explanation of the condition which we find in this northern section but I believe that it is the correct one.

The ground- and drain-waters in this section are quite similar in character, both carrying very significant quantities of carbonates. The ground-waters within 4 feet of the surface may carry sulfates principally but at a depth of 15 or more feet these give place to sodic carbonate, and at considerable depths, though the total amount of salts in solution may exceed 100 grains to the imperial gallon, there is so good as no sulfates, while the sodic carbonate amounts to 90 or even more grains to the gallon.

The chief difficulty in this explanation lies in our ideas of artesian waters, i.e., that they are waters confined between impervious strata so curved that they form a series of basins one inside of the other and that the water between a pair of these irpervious strata is under pressure enough to force the water above the surface in the case of a flowing well. The wells referred to in this bulletin are all flowing wells. The water that flows into the valley is all mountain water and contains sodic carbonate especially in such quantities as we find in the deeper wells only after it has been changed quite radically. The only way that the sodic carbonate can accumulate in the lower strata of these waters is apparently by passing through the strata into the water from above. I have mentioned the fact that there are in one locality small beds of sodic carbonate on the surface, but borings have failed to show other deposits of this salt.

LACK OF DRAINAGE CAUSES EXCESS OF ALKALI

The only difference between the two areas is that the one is fairly well drained while the other is not, owing to the form in which the strata of the valley were laid down while this whole area was occupied by a fresh-water lake across which the Rio Grande built a bar, or fan.

The water supplied to the valley has always been the same, i.e., the waters of the streams coming down from the surrounding mountains, some of which are never entirely free from snow, and yet the artesian waters from the two sections are wholly different.

We have in this valley a series of strata of common origin, attaining a very considerable thickness, which formed the bed of a fresh-water lake. These strata abut against the metamorphic or igneous rocks which surrounded the lake and now surround the valley. The valley abounds in alkalis of two kinds, the "white" and "black" alkali. The "white alkali" is very generally present but is probably nowhere a serious detriment. The "black alkali" is everywhere present, as would follow from our previous explanation, and is now being formed as one of the first products of the action of rain- and snow-water on the felspathic constituents of our rocks and soils, but, owing to its easy solubility and the inability of the soil to retain it, and also to the readiness with which it can be transformed into the sulfate, it has not accumulated in deleterious quantities except under special conditions. These special conditions in the case discussed are; First; that the sands and soils of the valley are identical in their mineralogical features with the rocks of the mountains; Second; that these conditions have been the same throughout the history of the valley; Third, that this portion of the valley has no sufficient drainage, owing to an old river fan or bar which divides the valley into two sections;. Fourth, that there has been an approximate equilibrium between the water supply and the rate of evaporation during a very long period of time, just so long as this valley has existed. The result being that we have in the one section a comparatively simple phase of the alkali qusetion in which the products resulting from the action of rain-, snow- and phreatic waters on the felspathic constituents of our rocks have been partly removed and those remaining only partially modified. For the sake of simplicity we can consider these products to be silicic acid, calcic, magnesic, and sodic carbonate with a little sodic sulfate and chlorid. Considering these to be the products of this action does no violence to the facts, as a reference to the analysis of the residue obtained from the Poudre River water will show. If anyone wishes to consider the results given in the analysis of the Rio Grande water as more typical, I call attention to the fact already pointed out that the difference is only a matter of aeration, and would support this by the results obtained by the examination of the water of the Arkansas, taken above Canon City, which is just below the entrance to the Royal Gorge.

The silicic acid would be removed from such a mixture by flowing through a soil containing soluble salts with which it might combine, or even by sand grains themselves. The calcic and magnesic carbonates can be precipitated by the simple removal of carbonic acid which holds them in solution. We find the most positive evidence of this deposition nearly everywhere in the soils of our State. This is the origin of the white, marly layer of soil encountered in the upper portion of our subsoil, sometimes as a veritable hard-pan. The soil particles possess the power to retain the sulfates and chlorids as such, but they have little or no power to retain the carbonates. The sulfates and chlorids are retained near the surface and the sulfates in particular are first carried into the soil by descending waters, are there seized upon by the soil particles and later may be brought to the surface again by ascending capillary currents to be left as efflorescences on the evaporation of the solvent water. When there are no salts present in the soil to affect a transformation of the sodic carbonate, and no autflowing water to carry it away, it must become more and more abundant until it becomes strong enough to prohibit vegetation. This is what has happened in the northern section of this valley. This I believe, to be the simple history of the 800 square miles of land included in this section. This is the reason why the artesian waters to a depth of 880 feet at least are, for all practical purposes, a simple solution of sodic carbonate. It will be noticed that these waters carry but little silicic acid and still less of sulfates and chlorids.

"WHITE" ALKALI REMAINS NEAR SURFACE—"BLACK" ALKALI GOES TO DEEPER STRATA

The "white" and "black" alkalis, then, are formed simultaneously as primary products of the action of waters containing carbonic acid. There is a tendency for the "white alkali" to be retained near the surface and for the "black alkali" to pass into the deeper-seated waters. If there be a deep under-ground movement of these waters out of the region, the "black alkali" goes out with them, if not, it must accumulate within the area. We have the former case in the one section and the latter in the other of the two sections that we have discussed.

There are other ways that "white alkali" is formed. I have already cited the production of sulfates by the oxidation of the sulfur in marcasite or other sulfids, principally of iron. While this is a widely distributed action it is not comparable in importance to the action of carbonated waters.

CHANGES WITHIN THE SOIL DEPEND UPON SALTS PRESENT

The changes that may take place in ordinary soils when solutions produced as above described, enter them will depend upon the salts in the soil and these changes will determine the character of the alkali of the locality. With us the general character is that of the sulfates. We have already seen that some sulfates are already present in the mountain waters, further that sulfates may be formed from the sulfur in the sulfids of iron which are widely distributed and also from other sulfids. Besides these sources there are already formed deposits of gypsum in certain geological horizons. This compound though not very soluble in water is a common constituent of our ground-waters. The manner in which this may act with sodic carbonate to form sodic sulfate is easily explained. If the two salts be brought together in solution they simply exchange the acids, forming a more difficulty soluble salt and an easily soluble one, the sodic carbonate becomes sodic sulfate and calcic sulfate becomes calcic carbonate. Another change which may take place is the result of the action of salt, sodic chlorid, on calcic sulfate, in which the sodic chlorid becomes sodic sulfate and the calcic sulfate becomes calcic chlorid becomes sodic sulfate and the calcic sulfate becomes calcic chlorid. There are many other changes of this sort that are possible and which undoubtedly take place in certain localities. It seems that we are compelled to apply this principle of exchange which we are quite sure takes place in some instances to other cases in which we are not so certain that the conditions are the same. We can feel quite satisfied that calcic chlorid has been formed from calcic sulfate and sodic chlorid if both of these salts are abundantly present in the soil, but if one of them is present in small quantities only, and we still find the calcic chlorid present, especially in spots, and that sometimes in improbable looking places, this explanation may fail to be entirely satisfactory. We find some such cases in Colorado. We find some magnesic sulfate and occasionally chlorid in some alkalis and I may say always in the ground- and many spring-waters. The fact that these magnesic salts are very easily soluble accounts for their presence in the waters and their formation may take place in a manner similar to the formation of calcic salts. If magnesic carbonate and sodic chlorid act upon one another, both products, sodic carbonate and magnesic chlorid, are soluble. Magnesic sulfate may be formed in a similar manner, and if magnesic sulfate and calcic chlorid chance to mingle, there will be a change resulting in the formation of calcic sulfate and magnesic chlorid. The magnesic salt occurring most frequently in our waters and alkalis is the sulfate. These salts sometimes make up as much as 35 percent of our ordinary alkali and occasionally they are even more abundant than this.

These sulfates, which constitute the so-called "white alkalis," while poisonous to plants, some of them in comparatively small quantities, are so modified in their action, when in the soil and mixed with one another that extremely large quantities fail to produce seriously injurious results. The calcic sulfate in some instances, as I have elsewhere mentioned, may, when very abundant, produce a yellowing of the leaves on apple trees, and lime salts may be the primary cause for the bleeding described in a previous paragraph, but ordinarily we do not obseve any ill effect from the presence of very large quantities of these salts in the soil. The poisonous action of the magnesic salts is so greatly reduced by the presence of other salts in the soil that in all ordinary cases we may neglect it altogether. I have cited four cases in illustration of the fact that the amount of alkalis which may be present in the surface portions of a soil without doing damage is so big that, unless there be other bad conditions, we need scarcely have any fear of them. This result of my observation is in keeping with the experience of large sections of our State.

"WHITE ALKALI" QUESTION PURELY ONE OF DRAINAGE

Water in the soil very frequently involves the question of alkali. As a general statement, we will all agree that our cultivated crops require a soil comparatively free from water and well aerated. The practice of sub-irrigation and the results obtained, even on strongly alkalied land, make one decidedly cautious in making very positive assertions. In this practice it seems never to be desired that the water-plane should fall lower than 24 inches below the surface; it is very generally maintained at from 22 to 18 inches of the surface, and in some cases, with good results, too, as high as within 12 inches of the surface. I scarcely believed this last statement and inquired regarding the reliability of the man making it. The man's reputation for veracity was good and the party of whom I made inquiry stated that he had himself seen the man's team mired in his potato field. These are peculiar conditions, but I am convinced that we must modify our views somewhat in regard to the height at which the water plane becomes dangerous to plants. In spite of such facts it remains entirely correct that, in large sections of the State, there is no considerable accumulation of alkali except in depressions which receive the run-off and seepage waters from higher lands. Drainage of such areas is necessary to remove the water and to prevent the accumulation of the alkalis. The chief deleterious effects of these conditions with us are upon the condition of the soil which, of course, may ruin the crop. In all such cases, and they are by far the majority of our cases, the alkali question resolves itself into one of drainage, a statement that I made 15 years ago or longer.

"BLACK ALKALI" RESULT OF PERMANENT GEOLOGICAL CONDITIONS

This is not the case with the "black alkali" or sodic carbonate. I believe that the geological conditions which have made the accumulation of this salt possible to be as permanent as the region itself and to be so serious that it is only by constant effort that we can in any successful measure ward off the practical destruction of the area as a productive farming section. A meagre agriculture will undoubtedly continue for years to come but unless a more rational system of irrigation be followed and continual remedial applications be made the final result can scarcely remain in doubt.

I have stated the original source of our alkalis and while the accumulations on the surface may be very heavy and may even impregnate the underlying strata to considerable depths, for more than 880 feet in the case of the sodic carbonate, their production has been the result of the action of carbonated waters on the minerals of the surface rocks, and the time of the production of the alkalis with which we have to do in the present period. The alkalis are in no probability older than the artesian waters containing them but are possibly in part younger, as they are now being formed. The mode of their formation can be imitated in the laboratory and is universal in its application.

NITRATES SOMETIMES MISTAKEN FOR "BLACK ALKALI"

I have previously made mention of the occurrence of nitrates, not in the sense in which these substances are usually mentioned as occurring in the soil, but in much larger quantities such as are sufficient to be very injurious. In the previous mention I suggested a doubt as to the propriety of including them among the alkalis. The only reason that would seem to justify our doing so is the fact that they have been mistaken very frequently for "black alkali". Some nitrates do occur in the area described in this bulletin as actually suffering from the presence of "black alkali", sodic carbonate, but they are not confined to this condition, though their formation may be facilitated by it, provided it is not too bad.

I have deemed the statement, relative to the composition of our river- and other surface-waters, especially as they show the absence of these salts, sufficient to show that their origin is not the same as that of our alkalis. These are formed by the action of meteoric waters on the rocks containing felspar, and particularly soda-lime felspars. These rocks do not contain nitrates nor yet any elements from which the neccessary nitric acid can be formed. I have further pointed out that the alkalis that we find are of recent origin, are confined to relatively shallow depths and are to be looked upon as having penetrated the soils and rocks, in some cases, from the surface. We find in many places that under favorable conditions various kinds of rocks contain in their superficial parts some nitrates but these do not penetrate very far and owe their formation to processes that are going on at the present time at the surface of these rocks. Of course these processes have been going on in the recent past just as they are today.

The simple facts in this case are these: We have areas varying greatly in size in which we find a great deal more nitrogen than in the surrounding lands, and a very large percentage of this nitrogen is in the form of nitrates.

I have already made it plain that our soils, generally speaking, contain alkalis among which sodic carbonate is usually found in small, but not injurious quantities. In this sense the nitrates are associated with the alkalis but they are not necessarily associated with the efflorescences usually meant when we use this term. An important question in this connection is, If they do not come in with the alkalis where do they come from? These salts are characterized by the presence of nitrogen. which is necessary for their formation. Chile saltpetre or sodic nitrate is an example. It is not intended to state that this salt actually occurs in these soils though it may either be alone or associated with other nitrates. The rocks, especially the minerals from which the alkalis are formed are found practically everywhere in our soils and very abundantly in our mountains, so if our alkalis and these nitrates had the same origin they should have the same general distribution. This is not the case. We believe that we have so good as no plants which can do without nitrates and, as we have plants growing and bearing their fruit, we must accept it as proven that these nitrates are present wherever we find such plants growing. The characteristic thing in the occurrences which we are discussing is that they kill plants and, of course, nothing grows where they occur. The complaint that the ranchmen send in is almost uniformly of "brown spots" on which nothing will grow. These spots are usually in cultivated fields which are elsewhere productive and I can testify that, judging from the whitened surface of these fields when not covered with vegetation, they are at the surface, very rich in alkalis and are brown and unproductive in spots only. We find these spots rich in nitrogen and especially in nitrates. We all have the same practical method of considering these questions. Why is not this nitrogen spread out everywhere just as generally as the alkali and why are these spots richer in nitrogen than the rest of the land? There are no deposits of these salts found anywhere except near or at the surface of the land. The deep portions of the rocks contain no nitrates for they are all soluble and have been washed out or destroyed as one of the changes which are going on all the time.

We know how the nitrates that our plants use are formed in the soil. There are different kinds of little plants that grow in the soil that are able to change ammonia, step by step, into nitric acid, and if there is some alkaline substance present to take up this acid we have nitrates formed. This is no more strange than the fact with which everyone is familiar that, if we keep cider under proper conditions it turns to vinegar, or that buttermilk is sour. In the former case a plant, but a different one, has converted the alcohol of the cider into acetic acid, and still another plant has converted the milk sugar into the lactic acid of the buttermilk. There is nothing so very unusual, then, in the production of nitric acid or nitrates in the soil, if we only have the nitrogen in the right form to start with.

In these days nearly every farmer has read, heard of, and seen root tubercles. If peas, clover or alfalfa will not grow, it is because the tubercle-producing organism is lacking in the soil and the plants do not get a sufficient supply of nitrogen. This statement is as common now as almost any other one of every-day life. These organisms are simply little plants that thrive best on the roots of peas, clover, alfalfa, vetches, etc., and have the power to help the plants to use nitrogen from the air in building up their nitrogen-containing parts. As this nitrogen, which these little plants help the peas to get, comes from the air, we say that they "fix" it. These little plants are supposed to need the help of the pea or the alfalfa to fix this nitrogen, but there are other plants growing in the soil that do not need help to use the nitrogen of the air to build up their structures, provided they have a sufficient supply of everything else. In other words, if the conditions are favorable, they will take care of themselves as far as nitrogen is concerned. These plants multiply, build up their tissues and increase the total nitrogen in the soil. These plants are usually present in all of our soils; only a few samples have been found entirely free from them. If the conditions are exceptionally favorable, they will grow very freely and the amount of nitrogen fixed in a comparatively short time may be quite large. These plants use this nitrogen from the air to build the same kind of compounds that are built by other plants from the nitrogen of the soil and when the plants die, these compounds go through the same processes of change that the similar compounds built up by other plants undergo. The end product of these changes that interests us at the present is the nitric acid, nitrates, into which this nitrogen is finally converted.

These nitrates are not colored, they are just as white as the "white alkalis" and the little plants that fix the nitrogen are also without color, but when there are nitrates enough present in the soil in which they are growing, whether it is natural or artificial, they color it eventually a deep, almost a black, brown. Matters in the natural soil are pretty well advanced when this takes place and this is the reason that samples taken from the brown spots prove to be rich in nitrates. The brown color is produced because the nitrates are present and serve as a good guide for us in judging whether the nitrates are there or not. Other things may cause the surface of the soil to become darker in some spots than others. Sodic carbonate gets its popular name of "black alkali" from the fact that it dissolves humus or eats the plant tissues and takes the products into solution with a very deep color, which leaves on the surface of the ground a black coating when it is evaporated to dryness. Calcic chlorid, one of the occasional constituents of alkali, causes the surface of the soil to be darker in spots where it chances to be because it takes water out of the air and keeps those spots more moist than the neighboring land. But humus and the calcic chlorid have nothing to do with the brown nitre spots.

One of the most difficult questions for us to answer is, Are there enough of these little plants and can they grow fast enough to build up all of the nitrogenous matter that is necessary to account for the nitrates that we find? A great many people think that we give them too big a job to do. I do not think that this is true. We have tried to find out not exactly what they may be able to do under very favorable conditions, but what they actually do in our ordinary cultivated soil, soil that we have growing wheat on and which we consider a good soil and in good condition, but not at all rich in nitrogen.

We imitated field conditions by taking 3,000 pounds of this soil from the field and made a bed of it where we could watch it, water it and keep the weeds out. We built a fence around it to keep animals off and to let the children know that we did not want them to go on it. We watered it with pure water of which we added only enough to keep the moisture in the soil around 15 percent. We protected our bed from being washed by heavy rains by fixing it so that we could cover it with canvass if it should rain, but the bed was open to the sun and air just as it would have been had we left it in the field. While we did not want to have our soil washed out by water from above we did not want any water to come up from below and bring a lot of salts up with it, so we put a tight board bottom under our bed with tight board sides to it. We added nothing to this soil but water. The plants had to get along on that soil. We even banked up the earth a little way from the bed to prevent any rain-water washing other dirt into it and to catch any blowing sand as far as possible. We analyzed the soil as we put it into the bed and every fifth day after that for 40 days. At the end of this time we found that it had more nitrogen in it than at the beginning, so much more that every million pounds of this soil had gained 36 pounds of nitrogen, which would be equivalent to 216 pounds of sodic nitrate if it were all converted into this form. Further, we found that the nitrates themselves had increased by 94.8 pounds for each million pounds of the soil. Our bed was 6 inches deep, so we had the equivalent of 198.6 pounds of sodic nitrate formed in the top 6 inches of this soil which weighs about 2,000,000 pounds per acre in 40 days. There was just about the same gain in the first and second 3 inches, and while this will be different in different cases, we may state the results for the acre-foot, which would be 397.2 pounds calculated as sodic nitrate. We did not pick a particular 40 days in which to make our experiment, so we have a fairly good right to assume that the same results would be obtained for any other 40 days of the season. The results at the end of the five-day periods may indicate whether this assumption is justified.

These results show that the increase was not uniform, but that there was sometimes a falling back, though it never got back in our experiments to the original quantity, but always showed that there had been a gain over the quantity with which we started. The gain during the last period of five days was almost the same as for the first period of five days. The results of the five-day periods indicate that the various changes going on in the soil are sometimes greater in one direction and sometimes in another direction. This is probably the case in a field. Still, where no nitrogen is removed from the soil but such as may escape into the air, the results show a net gain of 36 pounds for each million pounds of soil in 40 days, and for the nitrates in the soil, a gain of 94.8 pounds, which corresponds to the changing of 15.8 pounds of nitrogen into nitrates for each million pounds of soil.

BROWN SPOTS ILLUSTRATE EFFECTS OF TOO MUCH NITRATES

The nitrates, when present in too large quantities, will kill our cultivated plants, and we find that too much will also kill out these little plants that get their nitrogen from the air. The reason that these brown spots, of which the ranchmen complain that nothing will grow on them, are actually bare, is because of the presence of too much of these salts. I am sorry that I do not know how much or rather how little of these nitratres it takes to kill vegetation and that I do not know how they kill it, but it is certain that they kill. I put some sodic nitrate, from 5 to 25 pounds around each of a number of apple trees. I injured every one and killed one in four days. This was satisfactory proof that nitrate in too large doses, even 5 pounds to a tree, is poisonous to apple trees.

IRRIGATION IS CARRYING ALKALI FROM HIGH LANDS TO LOWER LEVELS

There is a very general notion that water brings the alkalis to the surface of the ground. There is no doubt but this is so in a certain measure, but it is also very often true in Colorado that it brings them "in", that is, that they are moved from the high lands to the low lands. This, however, can not well be the case with the two sections of country that we have told about in this bulletin, for the only high lands from which the alkalis could be washed are the mountains, and I have already told in what sense the alkalis are really washed from the mountains into the soil of the valley. But this is not what we mean when we speak of the alkalis being washed from high land down on the low land. In this case we mean that there is land, perhaps hills, into which former waters have carried alkalis and left them, or perhaps the alkalis now forming have accumulated there because there has not been water enough to wash them out before this, but now that we have been watering these lands, this water is carrying the alkalis to lower lands as it flows down to them. This is really happening in a great many places but the salts that are washed down into the low places were really formed in the high places, just as the "black alkali", told about in this bulletin was formed by the waters acting on the rocks of the mountains and has been carried down into the valley; and they would have all gone out of the valley with the water if the water itself could have gotten out. In the southern section of the San Luis valley the water has always been able to get out and the "black alkali" has gone out with it, because the soil cannot hold the "black alkali" back as it can the "white alkali". The same is true of the nitrates, the soil cannot hold them, they are easily washed out, and where the water runs out of a section it will carry both the "black alkali" and the nitrates out with it. This is the reason that we often find nitrates in waters. In our country this is true of water seeping out of the face of shale banks which have cultivated mesas or plateaus on top of them, or of water which may trickle along the surface of rocks, especially if it be the first portion that comes off, for nitrates may be forming on the surface of rocks; as well as on the surface of the land; but if these waters be sufficient to flow on they take the nitrates with them, if they evaporate on the surface, they may leave the nitrates. These have nothing to do with our brown spots, though these nitrates are formed by the same little plants as the nitrates in the brown spots. The formation of these nitrates is going on near, or at, the surface only, and they do not come up from any considerable depth, nor are they stored up in deep beds like common salt. It is unusual to find such quantities as we have except in arid climate. It is only in a few places that these salts are produced rapidly enough to accumulate in soils as they have done in some of ours and then under very different conditions. The formation of nitrates is going on in every soil and even on the surface of many rocks so their occurrence in any place where there has not been water enough to wash them out may be expected. I have found small quantities on the face of sandstones and more in the little pockets made in the sandstone by the winds. In these cases the nitrates were all on the surface. They do not penetrate in such cases to any depth. I do not know how deep they may go. I have given, on a preceding page, an instance in which the surface soil and ground-water were very rich in nitrates, rich enough to kill cattle, but the water obtained from the shales at 280 feet did not contain a trace. These salts are not usually found in any quantities in deep water. Some very deep wells may yield water containing four or even seven parts per million but this is about the limit.

In the cases that I have chosen to present the origin and character of our Colorado alkalis, we have not only the two big classes of "white", and the "black" alkalis in a large area, but we also have scattered through both areas occurrences of the nitrates in injurious quantities.

I have stated fully, without any reservations, the occurrences and composition of these alkalis, of the river-waters, of the ground-waters, of the soil, and of the well-water to a depth of 923 feet,and in none of these did we find any unusual amounts of nitrates, except in the brown spots, some of which proved to be so rich in nitrates that nothing would grow on them. The surface portions of the richest of these carried 5.6 percent of nitrates, calculated on the dry surface soil. These spots may be found anywhere in the San Luis valley, near the mountains or 20 miles away from them, but this would make no difference for there are only two things in this landscape, the mountains and the valley floor. There are no mesas, shales, or high lands from which these nitrates might come; besides, they are just in spots at first, though they may become numerous enough and grow big enough to run together and cover the better part, or the whole, of a large area of land.

I have explained how they come to be in these places, how the little plants enrich the soil in nitrogen by taking it from the atmosphere, how they, like other plants, die and their substance undergoes changes as other organic matter does. In our soils a large proportion of their nitrogen is changed into nitric acid or nitrates. So the nitrogen which is changed into nitric acid to form these nitrates does not come from the rocks, either as nitrogen or as nitrates, as the soda, lime, magnesia, chlorin and sulfuric acid, that form the white alkalis do, but is taken from the air by these plants just as truly as the carbonic acid is taken from the air by water which helps it to build up carbonates with the lime, magnesia and soda of the rocks.

SUMMARY

The alkalis that we usually meet with in Colorado are for the most part "white alkalis".

In a great many cases these are simply washed from the higher parts of the fields into lower parts, where the water gathers and, having no way to flow out, fills up the hollow and is removed by evaporation, leaving the alkalis. In this way a very bad-looking spot may grow to a considerable size. If this water could be let out by a drain this would be stopped.

When water carrying alkalis has to sink through the soil some of the alkalis are retained and the same is true of shales, so if moderate amounts of water have annually fallen on the surface where some alkali has formed, it will move it downward to leave it at a little lower level, so that together with the changing of any sulfide of iron by the action of the air, which will help to form sodic and calcic sulfate, any water that seeps out of banks of such materials may and often does carry a large amount of sulfates. Such waters should, if possible, be drawn out of a section by drains.

Our observation is that the bad effect of "white alkali" has been greatly over-estimated. There is, undoubtedly, a limit to the amount that may be present in a soil without danger to the crops, or trees grown on the land, but this limit is so high in the case of our soils that the danger line has not been observed.

We have not observed the death of any plant which we could with certainty attribute to "white alkalis", though we have seen some alkalis quite rich in magnesic sulfate.

The "black alkali", sodic carbonate, is very generally present in small quantities as a direct product of the action of carbonated waters on the rock particles, whether in the mountains or in the soils, but it passes into the drainage of the country to such an extent as to prevent its accumulation except under unusual conditions.

In one section of the State, which has been presented quite fully, unusual conditions occur and the "black alkali" has accumulated in injurious quantities. Irrigation by flooding, and the application of gypsum will probably lessen this evil but cannot be expected to wholly remedy the trouble.

The nitrates cannot properly be considered as alkalis in the sense that we use this term, but inasmuch as they are usually mistaken for "black alkali", and are injurious to crops, in the quantities that they occur in places, they have been discussed.

These nitrates are not derived from the rocks but are formed in several successive steps through the agency of small plants or micro-organisms which are present almost everywhere but which are much more active in our soils, especially in particularly favorable spots, than is usual.

"Black alkali", sodic carbonate, in small amounts, is said to favor the activities of these plants. The amount of sodic carbonate required to retard their development is greater than that which will injure the ordinary cultivated plants.

Bulletin 240 June, 1918

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

IRRIGATION BY MEANS OF UNDER-GROUND POROUS PIPE

By E. B. HOUSE

Fig. 6.—Subirrigated grain

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IRRIGATION BY MEANS OF UNDER-GROUND POROUS PIPE

By E. B. HOUSE

Many inquiries come to the Colorado Experiment Station from farmers of the State, concerning the installation of underground pipes for the purpose of sub-irrigation. This agitation on the part of the farmers is largely due to articles and advertisements published by our farm journals, daily papers, and weekly press, concerning this method of irrigation and the possibilities of tremendous crops whenever this system is installed. In order that these inquiries may be fully answered as far as certain sections and certain soils of the State are concerned, this bulletin is written.

In 1913 a business firm in the State of Colorado requested the State Agricultural College to allow them to install, on land to be chosen by the college, a subirrigation system. The Station in return was to furnish them with these data collected, and also with the conclusions to be drawn from these data. It was also agreed by both parties that a bulletin was to be published after the experiment had been running a sufficient time to give fairly reliable results.

A piece of land satisfactory to all parties was selected on the West College Farm. The area of this piece of ground was approximately 2½ acres. There was growing on the land selected for the experiment (1) an apple orchard, covering about one-third of an acre, (2) an alfalfa field of .7 acres, one year old at the time the subirrigation system was installed, (3) across the road to the north a tract of ground having an area of 1.6 acres. This land had just been plowed and upon this tract, it was planned to try out different cereal crops.

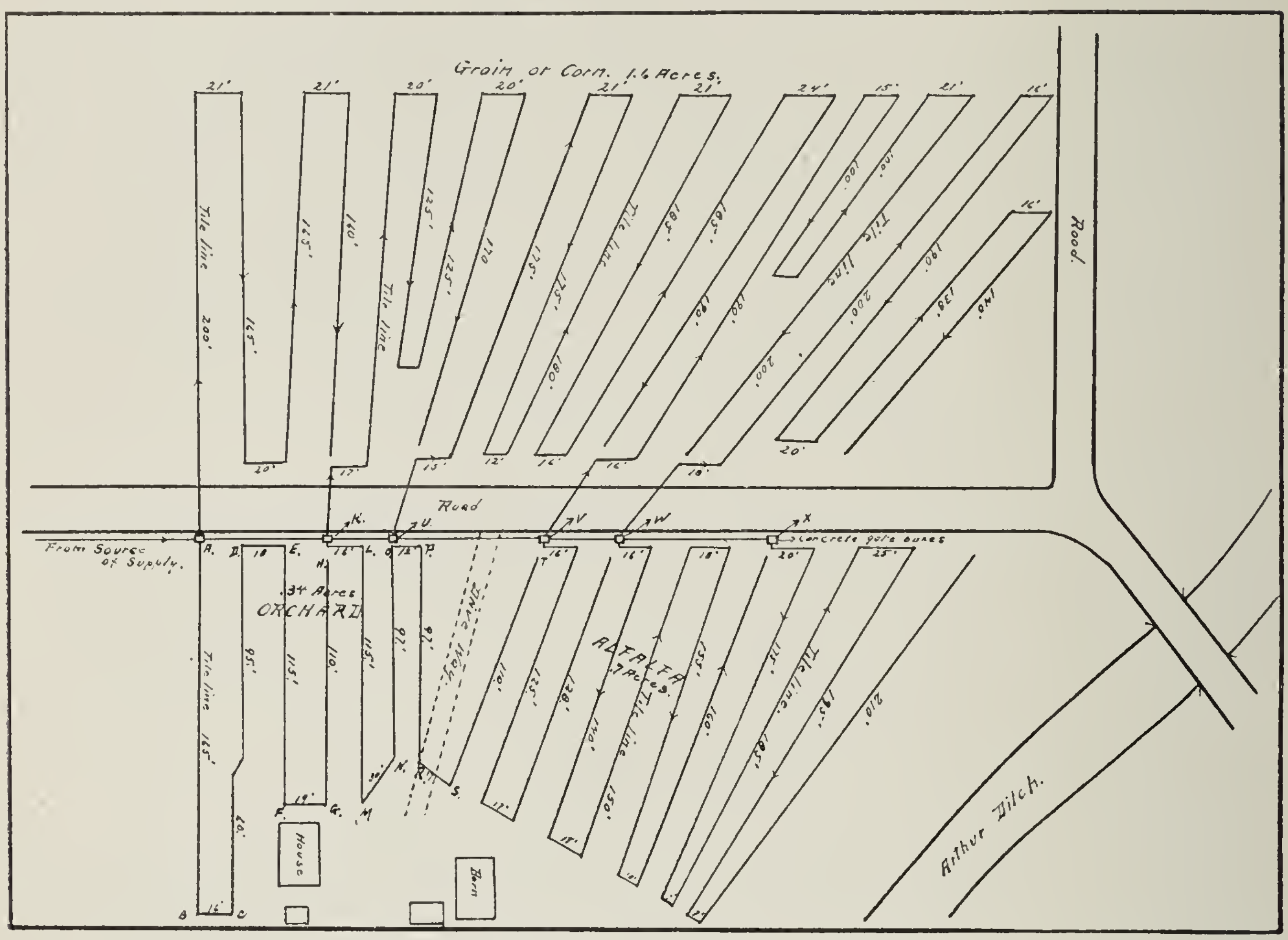
WATER SUPPLY

The water for the subirrigation system was supplied by a drain the outlet of which entered an irrigation ditch on the College farm, some 250 feet west of the tract chosen for subirrigation work. This drain furnishes an ample supply of water throughout the year for the purpose of subirrigation, but the quantity varied somewhat at different seasons. At no time, however, did the supply drop to so small a quantity as to make it impossible to keep the subirrigation pipes full.

INSTALLATION

The company sent their expert to plan and supervise the construction of the system. Figure 1 shows the plan of the subirrigation system as laid out by this expert.

Under his direction a careful survey was made and the pipe lines staked. These pipe lines coincided approximately with the contour of the ground. It should be stated that the orchard is practically level north and south, with a slight fall as one passes to the east. The alfalfa field is on a side hill, sloping down to the Arthur Ditch, the maximum slope being southeast. The grain field to the north of the road, however, has not as great a slope but it is similar in character to the orchard and alfalfa field mentioned above.



PLAN OF SUBIRRIGATION SYSTEM.

Fig. 1.

DESCRIPTION OF SYSTEM

It will be noted from Fig. 1 that the subirrigation system as installed consisted of a main supply line of 6-inch porous tile, running from the outlet of the drain connected with and supplying water to the four concrete wells, or boxes, marked A, K, U, V, W and X. Details of these boxes are shown in Fig. 2.

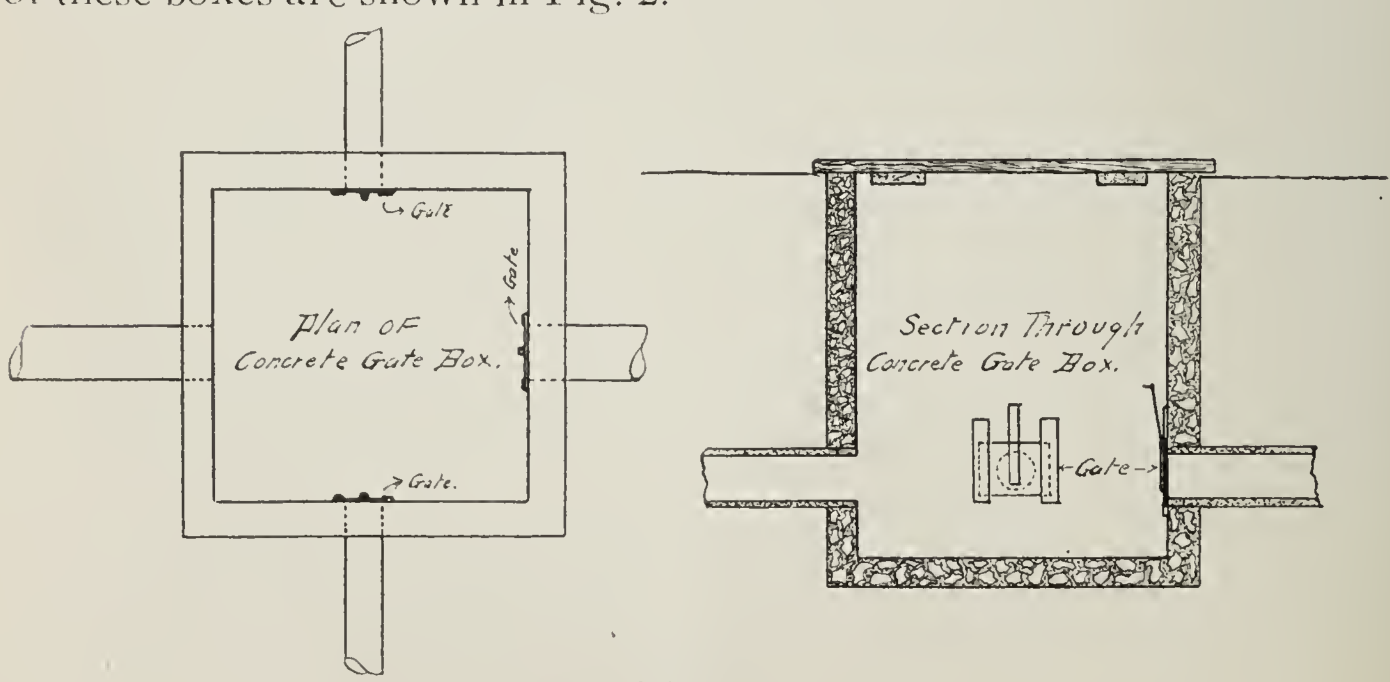


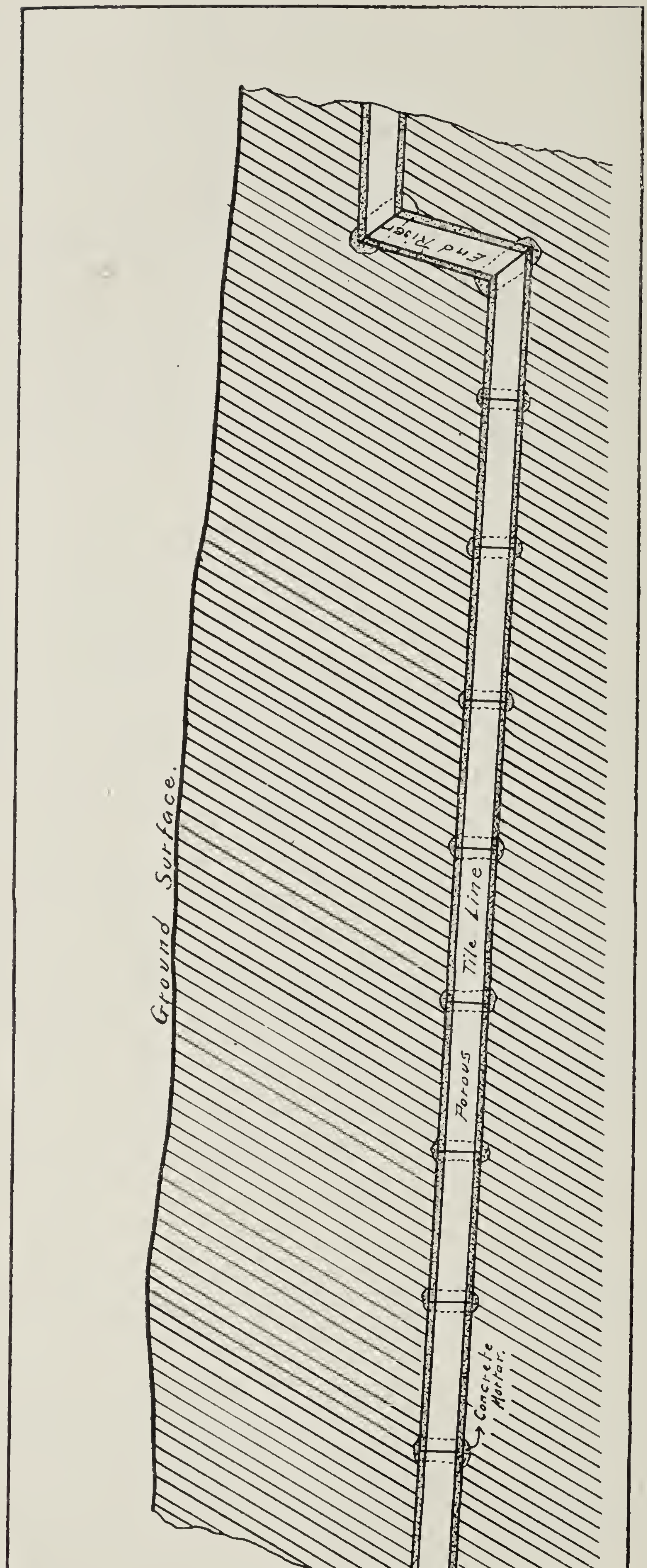
Fig. 2.

These boxes were constructed of concrete. They were 2 feet square at the top and 2½ feet deep. The side walls and bottom were 3 inches thick. Gates were placed in each box that the water supply in all lines leading from the box might be controlled. These gates were of ordinary galvanized iron, fitted in slides and placed so as to cover the entrance to the pipe line running from the box.

From Fig. 1 it will be noted that the subirrigation system was laid out in sections. Section No. 1 is made up of the lines A-B; B-C; C-D; D-E; E-F; F-G and G-H, the section ending at point H. Section No. 2 takes its water from the box K, and is made up of the lines K-L; L-M; M-N; N-O; O-P; P-R; R-S; and S-T, the section ending at point T. The remaining sections are similar and may be easily followed on Fig. 1.

SLOPE OF LINES

The long lines, such as A-B; C-D; E-F; etc., were carefully laid on a grade of 1/10 of a foot per 100 feet. These lines were so laid out on the field that this grade could be obtained and the lines kept approximately 2 feet below the surface at all points, except the extreme end of each line. The short connecting lines such as B-C; D-E; F-G; etc., were given the grade of the country at that place. These connecting lines vary from 7 to 30 feet in length and there may be a fall as great as 1 foot in this distance. In other words these short connecting lines were laid "on grade" but the grade varies with each line, the idea being simply to get down to the beginning of the next long line in order to fill that line with water and keep the same under a pressure head of approximately 1 foot.



Sectional View of Tile Line in Ground.

Fig. 3.

Fig. 3 represents a sectional view of ground and tile line. It will be noticed that at the end of this tile line is an upright section of tile called "end riser". This end riser was constructed by dressing off a section of tile and fitting it as shown in Fig. 3 to the horizontal line. This raises the end of each horizontal tile line about 1 foot in height. It is then carried at this elevation for one section of tile, (1 foot) and then given the grade of the connecting line, which is sufficient to bring the lower end of the connecting line 2 feet below the surface of the ground at the point where the short connecting line joins the next long distributing line. In Section No. 1, therefore, end risers would be found at points B, D, F and H. In Section No. 2 they will be found at M, O, R, and T.

THE TILE

The purpose of this end riser is to produce a pressure head of approximately 1 foot in each tile line before the water passes from the same, through the short connecting line, to the next long line.

The porous tile used for this system of subirrigation was a tile manufactured for this purpose by the company. It is impossible to state exactly how this tile was made and what material was put into the same. It was a secret process and the company was not at liberty to state the manner of manufacture. It may be stated, however, that these tile had the appearance of tile manufactured from cinders, sand and cement. They were guaranteed by the company to be porous enough to pass water freely, and yet to prevent any roots from entering and clogging the same. That they were porous enough to pass water was demonstrated, and also that roots from trees and alfalfa did not enter and clog the tile was also demonstrated as the experiment progressed.

The tile, however, were very soft. So soft that a great deal of difficulty was encountered in transportation. In the first shipment made fully one-half of the tile were found to be broken when the car was opened. Another shipment was ordered and that arrived in about the same condition, so that a third shipment was necessary in order to secure sufficient tile to complete the lines planned for the subirrigation system.

The tile were laid in the trench approximately 2 feet deep as ordinary drain tile are laid, with this exception, that each joint was carefully sealed with cement mortar. These mortar joints are shown on Fig. 3.

SIZE OF TILE

The tile can of course be made in any size desired, but the size recommended for the ordinary lateral line in a system of this kind was 2¾ inches, inside diameter. This makes the tile approximately 4 inches, outside diameter.

COST OF SYSTEM

The cost data for installation of this system are as follows:

300 feet 6-inch tile at 6c per foot	$ 18.00
7,382 feet 2¾-inch tile at 4c per foot	295.28
7,682 feet of trenching, laying tile and back-filling at 2.8c per foot	215.10
Hauling and distributing tile	3.48
Galvanized iron headgates	8.00
Construction of concrete boxes	18.65
Surveying	17.50
Total	$576.01

The amount of land irrigated by this system is 2.64 acres, making the cost per acre for installing a subirrigation system of this kind $218.18.

SOIL

The soil on the piece of ground covered by the subirrigation system is fairly uniform and is a deep silt loam. Just how deep this surface soil is cannot be stated, but investigations were made to a depth of 12 feet with a soil auger and they showed the same uniform silt-loam soil all the way down. It is a soil that could be called retentive, as far as moisture conditions are concerned, but it is a soil that would take water rather slowly and one would expect lateral percolation of the water to be fairly good.

SPREAD OF THE WATER FROM THE PIPES

Investigations were carried on from time to time to ascertain the spread of water from the pipe line. These investigations were made with a soil auger. Borings were made in lines at right angle to a tile line. The holes were spaced 6 inches apart. During the first part of the experiment soil samples were taken and the moisture content determined. In the latter part of the work this system was abandoned, and the lateral percolation of the water was determined by means of the soil auger alone. The results obtained in this part of the work were not very satisfactory. The data show a great variation in the lateral percolation of water from different lines, and also a large variation in this percolation of water on the same line at different places. Approximately an average condition is shown in Fig. 4.

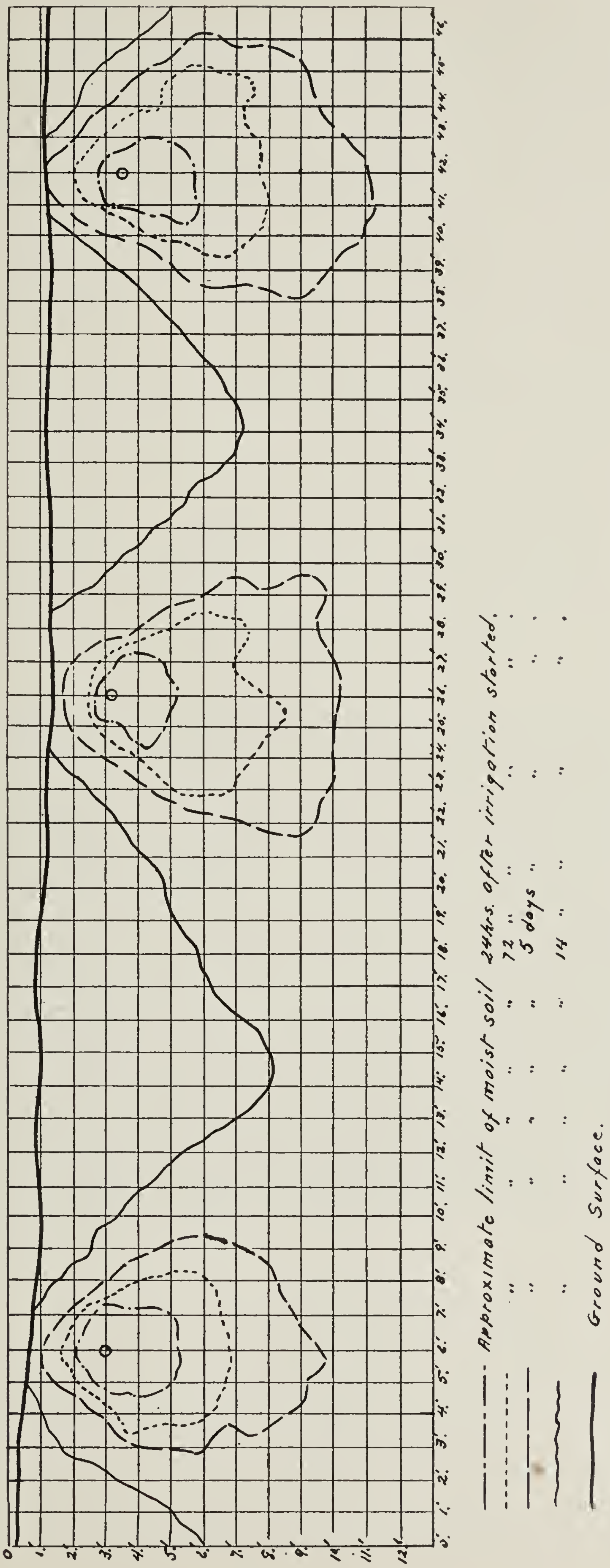


Fig. 4.—Percolation from subirrigation pipe line

Fig. 4 shows three tile lines. The first two are 20 feet apart, the second and third, 16 feet apart. It shows the progress of the percolating water from 24 hours to 14 days. The horizontal and vertical divisions represent 1 foot. From this drawing the lateral downward and upward percolation of the water may be easily ascertained. We find that, in this soil, moisture has a tendency to percolate downward much faster than to the side, and the depth of the moist soil between lines is such as to be beyond the reach of roots of many plants. This condition is further developed in studying the crops grown upon the ground and will be spoken of again.

AMOUNT OF WATER REQUIRED TO SUPPLY TILE LINES

The amount of water necessary to keep the tile lines full, varied with the amount of moisture in the soil and the length of time irrigation had been in progress. When irrigation was first started, .2 of 1 second-foot of water was sufficient to keep all tile lines full. As the irrigation proceeded it was necessary to cut down the amount of water supplied, or the water would rise in the cement boxes and overflow. During the latter part of an irrigation approximately .1 of 1 second-foot was sufficient to supply all pipe lines.

CROPS GROWN

During the four years that the experiment was in progress, the apple orchard mentioned above and shown in Fig. 1, thrived. All the irrigation water that it received was from the subirrigation system. The tile lines in this orchard were run about 4 feet to one side of a row of trees and within easy reach of the roots. The foliage of the trees would always respond to the application of water and a few days after the water was turned into the pipe lines, this foliage changed color slightly and looked fresher than it did preceding the irrigation period. No records were kept of the crop produced from this orchard as it was an old orchard and had been neglected for a number of years.

ALFALFA

The installation of the subirrigation system injured the alfalfa somewhat for the first year after installation of the system. The trenching cut out many plants, and the dirt at the side of the trench injured the first cutting of alfalfa materially for 1913. In 1914, '15 and '16, however, this alfalfa did well. The stand was even at the start and continued so. The roots of the alfalfa seemed to be able to reach plenty of moist soil, even at the midway points between tile lines. Fig. 5 shows a typical view of this alfalfa field. The alfalfa always responded immediately to the irrigation from the underground pipes, and within two days after the water was turned on at any time the foliage of the plants would show the effect of the water.

Water was applied at intervals during one winter on this alfalfa field to show the effect of winter irrigation applied in this way. In the spring the plants started a very thrifty growth, and no injurious effects whatever were noticeable from the winter irrigation of this field.

The record of the yield from this field is as follows:

1913—Alfalfa was not cut.
1914—With subirrigation 3.02 tons.
1915—3.02 tons.
1916—1.5 tons.

Two irrigations were applied to this field in 1913, three in 1914; winter irrigation during the winter of 1914 and 1915, together with two irrigations during the summer of 1915. Only one light irrigation was given to the field in 1916.

Fig. 5.—Subirrigated alfalfa

CROPS GROWN ON GRAIN FIELD

For the season of 1913, immediately after the subirrigation system was installed, the grain field was planted to barley and potatoes. The irrigation water was immediately turned on, about .1 of a second-foot, was kept running in the lines for 15 days, then shut off. The crop came up but was very spotted, and as it developed it showed a luxuriant growth immediately over the tile lines, becoming gradually poorer as the distance from the tile became greater until the middle point between two lines was reached. Especially was this true on the lines that were furthest apart and there practically no crop at all was grown.

This was true of both the potatoes and the barley. Fig. 6 is a photograph of this field, and illustrates the condition mentioned above. The crop of barley did not mature and was cut for feed. The potatoes were not worth digging. These two crops showed without question that the plants at distances greater than 5 feet from the tile lines did not receive sufficient water, and the subirrigation system was not able to supply it.

GRAIN FIELD FOR 1914

This field was seeded to wheat for the season of 1914, and although the season was fairly wet and a great deal of grain matured in this section of the country without any irrigation whatever, yet this field showed the same characteristic as mentioned for the barley field, but to a less degree.

Fig. 7 shows the spotted condition of the field due to a lack of water between tile lines. This wheat yielded about half a crop for this season.

Fig. 7.—Subirrigated grain

GRAIN FIELD FOR 1915

The crop on this field for 1915 was corn, and the field produced as well as any field on the farm. This was due to the fact that the summer of 1915 was much wetter than usual. Although not a great excess of rainfall came, yet it was so distributed that the summer was without any drought and crops not irrigated did about as well as crops under irrigation. For this reason it was not considered a fair test for the subirrigation system and no records were kept for the season of 1915.

GRAIN FIELD FOR 1916

Corn was again planted on this field for the season of 1916. It came up well and for a time gave promise of again giving a good yield. The season of 1916 was normal in this section of the State, and gave a splendid test of the effect of the irrigation water upon the corn crop on this field. Two irrigations were given during the season, and at the end of the same 12,411 pounds of corn were harvested for ensilage. The corn on this field during the season showed again the injury due to insufficient water between the tile lines, and tall thrifty corn grew directly over or in the vicinity of the tile lines, with a short stunted growth midway between the same. This is well shown in the accompanying photographs Figs. 8 and 9. Figure 8 shows the corn growing upon the subirrigation tract, and it is to be noted that the stalks midway between the two lines are as high as the waist of a man standing in the field. Whereas, the corn at the right and left of him immediately over the tile line is more than 6 feet high. This is good for Colorado corn.

Fig. 9 shows an adjoining corn field planted at the same time, and given the same attention as that shown in Fig. 8, with the exception that this corn field was surface irrigated in the ordinary way. The height of this corn is uniform and is approximately the same as the height of the corn directly over the tile lines shown in Fig. 8.

Fig. 8.—Subirrigated Corn

Fig. 9.—Surface-irrigated Corn

CONCLUSION

The conclusions drawn from this experiment are as follows:

1. Subirrigation by means of underground pipe is not to be recommended for any of the ordinary farm crops on account of the excessive cost for installation. It can be recommended only for the most intensive farming where water is very scarce and valuable, and only a small stream is available.

2. The lateral percolation of the water from the tile lines in deep silt-loam soil is not sufficient to warrant these lines being placed from 16 to 25 feet apart. More water percolates downward than upward or to the side, and it would be necessary to place these tile lines not more than 8 feet apart in order to bring the moisture to the roots of the growing crop. This applies to soil similar to that on the subirrigated field at the College farm only. It may be, and probably is, a fact that with a hard-pan or an impervious stratum of some kind slightly below the tile, and especially in early or porous soils, the lateral percolation of the water would be increased very much and the success of a system, with tile lines as far apart as 16 or 25 feet, could be guaranteed, but in deep silt-loam soil the lateral percolation of the water is disappointing.

3. With deep-rooted crops, such as alfalfa, or with orchards, this form of irrigation may be practiced with success as far as lateral percolation is concerned, but the cost of installation is so great that it cannot be recommended.

4. There has been no clogging of the lines due to the entrance of roots for the four years that the system has been in service.

5. The water used for this system was drain water which contained some alkali, but it was evidently not sufficient to cause disintegration of the tile lines as no trouble on this score was encountered.

6. A very small stream of water can be sucessfully used with a subirrigation system of this kind. A stream that would not answer at all for surface irrigation might be more than ample to supply a pipe system for subirrigation on a much larger area.

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THE HOME VEGETABLE GARDEN

By R. A. McGINTY

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THE HOME VEGETABLE GARDEN

By

R. A. McGINTY*

The scarcity and increasing cost of all kinds of foodstuffs make it necessary that everyone do what he can to relieve the situation. Much can be accomplished along this line by practicing economy in the use of foods and by increasing their production. In this connection, the home vegetable garden is of the greatest importance. Wherever there is a small area of ground adjacent to the home and suitable for cultivation, it should be made to produce something in the way of vegetables for home use. In towns and cities, back yards are often allowed to grow up to weeds, or remain unproductive because the owner is unfamiliar with the principles of vegetable culture which would enable him to realize considerable profit and pleasure from such a piece of ground.

The experienced gardener will find in these pages very little that he does not already know. This bulletin is published with the hope that it will assist those who are less experienced, but who wish to learn something of the art of growing vegetables. While many details of culture, which are important to the commercial gardener, must be omitted, it is hoped that the information contained herein will enable the amateur gardener to plant and cultivate his crop more intelligently.

THE PURPOSE OF THE GARDEN

The main purpose of the garden is, of course, to supply a quantity of fresh vegetables for the table during the growing season, but there are other purposes which the garden may be made to serve. These are to supply vegetables for canning and drying, and for storage, to be used during the winter.

There is a tendency with many gardeners to plant too many varieties of vegetables of a perishable nature and not enough of those kinds which may be stored successfully. Consequently, during the growing season, great quantities of such vegetables as radishes, lettuce, string beans, etc., go to waste, and when the fall of the year arrives, there are comparatively few carrots, onions,

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cabbage, and turnips to store for use during the winter. In some cases, the extra vegetables may be canned or dried, but, unless the aim is to do that, only what can be utilized should be planted.

WHAT TO GROW IN THE GARDEN

Whether the garden is located in the city or in the country will determine to some extent the kind of vegetables that should be grown. In the country, where space is not limited, anything which the gardener fancies may be grown. In the city, however, the garden plot is usually small, and it is necessary to forego the pleasure of growing those vegetables which take up considerable room. Squashes, melons, cucumbers, and sweet corn take up a large amount of space in comparison to the quantity they produce, and should, therefore, be left out of the small garden. Small gardens are usually located where space is valuable, and should, therefore, be cultivated intensively. By so doing, they may be made very profitable.

Individual taste will, of course, determine, in great measure, the kinds of vegetables grown, but the gardener should endeavor to provide a continuous supply of a good variety of those which he prefers, both for summer and winter use.

LOCATION OF THE GARDEN.

The city gardener has little choice in the matter of location—he must use what is available—but where space is less limited, a location having the following features is desirable: Near as possible to the house, for convenience; a southern or southeastern slope, for warmth and drainage, with buildings or trees on north and west sides for protection.

SOILS

Somewhat sandy soils are preferable for vegetables for several reasons. However, the soil may be easily modified by proper treatment, and no one should be discouraged because he does not happen to have just the right type.

Sandy soils dry out earlier in the spring, are warmer, more easily worked, do not become so hard from tramping, and in general produce earlier crops than the heavier clay soils.

If the soil is inclined to be too sandy, the addition of stable manure will cause it to hold water better, while, on the other hand, a clay soil is made lighter and more friable by the application of manure.

FERTILIZERS

Stable manure should be the chief dependence of the gardener for plant food material and should be applied at the rate of 25 or

30 tons to the acre in the fall before the ground is worked. If applied in the spring, it should be well decayed in order that the elements needed by the plants may be in available form.

Other kinds of manure besides stable manure are sometimes used. Cow manure used exclusively has a tendency to cause the soil to become compact and hard; sheep, chicken, and hog manure are concentrated forms that should be used somewhat sparingly and with care. Compost made of decayed leaves, plants, and other vegetable matter is valuable for applying to soils lacking in humus. No diseased plants should be used in making the compost. Wood ashes contains important elements of plant food and should be saved. Coal ashes, however, have no value as a fertilizer.

PREPARATION OF SOIL

The ground should be plowed or spaded up in the fall, if possible (an application of manure having been made previously), and left rough over winter. The depth to which the ground is broken should be sufficient for the development of long-rooted crops, such as carrots, parsnips, and beets. Usually six to ten inches is about the right depth. In the spring, the ground is simply harrowed or raked smooth when ready to plant.

When the soil cannot conveniently be prepared in the fall, it may be done in the spring. One advantage of fall preparation is that there are often two or three days in the early spring when such vegetables as onions, turnips, radishes, etc., may be planted, but not enough nice weather both to prepare and to plant the ground. Perhaps by the time the ground can be put in shape for planting, and before actual planting can be done, unfavorable weather sets in, and the ground is not in condition again to plant until too late for best success with vegetables that require early planting. Also, the action of the weather during the winter breaks up any clods and leaves the ground in good physical condition.

The importance of thorough preparation cannot be over-emphasized. A plot of ground properly prepared is easily and satisfactorily handled throughout the season, while a poorly prepared garden is difficult to handle, and not apt to give satisfactory results.

PLANNING THE GARDEN

In order to make the best use of the land devoted to the garden, it is well to make a planting plan on paper some time in advance of the date for sowing the first seeds. This plan should show the number, location and distance apart of the rows of vegetables, so that at planting time the work can proceed without delay. The different crops should be grouped somewhat according to their cultural requirements and length of season required to mature. By grouping together such crops as lettuce, radishes, spinach, etc., which require a short season, the ground may be utilized for planting another crop after these are out of the way. By planning ahead, the portion of the garden devoted to cabbage or cauliflower may be made to produce a "companion crop" of green onions. If the cabbage rows are to be 2½ feet part, plant the onions as early as the ground can be worked, placing the rows half way between where the cabbage rows will be planted later. The cabbage plants will be set out sometime later, and before they need all the room the onions will be gathered and out of the way. Radishes, lettuce, and beets are also often grown as companion crops.

Where horse cultivation is to be practiced, the rows should run the long way of the garden, so as to avoid turning as much as possible. In the small garden, where most of the cultivation is by hand, this is less important.

ROTATION OF CROPS

The same varieties of vegetables, or those closely related, should not be grown in the same part of the garden year after year. It is a good idea to follow root crops with those which bear their edible parts above ground, and vice versa. In this way, many plant diseases and insect pests may be avoided.

If the crops have been grouped according to cultural requirements, about all that is necessary for rotation is to shift the groups.

GARDEN SEED

In most of the larger towns and cities, there are reliable seed stores which carry good seed of the standard varieties of vegetables. In the smaller towns, however, it is often impossible to get dependable seed at home. In such cases, it is recommended that the gardener order seed from some well-known seed house.

It is not often advisable for the gardener to try to save his own seed unless he is familiar with the principles of plant breeding. Such seed is usually more or less impure, and, therefore, not the most desirable kind for planting.

Seedsmen advertise very widely certain "novelites" and "new creations," which appear to have superior qualities, but it is best for the gardener to plant standard, well-proven varieties for the most part, and leave the novelties alone until they have been well tested.

Only good seed, of course, should be used in planting. Seed which is too old or that has been injured in any way should be thrown away. When there is doubt as to the power of seed to germinate, it should be tested at home, or a sample sent to the Seed Laboratory, Colorado Agricultural Experiment Station, Fort Collins, Colorado, where it will be tested free of charge.

It is important that the supply of seed be ordered some time in advance of the planting season, so as to be sure of getting the desired varieties and to avoid any delay in planting.

Those who have grown but few vegetables often find trouble in estimating the quantity of seed necessary to plant the garden, and either buy too much or too little seed. Accordingly, the table below is given, showing amount of seed and plants necessary for 100 feet of row, together with planting distances.

PLANTING TABLE

Amt. of Seed Required and Distance Apart of Plants and Rows

VEGETABLES	100 Ft. of Row		Distance Apart of Rows		Distance Apart
	Seed	Plants	Horse Cultiv.	Hand Cultiv.	Plants in the Row
Beans	1 qt.		2½ ft.	1½- 2 ft.	4 in.
Beets	2 oz.		2½ ft.	1 ft.	4 in.
Brussels Sprouts	1 oz.	80	2 ft.	1½ ft.	15 in.
Cabbage	½ oz.	65	3 ft.	2½ ft.	15-18 in.
Carrot	1 oz.		2½ ft.	15-18 in.	4 in.
Cauliflower	¼ oz.	50- 65	3 ft.	2 ft.	2 ft.
Celery	⅓ oz.	200	4 ft.	2 ft.	6 in.
Corn, Sweet	½ pt.		3½ ft.	2½ ft.	1 ft.
Cucumber	1 oz.		6 ft.	4 ft.	2-4 ft.
Kohlrabi	⅓ oz.	100	2 ft.	1½ ft.	1 ft.
Lettuce	¼ oz.	125-200	2 ft.	15 in.	6-10 in.
Muskmelon	1 oz.		6 ft.	5 ft.	3-6 ft.
Onion Sets	⅔ qt.		2 ft.	15 in.	2-3 in.
Onion Seed	½ oz.		2 ft.	15 in.	2-3 in.
Parsley	½ oz.		2 ft.	15 in.	4 in.
Parsnips	½ oz.		2½ ft.	1½ ft.	4 in.
Pea	½ pt.		3 ft.	2 ft.	4 in.
Pumpkin	½ oz.		6 ft.	4 ft.	4 ft.
Radish	1 oz.		2 ft.	1½ ft.	1-2 in.
Salsify	1 oz.		2 ft.	1½ ft.	2 in.
Spinach	1 oz.		2 ft.	1 ft.	2 in.
Squash, Late	½ oz.		7 ft.	5 ft.	3-6 ft.
Tomato	⅛ oz.	35- 50	4 ft.	2 ft.	2-4 ft.
Turnip	½ oz.		2 ft.	15 in.	3 in.
Watermelon	½ oz.		8 ft.	6 ft.	3-8 ft.

HOTBEDS AND COLDFRAMES

Full details of making and handling hotbeds and coldframes may be found in Bulletin 221, Colorado Experiment Station, Fort Collins, Colorado. Every gardener who can should have one or both of these structures in order to secure such plants as tomatoes, cabbage, cauliflower, etc., for transplanting and to grow early crops of such vegetables as radishes and lettuce.

TIME OF PLANTING

In view of the varying conditions of climate, altitude, and latitude, it is not practicable to give planting dates for all parts of Colorado. The following, therefore, are given as the approximate dates for planting in the vicinity of Fort Collins. The time will vary north and south of this point and also as regards altitude. Approximately ten days difference may be allowed for each 1,000 feet of altitude and 100 miles of latitude.

It is necessary, in the case of many vegetables, of course, to start the plants inside during March or April. In order to do this, some place where the temperature can be controlled is necessary. Hotbeds, coldframes, small greenhouses, and even well-lighted windows on the south side of the house are suitable for this purpose.

March 1st to 15th

Sow seeds of the following in shallow boxes of light soil and grow in a warm living room or hotbed. After plants have developed three or four leaves, transplant into other boxes, putting plants about two or three inches apart each way:

- Cabbage
- Celery
- Cauliflower
- Tomatoes

April 1st

Outdoors: Plant one-year-old roots of asparagus.
Divide old roots of rhubarb and plant.
Plant root cuttings of horseradish.
Put out onion sets.

Indoors: Sow seeds of Brussels Sprouts.

April 15th

Sow seeds of the following in the field:

- Lettuce.
- Radishes
- Kohlrabi
- Onions
- Parsley
- Peas
- Spinach
- Turnips
- Parsnips
- Salsify

April 25th

Plant in the field:

- Beets
- Carrots
- Cauliflower Plants
- Swiss Chard
- Cabbage Plants

May 15th

(After danger of frost is past.)

Plant in the field:

Beans
Sweet Corn
Tomato Plants
Melons
Celery Plants (Early Crop)
Cucumbers
Spuashes
Brussels Sprouts Plants

SOWING THE SEED

It is very essential in planting garden seeds that the soil be in the best possible condition for working. In order to germinate, the seeds must have sufficient moisture and must come in close contact with the soil particles. Therefore, the soil must be as free as possible from clods and not too dry.

If the soil becomes too dry before planting, it will be necessary to irrigate in order to cause the seed to germinate. This should be avoided as far as possible, especially with the smaller seeds, but, if necessary, the water should be applied in a furrow slightly to one side of the row.

In large gardens, there is an advantage in sowing seeds with a seed drill, but in the small garden it is more expedient to sow them by hand. Most seeds, the small ones especially, should be planted more thickly than the plants will stand later, because some of the seeds will fail to germinate. If too many come up, they are thinned out.

Furrows for planting should be made as straight as possible, not only because they look better that way, but because cultivation and irrigation can be better and more satisfactorily done while the crop is growing. It is well to use a line in laying out the rows, if it can be done conveniently. For small seed, such as radish, lettuce, onion, carrot and parsnips, the mark made by drawing the end of a rake or hoe handle along a stretched line is deep enough for planting. Beans, muskmelons, and cucumbers should be planted about an inch deep, while peas and corn may be planted at a depth of two or three inches.

After the seeds have been covered, the soil over them should be slightly compacted to bring the soil particles in close contact. This may be done with the back of a hoe or rake, or by putting a long narrow board directly over the row and walking on it. Seed drills have a small wheel behind which presses the soil over the seeds somewhat.

THINNING

It is important that most vegetables be thinned, in order to secure normally developed plants. Thinning should usually be done about the time three or four leaves have developed so that the young plants will not grow too spindly by being crowded.

Radishes are usually thinned by pulling and using those which have developed sufficiently, leaving the others to grow for a longer time. Lettuce is sometimes treated the same way, but head lettuce should be thinned when the plants are small, otherwise good heads will not develop. Young beet thinnings are ordinarily used for greens. In thinning onions, the ones removed are often used as green onions and those which remain are allowed to mature, but thinning should not be postponed too long, or the mature onions will be small.

The strongest plants should always be left in thinning and enough room given them to develop properly.

SETTING PLANTS IN THE FIELD

The seeds of tender vegetables requiring a long growing season cannot be planted in the field early enough to produce a crop. Consequently, such crops must be started in March or April in hotbeds or greenhouses, or in some place where temperatures can be controlled and the plants set in the open after danger of frost is past. Plants can be grown at home or obtained from greenhouses or from people who make a business of growing them. Such plants should be vigorous, thrifty, and properly hardened off, so that when set in the field they will continue growth with as little delay as possible.

Transplanting is preferably done on cloudy days or late in the afternoon. If the soil is moist (transplanting should not be done when the ground is wet) it is not necessary to water the plants, but if it is dry, irrigation should follow closely after planting, or a small amount of water may be poured in the holes before the plants are set. In setting the plants, a mulch of dry soil should be put around them to prevent loss of water by evaporation.

A few hours before transplanting, it is a good idea to give the plants a good watering in order that their tissues may be full of water when they are set out. Cabbage plants, and others having large leaves, should usually have about one-half of their leaf surface removed to prevent them from wilting. The plants should be set somewhat deeper than they stood in the seedbed or box. Shading is practicable where only a few plants are involved, but the shade should be removed after two or three days.

CULTIVATION

If the garden is properly prepared to begin with, cultivation during the growing season is a comparatively simple matter, consisting of keeping the surface soil well stirred and preventing weed growth. In the small garden, the cultivation will be done by hand; hoes, rakes, and hand-wheel hoes being used. The latter are very serviceable implements and one should be owned by every gardener who can afford it. The farm garden, being on a larger scale, should be cultivated for the most part with horse-drawn cultivators, those of the seven and twelve-tooth types being desirable for the purpose.

Cultivation, as a rule, should be shallow and frequent. A depth of two or three inches is about right, and once every ten days is none too often to give the ground a good stirring. After each irrigation, as soon as the soil is dry enough, the irrigation furrows and surface soil should be cultivated, in order to conserve the moisture which has just been applied, and to prevent baking of the surface of the ground.

The gardener should continue to cultivate throughout the season. In early spring, he is usually enthusiastic and gets the garden started in good shape, but, as the summer advances, he loses some of his ardor and very often allows it to grow up to weeds. Consequently, he fails to reap a large part of the benefit which would have come had he persisted in giving it proper attention until the end of the season.

IRRIGATION

While the various vegetables require different amounts of water, it is thought advisable to treat the matter in a general way to avoid useless repetition. Vegetables contain from 85 to 90 percent of water, so it is very necessary that they have plenty of moisture. The soil in which the plants are growing should be moist at all times, and the plants should never become wilted or checked for lack of water. This condition is best maintained by thorough but not too frequent irrigation. The soil should be wet to a good depth and then not irrigated again until needed. This causes the plants to send their roots deeply into the soil, and economizes the use of water. Frequent, light irrigations induce a shallow root system, so that plants are much more easily affected by dry weather.

The furrow method of irrigation is preferable. It is more economical of water than the flooding method and is one factor in controlling plant diseases. Where a garden is irrigated with a lawn sprinkler, the tendency is always to give too little water. The soil appears to be wet when in reality it is not. If this method is used, the garden should be thoroughly soaked and not sprinkled again for a week. Small sprinklings every day or two will cause the plants to be shallow rooted.

GARDEN INSECTS AND DISEASES

Every gardener who has, or anticipates, any trouble with insects or plant diseases should obtain from the Colorado Agricultural Experiment Station, Fort Collins, copies of the following bulletins, which give information which will help him recognize and control these pests:

"Diseases of Colorado Crop Plants," Bulletin No. 212.

"Insects and Insecticides," Bulletin No. 210.

Farmers' Bulletin 856, "Control of Diseases and Insect Enemies of the Home Vegetable Garden," may be obtained from the Division of Publications, U. S. Dept. of Agriculture, Washington, D. C.

ASPARAGUS

If the plants used are purchased from a seedsman, good one-year-old plants should be procured. One may grow very satisfactory plants from seed. The seed are gathered when ripe and put in water in order to soften the pulp which surrounds them. They are mashed up and the hard seed worked out, washed, and dried. They are stored during the winter and planted in the spring. The rows should be two and a half or three feet apart to permit horse cultivation and the seed planted one to two inches apart in the row and about one inch deep. Seed may also be purchased from reputable seed houses. These plants will be ready for transplanting the following spring.

Asparagus plants are either pistillate or staminate, the former producing seed while the latter do not. It has been shown by experiment that the staminate plants produce the largest crop and these should be used when possible. It is hard to distinguish between the male and female plants before the end of the second year, when the seed are produced for the first time. Therefore, if plants are left in the seedbed until two years old, they may be separated and the male plants only used for planting.

When ready to set out the plants, trenches or furrows four and one-half or fiive feet apart and six to seven inches deep are made in the field, and plants set in the bottom of the furrows about two feet apart. When set, the plants are covered with two or three inches of soil. The furrow is not entirely filled at the time of planting, but this is done gradually during cultivation. To grow blanched asparagus, the plants are usually set a few inches deeper.

Clean cultivation is given during the summer, and before winter comes, the tops should be cut off and burned, after which a mulch of well-rotted manure three or four inches deep should be put over the bed. This prevents alternate freezing and thawing during the winter, which is detrimental to the plants. Manure which is free from weed seeds is best, and it may be worked into the soil in the spring.

Cultivation begins in the spring as soon as the ground can be worked and is kept up throughout the summer. None of the young shoots should be cut the second spring, as the plants will be much stronger if left undisturbed until the third spring. The crop is given practically the same culture each year. Shallow cultivation is the rule during the summer, and the old stalks are cut and burned after the berries have turned red. This is followed by the mulch of manure late in the fall. When the first shoots appear the third spring the soil is thrown toward the plants, hilling them up slightly. This is particularly desirable if bleached asparagus is to be grown. Soon after this, cutting of the young shoots begins, and they are kept cut clean for six or seven weeks. After this, the shoots are allowed to grow in order to provide for next year's crop.

The shoots are cut with a knife, or they may be broken off just below the surface of the soil, after they have attained a length of six or eight inches.

In growing bleached "grass," the rows are hilled up, and when the tips of the shoots appear above the surface of the ridge, they are cut off several inches below the top of the ground.

Varieties.—Some of the best varieties of asparagus are Conover's Colossal, Palmetto, Giant Argenteuil, and Columbian (Mammoth White).

BEANS

Types of Beans.—There are several types of beans, but the two of the most importance to the average vegetable grower are the kidney and Lima beans. From the former come our ordinary string or snap beans, while the large, flat-seeded kinds belong to the Lima type.

Culture of Snap Beans.—Beans are tender plants and cannot be planted until danger of frost is past. When ready to plant, make rows two and a half feet apart and plant the seed two or three inches apart in the row. Six inches would probably be the best distance if a perfect stand could be obtained. Beans planted this way will produce larger yields than when planted in hills eighteen inches or more apart. Plant the seed not more than two inches deep, and one and one-half inches is better.

Shallow cultivation should be given frequently during the growing period of the crop.

Culture of Lima Beans.—Lima beans require a longer season for maturing than snap beans, and, since they are more tender, should be planted a few days later. Plant the seeds about four or five inches apart in rows three to three and one-half feet apart, covering them with one to two inches of soil. Limas require about the same cultivation as snap beans.

Beans should not be cultivated when the plants are wet from dew or rain, as this may cause them to become diseased.

Varieties of Beans.—Snap beans: Stringless Greenpod, Bountiful, Red Valentine, Rust-proof Golden Wax, Refugee Wax.

Lima beans: Fordhook Bush Lima, Henderson's Bush Lima.

BEETS

There are four distinct types of beets: (1) The ordinary garden beet; (2) Swiss chard, the so-called leaf beet; (3) the sugar beet; (4) the mangel, or stock beet. Vegetable growers are concerned only with the first two.

Because of the roughness and irregularity of beet seed, they are handled with difficulty by the various seed drills, but on a large scale they must be handled by machines. Some modifications of the ordinary seed drill enable this to be done. In the ordinary garden, the best method is to plant by hand. The seed should be sown three-fourths to one inch deep, and where the crop can best be harvested all at one time, the plants should be thinned to stand from three to six inches apart in the rows, which are made eighteen to twenty-four inches apart. For the home or local market garden, it may not be necessary to thin the plants, but allow the largest ones to reach edible size, say one and one-half to two inches in diameter, when they are removed to make room for the others.

Beets for winter storage should not be planted until the middle of June or later as those planted earlier become tough and woody before time to harvest them in the fall.

Varieties.—Crimson Globe, Crosby's Egyptian, Detroit Dark Red, Eclipse, Columbia, Dark Stinson.

Swiss Chard.—This type of beet does not produce a thickened root, as do the others, but is grown for the leaves and the thickened leaf stalks, which attain the size of rhubarb leaves. The young leaves are often boiled the same as spinach, while the leaf stalks may be cooked and served in the same manner as asparagus.

In cultivation, it requires about the same conditions as the beet, but more room should be allowed between rows and between plants in the row.

Swiss Chard is a vegetable which deserves to be more extensively cultivated than it is at present. Giant Lucullus is the chief variety.

BRUSSELS SPROUTS

Brussels Sprouts is the name given to one of the variations of the cabbage. While the stem and leaves resemble those of the cabbage, it does not form one large head, but a number of small heads in the axils of the leaves.

Brussels Sprouts require about the same soil and climatic conditions as cabbage. The natural season of the vegetable is late fall and this is the time when it reaches its best development. The plants should be started in April and transplanted to their permanent locations about the middle of June.

When the small sprouts begin to form, the leaves along the stalk are removed to allow them to develop to good size. A certain amount of frost is thought to improve the quality of Brussels Sprouts.

CABBAGE

For the early crop, the seed should be sown in the hotbed in March, and, if possible, transplanted once before they are finally put in the field. They are put out in the open as soon as the weather will permit. The seed for the late crop, for winter use, may be planted in beds outside about June 1st, and the plants are transplanted to their permanent positions when they have attained sufficient size.

The leaf area of cabbage plants should be reduced one-third or one-half when transplanted so that transpiration, or evaporation of water through the leaves, will not be so great. This is accomplished by gathering the leaves of the plants together and shearing off the upper portion, being careful not to injure the buds.

Plants of the early varieties should be set in the field in rows 2½ feet apart, the plants being placed 15 to 24 inches apart in the row. In the case of the late varieties, the plants should be further apart each way, as they require more room for development.

Frequent cultivation is necessary for the best development of cabbage. There is an old saying that "cabbage should be cultivated every day." It seems to be benefited by shallow cultivation, even in very dry weather, when there is already a dust mulch over the area. Such culture retains moisture and keeps down weeds. Cultivation should be continued as long as the leaves will allow passage between the rows.

Varieties.—Early: Jersey Wakefield, Copenhagen Market, Charlestown Wakefield. Late: Flat Dutch, Danish Ballhead.

CARROTS

The carrot is usually considered a vegetable of secondary importance, but is grown to some extent in almost every garden and is becoming more popular all the time. In addition to its use as a vegetable, it is a valuable stock feed, and the large quantities produced per acre are responsible for its extensive culture as a farm crop.

Carrots are given much the same culture as beets. The seed is sown thinly, about ½ inch deep, in drills 18 to 24 inches apart. The plants are thinned, if necessary, and all weeds are kept down, especially while the plants are very young, as they are easily smothered at that stage. Carrots are ready to use when ½ inch or more in diameter.

Varieties.—Chantenay, Oxheart, Danvers Half-Long.

CAULIFLOWER

This is another variation of the cabbage and is grown for the thickened flower stems or curd, which forms a white compact head.

Cauliflower does not thrive in hot, dry weather, so it should be grown either as an early or late crop. For the early crop, start the plants in the greenhouse or hotbed in March, and, when they have four or five leaves, transplant, giving more room. Set the plants in the field when severe weather is past. The distance between plants should be about 18 inches in the row, and about 2½ to 3 feet between the rows.

For the late crop, the plants are started later and finally transplanted to the field about July 1st.

Frequent shallow cultivation is given throughout the growing season. One of the essentials to successful cauliflower growing is never to allow the plants to become checked in their growth.

When the head or curd begins to form, care must be taken to prevent it being discolored or injured by insects. This is accomplished by folding the outer leaves over the head and tying them in place, or by breaking two or three leaves over the head. The seed is always expensive, but it pays to secure the best obtainable.

Varieties.—Burpee's Dry Weather, Early Snowball, Dwarf Erfurt.

CELERY

Soil.—A moist loamy soil containing an abundance of vegetable matter is best suited to celery growing. It is better if the water table is only 3 or 4 feet below the surface, and, for this reason, the river bottoms of Colorado are best adapted to the crop. But celery may be grown profitably on higher land where the necessary moisture can be supplied by irrigation. The climate of this state is well suited to the growing of celery. It delights in our cool nights and bright days.

Seed-bed.—The growing of the plants in the seed-bed is one of the most exacting operations connected with celery culture. The seed are small and slow to germinate and great care in watering and shading is necessary for good results. The soil in the seed-bed should be fine and rich. For the early crop, the seed should be planted in hotbeds the first or second week in March, while that for the late or main crop may be planted during the early part of April. The seed should be covered very lightly, say about a quarter of an inch and sometimes sand is used for this. Between the time of planting and the appearance of the young plants is a critical period. The surface of the soil should not be allowed to become dry, but large quantities of water cannot be applied. The beds should be water with a fine spray, two or three times a day, if necessary. When the plants are very young, shading on warm sunshiny days may be desirable. Cloth or lath screens will serve for this. When the plants are large enough to handle, they should be transplanted, if it is possible to do so. They may be planted in beds with 2 inches between plants each way. This method gives much more stocky plants and a much better developed root system.

Setting the Plants in the Field.—For the early crop, the plants will be ready to set in the field in May, and for the late crop the latter part of June. The bed should be given a thorough wetting before removing the plants, and if they have made a vigorous growth, it will be advisable to cut the tops back slightly, in order to reduce transpiration. Usually, a dibble is used to make the holes in which the plants are set and for pressing the soil around the roots. Sometimes in dry weather, it may be necessary to apply a small amount of water around the roots of the plants as they are set out.

Distances to Plant.—The distances at which the plants are set depends entirely on the method of blanching. There are several methods of blanching employed. The most common one is that where the plants are banked up with earth. In this case, the rows are made 5 or 6 feet apart and the plants set 6 inches apart in the row. Sometimes, double rows, 6 inches apart, with 6 feet between the double rows, are planted. This method gives a greater number of plants per acre than the single row method where there is a distance of 5 feet between the rows. Another method used quite extensively with the early crop is to blanch the celery with boards about 12 inches wide and 16 to 20 feet in length. When this plan is followed, the rows are made 3 feet apart, and the plants set 6 inches apart in the row. Heavy paper is sometimes used instead of boards. With proper care this will last two or three seasons and is more easily handled than boards.

In addition to the above methods, celery may be blanched by wrapping the individual plants in old newspapers or by setting pieces of tile around them. In fact, anything which keeps out the light will serve the purpose.

Cultivation.—Frequent surface cultivation should be the rule with celery. The plant needs abundant moisture and everything possible should be done to retain moisture in the soil. In irrigating, a thorough wetting should be given and then water should be withheld until it is needed again. The grower must always keep in mind, however, that the plant requires a large amount of water.

Celery plants must never be allowed to become checked if possible to prevent it, as checking injures the quality and is apt to cause the plants to run to seed.

Blanching.—The methods of blanching celery have already been outlined. When the crop is blanched by means of boards, 20,000 to 30,000 feet of lumber are required for blanching an acre. If all the celery is not needed at one time, the same boards can be used for blanching two or three lots, so that less than the above will be required per acre. The time for blanching is from ten to thirty days. The early crop usually requires less time than the late crop. The plants should not be allowed to stay in the field after blanching, as the quality is injured thereby.

When the crop is blanched with earth it is almost always of better flavor than when other methods are employed. The banking up of the soil around the plants may be done by hand or a celery "hiller" may be used. This is a plow having large moldboards which banks the soil against the plants. Before it is used, a small amount of soil must be placed around the base of the plants to hold them in an upright and compact position. When celery is to be kept in storage for some time it is not necessary to blanch it in the field. If stored in a dark cellar, blanching will take place there. Sometimes the blanching is begun in the field by banking the soil partly up around the plants and the process is completed in storage.

Varieties.—Early: Golden Self-blanching. Late: Giant Pascal, Winter Queen, White Plume.

SWEET CORN

Sweet corn is not as well adapted to Colorado conditions as many other vegetables, but sufficient quantity for home use can be grown in the ordinary garden, except at the higher altitudes where the frost-free period is not long enough to allow it to mature. The early varieties will often mature in sections where later ones will not.

Rows should be laid off about 3 feet apart and the seed planted so as to have the plants 8 to 10 inches apart in the row. Another method is to plant in hills 3 feet apart each way, leaving about three plants in a hill. The seed are planted 1 to 1½ inches deep. Growers often take a chance with early corn and plant earlier than the normal season. Then, if the crop escapes frost, it matures earlier and is correspondingly valuable. If it is killed or fails to come up on account of the seed rotting, it may be planted again. In the home garden, in the warmer portions of the State, it is well to have a succession of plantings in order to supply the table for a considerable period.

Sweet corn is in the proper stage for gathering when the grains are plump, well developed and just entering the dough stage. It should not be gathered for the table or for canning more than two or three hours before it is cooked, as its quality is injured by keeping longer than this. The ideal stage of sweet corn on the stalk is of short duration, and it should be pulled at the proper time.

Varieties.—Early: Golden Bantam, Extra Early Adams, Peep-o'-Day. Late: Stowell's Evergreen, Country Gentleman.

CUCUMBERS

Since the cucumber is a tender vegetable, the seed cannot be planted until after danger of frost is past. Rows are laid off about 6 feet apart and the seed planted in hills 3 feet apart in the row. Six or eight seed should be planted in a hill and when the plants are well established all but two or three are thinned out.

In order to produce plants early, thus allowing for a longer growing period, the seed may be planted in strawberry boxes or paper pots in the hotbed about the middle of March and transplanted to the field when there is no longer danger from frost. Cucumber plants do not transplant readily by the ordinary method, but when put in strawberry boxes or pots a mass of soil adheres to the roots and they can be transplanted without any difficulty. The boxes, which will have become more or less rotten, can be easily broken away from the enclosed soil.

In order to keep the vines growing and bearing, the cucumbers must not be allowed to ripen. For slicing, they are picked when 6 to 8 inches long, but before the seeds become hard, while for pickling, they are removed when they have attained the desired size. Usually; the smaller the fruit the more desirable it is for pickling.

Varieties.—White Spine, Davis Perfect, Boston Pickling.

EGG PLANT

The egg plant requires a warm, loamy soil and a long, warm season to grow to the best advantage. In Northern Colorado, the season is too short to allow the crop to mature if the seed are planted in the field, so that every advantage must be taken to prolong the growing period. The seed may be planted about March 15th in the greenhouse or hotbed in strawberry boxes or pots and treated much like cucumbers started by this method. They may be planted in flats and transplanted to pots when two true leaves have developed. By doing this, the plants are of good size when the time comes for setting them in the field. Before finally planting them in the field, they should be hardened off in the cold frame.

The seed and young plants require careful attention as to moisture and temperature for best results. They must not receive too much water, especially while the seed are germinating, and the temperature must not be allowed to fall too low

When set in the field the plants are put in rows 3 feet apart and 18 to 24 inches apart in the row. They are given about the same cultivation as potatoes or tomatoes during the growing period.

KOHL-RABI

Kohl-Rabi is a vegetable with which the average American is not very familiar. It will grow well under the same conditions necessary for the production of good radishes and deserves to be cultivated more than it is.

Kohl-rabi is closely related to the turnip and produces a thickened stem or bulb above the surface of the ground. It has excellent quality and is sometimes called the "Lazy Man's Cauliflower," being cooked and served in a manner similar to cauliflower.

The plant is hardy and can be grown in sections where the cauliflower cannot. The seed should be planted as early in the spring as possible in rows 18 inches apart. The plants should later be thinned to stand 6 to 8 inches apart in the row. Successive plantings at intervals of two weeks will insure a supply for a longer period. The vegetable should be gathered as soon as ready, which is about the time the swollen stems are 1½ to 2 inches in diameter. It remains in prime condition only a short time, so for best results must be used when just right.

LETTUCE

Lettuce is the most important salad plant under cultivation and can be grown under a variety of conditions. The two types of lettuce most commonly cultivated are head lettuce and leaf lettuce. Head lettuce is somewhat more difficult to grow than leaf lettuce, but succeeds well in the cooler sections of the state. Lettuce is a comparatively hardy plant, and grows best in early spring or in the fall. For the early crop, the seed can be planted in the greenhouse or hotbed in March and transplanted to cold frames when large enough, or the seed may be planted directly in cold frames the latter part of March and when the plants are up, they are thinned to the proper distance apart and the crop allowed to mature where it stands. In cold frames, the plants should stand about 8 inches apart each way. Plants may be set in the field the latter part of April (seed may be sown in the field about April 15th) and in this case the rows should be 18 inches apart and the plants 6 to 8 inches apart in the row. Lettuce transplants readily and if properly handled the plants will be only slightly checked.

Lettuce which grows rapidly without being checked possesses the best texture and flavor, so the aim of the grower should be to cultivate the crop in a way to obtain this result.

Excellent lettuce may be grown in hotbeds and cold frames in early spring and late fall, and wherever these structures are available, some space should be devoted to lettuce, which is a desirable vegetable at all seasons.

Lettuce grown in hotbeds and cold frames is very susceptible to disease and particularly so when the surface of the soil and the folige of the plants are kept moist. In applying water, precautions should be taken to keep the leaves from getting wet.

Varieties.—Leaf Lettuce: Black Seeded Simpson, Grand Rapids. Head Lettuce: Burpee's Wayahead, Big Boston, May King, Deacon, Tennis Ball, All Seasons.

MUSKMELON

Under the term "muskmelon" is included a number of types of melons. The most common of these are the ordinary muskmelon, characterized by a large seed cavity, distinct ribs, and a surface more or less free from netting, and the cantaloupe, an ideal specimen of which has a small seed cavity and a heavily netted surface, showing no ribs at all. Much effort has been expended toward perfecting the latter type at Rocky Ford section and the type of melon grown there is well known throughout the country.

The muskmelon is naturally a tropical plant and requires a long, warm season for its best development. For this reason, we cannot expect to produce as profitable a crop in the northern part of the state as at Rocky Ford, but some should be grown for home use. A warm, sandy loam is the best soil for growing cantaloupes. Such land on which alfalfa has grown for two or three years is probably the ideal in this climate. The soil should be in the best of tilth and should be well, but not too heavily, fertilized with stable manure.

Rows are laid off 6 feet apart each way and 8 to 10 seeds planted at each intersection. The seed are covered to a depth of about 1 inch.

Thorough and frequent cultivation should be given. During the early stages of the crop, the ground should be stirred rather deeply and close to the plants, but as the vines spread cultivation should be more shallow and further away. Light, frequent irrigations have proven to be of more advantage than heavy soakings given at considerable intervals.

Muskmelons are said to have three stages in three days—green, ripe and rotten. While this is exaggerating the actual facts to some extent, the time when the melons are in the best of condition for picking is very short. If harvested too early or too late, the quality will not be up to the standard. It is hard to describe just the proper stage at which the melons should be picked. There is a slight change of color in the interstices of the netting which can be recognized by an experienced picker, and the melon "slips" from the vine, that is, the stem does not break off when the melon is pulled, but separates easily from it.

Varieties.—Early Watters and Rust-Resistant Pollock (both Rocky Ford varieties), Emerald Gem, Osage Extra Early Hackensack, and Honey Dew.

ONIONS

The growing of onions is an important industry in several sections of the State. They can be grown in practically all parts of the State for home use and for local markets and in some districts they may be grown with profit for disant markets.

Onions may be grown from seeds or sets. The latter are more often used in growing early green onions, while mature onions are usually grown from seed. In the latter case, two methods may be employed. By the first method, the seed are planted in early April in rows 14 to 18 inches apart. They are sown thickly and covered about one-half inch deep. When the plants are well up, they are thinned. More plants than are needed are left the first time and some of these are taken out later, finally leaving them 3 to 6 inches apart in the row.

The other method, which has many advantages and which should be employed more extensively, is what is known as the "new onion culture." The seed are sown in the hotbed about March 1st in drills 5 or 6 inches apart. When ready to put the plants outside, they are taken up, the roots cut back, to one-half inch in length, and part of the top removed, after which they are transplanted in the usual way, being set 3 to 6 inches apart in the row. By this method, the grower is able to lengthen the growing period by starting his onions early, and is thus enabled to grow to perfection the milder flavored onions which require a longer season than we normally have here. He also eliminates the tedious process of thinning and weeding and is sure of a perfect stand of good plants properly spaced. The ground can be cultivated before the onions are transplanted to it, and the first crop of weeds killed.

To offset these advantages are the disadvantages of transplanting and of supplying hotbed space. However, transplanting an acre of onions requires but little more labor than thinning the crop which has been planted the old way. About 150,000 plants per acre are required. One man can set 8,000 to 10,000 plants per day. The cost of hotbed sash is the most important item. It requires twenty 3x6 sash to grow enough plants to set an acre.

Frequent shallow cultivation should be given. The hand wheel hoe is best for this. Care must be exercised in irrigating. The tendency is to give too much water, causing a large percent of scullions. In the early part of the season, water should be given sparingly to promote strong root development. An irrigation every ten days is all that is necessary during the growing period. No water should be applied after August 15th, but withheld in order to allow the crop to mature

Breaking the tops of the onions down by rolling a light roller of some kind over them may sometimes be advisable when the crop is tardy about maturing. However, if the plants can be induced to mature naturally, a much more satisfactory product will result.

When ready to harvest, the roots should first be cut by running a U-shaped blade under the bulbs. Such a blade may be attached to a double-wheeled hand hoe, or a longer blade, cutting two rows at a time, can be attached to a horse hoe. The tops are then [illegible] off about half an inch above the bulb, and the onions are raked into windrows, preferably with wooden rakes, and allowed to dry for six or eight days. They are then put in sacks and sold, or they may be placed in storage.

Varieties.—Yellow Globe Danvers, Red Wethersfield, Southport Yellow Globe, Southport Red Globe, Silver Skin. For growing by the transplanting method: Prizetaker, Gigantic Gibraltar, Red and White Bermuda, and Denia.

POTATOES

Potatoes are rapidly becoming an important garden crop, not only on the farm, but also in the city and town gardens, and more space should be devoted to them. They yield more food for a given space than almost any other vegetable grown, and have the additional advantage of long keeping qualities.

Soil

In general, the best soil for potatoes is a deep, sandy loam, underlaid by a porous sub-soil. The character of the sub-soil is important. Even the heavier soils are often productive when the sub-soil is gravelly or open. Heavy soils which easily become puddled are not suitable for potatoes unless large quantities of well-rotted manure are applied, and the soil is plowed deeply or spaded in the fall.

Preparation of Soil

The preparation of the soil for potatoes should be thorough and deep, in order that the plant may have a large feeding area. Potatoes should never he grown more than once in succession on the same soil, and this is difficult to avoid on small areas. On the farms where a regular system of crop rotation is practiced, this difficulty is easily overcome. In garden practice, where farm rotation is not possible, rotation of vegetables from one piece of the garden to another is advisable. In order to supply the needed vegetable matter and fertility, the land should be given a heavy top dressing of stable manure. The older and more decomposed this manure, the better it is. On heavy soil, the manure should be applied in the fall and plowed or spaded into the land. The plowing or spading for potatoes should be 10 to 12 inches deep, to permit the root system to penetrate as deeply as possible. The land should be cross-plowed or spaded again in the spring a few days before planting. On lighter soil, the manure and the plowing may be deferred until spring, but the application of the manure and the plowing should be done sometime before planting. The land should not be plowed or worked while wet.

Planting

For garden purposes, the planting may be done by hand. A line is stretched across the lot, and a furrow or trench is opened along it to the depth of 4 to 4½ inches, depending upon the character of the soil. On heavy land, the potatoes should not be planted more than 4 inches deep, while on lighter land they may be planted as much as 5 inches deep. The seed should be placed 12 to 14 inches apart in the trench, and the trenches may be from 30 to 36 inches apart, depending upon the available space, 36 inches being about right for irrigation. The trenches are then filled up, and the ground left level.

Seed

For garden purposes, early varieties are most satisfactory; varieties like the Rose Seedling, Early Ohio, Triumph, and the Cobbler. Whenever possible, whole seed should be planted. The size should vary from one to three or four ounces in weight. When cut seed is used, each piece should have not less than one eye, and not more than two, and each piece should weigh from an ounce and a half to two or even three ounces.

Cultivation

Cultivation should begin soon after the crop is planted and before the plants are up, the object being to keep the soil aerated, to conserve the moisture, and to kill the weeds. After the plants are up, cultivation should be continued between the rows. If the ground has a tendency to bake, the first few cultivations after the potatoes are up should be rather deep, to loosen up the soil below.

Irrigation

Potatoes should never be irrigated by sprinkling. Furrows should be made between the rows to the depth of 6 or 8 inches, and the water led into these furrows slowly, and long enough to wet through the rows between the furrows. It is better to apply small quantities of water and keep it on for a longer period, than a large amount for a short period. As soon as the land is dry enough to permit handling, the surface of the soil should be cultivated to break the crust and prevent evaporation. When the vines cover the rows, the water may be applied in every other furrow. While the soil should be kept moist during the growing season, too much water is harmful.

In dry seasons, it will be necessary to apply water to get the plants up. When this is the case, the water should be run in a furrow a few inches from the row and allowed to soak through to the soil around the seed. After that, it will probably not be necessary to irrigate again until the potatoes commence to form. As soon as the surface soil is dry enough, after each irrigation, it should be cultivated in order to check evaporation.

PARSNIPS

The soil for parsnips should be rich and deeply prepared. Before planting, the surface should be thoroughly fined, as the seed are rather slow to germinate, and the young seedlings very delicate. The seed are planted as early in the season as possible, in rows 18 to 24 inches apart. Plant about ten seeds to the foot and cover not more than 1 inch deep. The plants should be thinned to stand 3 or 4 inches apart in the row when well up.

The roots will be ready for use by September, but they have not the quality then that they have later in the season. Parsnips are considered to have a better flavor if subjected to frost and they may be allowed to remain in the ground over winter, in which case they should be protected with a light mulch of some kind.

Varieties.—Guernsey and Hollow Crown (the latter is considered best).

PEAS

The growing of peas is of considerable importance in Colorado. They are adapted to most all sections of the State and are grown extensively for canning in the northern portion.

There are three types of peas under cultivation: (1) The smooth, round-seeded kinds; (2) the wrinkled-seeded kinds; and (3) those with edible pods. Only the first two are of importance. The different kinds are further divided into tall, medium, and dwarf-growing varieties. Generally speaking, the dwarf, round-seeded varieties are the earliest and most hardy. On the other hand, the tall-growing, wrinkled-seeded varieties are of better quality and have a longer fruiting period.

For the home garden, peas are often planted in double rows 6 inches apart with 2 to 2½ feet between the double rows, but the most common method is to plant them in single rows about 2 feet apart. The seed for the first crop should be planted as early in the season as the ground can be gotten in shape. It has been found that the vines will produce better and for a longer period if the seed are planted 4 to 5 inches deep. However, for the early plantings, it is advisable not to plant more than 2 or 3 inches deep as the ground is cold and wet early in the spring, and may cause the seed to rot before they will germinate. Successive plantings should be made in order to have them in edible condition for a longer period. The tall-growing kinds require a trellis of some kind to support them and this may be supplied by using brush stuck between the rows, or chicken wire may be used.

Varieties.—Smooth-Seeded: Alaska, Extra Early. Wrinkled peas: Gradus, Thomas Laxton, Nott's Excelsior, Stratagem, Telephone.

PEPPER

Pepper requires about the same conditions as the tomato. The seed are slow to germinate and should be started in the greenhouse or hotbed in March in order to have good-sized plants for setting out when danger of frost is past. The young plants should be transplanted once before they are finally moved into the field. The distances for setting the plants outside are 15 to 18 inches apart in rows which are 2 to 2½ feet apart. The subsequent cultivation of the crop consists in keeping down weeds and stirring the soil from time to time.

Bull Nose, Ruby King and Neapolitan are three popular varieties.

PUMPKIN

Pumpkins are very often grown as a companion crop with corn in the Northern and New England States. They are also grown as a separate crop, being handled the same as winter squashes. The seed are planted in hills 8 feet apart each way, five to ten seeds in a hill when there is no longer any danger from frost. The pumpkins should be harvested with a portion of the stem adhering before frost kills the vines in the fall. They can be kept for some time in warm, dry storage.

Two varieties are Small Sugar and Big Tom (Large Field).

RADISHES

The radish is one of the most popular spring vegetables on account of its hardiness, quick return and agreeable crispness and flavor.

For early radishes, the seed should be planted in rows 15 to 18 inches apart. About 30 or 40 seed planted to a foot of drill and these are covered three-fourths of an inch deep and the soil compacted over them. It has been found that it pays to use only the largest seed. A much better and earlier crop results when large-sized seed are planted than when smaller ones are used.

In addition to being planted in the above manner, radishes are very often grown as a companion crop with lettuce or as a catch crop between cabbage, beans, and potatoes. Radishes require only a short time for maturity, and when planted between the rows of these crops they reach maturity and are out of the way before the ground is needed by the other crop.

This vegetable is often forced in hotbeds or cold frames. Seed are usually planted in the hotbed or cold frame very early in the spring in rows about 6 inches apart with 30 or 40 seed to the foot. Grown in this manner, the crop will reach maturity in three to five weeks. Radishes are comparatively hardy plants and naturally grow in the cool parts of the year. Therefore, when grown in hotbeds, low temperatures should be the rule. A temperature of 60° to 65° Fahrenheit during the day and 45° to 55° Fahrenheit at night is about right.

Winter Radishes.—The winter varieties are comparatively little grown in this country. The seed may be planted in July or early September and cultivated until the approach of severe weather. Then they are taken up and placed in sandy soil in the cellar or put in pits in the field the same as turnips. In this way, they will keep in as good condition as turnips.

Varieties.—Varieties of radishes are numerous and the taste of the gardener as to color and shape should determine the kinds grown. Scarlet Button, Scarlet Globe, Scarlet Turnip White Tip, Long Scarlet Short Top, French Breakfast, White Olive Shaped, and White Icicle are all good.

RHUBARB

Rhubarb, or pie plant, is found in almost every garden. It is grown for its thick leaf stalks which are used in making pies and sauce. The stalks are also cut in cubes and canned for use as occasion requires. Rhubarb does best in northern climates.

Good strong one-year-old roots are the kind usually used for planting out permanent plantations. Such roots may be obtained from seedsmen or they may be grown by planting the seed. The latter method is cheaper, but requires one year longer.

When ready to plant, rows are laid out 4 or 5 feet apart and the plants are set rather deeply, 2 or 3 feet apart in the row. The crowns of the plants are covered 2 or 3 inches deep with soil. The plants should be set deep enough so after covering there is a slight depression over the crowns. The roots are set out early in the spring.

The crop should be carefully cultivated and liberally fertilized until it reaches bearing age. This is one or two years after the plants are set. It is better to wait until the plantation is two years old, as the roots will be stronger and better able to withstand the removal of the leaves.

After the plants reach bearing size, cultivation is usually delayed until after the harvest period in the spring. Then a heavy dressing of stable manure should be put on and cultivation given throughout the remainder of the growing period. Seed stalks must not be allowed to mature, as they are a heavy drain on the vitality of the plants.

Varieties.—Victoria and Linnaeus.

SPINACH

This is a plant grown in the early spring and late fall for "greens." While grown extensively in some sections its cultivation in the home garden should be more general. It is superior to any other salad plant grown for boiling.

Being a hardy vegetable, it is planted very early in the spring for the early crop. The seed may be sown thickly in rows 12 to 18 inches apart and the plants thinned out when well up.

For fall use, the seed are sown in July or August, and the crop is ready to harvest before severe weather sets in.

Varieties.—Long Season and Victoria.

SQUASH

There are two general types of squashes, known as summer and winter squashes. The former includes the summer crookneck, the scallop squash, and the cymling of the south, while the latter includes the "late-keeping" varieties like the Hubbard. The summer squashes require a much shorter period for maturing and are better adapted to localities where the growing season is short.

Squashes are planted about the same time as corn. Rows are laid off 4 to 8 feet apart, depending on variety, and six to ten seeds planted in each hill, the hills being placed from 4 to 8 feet apart in the rows. The seed are covered about 1 inch deep and when the plants are well up and danger from insects is past they are thinned to two or three plants in a hill. Subsequent cultivation consists in keeping down weeds with an occasional stirring of the soil.

For early planting, the seed may be sown in berry boxes in the hotbed, as suggested for cucumbers, and transplanted to the open after danger of frost is past.

The summer squashes are edible only before the shell begins to harden. As long as it is possible to cut through the skin with a slight pressure of the thumbnail, the squash is in edible condition, but after it becomes more resistant, it is not fit to be put on the market.

With the late-keeping kinds, however, the harder and more resistant the shell, the better. This type is not used until mature, and their hard shells enable them to be kept for some time in storage. In harvesting them, a small portion of the stem should be left attached to the squash and care observed not to bruise the fruits. They should be left in the field as long as possible in the fall, but must not be subjected to freezing weather. They will keep fairly well in dry, comparatively dark, cellars where the temperature ranges from 38° to 45° F.

Varieties:—White Bush Scallop, Golden Summer Crookneck, Hubbard, Essex Hybrid, Delicious.

SWEET POTATOES

Sweet potatoes, while not adapted to all parts of Colorado, can be successfully grown at the lower altitudes in the southern part of the State.

Sweet potatoes are propagated by means of sets, which are grown in large numbers from the smaller-sized potatoes placed in a hotbed a few weeks before planting time. A manure hotbed should be prepared in the usual way and the manure covered with about 3 inches of sandy soil. The potatoes are placed on this just far enough apart not to touch and covered with 3 inches of good sandy soil. This hotbed should be made about April 1st to 15th and the plants set in the field as soon as danger of frost is past.

The slips are ready to pull when about 6 inches high, and, after the first crop of sets is removed, a second crop will come up to take its place. They are removed by holding down the mother root with one hand and pulling the sets off with the other.

The plants are set about 15 inches apart in rows 3½ or 4 feet apart.

Thorough cultivation to prevent weed growth should be given until the vines begin to run, after which horse-drawn implements cannot be used.

Harvesting and Storing.—The crop is harvested at about the same time as Irish potatoes, and in much the same manner. Sometimes a turning plow equipped with two rolling colters which cut the vines on either side of the row is used. The potatoes are handled as carefully as possible to avoid bruising.

According to a bulletin issued by the Georgia Experiment Station, sweet potatoes can be kept over winter by the following method: As soon as the tubers are harvested, they are brought into the storage house and put in bins. The temperature is then raised to 90° or 100° F. and held there for seven to ten days, in order to dry out the excess moisture. The temperature is then gradually lowered to 50° or 60° and maintained at that point. This is the only satisfactory method, so far developed, by which sweet potatoes can be successfully kept during the winter.

TOMATO

The tomato, being a tropical plant, requires a long growing period, and any method by which the growing period can be lengthened in this climate will prove an advantage. This can best be accomplished at the beginning rather than at the end of the season. Seed may be sown in flats and placed in the hotbed from

March 1st to 15th. As soon as the plants are large enough to handle, they are transplanted to other flats or into small pots, giving them more room. As soon as the roots have filled the small pots or the plants have begun to crowd in the flats, they are transplanted again. They may be put into 6-inch pots or into the hotbed, or, if danger of severe freezing is past, into the cold frame, where they will have room for more growth before their final removal to the field the latter part of May. When treated in this manner, the plants will often be in bloom at the final transplanting.

The plants should be set about 4 feet apart each way in the field. Care should be observed to check their growth as little as possible. Leave as much soil as possible adhering to the roots when the plants are being moved.

The plants are trained sometimes to stakes 4 or 5 feet high. In this case, they are usually grown with a single stem (prevented from branching) and the plants tied to the stake. This method should give somewhat earlier ripening crops, as the fruits are better exposed to the sunlight than where the vines are allowed to sprawl over the ground, but the yield will not be as great.

Varieties.—Earliana, Early Jewel, John Baer, Prosperity, I. X. L., Bonny Best, Stone.

TURNIP

The turnip is grown either for early spring use or for use in the late fall and winter. The term "turnip" includes both the common turnip and the rutabaga. The former is grown as an early spring crop to be followed by some other crop, or it may be grown after early potatoes, peas, or beans, while the rutabaga requires the soil for a longer period, the seed being sown in May and the crop harvested in the fall.

The seed for the early crop are sown in March or April in rows 15 to 18 inches apart, and covered to a depth of three-fourths of an inch. When the plants are well up, they are thinned to stand 4 to 6 inches apart in the row.

For the late crop, the seed are sown in July or August following the harvesting of some other crop. They may be planted broadcast or in rows. When mature, the crop is harvested and the tops cut off. The turnips may then be stored in pits or cellars much as potatoes.

Rutabagas are treated in the same manner as the late crop except they must be planted in May instead of July or August.

Varieties.—Turnips: Purple Top Milan, Red Top White Globe, White Egg. Rutabagas: Large White, Burpee's Breadstone, Golden Neckless.

WATERMELONS

Watermelons are much less widely cultivated in Colorado than the muskmelon, but with proper care they can be grown in many parts of the State.

The watermelon is a tender plant, so that planting must be delayed until danger from frost is past. The seed should be planted in hills about 8 feet apart each way and covered 1 inch deep. It is best to use a dozen or more seed to each hill in order to be sure of having a perfect stand. After the plants have become well established they should be thinned, leaving two or three to a hill.

In the northern part of the State a better plan to follow is to sow seed in pots, strawberry boxes, or on pieces of sod placed in the hotbed. By this method, the seed may be planted in March or April, and the plants removed to the field after cold weather is over. The plants can be moved without checking them at all, and the advantage gained by lengthening the growing period is considerable. Moreover, when in the greenhouse or hotbed, the growing plants can be much more easily protected at the most critical stage from insects and other troubles than if they were scattered over a field.

The best culture possible should be given the crop early in the season so that a small amount will be required later when the vines begin to cover the ground.

Varieties.—Cole's Early, Kleckley Sweets, Tom Watson, Phinney's Early.

HARVESTING VEGETABLES

The quality of many vegetables depends upon the time and stage at which they are harvested, therefore a few points in this connection are given below.

Many vegetables are best harvested in the early morning, as they are then full of water and crisp. This is especially true of vegetables used in a green state, as lettuce and radishes.

Peas and sweet corn are of much better quality when gathered only two or three hours before being prepared for the table. They deteriorate rapidly after being removed from the plant.

The quality of radishes, carrots, beets, and kohl-rabi depends usually upon their size, the smaller the vegetable the better the quality. When allowed to grow too large, kohl-rabi and beets become somewhat woody. They should be used when about 2 to 3 inches in diameter.

Leaf lettuce should be used as soon as the leaves are large enough, but head lettuce should be left alone until good, firm heads are formed.

Cauliflower should be harvested as soon as the heads reach good size and before they begin to deteriorate.

Cabbage and celery will stand some frost in the fall, but should be harvested before severe weather sets in. Late celery may be banked up where it stands in the field and left for a time, even after cold weather comes.

Potatoes must be dug before there is any danger of the tubers freezing. Where the tubers grow close to the surface, they are sometimes hilled up slightly to prevent injury from light freezes. Immature potatoes will not keep well, so they should be left in the ground as late as is safe in order to allow them to ripen as well as possible.

Parsnips may be left in the ground all winter if desired, but, owing to the difficulty of getting them out of the frozen ground, some should be dug in the fall and stored for use during the winter.

STORING VEGETABLES FOR HOME USE

It is to the interest of every family to grow each season a supply of those vegetables suitable for storage, and to see that they are properly stored for use during the winter months when prices are high and vegetables often hard to get. Storage is one of the important ways of conserving our food supply and it is to the interest not only of the family but of the nation as well.

Less work and less expense are involved in storing vegetables than in keeping them by other methods, as canning, drying, and preserving, and the product retains it characteristic flavor much better.

Planting for Storage.—When it is the plan to store a certain part of the crop, some of the kinds should be planted with this in mind. Beets and carrots, for instance, when planted for early use, become too tough and woody before fall to be desirable for storage purposes. They should be planted somewhat later in order to be of good quality for winter use.

ROOT CROPS

Potatoes
Beets
Carrots
Parsnips
Winter Radishes
Turnips
Rutabagas
Salsify
Kohl-rabi

Small Quantities.—Store in boxes (or heaps) of slightly moist (not wet) sand or sandy soil in cellars. Put in alternate layers of sand and vegetables. Vegetables stored in this way will not shrivel. Tops of vegetables should be removed, of course, before storing. Do not cut beet tops too close.

Large Quantities.—Store in root cellar in bulk, or in outdoor pits, as follows: Make excavation 6 or 8 inches deep, 4 feet wide, and as long as necessary. Cover ground with layer of straw, and place vegetables in conical heap of any desired length. Cover with 12 to 18 inches of straw. On the layer of straw, as the weather gets colder, place a layer of soil 4 to 6 inches in depth. If some straw is left protruding at the top of the pile at first, it will provide for the passing off of any heat which may be generated when the vegetables are first covered.

This protection will suffice except in the most severe weather, when an additional layer of straw or strawy manure may be put on.

In removing the vegetables from the pit after the layer of soil is frozen, a small hole may be chopped in one side and the vegetables needed taken out.

CABBAGE

Small Quantities.—When it is desired to store a small quantity for two or three months, the stems and outer leaves may be removed, and the heads stored in a cool cellar. Keep the temperature low to prevent premature growth.

Pit Storage.—A common method for outdoor storage is to dig a trench 6 or 8 inches deep, wide enough to accommodate three heads, and as long as necessary. The plants are pulled up roots and all and placed heads down in the trench, leaving the outer leaves and stems intact. On top of the three rows of heads, put in the trench in this way, are placed two more rows, between the stems of the first. A layer of straw is put next to the cabbage, and on top of this a layer of soil, which is increased as the weather gets colder. It is not necessary to cover sufficiently to prevent freezing, as some freezing does not injure cabbage stored in this way.

CELERY

Cellar Storage.—Dig plants as late as possible (avoid injury from severe freezing) with some soil adhering to roots, and partially replant the plants in an upright position, placing them closely together, in a cool cellar. The soil or sand in which the roots are replanted should be kept moist by watering. In watering, do not wet the tops of the plants. Keep cellar well ventilated, and the temperature just above freezing, if possible.

Trench Storage.—Dig a trench in the field about 1 foot wide, deep enough so that tops of plants come to the surface of the ground, and as long as necessary. Set the plants, which should be dug with good portion of root system left on, as closely together as possible in this trench, and water the soil around the roots, being careful not to wet the tops. Nail two planks together to form a trough, and invert this over the trench. Until severe weather, ventilate by putting blocks under trough during warm weather. As the weather gets colder, put on straw, strawy manure, or soil in sufficient quantity to prevent plants from freezing.

ONIONS

Common Method.—Keep in cool cellar (temperature just above freezing point) where it is dry and where there is good ventilation. Store in slat crates or shallow trays, not in bulk.

Another Method.—Onions may be stored in a dry cold place, such as a barn loft, where they are allowed to freeze and remain frozen until ready to use. After freezing, cover them with a layer of straw, so they will not freeze and thaw alternately. When ready to use them, place the onions where they will thaw out very slowly (as in a cool cellar). Handle carefully and as little as possible while frozen.

VEGETABLES REQUIRING WARM STORAGE

Pumpkins
Sweet Potatoes
Squashes

These vegetables require dry, comparatively warm storage. The temperature should be around 45° to 50° F., which is considerably warmer than for other vegetables. The cooler parts of a furnace room are often satisfactory for these vegetables.

When harvesting squash and pumpkins, leave the stems on, as decay at the stem end is then less likely to occur.

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MILLET SMUTS AND THEIR CONTROL

By H. E. VASEY

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MILLET SMUTS AND THEIR CONTROL

By H. E. VASEY

This bulletin is prepared after two years of study on the smuts of the common varieties of millets. The study is incomplete in a number of its phases but, owing to the fact that positive results have been obtained in regard to control measures, it has seemed advisable to issue this bulletin now in order that farmers, this season, may take advantage of the methods of seed treatment which have proven effective.

The millets have become valuable forage and grain crops in the North Central States and Great Plains region of the United States. Smut is the chief disease affecting millet in these states, particularly in Colorado, where its occurrence has so increased of late years that serious consideration has been directed towards its control. Doubtless the disease has been fairly abundant for several years past, occurring only in sufficient amounts to attract attention locally, but owing to continued use of smutted grain, the smut has reached relatively large proportions generally over the State.

Owing to repeated calls for information concerning the smut and its control, an investigation was begun in the fall of 1915* for the purpose of ascertaining the kinds of smut affecting millets, the character of these smuts, the losses inflicted by them, facts in their life history, and the most practical methods for their eradication. Heretofore very little study has been given to the smuts affecting millet, and the control measures recommended by others are much at variance and, therefore, uncertain. Formalin has been generally adopted as a suitable dsinfectant, some recommending the steeping of grain in a solution of 1 pint to 45 gallons of water for two hours, others using 1 pint to 30 gallons for ten minutes and others, 1 pint to 48 gallons of water immersed for five minutes.

DISTRIBUTION AND LOSSES

In the United States millet smut undoubtedly occurs in varying amounts wherever millet is grown. It attracted attention in Iowa in 1908 and 1909, and has received some attention in Illinois, North Dakota and Indiana, although, to the writer's knowledge has not been reported to be of serious import in these states. In Colorado, how-

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* This study was organized and begun by Dr. W. W. Robbins and Mr. Otto A. Reinking, to whom credit is due.

ever, much complaint of the disease has been received at the Agricultural Experiment Station, especially of late years.

Fig. 1. Experimental millet plots, 1917.

Millet smut occurs most abundantly in El Paso, Phillips, Weld, Washington, and Yuma counties. A few reports have come from the western slope, stating that the disease was present in Montrose, Mesa and Delta counties. (Fig. 2.) One correspondent from Montrose county stated that "German millet was badly smutted during the season of 1917." A correspondent from El Paso county stated that "Millet smut was quite general the past season (1917), the common and Proso varieties being most attacked. About 25 percent of the Proso millet in El Paso county was smutted in 1917. The Siberian millet was also smutted although, much less than the Proso." In Weld county one correspondent estimated the loss to be between 25 and 30 percent in the Proso variety. Siberian and German varieties were not badly attacked. One may find frequently in a field as many as 50 percent of the plants smutted. In the experimental plots at the Colorado Agricultural College the losses ran as high as 65 to 75 percent. A summary of the millet smut losses for the past season would average 6 to 7 percent of the State's production. Obviously, this represents a large loss, because affected plants are not only rendered worthless in grain production but are much impaired in yield of forage as well. Losses such as these are quite unnecessary since, by the

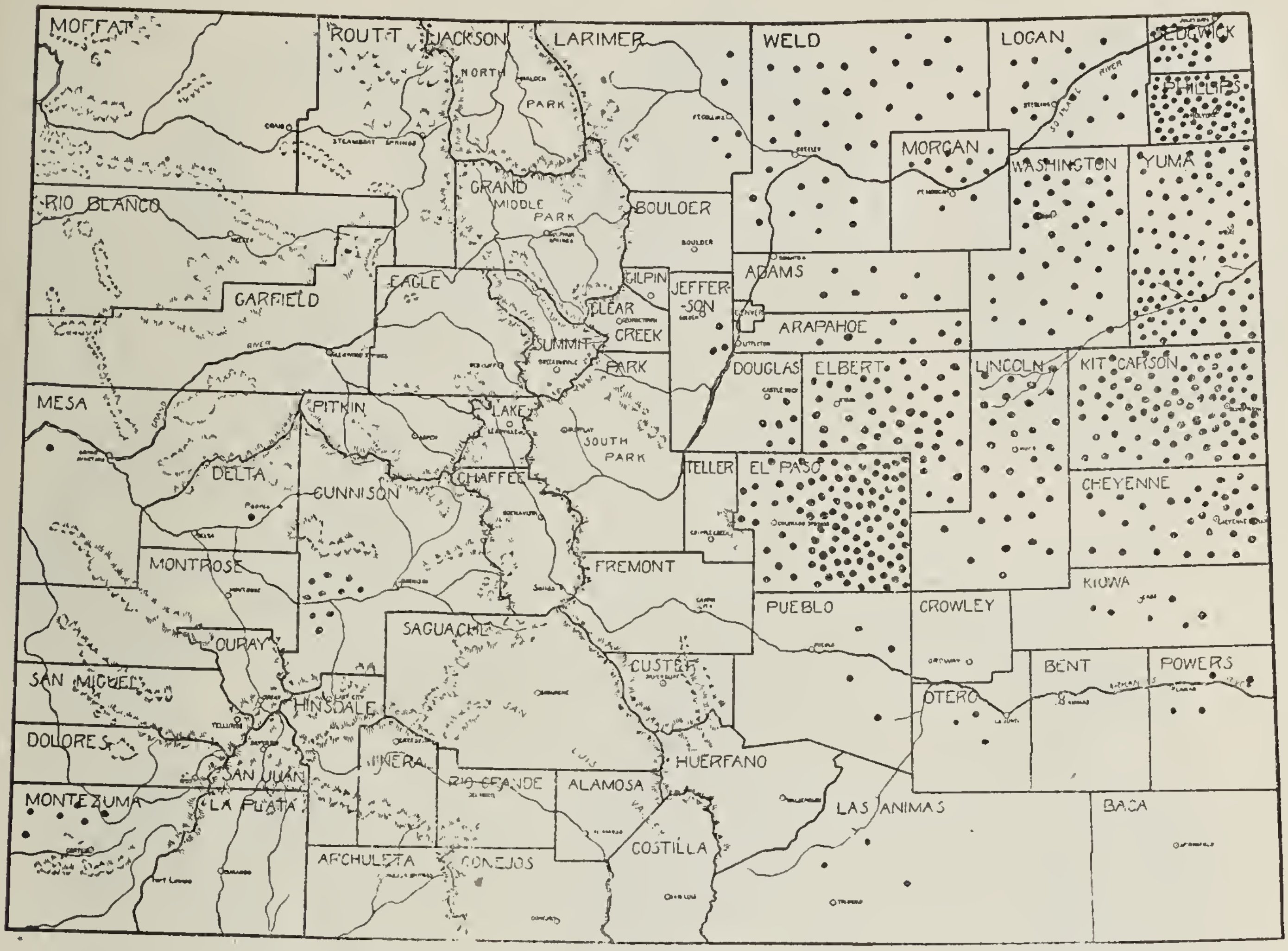

Fig. 2. Acreage of millet in Colorado, 1909; Total acreage, 30,926. Each dot represents 50 acres.

use of a simple seed treatment, we are able to eliminate smut from millet crops with a minimum of expense and trouble.

DESCRIPTION OF THE APPEARANCE OF SMUT IN MILLET

In these experiments, two types of millets chiefly were studied, namely, Foxtail millets *(Setaria italica)*, represented by the common German, Kursk, Goldmine, Hungarian and Siberian varieties, and the Panicum millets *(Panicum miliaceum)*, represented by Proso, hog and broom corn millets.

Foxtail Millets *(Setaria italica)*

In general appearance, smut in the Foxtail varieties resembles the stinking smut of wheat. In affected fields of the common and German varieties there may be seen the somewhat sickly yellow heads early in the season and the slightly darkened heads in the fall. If a smutted head be carefully examined, one sees at the base of the undeveloped grain (ovary) the dark mass of spores dimly showing thru the thin membrane that encloses it. (Fig. 3.) The base of the ovary appears enlarged. Generally, the spores are not disseminated; they usually remain so enclosed that close examination is necessary in order to recognize heads that are smutted. It requires examination of each

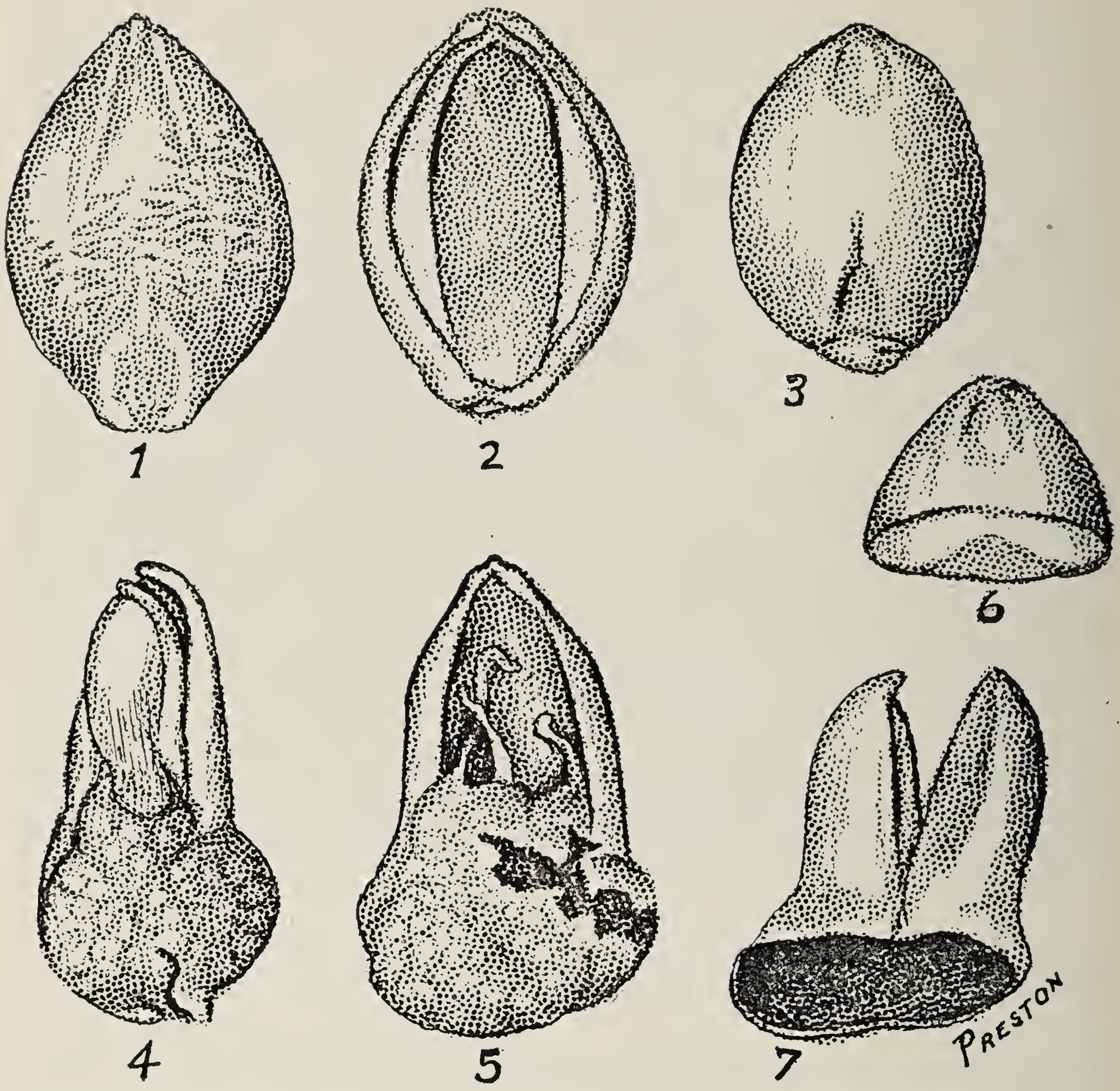

Fig. 3 Healthy and affected grains of common millet; 1, 2, 3, and 6, healthy grains; 4, 5, and 7, smutted grains.

head in the case of Kursk, Hungarian and Siberian millets before one can determine whether plants are smutted or not. This is because the dark orange or yellowish color of the mature heads obscures the characteristic color of affected heads.

Aside from the smut masses evident in the head, affected plants exhibit no other external evidence of the smut. The leaves and stem show no signs of the disease, except that affected plants are usually stunted and the heads frequently misshapen (Figs. 4 and 5 and 6.) Examination of affected heads shows that in most cases every grain of the head is destroyed, altho it often occurs that only a part of the head is smutted and, furthermomre, only a few gains free from smut may be found between the diseased ones.

The disease is evident in the heads even before they emerge from the sheath; the glumes enclosing the smut masses appear whitish and translucent. Except for the peculiar yellowing of the heads, as in the common and German varieties, affected stalks nearly always escape our notice.

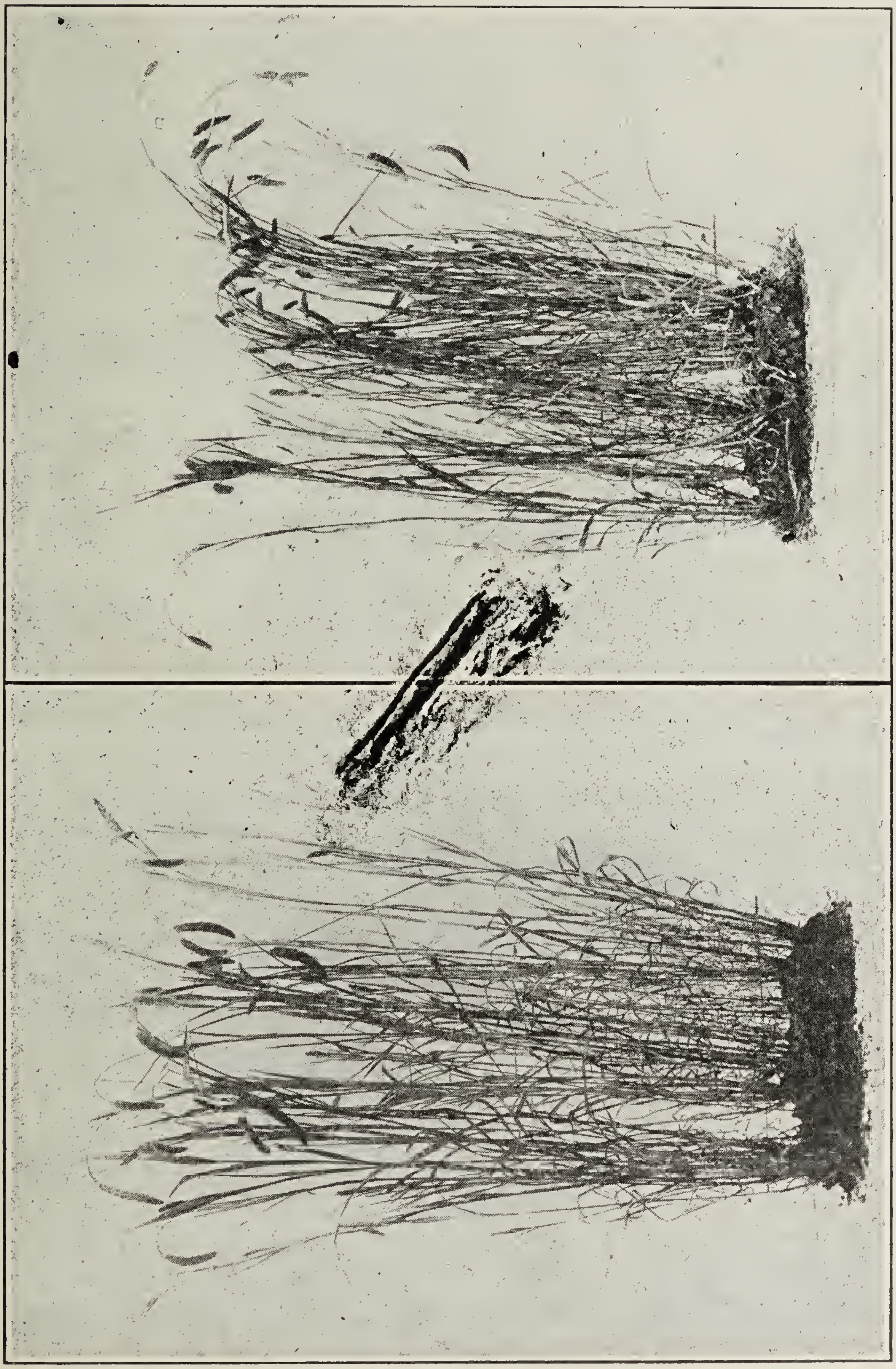

Fig. 4. Healthy plant of Hungarian millet.

Fig. 5. Smutted plant of Hungarian millet. Note that the plants are stunted and heads are shorter than in the healthy plants shown in Fig. 4.

Panicum Millets *(Panicum miliaceum)*

The smut in Panicum millets, such as Proso or Red Hog varieties, is especially characteristic in appearance. Here the heads are always empty and fully destroyed. They are noticeably shorter than normal ones, frequently exposed but very little beyond the leaf sheath. The smutted ovaries of the grain are massed together, enclosed by a whiteish membrane, the whole resembling a thickened or an elongated boil. Smutted heads *(panicles)* appear in much contrast to the normal spreading ones and are therefore readily recognized, even at a distance. Usually the smut masses are ruptured or broken before harvest time and the black, powdery mass is scattered by wind and insects to the healthy grain of other plants. Certain insects feed upon millet smut, more or less, and break open the enveloping glumes, exposing the dark spore masses and thereby rendering the affected heads more conspicuous and easily recognizable. (Figs. 9 and 10.)

DESCRIPTION OF CASUAL ORGANISMS OF SMUT

It should be generally recognized that all the smut diseases, as well as fungus diseases in general, are caused by minute and parasitic forms of plant life, so small in fact that the individuals cannot be seen with the naked eye. Such disease-causing organisms are collectively referred to the group known as "fungi", while an individual of the group is called a "fungus".

Obviously, the fungi are very simple plants, the plant body itself consisting of minute threads *(mycelium)* which penetrate and destroy living plants and thereby give rise to some form of disease. In the case of the smut diseases, the fungus becomes evident in the grain generally, and is represented by the masses of black, powdery spores which constitute the reproductive bodies of the fungus. From the standpoint of their role in perpetuating the disease, the spores may be likened to the kernels of corn in which lies the power of producing new corn plants. Similarly, the smut spores are the bodies which carry the disease to new plants, resulting in the continued increase of smut, year after year.

The spores of the millet smut fungi are rounded and very small, the individual spores being visible only under high-power magnification. If placed side by side, it would require 20 spores to measure the width of one human hair. (Fig. 11.) Owing to the small size and light weight of spores, they are readily disseminated by air currents, rain, and insects, and upon coming in contact with healthy grains, readily find lodgment under the scales or any protective parts of the grain.

*Smut of the Foxtail millets may be looked upon as distinct from that of Panicum millets, altho, in external appearance, the two are somewhat alike. The former is generally regarded incapable of producing smut in the Panicum varieties, and if this be true, there is no danger of the Foxtail millets becoming smutted from association in the field with smutted Panicum varieties. Our experimemnts in 1916 bore out this conclusion, but in 1917 some negative results were obtained. Further study is to be carried out on this question of cross inoculation.

The parasite grows up within the millet, giving no external evidence of its presence until just before heading-time, at which time the mycelium enters the developing ovaries and forms therein the characteristic masses of spores (Fig.) which give the plant its smutted appearance.

These spore masses remain enclosed by the bracts or scales of the grain usually until the millet is threshed, when they are broken up and the spores disseminated to normal grains. Lodgement of spores takes place upon or underneath the bracts, where they remain in a dormant state until the grain is sown and conditions become favorable for their germination and infection of the seedling millet.

This simpl life cycle occurs alike in the smuts of both Foxtail and Panicum varieties. Obviously, any treatment of the seed that can effectively destroy the spores lodged upon the surface and yet effect no injury so the seed itself will control the smut.

TIME AND PLACE OF INFECTION

Seeding infection is here the most probable, if not the only, type of infection. The germ tubes are capable of growing into the germinating seedling only over a short period of time, probably never taking place after the seedling reaches a height of 3 inches and generally about the time the first leaf is pushing out from its protective sheath. Spore germination begins by the rupturing of the spore wall, from which emerges a stout germ tube (Fig.). The germ tube either penetrates the seedling directly or produces secondary spores *(sporidia)* which later germinate and bring about infection. In either case, the germ tubes penetrate the tender tissues and form a much-branched

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* **Ustilago crameri** Korn. Sori dark-olivaceous; ovary infection; spores very irregular, rotund or oblong-angular, pellucid, 10-12 by 6-9 microns, brownish, olivaceous, smooth, sometimes very finely reticulated.

Ustilago panici-miliacei (Pers.) Wint. Sori black, pulverulent; panicles affected, and ovary of flower destroyed; spores globose to ellipsoidal, 9-12 by 8-10 microns, rarely angular, epispore yellowish-brown, smooth to punctate; promycelium filiform, cylindrical, commonly 3 septate; sporidia lateral or terminal, oblong-elliptic to ovoid.

Fig. 6. Smutted heads of common millet.

network of fungus threads within the growing point of the stem. There they grow, keeping pace with the upward growth of the stem.

Brefeld, in his researches on cereal smuts suggested a possibility of blossom infection in the millet smuts, although he obtained negative results. The occurrence of a small number of diseased grains among healthy grains in the head is suggestive of blossom infection, altho our experiments indicate such to be of little importance practically. However, further study on this point will be continued.

SOURCE OF INFECTION

The increased prevalence of millet smut in Colorado has come about largely thru the continued use of seed from fields containing relatively small amounts of smut. Up to the present time, virtually no interest has been taken in controlling the smut. (No mention of seed treatment in Colorado has been made either thru correspondence or thru actual observation of seed treatment.) Naturally, the amounts of smut have steadily increased year after year until now the annual losses are so important that growers are beginning to take steps to control the smut.

Aside from the presence of smut in the crop itself there is much likelihood of infection from related grasses such as the wild Foxtail

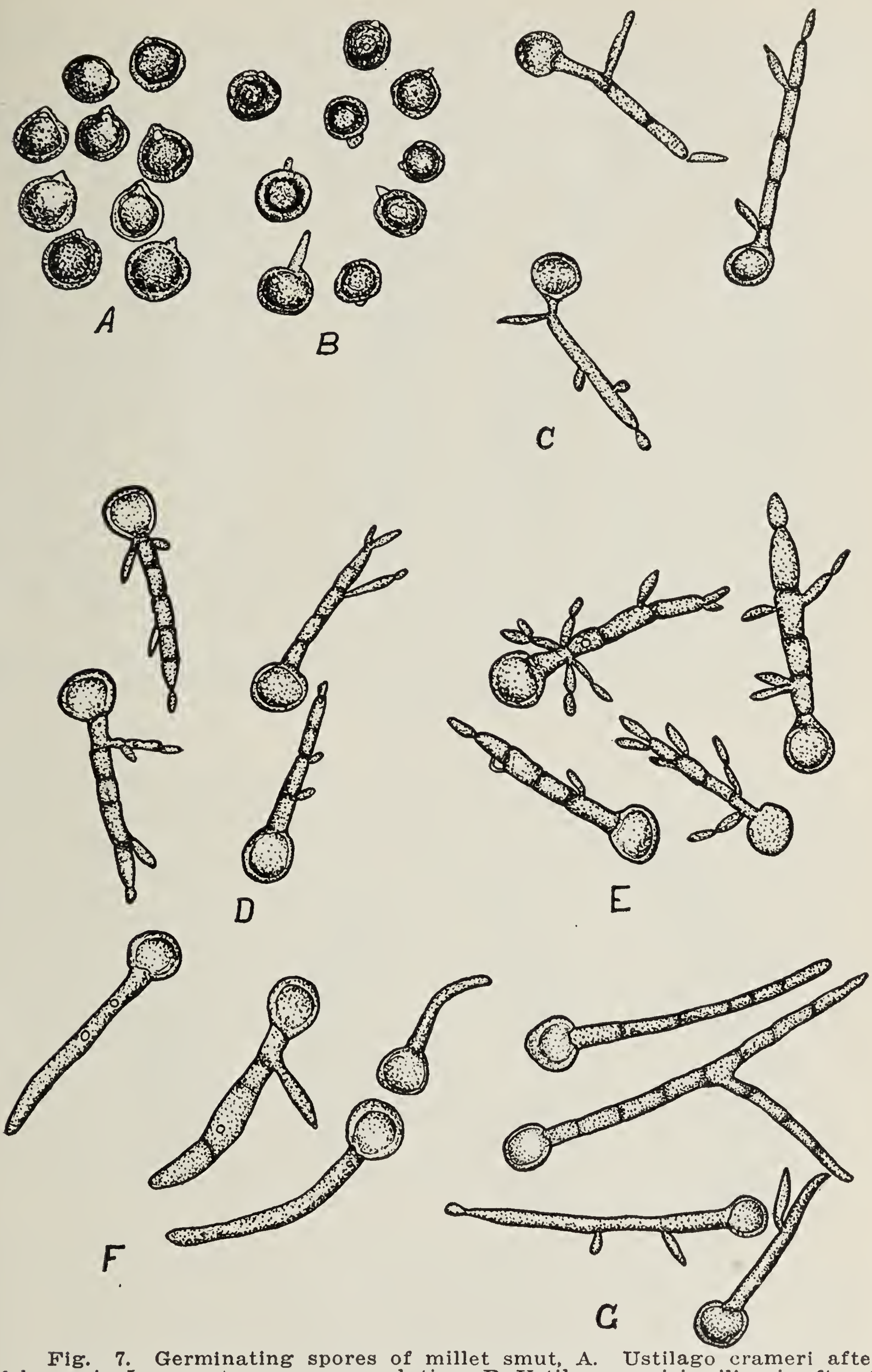

Fig. 7. Germinating spores of millet smut, A. Ustilago crameri after 6 hours in 5 percent cane sugar solution; B, Ustilago panici-miliacei, after 6 hours in 5 percent cane sugar solution; C. U. panici miliacei, after 14 hours in water; D. U. panici-miliacei, after 18 hours in water; E. U. panici-miliacei, after 24 hours in water; note the abundance of sporidia; F. U. panici-miliacei, after 18 hours in 5 percent can sugar solution; G. U. panici-miliacei, after 24 hours in 5 percent cane sugar solution.

and Panicum grasses. This phase of the work will be studied further the coming season.

Millet growers are in further danger of introducing smut by the use of seed imported from without the State, since large amounts of millet are imported into Colorado annually.

EFFECTS OF FORMALDEHYDE GAS UPON SPORES

In order to measure the effectiveness of formalin gas in destroying the germinative power of smut spores, a sterile cage measuring 28x34x32 inches was prepared. Three cubic centimeters of formalin gas was atomized within it and spore suspensions in water were introduced and allowed to stand 4, 6, and 12 hours, and then removed. In no case, were any of the spores observed to germinate. Water cultures of spores from the same source and placed under the same conditions, except that no application of formalin gas was made, yielded abundant germination of spores. Frequent trials of this treatment demonstrated beyond any doubt the effectiveness of the formalin gas in destroying the viability of the spores.

FACTORS AFFECTING VITALITY AND GERMINATION OF SPORES

The length of life of millet smut spores has not been studied fully. Our studies thus far show that spores are capable of a high percentage of germination after a period of three years. Undoubtedly, the viability lasts for seven or eight years, altho it is likely that it is seriously impaired at the end of such periods. Spores which were collected 27 years ago could not be made to germinate in water or nutrient cultures. Spores taken from smutted heads just after they had emerged from the leaf sheath were found to germinate readily in distilled water, thus requiring no resting period before germination.

The lasting viability of the smut spores disproves the theory held by some people that the storing of seed for a few years results in ridding it of the liability to smut. This practice should, therefore, be discontinued because the viability of smut spores is certain to outlast that of the millet seed.

Little can be said at present regarding the effects of moisture and temperature and other soil factors upon spore germination and infection in the soil. Temperature conditions prevailing at the time the seed and smut spores germinate may determine whether an attack will result or not. It has been shown in stinking smut of wheat that late sowing results in a greater percentage of smut in the crop than does early sowing. This is explained on the basis of low resistance of the

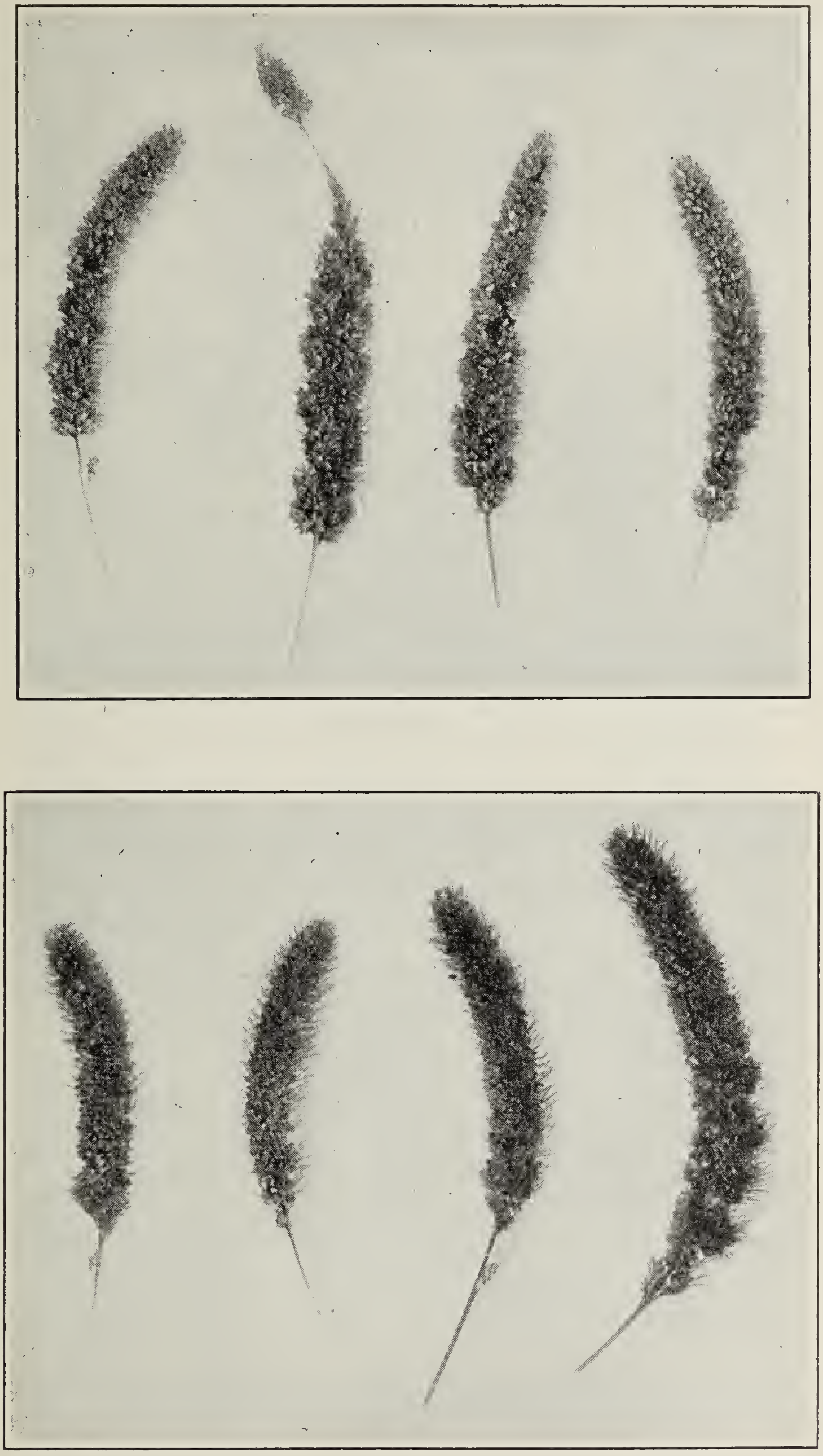

Fig. 8. Smutted heads of Siberian millet (above) and Kursk millet (below).

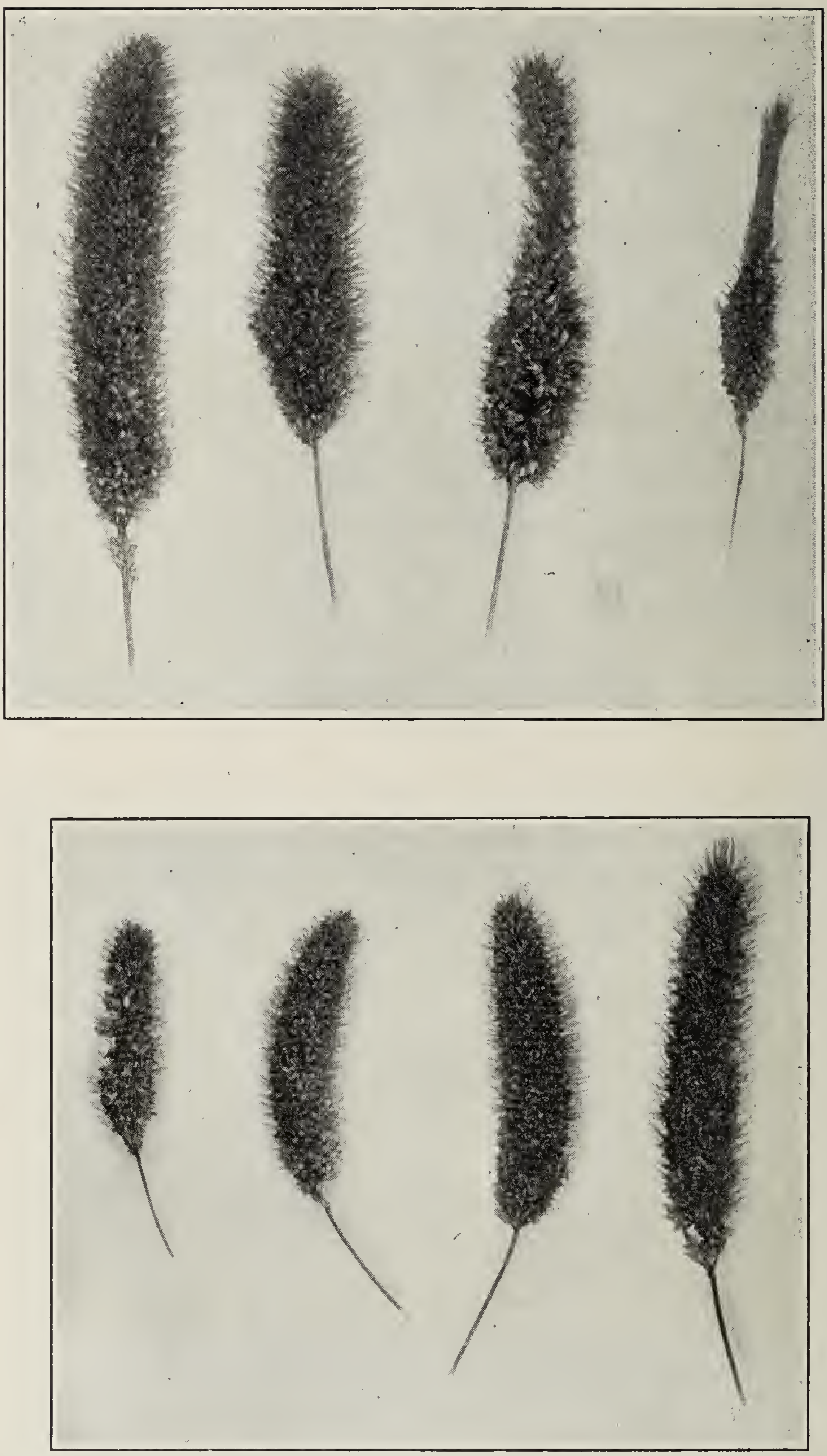

Fig. 9. Smutted heads of Siberian millet (above), and Hungarian millet (below).

wheat, due to impaired growth at low temperature. The same condition may obtain in millet germination and infection. It is less likely to be a serious factor, however, since millet is generally seeded in a warmer part of the season.

However, it is known that the period of infection is limited to a brief stage in the early growth of the plant and that outside conditions, especially moisture and temperature, which obtain at this period may affect materially the amount of infection that takes place.

Fig. 10. Smutted Red Hog millet.

MEANS OF SPORE DISSEMINATION

There are many ways whereby the spores of smut may be disseminated. Very little dissemination is carried on by wind, because the smut masses are enclosed usually until harvest. In the event of rupture of the membranes, the spores are freed and may then be carried to healthy grains by means of wind, rain, insects or other agents.

A very small form of beetle *(Phalacrus politus Mels)* was found working in large numbers upon the millets of our experimental plots. It was found that they fed upon the smut, breaking open the glumes, and scattering smut spores from plant to plant. Wherever this little beetle was found at work, the smutted heads were noticeably darker than unaffected ones and could be recognized at some distance. The beetle undoubtedly plays an important role in spreading the smut in fields where it is present.

Other common means of disseminating smut spores are those of harvesting and threshing the grain. Whenever healthy and unhealthy stalks are handled together there is danger of contamination. In the

Fig. 11. Smutted Proso millet.

process of threshing, where both smutted and healthy grains are run thru at once, it is to be expected that the grain will be contaminated, and if used for seed, will bring forth a partially diseased crop. The same holds true for all cereal smuts as well, hence this phase of handling the crop is especially deserving of consideration, particularly should there be only small amounts of smut in the crop.

CONTROL EXPERIMENTS

The following experiments were carried on during the seasons of 1916 and 1917 on the Experimental Station grounds at Fort Collins, Colorado. The experimental plots were irrigated; the soil consisted of a loan-or silty loam.

A large amount of smut material of both species *(U. crameri* and U. *panici-miliacei)* was secured for the purpose of inoculating various varieties of millet. The smut spores of *U. crameri were* thoroly mixed with the seed of the following varieties: Broom Corn, Common United States 1429, German U. S. 33133, Goldmine, Japanese, Hungarian, Kursk, Pearl, Proso, Red Hog, and Siberian. Spores of the other species *(U. panici-miliacei)* were mixed with these varieties in the same manner. The system of plotting the experiments was

TABLE I.—RESULTS OF INOCULATION WITH THE TWO SPECIES OF SMUT FOR 1916 & 1917.

	Ustilago crameri		Ustilago panici-miliacei.
	Percentage of smut 1916	Percentage of smut 1917	Percentage of smut 1916
Broom Corn	0	0	30
Common	45-55	58	0
German	50-60	72	0
Gold Mine	50-60	—	0
Hungarian	55-60	55	0
Japanese	0	0	0
Kursk	30-35	35	0
Pearl	immature	immature	immature
Proso	0	9	35
Red Hog	0	—	35
Siberian	31-35	32	0

modified somewhat the second season from that used in the first. i. e. instead of growing plants inoculated with both species in the same plot, these were plotted separately the second season.

Plot 1.—All varieties inoculated with *U. panici miliacei;* no disinfection of seed.

Plot 2.—All varieties inoculated with *U. crameri*; no disinfection of seed.

Plot 3.—All varieties inoculated with *U. crameri;* seed disinfected with formalin 1 pint to 40 gallons by soaking for 1 hour.

Plot 4.—Same as plot 3 except plants were inoculated with *U. panici-miliacei.*

Plot 5.—All varieties inoculated with *U. crameri;* seed disinfected with formalin, 1 pint to 40 gallons water, by sprinkle method.

Plot 6.—Same as plot 5 except plants were inoculated with *U. panici-miliacei.*

Plot 7.—Check.—Clean seed planted in clean soil.

Careful notes were kept on the plots thruout the season. The percentage of smut in each was determined in August and October.

TABLE II.—RESULTS OF INOCULATION WITH **USTILAGO CRAMERI.**—SHOWS DIFFERENCES IN THE AMOUNT OF SMUT APPARENT ON AUG. 15th. AND OCT. 30.

Variety	Percentage of smut Aug. 15	Percentage of smut Oct. 30
Broom corn millet	not headed	0
Common	12	58
German	35	72
Hungarian	27	55
Kursk	24	35
Pearl	not headed	not headed
Proso	7	9
Siberian	27	32
Japanese	not headed	0

METHODS OF ELIMINATING SMUT

It is a well known fact that one of the b st methods for the prevention of smut in the crop is that of securing seed free from all evidence of smut. Obviously, this must be accomplished by securing seed from fields that had no smut in them. It is difficult to do this owing to the difficulty with which the smut is recognized in the field. The cleanliness of millet seed can hardly be judged by a mere examination. Hundreds of spores may be lodged upon the grain yet be entirely indistinguishable on casual examination. A thoro examination of both field and harvested grain is necessary to judge the presence or absence of smut in any small quantities. If more attention could be given to the source and cleanliness of the seed, the losses would be greatly diminished. It is usually the case that imported seed is bought and sown with no knowledge whatever of the field with respect to smut infection or even subsequent handling of the grain where, if it were associated with smutted grain, it would invariably become contaminated to some extent. Hence, it is advisable to have some knowledge of the field from which the seed millet comes, and if this knowledge is impossible, there is one other alternative, and that is seed treatment.

It is clear from the foregoing that every spore which goes into the soil in contact with the seed is capable of reproducing the smut, since it is from these spores that the millet becomes infected. For this reason, the best method of control lies in a good, thoro disinfection of the seed whereby the smut spores are killed, but the vitality of the millet is uninjured.

TABLE III.—EFFECTS OF FORMALIN UPON SPORE GERMINATION

Cultures	Treatment	Percentage of Spore Germinations
1.	Formalin 1 pint to 40 gals. water	0
2.	" " " " 50 " "	0
3.	" " " " 60 " "	0
4.	" " " " 80 " "	0
5.	" " " " 100 " "	Slight
6.	" " " " 120 " "	0.1
7.	" " " " 140 " "	Free germination

Ustilago crameri **Plot 11, Row 2—1917**

The seed treatment recommended herein is very simple, readily performed, effective, and quite inexpensive. Considering these facts, in judging the advisability of treating smutted grain, there should be but one conclusion—treat all affected seed yourself and thereby insure the crop against unnecessary losses from smut.

In organizing experiments on the control of millet smut, it seemed advisable to experiment exclusively with formalin since it is now adopted as a standard method of control for all the cereal smuts where seed treatment is needed. Formalin is a commercial name applied to a 40 percent solution of formaldehyde, which is a gas. While not poisonous, it has a very pungent odor, and is one of the most effective disinfectants and fungicides now in use. In order to determine the best proportion of formalin and water to be used, it was necessary to expose both millet and smut spores to the disinfectant in various strengths for varying lengths of time.

TABLE IV.—EFFECT OF FORMALIN UPON VIABILITY OF MILLET SEED

The seed was soaked in the solutions listed below from 40-60 minutes and then dried

Lot	Treatment	Germination after 4 days Common	German	Siberian	Average
1.	Formalin 1 pint to 20 gals. water	75	73	75	74.3
2.	" " " " 25 " "	78	80	77.5	78.5
3.	" " " " 30 " "	83	86	78.5	82.5
4.	" " " " 35 " "	84	91	85.5	86.8
5.	" " " " 40 " "	86	82	86	84.6
6.	" " " " 45 " "	87	86	87	86.6
7.	" " " " 50 " "	89	92	83	88
8.	Creck untreated	91	94	89	91

Some have recommended a treatment of the grain in this solution for two hours but in these experiments a shorter time was tried out, and positive results were obtained thru a treatment for 40 to 60 minutes.

Method of Disinfecting the Seed

Solution Required: One pint of 40-percent formalin mixed with 40 to 45 gallons of water. Formalin is sold by nearly all druggists at a price ranging from 50 to 70 cents per pint. The solution should always be of guaranteed 40-percent strength.

Application to Grain: Two methods may be used according to the preference of theh farmer. Both are equally successful; the same strength of formalin solution is used in both methods.

Immersion Method

1. Use a barrel or any vessel of convenient size.

2. Put a sufficient amount of the solution into the vessel to immerse a sack of seed.

3. Leave plenty of room in the sacks; if it is filled too full, the solution will penetrate the interior of the sack with difficulty.

4. Put the sack of grain into the solution, move or dip it so that the solution can readily get to the interior of the sack and thoroly wet the grain. A block and tackle will be found very useful to raise and lower the sack, tho it is not necessary.

5. Leave the seed in teh solution not less than 40 minutes or more than 1 hour.

6. Raise the sack and allow to drain back into the vessel. Then empty in a pile upon a clean floor, and cover with wet cloth or gunny sack in order to prevent the escape of the formalin gas.

7. At the end of two hours spread the grain out to dry. Shoveling over frequently will help materially in drying it, or if a draught can be lead over it the drying will proceed much faster. To further facilitate drying, the grain should be spread as shallow as possible, one inch or so in depth, if possible.

TABLE V.—RESULTS OF EXPERIMENTS IN SEED DISINFECTION
(Percentage of Smut After Treatment)

	Sprinkle Method		Immersion Method	
Varieties	U. crameri	U. panici-miliacei	U. crameri	U. panici-miliacei
Broom Corn Millet	none	none	none	none
Common	"	"	"	"
German	0.1	"	"	"
Hungarian	"	"	"	"
Japanese	"	"	"	"
Kursk	"	"	"	"
Pearl	"	"	"	"
Proso	"	"	"	"
Siberian	"	"	"	"

Sprinkle Method

This method is very simple and easy. Two men can treat large amounts of grain in one day, depending upon the facilities at hand.

1. Use a clean granary floor or wagon-bed, or canvas in the open. A bushel or so of grain should first be spread upon the floor and sprinkled with the formalin solution mentioned above. A common garden sprinkling can is best for this purpose.

2. Apply the solution at the rate of ¾ to 1 gallon to a bushel of grain. While it is being applied, the grain should be shoveled well so that each grain will be thoroly wetted.

3. After all grain has been treated by adding both grain and solution to the pile as long as convenient, the whole should be piled and covered for 2 hours as in the previous treatment.

After drying, the grain should be put in clean sacks and stored in a place where it will be free from danger of contamination by smut spores. Sweeping in the granary, where any amount of smutted grain has been kept, should never be done until the treated seed has been removed. By sweeping, the large numbers of spores which have settled upon the floor and walls are put in motion and are likely to find their way back again to the treated grains.

Tables Nos. 3 and 4 give the result of spore and seed treatments. It will be noticed in Table No. 3 that the formalin solution is effective even to a dilution of 1 pint of formalin to 100 gallons of water. However, with this dilution a small percentage of spores appeared to be germinating, altho they never developed definite germ tubes.

Pammel and King in 1909, treated spores of *Ustilago crameri* with formalin solution diluted to 1 part to 320, 500 and 1000 parts of water. It was found that no germination resulted when spores were treated with the 1-320, (1-40 gals.) and 1-500, (1-63 gals.) proportions but "abundant germination" occurred in those treated with 1 to 1000 (1 to 125 gals.)

Table No. 4 gives the results of different strengths of the formalin solution upon the germination of millet seeds. The averages of many tests demonstrate the injurious effects of the solution when not diluted sufficiently. A solution of 1 pint to 20 gallons of water is entirely too strong, and unnecessary to destroy the spores. It impairs the germinative ability of the grain over 15 percent. On the other hand a solution of 1 pint formalin to 40 to 50 gallons of water causes no appreciable injury when the grain is steeped therein for a period of 40 to 60 minutes.

SUMMARY

Smut is the chief disease affecting millets in the Great Plains states.

Two different smuts affect millet; the Foxtail varieties are attacked by *Ustilago crameri,* and the Panicum millets attacked by *Ustilago panici-miliacei,* both of which infest the individual grains. converting the whole head or panicle into a large black mass, enclosed by bracts in the Foxtail millets and by a thin, white membrane in the Panicum types.

Experiments in the field demonstrate the possibility of infecting plants by inoculating the seeds with spores of the smut.

Smutted plants are difficult to recognize in the field, except by careful examination. This accounts for the fact that smut most always escapes notice in the field.

The spore masses are enclosed by the glumes (Foxtail) or by a thin membrane (Panicum) which prevent spore dissemination before harvest.

Generally only the lower parts of the glumes are destroyed in Foxtail millets, while the ovary is entirely destroyed. In Panicum millets, affected heads are shortened and resemble a dark, thickened boil.

The injurious effects of formalin gas upon the germination of spores was fully demonstrated. Spores in water cultures subjected to the gas for 4, 6, and 12 hours, failed to germinate in all cases.

The viability of smut spores lasts fully three years and probably much longer.

The period of infection is restricted to a brief stage in the early growth of the plant.

Spore dissemination in the field is effected at least to some extent by a small beetle, *(Phalacrus politus Mels).* Other means of disseminations are wind, rain, and the harvesting and threshing of grain.

Seed treatment is required in order to free the grain from smut. Seed may be thoroly cleaned by means of formalin disinfection. A solution of 1 pint of formalin to 40 to 45 gallons of water is recommended for treatment.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

POTATO CULTURE IN COLORADO

By E. P. SANDSTEN

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The Colorado Agricultural College

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POTATO CULTURE IN COLORADO

By

E. P. SANDSTEN

The potato crop is rapidly becoming one of the leading crops in Colorado. The soil and climatic conditions in many sections are ideal for the normal development of the plant and for the production of a high quality. Cool nights and moderately warm and sunny days favor a gradual growth with a maximum development of the starch content, together with firmness and cooking qualities. Poor quality in Colorado potatoes is not due to soil or climatic conditions, but to methods of irrigation and culture.

The past year's experience has shown that the potato can be grown successfully as a garden crop and on city lots and gardens, and we may expect in the future that a large share of the city gardeners will plant potatoes in place of the more perishable vegetables.

The success of potatoes as a garden crop will depend largely upon the grower's ability to rotate his crops so that potatoes will not be grown oftener than once in three or four years in the same soil; also to his ability to provide the soil with the needed fertilizer in the form of humus materials. The problem of rotation is more difficult in garden work than under field culture, due to limited area of the garden plots. But, where well rotted stable manure or rotted street sweepings are obtainable, the problem of rotation is easily solved.

So far as food values are concerned, potatoes will yield more for a given space than any of the common vegetables grown, and have the additional advantage of keeping qualities.

Under field conditions, the potato crop fits well into a rational system of rotation and has the advantage of leaving the land in the best possible condition for other crops.

Success in potato growing is never obtained by hit and miss methods nor by constantly changing from small to large acreage, and vice versa, in order to "catch the market." The farmer should adopt a standard rotation for his farm and hold to it from year to year. This implies that the acreage devoted to potatoes in settled communities should be about the same from year to year. If this method were uniformly followed, we should not have the large fluctuation in acreage nor in price. This would stabilize prices, and at the same time make for better farming methods.

POTATO PRODUCTION IN COLORADO FOR THE YEAR 1917

The year 1917 was a banner year for potato production in Colorado. The total acreage was, in round numbers, 45,000, and the average yield for the state about 200 bushels to the acre, a total of 9,000,000 bushels. The yield per acre for the state is the highest recorded and places Colorado near the top in the yield per acre. Figuring the consumption of potatoes for the State at 3,000,000 bushels, we have a surplus of 6,000,000 bushels for outside shipments.

The high yield per acre in Colorado this year is due to a number of factors. Chief among these were favorable climatic conditions, better cultural methods, crop rotation, seed selection, seed treatment, and a more intelligent use of irrigation water. While the grower has no control over climatic conditions, he can, to a great extent, modify his cultural methods so as to offset the effect of unfavorable weather. This would imply that a grower can not lay down a definite cultural program to be followed from year to year, but rather he should have a general plan that can be modified to meet the variable climatic conditions as they occur from time to time.

From these figures, one gains an idea of the importance of the potato growing industry in the State.

While the above figures are imposing and show a gratifying increase both in acreage and yield over previous years, the possibilities for further increase is practically unlimited. With better transportation facilities and with the settling up of the western part of the State, thousands of acres of the finest potato land in the world will come into production.

The growing of seed potatoes for the southern planter is a new and unexplored field for Colorado potato growers which offers practically unlimited possibilities. The soil and climatic conditions of Colorado make it possible to grow seed potatoes of high quality and vitality.

THE POTATO PLANT

A knowledge of the general nature of the potato plant is essential to an understanding of the requirements of the plant and to the production of a maximum crop of high quality.

While most agricultural crops, like the cereals, are grown principally for the grain (seed), the potato is grown for its tubers or underground stem. The tubers are essentially a vegetative part of the plant which have become modified into a storage for food material by which the plant is able to pass through a period of rest and to start another season's growth. The potato being a modified underground stem, it is capable of functioning as a stem and developing chlorophyll or green coloring matter, stems and leafbuds. When we speak of potato seed, we do not really mean seed, but a stem or a vegetative cutting, the same as a cutting of a Geranium or Coleus. From this one can readily see that for the best development of this cutting, certain soil and climatic conditions are necessary. The ability of the plant to produce tubers is in direct ratio to the soil conditions, fertility, and climatic conditions with which we surround the plant. To make a success of potato growing, the growers should know the nature and requirements of the plant. These requirements will be discussed under different headings.

SOIL

While potatoes may be grown on most types of soil, a sandy

Knarly and rough potatoes are the result of poorly prepared land and improper irrigation loam soil well supplied with vegetable matter and containing all the elements of fertility will give the best results both in yield and quality. The heavier types of soil have a tendency to puddle after heavy rains and after irrigation, which greatly impedes the development of the tubers. Potatoes grown on heavy lands are apt to be rough and ill shaped. This is due to the fact that when the growing tuber comes into contact with hard and lumpy soil, it yields and grows in the direction of least resistance.

Heavy soil, as a rule, is difficult to aerate, that is, to get a supply of air into the soil which is necessary for the normal development of the root system and the tubers. When there is no choice and potatoes have to be planted on heavy land, fall plowing and the turning under of green crops in the fall is helpful in loosening up the soil. Under a regular system of rotation, where alfalfa precedes the potatoes, the last crop of alfalfa should be turned under to increase the vegetable content of the soil, thus making the soil looser and more friable.

FERTILIZERS

Commercial fertilizers are not used to any extent in Colorado and for the present, at least, there is little call for their use. In general farming, where a regular system of rotation is followed, soil fertility and proper soil conditions are maintained by the plowing under of alfalfa or clover, and, with the application of barnyard manures. In the non-irrigated sections, a longer system of rotation should be followed, together with the plowing under of any green crop that can be grown. Often a crop of weeds may be grown and turned under. The raising of livestock in the non-irrigated sections is now looked upon as necessary to success in order to provide the much needed fertilizers.

One crop farming has proven a failure as a permanent type of farming in every section of the country. It not only robs the soil of its fertility, but it also burns out the vegetable matter and leaves the soil dead and unproductive. Rotten stable manure is the best fertilizer for potatoes in Colorado. Fresh stable manure should not be applied on the land immediately before planting, as it generally has too much straw in it and tends to dry out the soil, and, further, it takes a full season under our arid conditions for the strawy manure to decompose and during this period it does more harm than good. This is particularly true under dry farming conditions. Under irrigation, there is less objection to the use of strawy manures, as the decomposition is more rapid.

The custom of applying fresh manures to the land in the fall and early winter is less objectionable, as it has a chance to be acted upon by the rains and snow before the crop is planted.

In the plowing under of green crops, the decomposition is more rapid and the potato plants get the benefits, not only of the fertilizer element in the green crop, but also the benefits of the improved soil conditions. It can not be emphasized too strongly that the proper soil conditions for the potato are as important as the elements of fertility, and soil fertility in its broadest sense includes proper soil conditions.

PREPARATION OF THE LAND

Plowing.—Deep plowing is necessary on most kinds of soil, especially on lands which have a tendency to bake and become hard, either after rain, or after irrigation. The potato plant is a deep feeder, and for the maximum production the soil should be plowed 10 to 12 inches deep. The plowing under of alfalfa should be done in the fall. The fall plowing should be just deep enough (about 4 or 5 inches) to kill the alfalfa plant. In the early spring, the land should be cross-plowed to the depth of 10 or 12 inches, and harrowed and thoroughly pulverized. It is an excellent practice on heavy soils to follow the alfalfa with a small grain crop, fall plow the land to the depth of 10 to 12 inches, and then cross plow in the spring, fit the land and plant potatoes. The potato crop will then receive a greater benefit from the plowed-under alfalfa, as the roots and stems have had a chance to decompose and the soil is in better physical condition for the potato plant.

ROTATION OF CROPS

All successful potato growers now agree that potatoes should not be grown more than once in succession on the same land, and that a potato crop should be preceded with the plowing under of a crop of alfalfa or clover. Whether the potatoes should follow immediately after the alfalfa or clover, or the year following, depends upon soil conditions. Equally good results have been obtained from both methods. On the heavier land, the soil undoubtedly would be in better condition for potatoes if an intervening crop of grain were planted between the alfalfa and the potatoes. On the lighter soils, this is not necessary. Usually the second or the third cutting of alfalfa is plowed under, or the second crop of clover. Clover is now extensively planted in higher mountain valleys in place of alfalfa, and is giving excellent results. It is easier to kill out, and the soil can be put into perfect condition with less expense than after alfalfa.

A crop of potatoes puts the soil in best possible condition for small grains, and the labor expended in the preparation of the land for potatoes is repaid, not only from the potato crop, but from the higher yield of small grains planted on the land. Clover lends itself better to short crop rotation than alfalfa, and, for this reason, the farmers in the higher mountain valleys can place their farms on a four-year system of rotation, while in the warmer valleys and in the irrigated sections of the plains, a five- or perhaps six-year rotation is better.

While at present the plowing under of alfalfa and clover has been a main source of soil fertility, the time will undoubtedly come when this will have to be supplemented with the application of stable manures, and this is already done to a great extent by our best growers.

SEED

During the last two years, more attention has been devoted to the question of seed selection and type than to any other phase of potato growing. Gratifying results, both in yield and quality, have been obtained. While seed selection is important to success, it is only one of the grower's problems. No matter how good the seed may be, the returns will not be satisfactory unless the grower is willing and able to perform the cultural work, and provide the right kind of soil conditions to enable the plant to make a satisfactory growth. The grower must first see to it that

Perfect type of Rural seed. The kind to plant a plant has the proper conditions for full development, and then provide the proper kind of seed. There is a tendency to over-emphasize seed selection, and substitute good seed for proper cultural methods. This does not mean that the grower should neglect the seed end of the business, but rather that we should aim to provide the best possible condition for seed planted. When we speak of pedigree seed, we do not really mean pedigree in the sense that is used by the plant breeder, for we are not dealing with seed in the proper sense of the word, but we are dealing with a cutting.

While the cutting will produce a plant like that from which the cutting was taken, insofar as the general character of the plant is concerned, the potato or tuber is an underground stem for the purpose of storing up food for another season's growth, and, if we remember that the storing up process is dependent upon the soil, climate, and the general conditions that surround the plant, we can readily realize that the cultural side of potato growing is the most important factor in the production of a larger crop.

Hill Selection.—This method of obtaining good seed is now recognized to be the most effective. It consists in going over the field during the month of August, and marking the strong, vigorous hills, such as the grower considers ideal in both growth, habit, and in yield. These marked hills are dug in the fall previous to the digging of the main crop, and, if at digging time they measure up to the requirements set, they are saved, kept separately for seed, and planted in a separate plot the following year. All tubers from these selected hills are saved, as a small tuber from a good hill is better than large tubers from a poor hill.

Bin Selection.—Many growers practice bin selection, that is, the grower picks his seed from the stock of potatoes on hand, either during the winter or in the spring before planting. This method is good, but is subject to some objections, for often poor productive hills, and even diseased hills, will produce smooth and true-to-type tubers, and these are selected with others and planted.

Screenings.—A large share of potato growers use the screenings for seed, and claim that they are justified in so doing both by reason of economy and yields obtained. The practice is not advisable under the best system of potato growing. It may be tolerated in years of seed shortage, but it should never be made a main practice. A modified method of using screenings for seed is adapted by some growers. It consists in selecting the best potatoes from the screenings, and using these for seed. This method is preferable to the former, but is not recommended in good farming.

Seed Plots

The question whether the farmer should grow his own seed or purchase the same from the seed grower is open for discussion. Personally, we believe that every potato grower should grow his own seed, and have his own seed plot. This will enable him to give his seed plot different treatment from the main crop without much additional expense.

Whole Versus Cut Seed

Whether whole seed is better than cut seed depends upon the conditions under which the grower is operating. In districts where the fusarium disease is prevalent, and where conditions are such as to require the farmer to irrigate up his seed, whole seed is preferable. Whole seed will, as a rule, under these conditions, give a better stand, as the seed is not so apt to rot when whole. In sections where the soil conditions at planting time are favorable, cut seed will give equally good results. There is one objection to whole seed, namely, many varieties have numerous eyes, especially at the seed end, and are apt to produce a hill with numerous weak shoots, which invariably produce small tubers, while with cut seed, where only one or two eyes are left to the piece, the shoot or shoots are stronger, more vigorous, and more productive. More seed is also required in planting whole seed and when seed stock is high it adds considerable to the total expense.

Under dry farming methods, whole seed is preferable to cut seed, since a whole seed does not rot as readily as a cut seed, thus giving the plant a better chance to establish itself, and a longer time during which it can obtain food supply from the seed. The question of the size of the whole seed is one of importance to the grower. In general practice, the seed should not weigh less than 1 ounce or 1½ ounces. If too small, the growth from the seed is weak and the plant produced lacks vigor and productiveness. Seed about the size of an average hen egg is best. The size of the cut seed will depend somewhat upon the soil conditions, though pieces weighing not less than 1½ ounces should be used in general practice.

Treating Cut Seed

Experienced potato growers have found it advantageous to cut the seed three or four days before planting, and sprinkle the seed with air-slaked lime. This has a tendency to dry off the cut surface, and, in a measure at least, stop the premature rotting of the cuttings; even leaving the cut seed for a few days untreated seems to have the same result.

Mature versus Immature Seed

Much has been said and written as to the relative value of immature seed as compared to mature seed, but no definite conclusion has been reached by the practical grower. The favorable results obtained by potato experts with the use of immature seed would indicate there are some advantages in the use of this kind, but in most cases the immature seed had been grown in seed plots from hill selection, and naturally would show the result of such selection, rather than from the intrinsic value of the immaturity. It is undoubtedly true, as one would expect, that in an immature seed the buds or eyes are relatively more active because they are younger and would start to grow more quickly than eyes from a well matured tuber. Whether there is any particular gain in the rapid development of the sprout is questionable. However, what is often termed immature seed is not immature seed at all, but seed that is full matured in every respect, except that the tubers are below medium in size, and this is obtained by closer and late planting of the seed plot. Under average farm conditions, the mature seed has given satisfaction, and we are not yet ready to advocate a new departure.

Greening the Seed

The practice of exposing the tubers intended for seed to the sunlight and air for a period of one or two weeks before planting is advocated by some growers in Colorado. It is particularly valuable in the South in connection with the planting of the second crop of tubers, as it hastens the growth of the plant. When potatoes are exposed to the air and light, the tuber begins to function in the same manner as the green branch or a leaf. In other words, it turns green, showing the development of chlorophyll, or a green coloring matter, and with this begins to sprout. This sprouting is equivalent to the new growth on trees and bushes in the early spring, so that the greening process is simply a method of stimulating the growth activity of the buds. When this is obtained, the tubers are planted, and the shoots will soon come out of the ground. In Colorado, this practice may sometimes be resorted to, especially if unseasonable weather delays the planting. Progress can then be made by greening the potatoes, so as not to lose too much time after planting before the potatoes come up. Under average normal conditions, it is questionable whether there is any real advantage in this practice, and further, it places an additional expense on the grower. If greening is resorted to, the potatoes should be placed in shallow boxes or crates, and exposed to the full influences of sunlight. The temperature also must be such as to stimulate growth activity.

PLANTING

The time of planting depends entirely upon the season and the locality. In some sections of the State, planting is delayed until early in June. This delay makes the season rather short for potatoes, and, as a result, the crop is often immature and low in quality. Under average Colorado conditions, we believe that earlier planting will give better results, not only as to yield, but in the quality of the crop produced. The latter part of May is about the right season for most sections of the State. This refers to the main crop. Seed plots, or potatoes intended for seed, may be planted as late as July.

Depth of Planting

Soil conditions generally determine the depth at which potatoes should be planted. On the average land in irrigated districts, potatoes should be planted about 4 inches deep. The rows should be from 36 to 40 inches apart, and the seed dropped 12 to 14 inches apart in the row. On the more level land, it is important that the rows be at the maximum distance apart, in order that the hilling may be deep enough to carry off the water without coming into contact with the potato plants. On land having a good fall or slope, the rows may be closer together, as high hilling is not necessary. In the dry-farming sections, the rows should be 4 feet apart, and the seed from 18 to 24 inches apart in the row.

Potato Planters

There are numerous makes of potato planters on the market, most of which are generally satisfactory to the grower. We believe, however, that the picker type of planters are less satisfactory than the disk type. While it requires an extra man or boy to watch so that each compartment in the disk has its seed, it insures a perfect stand, while the picker type of planter often misses the seed, and sometimes spears the eye, resulting in an imperfect stand of plants. Farmers, as a rule, pay little attention to this phase of the operation, but the loss from missing plants in a field is considerably greater than one expects. We have found that, taking the State as a whole, the growers are losing on the average of 15 percent of the crop through imperfect stands, generally caused by the failure of the planter properly to perform its function. This item alone amounts to many thousands of dollars, and even on individual farms is often sufficient to decide whether a crop is raised at a profit or at a loss.

CULTIVATION

After potatoes have been planted, the spike-tooth harrow should be put in use and kept going so that the field will be harrowed at least once every week or ten days, until the potatoes are about 4 inches above the ground. If there is danger of tearing the young plants during the last harrowing, the teeth may be set so as to slant away from the draft, which will result in less injury to the plants. As soon as the plants are large enough to permit of cultivation between rows, the first cultivation should be as deep as possible. Eight to ten inches is not too deep. This will loosen the sub-soil, and permit the soil to become aerated. As the plants increase in size, with a corresponding development of the root system, the cultivation should be correspondingly shallow. In the right kind of potato soil, the roots of the plant will often penetrate to the depth of 2 feet, and laterally 2 or 3 feet. The more thorough and frequent the cultivation, the better will be the soil conditions for the development of the root system and the tubers. On non-irrigated land, the cultivation should be shallow throughout the season.

Hilling

On level land, deep hilling, is necessary, as standing water should not be permitted around the potato plant. On land having a good slope, so as to insure perfect drainage, the hilling should be less extensive. It is better at least, on land having a slope, to hill gradually, as it will keep the soil cooler, and permit the breaking up of the crusts by cultivation between irrigations. On the level land, little or no cultivation can be done after the hilling. Where high hilling is practiced, there is considerable danger of over-heating the soil, due to the extensive exposure of the soil in the hilling. The undue raising of the temperature in the hill creates favorable conditions for very rapid growth of the plant, and also very favorable conditions for diseases. The cooler the soil can be kept during the warm season, the more normal and the more healthy will be the plant. Also, it will be less susceptible to disease attack.

On non-irrigated land, hilling is detrimental, as it tends to dry out the soil, and thus deprive the growing potato plant of the much needed moisture. Generally all that is needed in the way of hilling is accomplished by using a broader tooth in the rear of the cultivator, which will throw a small amount of soil toward the plants. Even this is unnecessary if the seed is planted deep enough to keep the growing tubers from pushing out of the soil.

IRRIGATION

The Horticultural Department is frequently called upon to give advice as to when and how potatoes should be irrigated. To answer such questions intelligently, a knowledge of soil conditions is absolutely necessary. Many growers believe that potatoes should not be irrigated until the vines are setting the tubers, even though the vines are actually suffering from lack of water. This may work out all right, but one may well question the wisdom of following such a rule. It is a universal rule that when a growing plant needs water and shows signs of wilting, water should be applied, so that the normal growth will not be checked. When the tubers have once set, it is necessary to irrigate so as to keep the soil in best growing condition possible for the balance of the season, or until the crop is matured. In other words, there should be no check to the growth of the plants after the tubers have once started to develop. If a check is given during this period, and the plant resumes its growth afterwards, knobby and gnarly tubers result. Hence the importance of keeping the young potatoes growing without check throughout the season.

Second growth of tubers caused by improper irrigation

In irrigating potatoes, it is much better to apply enough water thoroughly to saturate the ground, rather than small amounts of water at frequent intervals, as frequent applications of water will puddle and harden the soil to a much greater extent, and there is danger that some plants will not get enough water. A small stream running for a long period is better than a large stream for a short period.

On the Eastern slope, it is preferable to apply the water during cloudy days or at night time. When the potatoes have reached their full growth, which depends largely upon the season and locality, it is advisable to withhold the water so that the skin of the tubers may ripen and harden. Otherwise, the keeping quality of the potatoes will be impaired. Keeping the tubers growing up to the harvest time results in poor quality.

There is a tendency in some potato-growing sections to crowd the growth and development, or, as some express it, to make the crop "in the shortest possible time," during the month of August and half of September, by the liberal use of water. This practice may be advantageous during favorable seasons, but such practice invariably results in a poorer quality of the crop produced, and the tubers are watery and soggy, with poor keeping qualities. Further, seed potatoes grown in this way lack vigor. A normal growth development when the plant is not forced is preferable, so far as quality is concerned. It is also probable that undue forcing of the plants make them more susceptible to disease attack.

HARVESTING

The harvesting of a potato crop may appear to be a simple operation which can be performed by anyone. As a matter of fact, the harvesting is one of the most important operations that a grower has to perform. The question of damage, due to the digger, and the problem of curing the potatoes so that they will stand up in storage, have to be looked after. Generally, a considerable percentage of the crop is injured by not having the digger set deep enough, thus cutting or mutilating the tubers. On heavy land, not properly prepared, it is difficult to get the digger below all the tubers. On sandy lands, this difficulty should not exist. The tubers injured by the digger are very apt to decay in storage, and besides, they will spoil the salability of the crop.

Again, the practice of picking up the potatoes immediately after the digger is not good. In the first place, it is difficult to sort thoroughly the potatoes, and the diseased ones are apt to go with the good ones. Further, a small percentage of soil generally adheres to the tubers, and is carried along with them. If possible, the potatoes should be left on the field for several hours, so that they may become thoroughly dry. This will help in hardening the skins, and improve the keeping qualities of the potatoes. Potatoes cured in this manner in the field will keep much better and make a more salable product.

In many irrigated sections, where the growing season is relatively short, and when the vines are growing vigorously up to the time they are killed by the frost, the tubers are not mature, but are watery, and the skin peels off readily. When this condition exists, the curing of the tubers after digging is very important. Where the best grade of potatoes are grown, and where they are wanted for storage, a good plan is to pick up the tubers after they are dry, and place in piles of 40 to 50 bushels, and cover slightly with straw. Where heavy frosts are apt to occur, the covering should be increased. After a few days, the potatoes will have gone through a curing process which will make their keeping qualities much better. This practice is not advisable where the potatoes are sold directly from the field and where the question of labor enters in.

GRADING

Ordinarily, the hand potato grader is the only grading machinery used on the farm. In many cases, no grading is done apart from the slight separation in the picking up of the potatoes after the digger. Where the hand grader is employed, the workers are usually so busy that the grading or screening is not thorough and little good is accomplished by it.

The time has come when the potato grower must conform to some standard of grading for his potatoes in the same manner that the fruit grower conforms to the standard of grades in apples. It can be truthfully said that there is more waste in the potato crop due to poor handling and grading, than any crop raised on a farm. A conservative estimate of the waste shows that from 15 to 25 per cent of the total potato crop harvested is wasted. This does not mean that the waste of the actual product is this high, for a portion of the waste is represented in dirt or soil which adheres to the tubers, and which is never separated from them. Though this waste is not equally large in all sections, yet the total figure is enormous. The largest waste comes from the presence of small, ill-shaped, and decayed tubers which cannot be utilized for food purposes, but on which the farmer is paying for containers, railroad freight, and commission charges. This waste should be left on the farm, and utilized for livestock feed. Further, the presence of small, gnarly, and diseased tubers gradually decrease the consumption of the potato and is the source of dispute between the commission man and the farmer. For the farmer's own protection, the potatoes should be properly graded and marked, and the grade should be standardized so that interstate shipments would be uniform. The State Potato Growers' association endorsed and adopted the U. S. standard of grading as recommended by U. S. Department of Agriculture, and the U. S. Food Administration. It is as follows.*

U. S. Grade No. 1

*"This grade shall consist of sound potatoes of similar varietal characteristics, which are practically free from dirt or other foreign matter, frost injury, sunburn, second growth, cuts, scab, blight, dry rot, and damage caused by disease, insects, or mechanical means. The minimum diameter of potatoes of the round varieties shall be one and seven-eights (1⅞) inches, and of potatoes of the long varieties one and three-fourths (1¾) inches. In order to allow for variations incident to commercial grading and handling, 5 per centum by weight of any lot may be under the prescribed size, and, in addition, 3 per centum by weight of any such lot may be below the remaining requirements of this grade.

U. S. Grade No. 2

This grade shall consist of potatoes of similar varietal characteristics, which are practically free from frost injury and decay, and which are free from serious damage caused by dirt or other foreign matter, sunburn, second growth, cuts, scab, blight, dry rot, or other disease, insects, or mechanical means. The minimum diameter shall be one and one-half (1½) inches. In order to allow for variations incident to commercial grading and handling, 5 per centum by weight of any lot may be under the prescribed size, and, in addition, 5 per centum by weight of any such lot may be below the remaining requirements of this grade."

VARIETIES

Experience has shown that certain standard varieties do better in some localities than others, and this preference or adaptation to soil and climatic conditions is now fairly well established for Colorado. With these facts known, the grower need not experiment with new varieties or with old ones, but can take up the work at once without passing through the period of experimentation. For the convenience of potato growers, we may divide the State into districts, based upon climatic conditions, geographical location, and soils, and assign varieties to these districts which have proven best adapted to them. Number 1, the Greeley district, comprising Northeastern Colorado, with Greeley as a center; No. 2, Divide district, comprising Douglass, Elbert, and El Paso counties; No. 3, Northwestern district, comprising Moffat and Routt counties; No. 4, Intermountain district, including the valleys and mesas of Garfield, Eagle, and Pitkin counties; No. 5, Western Slope district, including Mesa, Delta, and Montrose counties; No. 6, Southwestern district, including Montezuma and La Plata counties; and No. 7, San Luis Valley.

District No. 1 is the oldest potato-growing section in the State, and the crop is grown as a part in the regular rotation.

Types of the Rural variety, a standard late variety. Widely grown in many districts of the State

The two standard varieties grown are the Pearl and the Rural. The Pearl leads to the extent of 75 percent of the total planting, though many growers are beginning to plant the Rural more extensively. The Pearl variety out-yields all others, and seems to be particularly adapted to the soil and climatic conditions obtaining in the district.

District No. 2, comprising what is known as the rain belt of the Eastern Slope, occupies the central elevated portion of the Eastern Slope from the mountains towards the plains. Little or no irrigation is practiced in this section, the rainfall being from 14 to 20 inches, and fairly well distributed. The altitude varies from 5,500 to 7,000 feet. The fact that potatoes are grown without irrigation makes it necessary that the crop mature early in order that it may not be damaged by the late summer drought. Early maturing varieties are mostly planted, and these have proven a success. The Early Ohios, the Chicago Market, and Six Weeks are most extensively planted, Early Ohios being the leading variety. In the sections where the rainfall reaches 18 to 20 inches, the Pearl variety is grown with success.

District No. 3, the Northwestern district, is characterized by a short season, due to its high elevation and cool nights. Late maturing varieties should not be planted. Russet Burbank, Early Ohios, and the Rural are leading varieties.

In District No. 4, which is the Intermountain district, the soil is medium heavy and admirably adapted for the growing of high

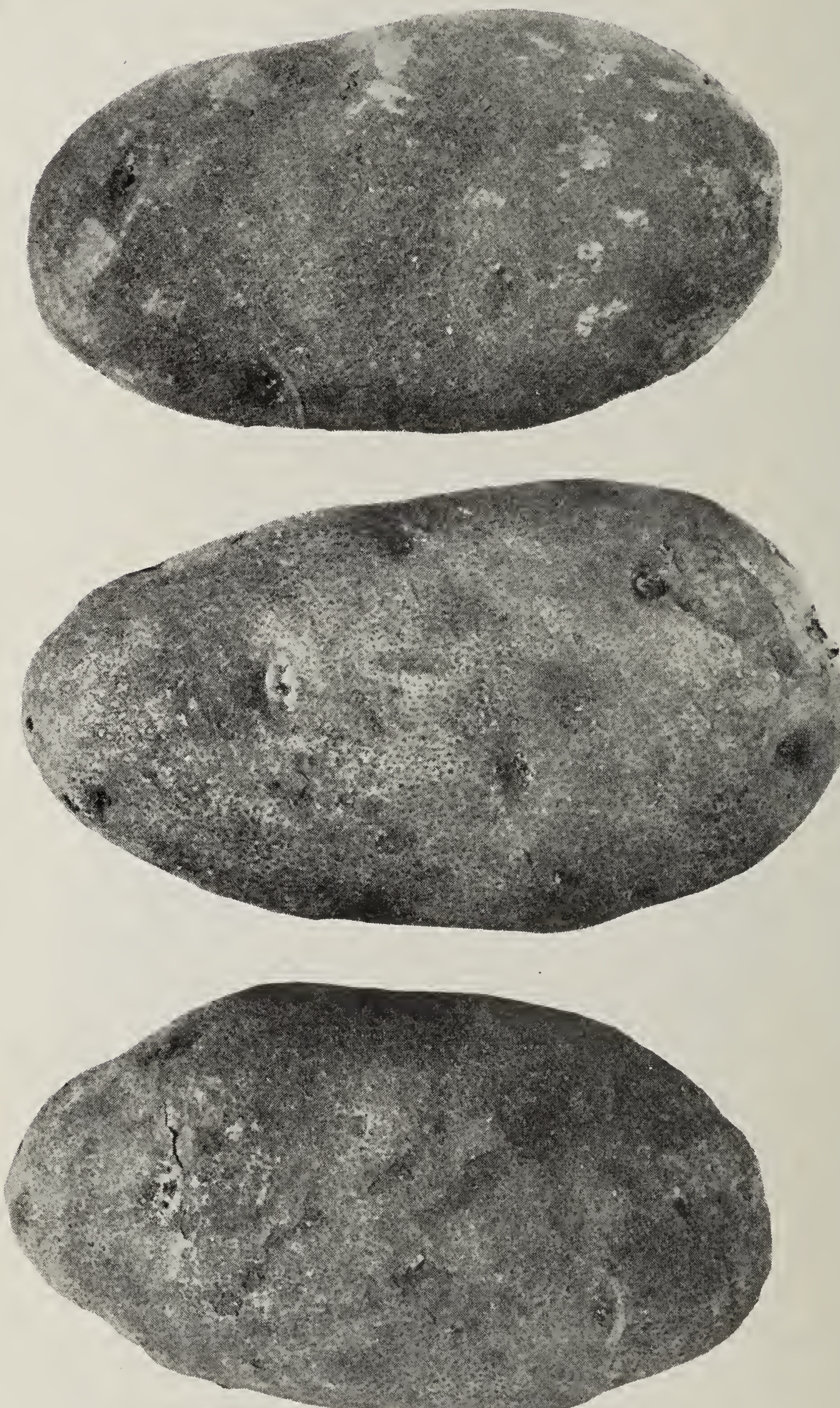
Good types of Early Ohio—A desirable early variety for the dry farming sections

Perfect type of the Peach Blow variety. This variety grows to perfection in the Eagle and Carbondale district

Bliss Triumph potato. An early variety of high merit

quality tubers. Varieties grown are the Peachblow and the Russet Burbank. The Rural and the People's are grown to a limited extent, but possibly 80 percent of the acreage is devoted to the first-named varieties.

District No. 5, comprises the valleys of the Grand, Gunnison and Uncompahgre rivers, together with the irrigated mesas adjoining. These valleys have some excellent potato soil, and the



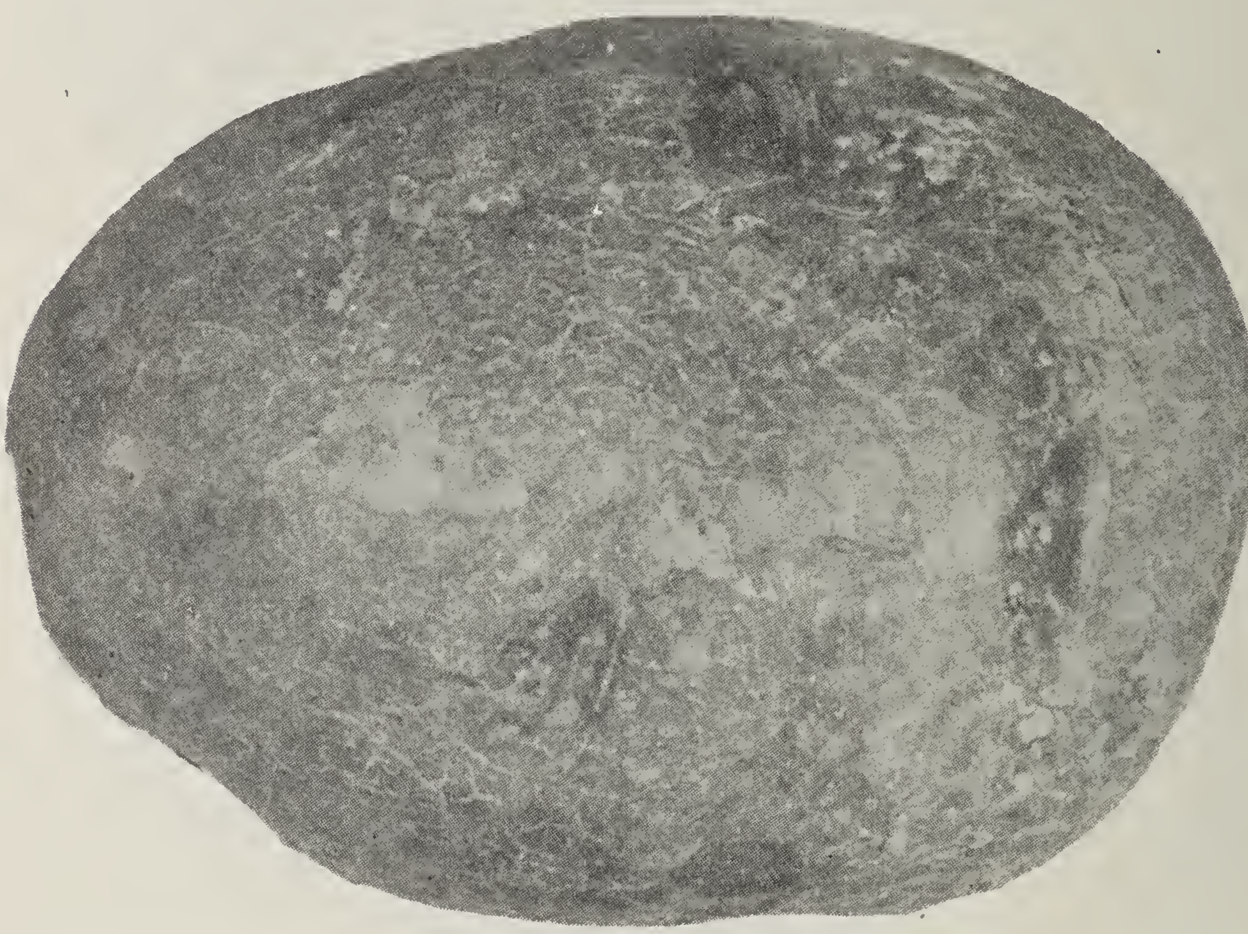
Typical tubers of Russet Burbank, a profitable variety for the intermountain valleys industry is developing rapidly. Leading varieties are the People's, Rural, Russet Burbank, Downing and Cobbler. This district grows a greater range of varieties with success than any other district.

Pearl tuber showing typical characteristics. A great favorite in the Greeley district

A perfect specimen of Brown Beauty potato, a variety especially adapted to the San Luis Valley

District No. 6, which takes in the irrigated sections of Montezuma and La Plata counties, grows principally Russet Burbank, Rural, and Early Ohios.

District No. 7, which includes the San Luis Valley, is one of the largest potato-growing sections of the State. The leading variety for the valley is Brown Beauty, Russet Burbank, People's, and the Rural. These are planted in the order named.



Typical specimen of the People's variety, grown extensively in the Gunnison and Uncompahgre valleys. A heavy yielder and fine shipper. Shows a tendency to grow rough.

It is not remarkable that each section should have developed somewhat different cultural methods, which in turn are based on the experience of the grower. When one considers the great diversity in soils, altitude, and climatic conditions of these different sections, one can readily understand why this diversity in cultural methods should occur. Any prospective potato grower locating in any of these sections should follow the methods and practices of the best potato growers in the district, rather than rely upon information obtained elsewhere. The effort of the Horticultural Department and the State Potato Growers' Association to standardize varieties for each district has met with a ready response from the growers, and there is a marked tendency in all districts to reduce varieties planted to one or two leading sorts. This tendency is having and will have a marked influence upon the marketing of the crop for the different districts. The buyer will be assured of uniformity in variety and quantity. The growing of numerous varieties always has a demoralizing effect upon the market and upon prices.

THE RUNNING OUT OF VARIETIES

It is a common complaint among potato growers that a given variety, after being grown for a series of years in the same locality, or at least on the same piece of land, runs out, that is, shows a decrease in vigor and productiveness. Investigations tend to confirm the common opinion that varieties decline under the ordinary methods of culture and seed selection. It is undoubtedly true that a good variety grown on a certain type of soil tends to show a decline, especially when no efforts are made to keep up the production through the selection of seed. The common practice of using the small potatoes or the screenings for seed must inevitably lead to a decline in yield, as poorer stock is being planted from year to year. Undoubtedly, the system of cultivation may have something to do with the decline, also the climatic conditions under which the grower is farming. On the other hand, we have abundant evidence that with proper seed selection, proper cultural methods, the right kind of soil and climatic conditions, a given variety does not decline, neither in vigor nor productiveness, but on the other hand shows an actual increase. This would indicate that the decline in yield, as commonly believed, is due to preventable causes over which the grower has control. We know personally of several growers in the State who have been growing the same variety for the last twelve or fifteen years, and during this time there has not been any decrease in production, but on the contrary a considerable increase. These growers, however, practice seed selection by the hill method, and grow the potatoes for seed separately in seed plots. With these facts before us, we are inclined to dissent from the general opinion that the varieties run out, but believe that the running out is due to the lack of seed selection and the lack of proper cultural methods and soil conditions.

TRUENESS TO TYPE

The standard varieties of potatoes grown in Colorado are recognized by a certain type or form that the tuber assumes when grown under normal conditions. While this statement is true, it should be born in mind that elevation, soil and climatic conditions influence the type to a marked degree, and that the grower can only hope to maintain a perfect type of the variety grown when he practices the best cultural methods and careful selection of seed that is true to type.

In heavy soil, it is difficult to maintain the type of the variety, as in growing the tuber yields to the pressure exerted by the soil, and will expand in the direction of least resistance. This causes the tuber to grow irregular and rough. It is easier to maintain the type in loose and open soils where the tuber can expand without unequal pressure from the soil. Ill-shaped or knotty tubers generally occur when the growth of the tuber is checked, usually on account of lack of water, and then starts the second time, the knobs representing the second growth. From this, it will be seen that it is necessary to keep the soil conditions such that the tuber can continue a normal development without check.

SEED CERTIFICATION

With the development of the potato-growing industry in this State, some provisions are necessary to secure the purchaser of seed potatoes against an inferior product. To obtain this condition a system of seed certification is necessary. It is true that here and there are seed producers who make a specialty of producing high-grade potatoes from which the average grower may obtain high-class seed. But these seed growers are few and far between, and as the welfare of an industry depends upon the intelligence and standards of the average grower, it is necessary that the largest possible number of them should have access to high-grade seed.

A system of seed certification by properly qualified officials who can certify to the quality of the seed is necessary. This would tend to raise the general standard of the product, and also furnish an incentive to many growers to produce certified seed.

A system of certification was formulated by the Colorado State Potato Growers' Association and incorporated in its constitution and by-laws. This certification calls for two inspections of the growing field during the summer, and a bin inspection after the harvest. In the field inspection, special attention is paid to the health and vigor of the plants, the absence or presence of disease, the fullness of the stand and the uniformity of the plants in the field. The two field inspections should be made at intervals of four to six weeks. The last inspection should be made as late as possible before the harvest, so as to detect the most dangerous diseases.

The bin inspection gives the inspector an opportunity to determine the trueness to type of the variety grown, the freedom from scab and the general quality of the tubers. If after inspection, the inspector finds that the product measures up to the standard, a certificate to this effect is granted to the grower. This certificate states the variety, the results of the inspection, and in fact all possible information connected with the potatoes. The grower may then use his certificate in advertising his product and the fact that his potatoes have passed the necessary inspection gives the grower a prestige over those who do not hold such certificate. Application for seed certificate should be made to Horticulturist, Colorado Agricultural College, Fort Collins, Colo., not later than June 15 each year.

It is a fact that the Colorado potato growers every year find considerable difficulty in obtaining first-class seed. This is especially true during a year like the present one when prices were abnormally high and where the grower disposed of his product regardless of standards. A year of extremely high prices tends to demoralize standards, but the grower should bear in mind that extremely high prices are the exception rather than the rule with a standard crop like potatoes, and the success of a grower is not based alone upon the large profit obtained in a single season. We must provide for the average years and average prices and raise the standard of the product so that during the year of average prices the grower still can make a profit and find a market because of the excellency of the tubers produced.

A State law fixing standards both as to grading and seed would be beneficial to the grower, but it is doubtful if such law could be passed until there is a greater demand for it. Meanwhile, it is the duty of organizations and individuals to do everything possible to raise the general standard of the crop.

Our potato growers do not realize the future before them in the production of high-grade potato seed for the Southern planters. This phase of potato growing has unlimited possibilities, as the demand for high-grade seed is constantly growing. Colorado is the natural territory to supply the seed for this section of the country, not only because of the advantages in soil and climate, but also because of the nearness to the markets and the lower transportation charges.

The demand for seed potatoes from the South calls for the growing of varieties that are not now grown to any extent. The varieties in demand for seed are the Cobbler and the Triumph. Both of these can be successfully grown in most parts of the State. From all indications, the Triumph is well adapted to the conditions in the San Luis Valley, while the Cobbler can be grown successfully in every section of the State.

This department has had numerous requests for seed potatoes of these two varieties from the South, and these requests have been more numerous during the last two years than before, indicating that the Southern growers are beginning to learn the value of Colorado-grown seed.

POTATO DISEASES

Late Blight.—This disease, so destructive in the East, does not occur in Colorado. The climatic conditions of the State do not favor the development of the disease, as it requires a humid atmosphere with high temperature. The reported occurrence of late blight in Colorado has in every case turned out to be the fusarium disease. It is indeed fortunate for the State that the late blight does not find a congenial home here, as the fighting of this disease entails considerable expense.

Early Blight.—It occurs in the State, especially in the warm, heavily irrigated valleys of the Western Slope. Some seasons when rainfall is above the normal and when the temperature is relatively high, it causes considerable damage to the grower. It occurs during the month of July, and is easily distinguished by dark brown patches or rings on the foliage. In extreme cases, the whole foliage becomes affected, and the leaves drop off, and often kill the plant. In milder cases, it reduces the yield and the potatoes produced are small and worthless.

Spraying with Bordeaux mixture is effective, but it should be done before the disease has made any headway. If the weather conditions are such as to encourage the development of the disease, the grower should spray before the disease makes its appearance. Its rapid spread over the field and the rapid progress of the disease makes the application of the Bordeaux of little effect if the disease has gained a firm foothold. During the last five years, in only one season has this disease done any damage.

Fusarium.—This disease is present in every potato growing district of the State, and is the most destructive disease with which the grower has to deal. It remains in the soil for a number of years, and there is probably not a potato field in the State where the disease cannot be found. It is favored in its development by hight temperature, moisture, and poor soil drainage. In heavy soils, the disease appears to be particularly bad. It may be introduced into the soil either by previous crops, or, we believe, by the seed. The fact that the disease remains in the soil for a number of years makes the subject of crop rotation important to the grower, and is one of the main reasons why we advocate the growing of potatoes only one year on the same piece of land without the intervention of other crops.

The presence of the disease in seed potatoes can easily be ascertained by the cutting off of a thin slice of the potato at the stem end. A dark circular discoloration just inside of the skin indicates the presence of the disease. Seed potatoes showing the presence of the disease should not be planted, as a matter of safety. While it is true that seed potatoes showing the presence of the disease often produce healthy, normal plants with a satisfactory yield, the fact is that the disease is present and may, under favorable conditions, develop and attack the growing plants. It is also believed, though not proven by careful experiments, that cut seed is more apt to become infested with the disease than whole seed. This may be due in some cases at least to the lack of vigor of plants grown from small seed pieces. It would seem that where the disease is prevalent and where the conditions are favorable for its development, that whole seed would give better results. The planting of whole seed, however, does not insure the grower against loss by this disease, as it may attack the growing sprout and cause great losses.

The disease being internal, it cannot be reached by any remedy that we may use against it. Precautionary methods, such as planting of disease-free seed, crop rotation, and the best cultural methods, will be in the main effective in preventing the disease from doing great damage.

The appearance of the disease in the field is in many cases identical with that of the early blight, with the exception that the leaves turn a paler shade of yellow, and do not show the brown patches and circles. The stem of the plant is first attacked, and if a cross section is made of the stem close to the ground, dark areas will be found in the bundle or the fiber portion of the stem. These dark areas indicate the presence of the disease, and its presence greatly interferes with the transportation of food materials.

Curly Leaf.—This is a disease of unknown origin, which occurs some seasons in the State. As the name would indicate, the leaves assume more or less of a curly outline, and the plant becomes more or less stunted in its growth. It is believed that this disease is transmitted or carried by the seed tuber. The fact that the plant does not show any marked discoloration is responsible for the fact that this disease is often passed over by the grower and no attention is paid to it, although the loss from the disease may be considerable. The grower should be on the lookout for plants showing the symptoms of the disease, and destroy them at once.

Rhizoctonia.—This disease is present in practically all of our cultivated fields, and, under favorable conditions, does considerable damage. It is more destructive in the higher mountain valleys than on the plains. Its presence on the vines can easily be distinguished by the brown lesions that occur along the base of the plant. In some cases, these wounds or lesions extend around the whole plant, and completely shut off the food supply from the leaves to the tubers. In most cases, only one side of the stem becomes diseased, and in such cases the plant continues to grow, though the yield is considerably decreased. The disease may occasionally be found on the tubers in the form of small black spots, or wart-like growths all over the skin. These little dark areas vary in size from a pin-head to that of a dime. They are known as "sclerotia," and contain the "seed" which is carried over in this manner from year to year. During some years, the disease is particularly bad and causes considerable damage. If the spots on the tubers are not large or conspicuous, they do not interfere with the salability of the crop.

This disease can be controlled so far as dissemination from diseased tubers is concerned, by means of disinfection. While this method of treatment is efficient against the disease, it does not prevent infection from the soil, and hence the seed treatment against this disease does not always show satisfactory results. In this connection, it should be borne in mind that this disease is native to the soil, is always present, and under favorable conditions will attack the plant whether the seed has been treated or not.

The most effective method of seed treatment is with corrosive sublimate, using 4 ounces of corrosive sublimate to 30 gallons of water. The solution should be made up in wooden vessels, such as a barrel, and the potatoes to be treated suspended in a gunny sack for one and one-half to two hours. This solution will penetrate the "sclerotia" and kill them. The treatment should be made before the potatoes are cut. The potatoes treated cannot be used for livestock, as the solution is exceedingly poisonous, and care should be taken to protect livestock against drinking the solution. The solution can be used only three times, after which a new mixture should be made up.

Potato Scab.—This well-known disease is common in every section of the State, and during some years does considerable damage to the crop. The disease is external, penetrating the tubers only to a very small extent. Its greatest damage is to the appearance and keeping quality.

There is very little excuse for the existence of this disease, as it can easily be controlled by treating the seed potatoes. The same treatment as recommended for Rhizoctonia disease should be used, that is, the potatoes, before cut, should be dipped into a solution containing 4 ounces of corrosive sublimate to 30 gallons of water. The easiest way of treating the seed is to make up the solution in a barrel holding about 50 gallons. The barrel should contain about 30 gallons of the solution and the potatoes placed in a gunny sack and suspended in the solution for an hour and a half, after which the seed may be cut and planted. Precautions should be taken not to feed the treated seed to livestock, as the poison is very deadly.

Numerous complaints have been received that the scab has occurred in some fields in spite of treatment, and often when clean seed has been used. In such cases the presence of the scab fungus is undoubtedly due to the feeding of cattle on the field the season before planting. This disease propagates very readily on the manure dropped by the cattle, and in this way the land becomes infested. If the disease is in the soil, the treatment of the seed potatoes cannot be effective against it. Clean land, as well as clean seed, is essential for the production of clean tubers.

Dry Rot—Dry rot is caused by one of the fusarium organisms and is essentially a disease of the cellar or storage. It has been particularly bad in the western valleys where it has caused serious losses to the growers. The dry rot should not be confused with the fusarium wilt disease, common in the field where it attacks growing plant and tubers. As a rule, the dry rot disease does not attack perfectly sound tubers, but tubers which have become bruised or cut in harvesting, or in handling. The disease is favored with high temperature and high moisture contents of the cellar or storage, and spreads rapidly from tuber to tuber under these conditions.

Last season a large percentage of the crop was stored under unfavorable conditions, and the tubers in many instances immature and the skin peeled easily in handling. The potatoes contained a relatively high percentage of water. Due to the heavy frosts, the potatoes were placed in storage rapidly, giving the tubers little or no chance to dry out, or cure, before being stored. The cellars were also utilized to the fullest capacity, and potatoes were piled high in the bins.

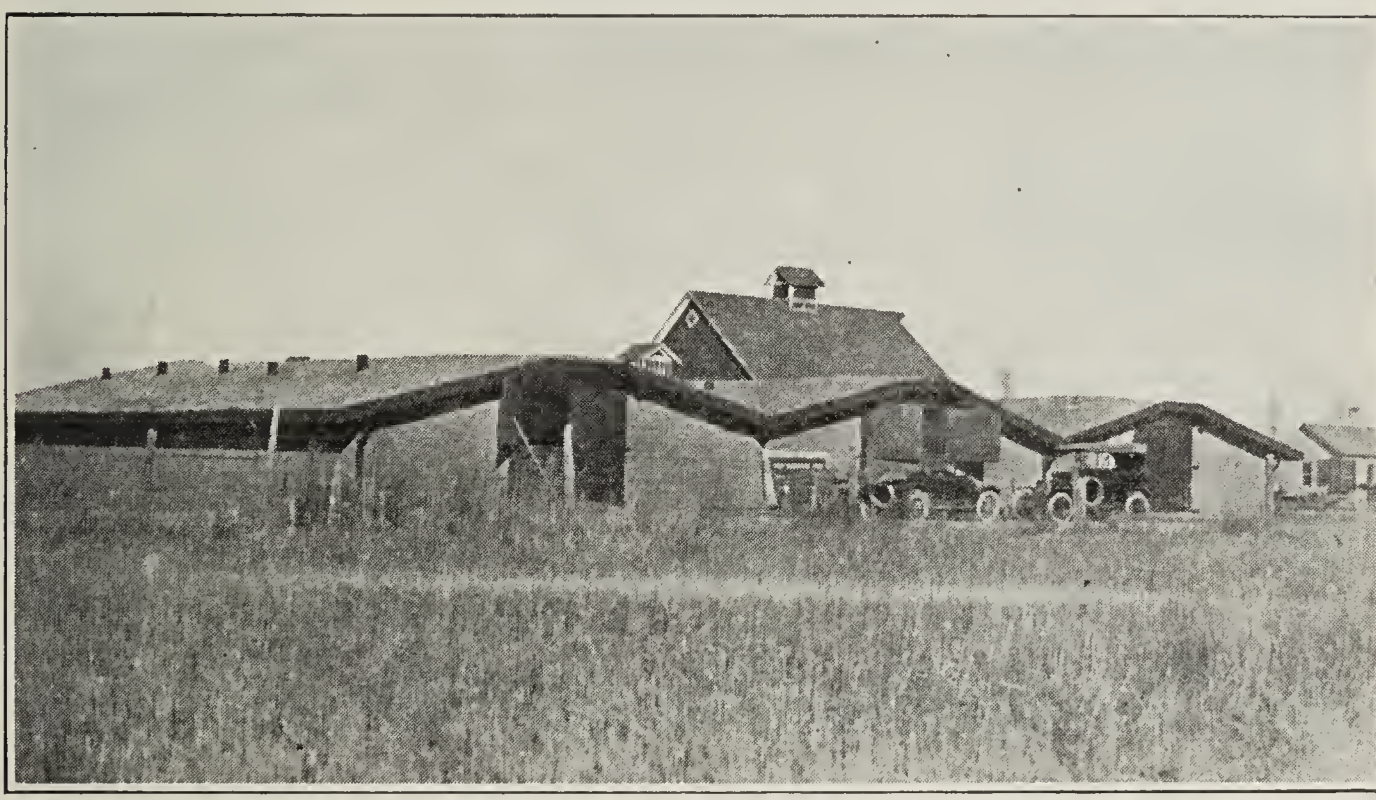
Potato cut by digging machine and infested with dry rot in storage

Most of the cellars have ventilators placed at the roof, and few, if any, have an intake or ventilator opening at the floor. When only one set of ventilators are provided there is no circulation of air, and the condition of the air in the storage is not changed. Few storages or cellars have floors. Proper ventilation of the storage will, to a large degree, eliminate the dry rot, and most cellars can, with slight modification, be properly ventilated. An extra intake or ventilator should be provided for either at the base of the door, or at the side of the door, one in each end of the storage. These ventilators should be so constructed as to permit the operator to close them when not needed. When a large quantity is stored, the bins should have the false floor, so as to permit a circulation of air from below. There should also be ventilators made of slats in the shape of tiles, but perforated so as to permit a circulation through the middle of the bins. If proper ventilations are provided for, the disease is not apt to make much of a progress.

More care should be exercised in the sorting of the potatoes before storing, since the dry rot affects potatoes injured or bruised and the grower should eliminate potatoes that are cut in digging, so as not to infect the sound ones. Potatoes infested with the dry rot should not be used for planting. The disease is believed to be a native of the soil, and may be perpetuated from year to year though sound tubers taken from an infested cellar may be planted. Cellars in which potatoes are infested with dry rot should be fumigated before another crop is stored.

STORAGE

Every potato grower should have farm storage for his crop. The lack of proper storage often compels the grower his crop. The lack of proper storage often compels the grower to market his crop at a harvest time when there is a glut in the market, and when transportation facilities are difficult to obtain. Potatoes marketed direct from the field are, as a rule, poorly graded and of inferior keeping qualities. Proper storage permits of proper grading and the work can be distributed over a longer period of time. Storing facilities also permit a more even distribution of the crop.



A battery of adobe potato storage—an ideal storage for the San Luis Valley

The kind of farm storage depends upon the growers' location with reference to building materials, topography, and water table. The common type of storage in Colorado is the half-underground cellar, usually constructed of round timber and poles. It is a cheap storage when timber can be obtained from the forest reserve, and ordinary farm labor is used. In many sections, the natural soil is used for side walls with post for roof support. The two ends may be made of planks or cement. Where conditions permit, the hill-side cellar properly constructed is ideal, as the drainage is generally perfect, and the cellar itself is better protected against cold.

In San Luis Valley, where the water table is close to the surface, adobe cellars are largely used. These are built entirely

Interior of Potato cellar—round timber construction

above ground, and when rightly constructed are both durable and economical. They are easily ventilated and retain an even temperature during winter.

The main thing in building a storage is to provide for adequate ventilation, and two sets of ventilators should be provided. Most potato cellars have only top ventilators. These will do little or no good unless there are one or more intakes to create a current or circulation of air. The intake should be at the base of the cellar. The bins should also have a false floor to permit a circulation of air from below through the bin. If the potatoes are piled high in the bins, perforated stacks should be placed at intervals so as thoroughly to aerate the tubers. Cellar rots or decays can, in most cases, be prevented by proper ventilation.

CELLAR FUMIGATION

One of the fertile sources of loss in potato storage is due to poor and disease-infested cellars. The cellar should be cleaned out and fumigated every spring after potatoes and other stored articles have been removed.

The best method of cellar fumigation is undoubtedly the formalin permanganate method. The following formula is recommended:

For every 1,000 cubic feet of cellar space use 3 pints of formaldehyde and 23 ounces of potassium permanganate. The permanganate is placed in a shallow dish or earthen vessel and the formaldehyde solution is poured over it. The operator must leave the cellar immediately and close it up tightly to escape the fumes. If the cellar is large and requires large quantities of chemicals, several vessels or dishes should be used, placing them in different portions of the cellar so that the fumigation may be more uniform. The cellar should be left closed for 48 hours, or longer.

Bulletin 244 June, 1918

The Colorado Agricultural Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

By WM. P. HEADDEN

PART IV

PUBLISHED BY THE EXPERIMENT STATION

FORT COLLINS, COLORADO

1918

Colorado Agricultural College

FORT COLLINS, COLORADO

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A STUDY OF COLORADO WHEAT

By WM. P. HEADDEN

PART IV

Bulletins Nos. 205, 208, 217 and 219 present the work previously reported in connection with our study of Colorado wheats. The general results in a more popular and less detailed manner have been given in Bulletin No. 237. In this bulletin we propose to record our further study of the properties of the wheats and flours produced in the course of our experiment, together with some flours produced from Colorado wheats by various mills in the State.

CHARACTER OF GRAIN DEPENDS ON RELATIVE SUPPLY OF PLANT FOOD

A brief statement of the conclsions reached may be advisable. The most important one is that, given conditions under which the plant will reach normal maturity, the character of the grain depends upon the relative supply of the respective plant foods.

In our case the important ones are nitrogen and potassium. If the latter predomintes, the character of the wheat will be mealy or soft, in which case the kernels will be large and plump. If the nitrogen present as nitrates be sufficient and in the right proportion to the potassium, the kernels will be flinty and of good size. If the nitrogen present as nitrates be excessive the plants will grow too rankly, will be susceptible to rust, will lodge, and will produce small flinty, hard and shrunken kernels. The crop will be smaller than in cases where less nitrogen in this form is present.

Organic or other forms of nitrogen than nitrates or ammonia salts whose nitrogen is easily converted into nitrates, is not sufficiently available to the wheat plant to affect the quality of the crop though it may increase the production of both straw and grain.

Phosphorus in our experiments produced no effects upon the yield or character of the grain that we could interpret as directly due to the effects of the element. The reason for this is probably that the phosphorus present in our soil is sufficiently available to procure a maximum effect and the addition of more phosphorus is at the present time useless. This condition may change with further cropping.

There is so near an approach to the desirable ratio between the nitric nitrogen and available potassium in our soil that comparatively small quantities of nitrates produce a big effect upon the growth of the plant and the character of the grain. The nitric nitrogen usually present in our soils is adequate to the production of good crops but not always adequate to the production of the best quality of grain. This is the reason why the application of sodic nitrate affects the character of the grain but in our experiments has not increased the yield to any marked extent; on the contrary, we have in many instances depressed it.

EFFECTS OF IRRIGATION

As irrigation is an indispensable portion of our practice, we have to determine the water supply necessary to produce the best crop and the effect of the water upon the character of the grain produced.

Our results show that if the plants be brought to the period of early head or to the time when they are well advanced in the boot in a healthy manner and are then irrigated liberally no further irrigation is, in ordinary seasons, necessary. Subsequent irrigation in our experiments proved to be useless in every respect, i.e., it neither increased the crop nor influenced the character of the grain, while the soaking of the ground exposed the crop to some danger.

The effects of water upon the quality of the grain depends upon conditions. Excessive water applied to the soil does not affect in any material degree the composition of the grain but if the plants be kept wet and the weather be dull and warm the crop will suffer greatly, in fact, will probably be ruined.

The leaching effects of water upon the soil may in some instance be a danger but in our experiments we could not discover any bad effects due to this cause.

As our soils contain a total supply of 2.25 to 2.5 percent of potash of which, roughly, one-quarter is soluble in dilute hydrochloric acid, we have an abundant supply of this element for many years. This means that we have from 22,500 to 25,000 pounds of potash in each million pounds of soil with from 5,600 to 6,250 pounds soluble in dilute acid at the present time. These quantities are so large that it does not matter whether we are quite right in tacitly assuming that being soluble in dilute hydrochloric acid is the same as being available to the plant or not. It is evident that the supply is very abundant.

NITROGEN OF PRIMARY IMPORTANCE

We have given the cultural reason for stating that the supply of phosphorous in this soil is adequate. As a matter of fact it is about three times as much as is considered adequate in a soil of similar composition. These analytical considerations indicate that the plant food of primary importance to us is the nitrogen. This is also the conclusion to which our experiments lead.

Availability, Not Quantity, Affects Grain

Our soils are only moderately well supplied with total nitrogen. The one on which our experiments were made carried about 0.145 percent. This is neither poor nor especially rich, still it is sufficiently available to produce, under ordinary tillage, abundant crops of wheat, 30 to 48 bushels, without the application of any kind of fertilizer. These results were obtained with wheat following wheat. The total amount of nitrogen present is not so abundant or necessarily of such a character as to assure us of a continued abundant supply of available nitrogen, and yet for five years in succession we have detected, so far as the crop indicated, no lack of nitrogen, while the addition of 10 lbs. of nitrogen in the form of sodic nitrate to a milion pounds of soil has not failed to change the character of the wheat produced without increasing the crop, except in a few instances and then only slightly. We can interpret these facts in only one way and that is that it is not the amount of total nitrogen but the amount present in an available form, in this case as nitrates, that is important. If the crop in our experiments had been increased and the character not changed the only inference that we could have drawn would have been that there was not enough of this form of nitrogen present in the soil to produce the best crop and its addition for this purpose would be advisable. This was not the case, but, the reverse. The size of the crop was not favorably affected but the quality of the crop was, which we have interpreted as proof that the supply of nitrogen in this form was sufficient to produce a maximum crop but not sufficient to produce a maximum quality.

It may be a question in the minds of some whether we have a sufficient basis for making the statement without any qualifications, that the results obtained were specifically due to the form in which the nitrogen was applied. The fact that we obtained this result more than 50 times without any exception when we applied the nitrogen in this form does not prove that organic nitrogen would not have produced the same results though it does prove that the results observed are uniformly the effects produced by nitrogen in the form of nitrates when present in sufficient quantities. In our soil the addition of 10 pounds of nitrogen in this form to 1,000,000 pounds of soil is really too much, for in many instances there was no question about our having done injury. We have experiments in which we added nitrogen in the form of farmyard manure at the rate of at least 120 pounds of nitrogen to a million pounds of the soil or 12 times the amount added in the form of nitrates and it produced no effect upon the composition or physical properties of the wheat. This establishes the inference drawn from the uniformity of the results obtained in the use of nitric nitrogen, i.e., that the results observed were the specific effects of the nitrogen in the form of nitrates and not of organic nitrogen. Nitrogen in the form of ammonia has been shown by Ritthausen and Dr. R. Potts to produce the same effects that the nitrates do. The nitrogen in the ammonia salts, when these are applied to the soil, is readily converted into the nitrate form so their effects are really the effects of nitrates.

HARDNESS OR SOFTNESS DEPENDS ON RELATIVE SUPPLY OF NITROGEN IN THE FORM OF NITRATES

The question of the properties of our whaets whether they are hard or soft, flinty or mealy, depends upon the relative supply of nitrogen in the form of nitrates. If the supply of these in the soil is in the right proportion to the supply of potassium our wheat will be all that anyone could desire. It will be large-grained, plump and flinty, which is to say rich in protein.

The amount of nitrogen in our soil is not a fixed quantity but varies from time to time both in the total amount present and in the portion of it which may be present in the form of nitrates. Experimental proof has been adduced in preceding bulletins that in contiguous areas of 1 square foot the total nitrogen as well as that in the form of nitrates not only may, but actually does vary by significant quantities. Data obtained, both by laboratory experiments and on a larger scale in imitation of field conditions, establish it as an easily demonstratable fact that the soil in which we grew our wheats varies in its amount of total nitrogen from time to time. To establish this we made observations on 3,000 pounds of soil taken from the field and found that we had a maximum increase of 62 pounds per million of soil and that while the total nitrogen varied, it at all times showed an increase over the amount present at the beginning of the experiment. At the end of 40 days the total amount of nitrogen present exceeded that present at the beginning by 36 pounds per million. The nitrogen present as nitrates at the end of this experiment exceeded that present in this form at the beginning by 15.79 pounds per million. The increase in total nitrogen is due to fixation and the increase in the form of nitrates shows how actively the process of nitrification was going on. The 3,000 pounds of soil made a bed, as we prepaerd it, 6 inches deep Other and fuller data on the increase of the nitrogen present as nitrates will be found in Bulletin No. 217, pp. 42 and 43.

The significance in the increase of the total amount of nitrogen is that it is sufficient to maintain a reasonable supply and beyond question is present as living organisms, susceptible of rapid changes. The nitric nitrogen is directly available to the wheat plant and the quantity formed during the 40 days of our experiment, 15.79 parts per million, is one and a half time the amount applied in some of our experiments, which was sufficient to determine the character of the growth of the plant and the physical and chemical characteristics of the wheat produced.

EFFECT OF FALLOWING ON NITROGEN CONTENT

The bearing of these facts upon the fallowing of our land has been pointed out elsewhere, but we will point it out again. We have repeatedly given analytical data to illustrate this fact. Perhaps as good an illustration of the effect of fallowing upon the amount of nitrogen accumulating in the soil as we have, is an experiment made in 1915. On 3 August, 1915, we found that land cropped to wheat contained nitrogen as nitrates equal to 46.9 pounds of sodic nitrate in the top 4 feet of soil, whereas the same land from which the wheat had been removed as soon as it came up contained nitrogen as nitrates equivalent to 285.5 pounds per acre taken to the same depth. In this case there is 6 times as much nitrogen present as nitrates in the fallow land as in the cropped land.

We are by no means compelled to depend upon our analytical results to establish this fact, though they constitute more direct proof than the crops grown on ground fallowed the preceding year. In order to avoid the statement of several analyses I will state that the results of our experiments show that nitrate applied to wheat increases the nitrogen and depresses the phosphorus contained in the grain. With this explanation the following data will suffice for our present purpose.

A sample of Red Fife grown on land fallowed the preceding year, 1912, contained of nitrogen 3.008 percent and of phosphorus 0.414 percent. The same variety of wheat grown on a check plot which had been cropped the preceding year, 1912, contained of nitrogen 2.270 and of phosphorus 0.453 percent. The difference in the composition of these grains grown on plots of land separated by a 16-foot alley was due to the nitrogen accumulated in the one plot during its year of fallow, whereas the cropped land had been deprived of this advantage. This is probably the correct explanation for the flintiness of our dry-land wheats rather than a scanty supply of water. The dry-land practice is to cultivate fallow one year to facilitate the storage and conservation of moisture which at the same time increases the supply of nitrates.

There is another test which we can apply to these dry-land wheats which will lead us to the same conclusion. We have seen that the addition of nitrogen to the soil in the form of nitrates produces flinty berries and that the lack of it produces the condition designated as yellow-berry. Dry land planted to wheat continuously, produces wheat very badly affected by yellow-berry, which is the same effect that is produced on irrigated ground.

A TEST OF THE BREAD-MAKING QUALITIES OF VARIOUS WHEATS

These, briefly stated, are the most important conclusion presented in the previous statements of our work. We have further endeavored to ascertain whether the bread-making value of our flours and the milling qualities of these wheats have been as decidedly affected as the physical properties and the chemical composition of the kernels have been. It would have been almost impossible that it should be otherwise but as the whole subject of the bread-making quality of our flours has been an open question, concerning which a decided doubt has prevailed for many years, it seemed that to leave this feature of the study untouched would appear to be an evasion of a duty to avoid having to confirm the public in its bad opinion of Colorado flours for bread-making. This is the only weakness in Colorado flours of which I have ever heard complaint. At the beginning I had a lack of confidence in the representative quality of flour made by grinding small samples, especially when the grinding was done by a person who was not an experienced miller. I still entertain these misgivings and believe that samples should be ground only by an experienced and skillful miller on a commercial scale in order to determine the actual milling qualities of a wheat. I am convinced that the quality of the flour depends to a very large extent upon the judgment and skill of the miller. The college employee has no time to acquire this judgment and skill and he might at best make but a sorry job of milling. This was our situation and there has been no intention of establishing a Section of Cereals and Milling which would justify us in establishing a larger plant. We had a definite object in view which we have already stated but it has seemed advisable to extend it to include these additional features.

We actually had large samples milled on a commercial scale but we stored these samples in 50-pound lard cans without previously drying them. We had more analytical work to do than our force could get done in the time at our disposal, so these flour samples were stored in the sample room. The lard can kept out the mice and insects but the flours became musty and rancid before we could take up the study of their baking qualities. For these reasons we were after all compelled to grind small samples in an Allis & Chalmers mill. These samples answer the purpose of our study very well but the flours that we made do not represent the commercial flours produced from our wheats by the mills of the State; they are decidedly inferior. We, of course, milled the wheat representing the different fertilizers as separate samples and used the flour for baking. The flours on the market are not often made from a single variety of wheat and are seldom straight flours. Our home-ground samples are hardly comparable with the better-brands of flour on the market, but as stated, they serve our purposes. We milled the wheat with the rolls set too close all of the time and practically produced a straight flour.

The wheats yielded in our different crops varied in their composition as is set forth in detail in Bulletin No. 219 but for any given year they are clearly and naturally divided into two classes those grown with and those grown without the application of nitrogen in the form of sodic nitrate. Any attempt to distinguish any differences between the wheats grown with the application of phosphorus, potassium and the check plots would be based upon small and irregular differences to such an extent as to have no value. This is not true of the physical properties of these samples; the differences in this respect being usually very plain, even strikingly so. The wheat grown with the application of nitrogen in the form of nitrates on the other hand differed in an easily recognized manner both physically, in that it was always flinty and often more or less shrunken, and in its chemical composition in that it was always higher in protein and lower in starch and phosphorus but fully as rich as the other samples in potassium. While the differences in the amount of starch present may be less than the differences in the physical appearance of kernels might lead one to expect, they are marked and constant enough to justify their mention as distinctly characteristic effects, attributable to the nitrate applied. These differences are shown by the average composition of the general samples for the three years, 1913, 1914 and 1915 which follow:

AVERAGE COMPOSITION OF WHEATS INCLUDING THE THREE VARIETIES

	1913		1914		1915	
	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent
Protein	12.530	14.170	9.416	11.607	8.950	11.500
Starch	62.190	60.930	64.020	61.960	61.350	58.070
Wet Gluten.	25.850	31.240	23.900	30.280	21.340	29.890
Dry Gluten.	10.650	12.550	9.910	12.430	8.840	11.870
True Gluten	7.580	9.110	6.910	8.670	5.670	7.870
Phosphorus.	0.453	0.413	0.398	0.368	0.383	0.369

AVERAGE COMPOSITION OF THE INDIVIDUAL VARIETIES GROWN IN 1913*

	Defiance		Red Fife		Kubanka	
	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent
Moisture ...	11.338	11.469	10.372	10.200	11.047	11.568
Ash	1.893	1.873	2.047	1.904	1.937	1.771
Fat	1.771	1.685	1.790	1.809	1.903	1.984
Fibre	2.614	2.634	2.588	2.609	2.557	2.550
Nitrogen ...	2.045	2.452	2.392	2.608	2.158	2.401
Protein, Nx5.7	11.656	13.493	13.632	14.863	12.302	13.719
Starch	62.558	61.179	62.108	60.717	61.961	60.492
Sucrose	1.256	1.166	1.319	1.339	1.438	1.601
Wet Gluten.	23.790	30.343	27.780	32.780	26.160	30.610
Dry Gluten.	9.770	12.150	11.250	12.980	10.950	12.540
True Gluten	6.863	8.934	8.146	9.465	7.743	8.931
Phosphorus .	0.446	0.423	0.479	0.445	0.432	0.399
Potassium .	0.449	0.454	0.452	0.485	0.473	0.455

*Analyses of the wheats grown in 1913, 1914 and 1915 may be found in Bul. No. 219.

NOTE.—Succeeding pages, in pairs, give complete results, including composition of flour, milling results, and baking tests for the years 1913, 1914, and 1915. The composition of wheat for 1917 is given, thus requiring three pages to complete the results for that year.

COMPOSITION OF FLOURS—CROP OF 1913—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos phorus	Potas-sium
Defiance													
Nitrogen	10.910	0.834	0.666	0.331	1.8055	10.2914	67.949	0.360	32.50	12.086	9.483	0.1196	0.1465
Phosphorus ...	10.444	0.761	0.602	0.309	1.6888	9.6262	69.911	0.406	29.43	11.023	8.471	0.1251	0.1422
Potassium	10.798	0.817	0.920	0.329	1.6707	9.5233	68.788	0.396	29.83	11.451	8.807	0.1213	0.1533
Check	10.218	0.840	0.984	0.302	1.7242	9.8518	68.067	0.351	29.90	10.966	8.523	0.1146	0.1418
Red Fife													
Nitrogen	7.750	0.740	1.045	0.335	2.1801	12.4267	69.820	0.347	40.07	15.219	11.361	0.1190	0.1533
Phosphorus ...	7.688	0.797	0.961	0.293	1.9793	11.2820	70.083	0.370	32.73	13.022	10.345	0.1217	0.1426
Potassium	8.304	0.824	1.206	0.362	1.9732	11.2474	70.292	0.408	35.33	13.565	10.436	0.1254	0.1322
Check	8.100	0.775	1.214	0.348	1.9906	11.3464	69.989	0.331	33.65	13.022	10.254	0.1218	0.1383
Kubanka													
Nitrogen	7.790	1.033	1.060	0.342	2.0428	11.6440	68.818	0.451	35.57	14.039	10.998	0.1684	0.2087
Phosphorus ...	7.702	1.085	1.210	0.361	1.9322	11.0138	69.226	0.519	32.00	12.778	9.985	0.1764	0.1993
Potassium	7.520	1.028	1.230	0.343	1.9841	11.3093	69.095	0.553	32.73	13.240	10.430	0.1754	0.1965
Check	7.968	0.864	1.291	0.281	2.0609	11.7470	69.605	0.457	38.97	15.156	11.111	0.1440	0.1662

OTHER FORMS OF NITROGEN—CROP 1913

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0211	0.1404	0.6815	0.9584	0.1146
Phosphorus	0.0248	0.0989	0.6538	0.8858	0.1005
Potassium	0.0315	0.1060	0.6632	0.8718	0.1139
Check	0.0319	0.1137	0.6629	0.9198	0.1180
Red Fife					
Nitrogen	0.0727	0.1308	0.6783	1.2984	0.1139
Phosphorus	0.0726	0.1235	0.6369	1.1461	0.1464
Potassium	0.0717	0.1146	0.6348	1.1556	0.1470
Check	0.0471	0.1018	0.6901	1.1537	0.1458
Kubanka					
Nitrogen	0.0433	0.1304	0.6522	1.2169	0.1507
Phosphorus	0.0431	0.1231	0.6275	1.1391	0.1495
Potassium	0.0544	0.1304	0.6532	1.1456	0.1636
Check	0.0612	0.1231	0.6631	0.2138	0.1451

MILLING RESULTS—CROP OF 1913

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in-Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.70	5.35	2.25	23.70	7.00	7.50
Phosphorus	61.30	4.95	2.15	24.75	6.85	7.75
Potassium	63.10	4.30	2.48	22.00	8.12	5.70
Check	62.35	3.90	2.90	21.60	9.25	7.40
Red Fife						
Nitrogen	58.50	3.48	3.80	26.45	2.77	6.40
Prosphorus	59.50	3.40	3.10	27.10	6.90	7.50
Potassium	56.75	5.75	5.20	27.10	5.20	5.92
Check	62.85	4.45	2.60	23.95	6.15	6.90
Kubanka						
Nitrogen	61.40	6.10	3.45	24.70	4.35	6.82
Phosphorus	58.20	7.50	4.20	22.35	7.75	6.10
Potassium	65.50	4.70	4.30	22.75	2.75	4.73
Check	58.00	6.20	4.30	25.25	6.25	8.30

BAKING TESTS*—CROP 1913

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	350	250	549	157	1580	451
Phosphorus	350	250	540	154	1480	423
Potassium	350	250	535	153	1490	426
Check	350	250	532	152	1470	420
Red Fife						
Nitrogen	350	245	540	154	1600	457
Phosphorus	350	245	546	156	1450	414
Potassium	350	245	551	157	1570	449
Check	350	245	540	154	1480	423
Kubanka						
Nitrogen	350	245	546	156	1700	486
Phosphorus	350	245	538	154	1640	469
Potassium	350	245	538	154	1500	429
Check	350	245	537	153	1510	431

*These doughs were made quite slack.

COMPOSITION OF FLOUR—CROP 1914—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phosphorus	Potassium
Defiance													
Nitrogen	8.915	0.841	1.174	0.281	1.5896	9.0609	71.550	0.455	31.75	11.697	8.275	0.1218	0.1404
Phosphorus ..	8.924	0.809	1.334	0.248	1.4312	8.1575	71.095	0.418	26.87	9.863	7.220	0.1169	0.1385
Potassium	10.032	0.791	1.269	0.260	1.4782	8.4260	71.315	0.437	26.96	10.423	7.564	0.1137	0.1316
Check	8.568	0.749	1.343	0.245	1.4983	8.1501	72.624	0.421	31.35	10.983	7.779	0.1117	0.1361
Red Fife													
Nitrogen	8.304	0.726	1.287	0.229	1.7005	9.0925	69.486	0.415	38.01	13.362	9.381	0.1062	0.1201
Phosphorus ...	8.035	0.707	1.203	0.253	1.6314	9.2985	70.991	0.371	34.48	12.311	8.837	0.1036	0.1461
Potassium	8.936	0.756	1.311	0.240	1.5426	8.4930	70.300	0.452	30.23	11.041	8.033	0.1129	0.1217
Check	7.808	0.727	1.273	0.324	1.6130	9.1940	73.173	0.377	33.20	12.334	8.677	0.1092	0.1267
Kubanka													
Nitrogen	7.334	0.958	0.911	0.297	1.7030	9.7070	69.725	0.552	25.96	10.013	8.028	0.1453	0.1768
Phosphorus ...	7.780	0.805	1.389	0.296	1.5956	9.0950	73.165	0.280	33.08	12.217	8.491	0.1195	0.1306
Potassium	6.566	0.932	1.367	0.291	1.6225	9.2480	71.041	0.372	32.31	11.733	8.701	0.1455	0.1790
Check	7.130	0.873	0.726	0.329	1.6435	9.3677	71.101	0.343	25.43	9.382	7.582	0.1484	0.1797

OTHER FORMS OF NITROGEN—CROP 1914

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0146	0.1161	0.7115	0.7464	0.0796
Phosphorus	0.0146	0.1025	0.6254	0.6857	0.0864
Potassium	0.0109	0.0937	0.6744	0.6993	0.0821
Check	0.0153	0.1223	0.7190	0.7187	0.0814
Red Fife					
Nitrogen	0.0224	0.1165	0.7066	0.8555	0.0887
Phosphorus	0.0221	0.1030	0.7086	0.8357	0.0827
Potassium	0.0217	0.1301	0.5905	0.8004	0.0796
Check	0.0258	0.1031	0.6227	0.8614	0.0820
Kubanka					
Nitrogen	0.0260	0.0888	0.7644	0.8242	0.3234
Phosphorus	0.0221	0.1100	0.6008	0.8627	0.0907
Potassium	0.0261	0.1042	0.6293	0.8618	0.1121
Check	0.0374	0.0749	0.6766	0.8546	0.1831

MILLING RESULTS—CROP OF 1914

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.35	4.95	2.75	28.40	2.45	6.34
Phosphorus	55.35	6.35	3.95	27.45	6.90	7.37
Potassium	58.85	6.50	3.10	26.60	4.95	8.40
Check	57.85	4.20	2.60	28.80	6.55	7.67
Red Fife						
Nitrogen	63.50	4.70	2.40	23.75	5.65	6.62
Phosphorus	60.60	6.10	2.70	23.75	6.85	6.91
Potassium	60.85	4.85	3.60	27.35	3.35	7.66
Check	61.31	6.10	4.90	25.85	1.80	6.89
Kubanka						
Nitrogen	56.95	8.85	5.30	25.80	3.10	5.12
Phosphorus	53.50	8.60	5.75	25.45	6.70	7.85
Potassium	54.35	7.65	5.40	25.35	7.25	6.30
Check	57.70	7.55	4.10	24.60	6.05	5.00

BAKING TESTS—CROP 1914

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf	Volume per 100 grms. of flour
Defiance						
Nitrogen	350	240	526	150	1600	459
Phosphorus	350	240	519	148	1420	406
Potassium	350	240	538	154	1420	406
Check	350	240	523	150	1420	406
Red Fife						
Nitrogen	350	220	513	147	1590	454
Phosphorus	350	220	537	153	1590	454
Potassium	350	220	508	145	1720	491
Check	350	220	518	148	1520	434
Kubanka						
Nitrogen	350	230	533	148	1640	469
Phosphorus	350	220	509	145	1590	454
Potassium	350	225	509	145	1460	417
Check	350	225	522	149	1520	454

COMPOSITION OF FLOURS—CROP OF 1915—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phosphorus	Potassium
Defiance													
Nitrogen	10.435	0.897	1.443	0.380	1.9810	11.292	67.716	0.541	34.00	12.466	7.842	0.1466	0.1942
Phosphorus ..	10.448	0.696	1.126	0.355	1.4351	8.180	69.827	0.341	27.00	9.774	7.232	0.1067	0.1259
Potassium ...	10.767	0.787	1.121	0.414	1.4572	8.300	68.676	0.329	28.13	10.505	7.537	0.0962	0.1409
Check	8.908	0.773	1.226	0.370	1.4770	8.419	71.161	0.347	26.07	9.984	7.458	0.1284	0.1321
Red Fife													
Nitrogen	8.817	0.715	1.197	0.282	1.5211	8.670	71.128	0.212	30.60	11.225	8.020	0.1297	0.1174
Phosphorus ..	8.643	0.718	1.179	0.243	1.3775	7.852	72.653	0.241	26.17	9.479	6.643	0.1022	0.1169
Potassium ...	8.302	0.766	1.236	0.287	1.4324	8.166	69.240	0.243	24.90	9.461	7.177	0.1104	0.1453
Check	8.170	0.830	1.298	0.296	1.4315	8.160	73.616	0.280	24.17	9.236	7.046	0.1160	0.1408
Kubanka													
Nitrogen	9.714	1.008	1.350	0.293	1.7288	9.832	68.179	0.364	33.97	12.679	9.203	0.1480	0.1826
Phosphorus ..	7.826	1.031	1.417	0.276	1.4100	8.037	69.979	0.323	35.40	12.992	9.462	0.1510	0.1992
Potassium ...	8.124	0.988	1.605	0.273	1.6412	9.355	70.993	0.382	32.63	12.087	8.633	0.1372	0.1721
Check	7.766	1.142	1.406	0.282	1.6407	9.388	70.688	0.383	32.50	12.334	9.461	0.1521	0.1880

OTHER FORMS OF NITROGEN—CROP 1915

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0042	0.1400	0.9030	0.8960	0.0907
Phosphorus	0.0179	0.1074	0.6192	0.6819	0.0907
Potassium	0.0215	0.1071	0.6173	0.6789	0.1402
Check	0.0183	0.1094	0.7063	0.6795	0.1206
Red Fife					
Nitrogen	0.0218	0.1014	0.6932	0.7483	0.1152
Phosphorus	0.0147	0.1098	0.5837	0.7018	0.0851
Potassium	0.0148	0.0886	0.6995	0.6592	0.1108
Check	0.0220	0.0952	0.6399	0.7186	0.0913
Kubanka					
Nitrogen	0.0323	0.1148	0.6935	0.9487	0.3204
Phosphorus	0.0260	0.1263	0.7022	0.9730	0.3780
Potassium	0.0294	0.1248	0.6782	0.8676	0.1488
Check	0.0294	0.1028	0.6811	0.9977	0.3645

MILLING RESULTS—CROP OF 1915

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in-Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	56.25	4.00	2.15	31.60	6.00	7.30
Phosphorus	53.50	5.50	2.05	33.25	5.70	8.40
Potassium	58.00	3.50	1.60	30.35	6.55	7.30
Check	54.45	4.70	2.20	33.35	5.30	6.30
Red Fife						
Nitrogen	58.00	2.55	5.25	29.25	4.95	4.70
Phosphorus	58.20	3.90	2.60	31.50	3.80	6.30
Potassium	58.50	3.45	2.75	31.10	4.20	5.30
Check	59.95	2.95	3.05	28.40	5.65	6.30
Kubanka						
Nitrogen	49.75	7.85	5.85	31.25	5.30	4.80
Phosphorus	55.25	8.75	4.20	27.50	4.30	6.70
Potassium	60.20	6.70	2.70	24.60	5.80	5.20
Check	56.50	8.25	4.95	23.35	6.95	7.00

BAKING TESTS—CROP 1915

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	350	220	534	148	1480	465
Phosphorus	350	220	504	144	1260	389
Potassium	350	220	511	146	1640	469
Check	350	220	505	144	1420	406
Red Fife						
Nitrogen	350	220	504	144	1580	451
Phosphorus	350	220	511	146	1360	389
Potassium	350	220	517	148	1520	438
Check	350	220	513	146	1340	383
Kubanka						
Nitrogen	350	225	519	158	1500	429
Phosphorus	350	220	529	151	1120	320
Potassium	350	220	515	147	1220	349
Check	350	220	525	150	1200	343

COMPOSITION OF WHEAT—CROP OF 1917

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos-phorus	Potas-sium
Defiance													
Nitrogen, 80 lbs.....	12.943	1.317	1.708	2.608	2.293	13.070	57.454	1.427	34.733	14.166	7.181	0.314	0.408
Phosphorus, 40 lbs..	13.098	1.569	1.913	2.810	1.728	9.849	62.568	1.267	22.933	9.633	6.346	0.356	0.400
Potassium, 150 lbs..	12.483	1.430	1.828	2.765	1.724	9.827	61.200	1.295	25.266	10.466	6.662	0.353	0.399
Check, none	12.383	1.488	1.953	2.890	1.692	9.644	60.660	1.210	24.600	9.866	6.559	0.342	0.382
Red Fife													
Nitrogen, 80 lbs.....	12.220	1.346	1.872	2.753	2.276	12.973	59.932	1.485	38.000	15.133	7.715	0.350	0.320
Phosphorus, 40 lbs..	12.335	1.553	1.840	2.878	1.793	10.220	60.966	1.592	26.966	11.166	7.077	0.394	0.376
Potassium, 150 lbs..	12.400	1.371	1.808	2.760	2.048	11.673	60.534	1.583	31.000	12.433	7.390	0.404	0.382
Check, none	12.475	1.590	1.825	2.770	1.870	10.659	59.724	1.504	30.566	12.200	7.433	0.397	0.381
Kubanka													
Nitrogen, 80 lbs.....	12.493	1.220	2.005	2.740	2.259	12.876	58.140	1.794	38.300	14.833	7.204	0.329	0.365
Phosphorus, 40 lbs..	11.713	1.281	2.263	2.750	1.814	10.340	61.140	1.721	26.200	10.866	7.022	0.382	0.397
Potassium, 150 lbs..	11.700	1.583	2.060	2.698	1.946	11.092	60.570	1.697	31.666	12.566	7.191	0.378	0.427
Check, none	11.675	1.633	2.190	2.800	1.891	10.778	60.768	1.663	29.666	11.733	6.946	0.388	0.393

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS (Wheat)

Variety and Fertilizer	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen
Defiance				
Nitrogen, 80 pounds	0.098	0.210	0.728	1.257
Phosphorus, 40 pounds	0.077	0.182	0.518	0.951
Potassium, 150 pounds	0.056	0.196	0.518	0.954
Check, None	0.070	0.182	0.518	0.922
Red Fife				
Nitrogen, 80 pounds	0.049	0.238	0.714	1.275
Phosphorus, 40 pounds	0.084	0.196	0.511	1.002
Potassium, 150 pounds	0.091	0.210	0.539	1.208
Check, None	0.098	0.238	0.569	1.065
Kubanka				
Nitrogen, 80 pounds	0.077	0.210	0.679	1.293
Phosphorus, 40 pounds........	0.070	0.224	0.455	1.065
Potassium, 150 pounds	0.077	0.224	0.511	1.134
Check, None	0.084	0.224	0.441	1.142

COMPOSITION OF THE FLOUR—CROP 1917

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos-Phorus-	Potas-sium
Defiance													
Nitrogen	9.775	0.515	1.198	0.328	2.289	13.047	66.564	0.740	47.833	16.500	7.425	0.1398	0.1748
Phosphorus	9.805	0.619	1.295	0.270	1.701	9.596	72.072	0.745	31.132	10.833	7.555	0.1431	0.1655
Potassium	9.743	0.564	1.208	0.263	1.708	9.736	70.884	0.747	34.600	11.566	7.086	0.1314	0.1646
Check	10.245	0.595	1.398	0.225	1.701	9.596	70.273	0.786	31.633	10.300	7.606	0.1472	0.1597
Red Fife													
Nitrogen	9.575	0.525	1.330	0.203	2.366	13.468	67.485	0.821	49.900	16.733	6.905	0.1212	0.1344
Phosphorus	9.801	0.488	1.305	0.183	1.834	10.454	69.998	0.854	40.333	12.633	6.980	0.1358	0.1359
Potassium	9.673	0.487	1.395	0.263	2.044	11.651	69.434	0.785	43.000	15.800	6.748	0.1614	0.1418
Check	9.500	0.479	1.513	0.345	2.023	11.531	68.364	0.833	41.200	14.600	7.065	0.1540	0.1296
Kubanka													
Nitrogen	9.570	0.791	1.693	0.283	2.384	13.589	64.530	0.952	48.666	16.966	7.447	0.1782	0.2055
Phosphorus	9.185	0.732	1.643	0.343	1.785	10.175	69.264	0.953	32.633	12.200	7.403	0.1910	0.1982
Potassium	9.135	0.566	1.558	0.270	1.834	10.454	69.372	0.921	36.166	12.900	7.274	0.1864	0.2118
Check	8.263	0.551	1.503	0.305	1.799	10.254	70.452	0.998	35.333	13.033	7.651	0.1690	0.1828

OTHER FORMS OF NITROGEN—CROP OF 1917 (Flour)

Variety and Fertilizer	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.042	0.168	0.910	1.169	0.1201
Phosphorus	0.042	0.112	0.651	0.896	0.0723
Potassium	0.042	0.266	0.525	0.882	0.0698
Check	0.056	0.154	0.609	1.309	0.0772
Red Fife					
Nitrogen	0.077	0.182	0.798	1.001	0.0883
Phosphorus	0.049	0.154	0.630	1.134	0.0760
Potassium	0.077	0.154	0.679	1.106	0.0919
Check	0.056	0.154	0.707	1.376	0.0858
Kubanka					
Nitrogen	0.056	0.238	0.714	0.966	0.0833
Phosphorus	0.061	0.168	0.590	1.071	0.0895
Potassium	0.042	0.168	0.553	0.994	0.0858
Check	0.035	0.168	0.602	0.896	0.0772

MILLING RESULTS—CROP OF 1917

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.5	4.6	4.1	23.9	6.3	6.1
Phosphorus	60.1	3.3	3.6	24.0	8.2	5.2
Potassium	60.7	4.2	2.8	25.2	7.1	4.9
Check	62.5	3.7	2.3	24.6	6.9	4.2
Red Fife						
Nitrogen	64.9	1.7	1.5	25.1	6.8	5.0
Phosphorus	63.5	2.1	1.7	28.2	6.0	5.0
Potassium	64.7	2.2	1.6	26.5	5.0	5.3
Check	64.4	3.4	2.1	26.5	5.4	4.8
Kubanka						
Nitrogen	66.9	2.1	1.9	23.9	5.2	5.8
Phosphorus	65.2	3.8	3.2	26.1	2.9	4.5
Potassium	62.7	3.4	1.4	27.6	4.9	5.4
Check	63.7	3.0	1.5	30.3	3.7	4.0

BAKING TESTS CROP 1917

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	400	235	572	143	1980	495
Phosphorus	400	250	583	146	1660	415
Potassium	400	242	577	144	1760	440
Check	400	234	567	142	1680	420
Red Fife						
Nitrogen	400	240	590	148	2040	508
Phosphorus	400	236	589	147	1880	470
Potassium	400	241	577	144	1900	475
Check	400	235	572	143	1740	435
Kubanka						
Nitrogen	400	250	571	143	1860	465
Phosphorus	400	250	573	144	1720	430
Potassium	400	250	587	147	1780	445
Check	400	240	567	142	1740	435

WHEAT GROWN BY THE DEPARTMENT OF AGRONOMY—CROP OF 1917
MILLING RESULTS

Variety	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Kanred	62.7	3.1	1.4	27.6	3.1	4.0
Beardless Turkey (light)	68.4	1.4	1.6	26.1	4.8	3.8
Beardless Turkey (dark)	67.9	1.9	2.1	24.8	3.4	5.4
Marquis	65.3	1.6	1.5	28.9	2.8	4.7
Fultz Mediterranian	65.7	1.7	1.4	28.6	2.6	3.5
Defiance	62.7	2.4	1.7	30.5	2.7	4.9
Red Russian	62.5	2.1	1.6	30.1	3.9	5.8
Turkey Red (Dry land)	63.1	1.6	1.1	29.4	5.0	5.3
Preston	67.4	1.6	1.1	25.7	4.1	4.1

BAKING TESTS—CROP OF 1917*

Variety	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Kanred**	400	240	576	144	1800	450
Beardless Turkey (Light grains)	400	228	575	144	1700	425
Beardless Turkey (dark grains)	400	235	574	144	2000	500
Marquis	400	270	619	155	1790	448
Fultz Mediterranean	400	250	598	150	1800	450
Defiance	400	240	580	145	1930	483
Red Russian	400	233	579	145	1960	490
Turkey Red Dry land	400	260	601	150	1880	470
Preston	400	250	597	149	1940	485

*These samples were milled in the laboratory and represent straight flours.
**This sample was grown in Kansas.

BAKING TESTS OF FLOUR FROM SOME COLORADO MILLS *1917.

Brand and Where Milled	Flour used Grams	Water Added c.c.	Weight of Loaf	Bread per 100 flour	Volume of Loaf	Volume per 100 Gms. flour	Remarks
Defiance							
Lindell Mills, Fort Collins	400	230	568	142	1960	490	
Lindell Mills, Fort Collins	400	229	574	144	1880	470	
Lindell Mills, Fort Collins	400	230	579	145	1820	455	
Lindell Mills, Fort Collins	400	230	567	142	1825	456	Defiance 50 Idaho 50
Lindell Mills, Fort Collins	400	230	566	142	1990	498	
Lindell Mills, Fort Collins	400	240	579	145	2020	505	
Hoffman's Best							
Fort Collins	400	260	594	149	1960	490	
Fort Collins	400	255	593	148	1860	465	
Fort Collins	400	273	611	153	2044	511	
Fort Collins	400	288			2065	516	
Fort Collins	400	250	592	148	1970	492	
Fort Collins	400	245	576	144	1900	475	
Fort Collins	400	212	555	139	1920	480	Defiance & Winter Wheat
Major C							
Pueblo	400	230	563	141	2000	500	Hard Wheat
Pueblo	400	230	586	146	1900	475	Straight Flour
Nonpariel							Intentionally Underproved
Longmont	400	240	582	146	1800	450	
Pride of the Rockies							
Longmont	400	250	599	150	1980	495	
Longmont	400	266	615	154	1900	475	
Longmont	400	270	601	150	1990	498	
Longmont	400	266	617	154	1980	495	
Bread King, Boulder	400	250	590	148	1900	475	
Golden Seal, Golden	400	250	585	146	1960	490	Spring 50 Winter 50, a 70 percent patent
Silver Bell, Alamosa	400	240	577	144	1960	490	Soft wheat
White Loaf, Denver	400	235	577	144	2005	501	
Golden Seal, Golden	400	250	585	146	1960	490	
Pure Gold, Denver	400	225	569	142	1860	465	
La Junta	400	235	580	145	2000	500	
Loveland	400	235	575	144	1745	436	
Velvet, Berthoud	400	250	585	146	1840	460	Turkey Red Straight
Snow Flake, Greeley	400	235	584	146	1900	475	(53 percent white 35 percent red 30 percent Marquis)

*I am indebted to the Colorado Milling and Elevator Company for many of these samples which they kindly provided for me.

MOISTURE, NITROGEN AND PROTEIN IN SOME FLOURS FROM DIFFERENT PARTS OF THE STATE

Brand	Where milled	Percent Moisture	Percent Nitrogen	Percent Protein
Major C	Pueblo	11.32	2.156	12.2892
Nonpareil	Longmont	11.05	1.708	9.7356
Golden Seal	Golden	12.01	1.827	10.1439
Silver Bell	Alamosa	11.28	1.407	8.0199
White Loaf	Denver	10.71	1.869	10.6533
Pure Gold	Denver	11.31	1.785	10.1745
————	La Junta	11.47	1.883	10.7331
————	Loveland	11.90	1.701	9.6957
Velvet	Berthoud	11.22	1.652	9.4164
Snow Flake	Greeley	11.06	1.771	10.0947

BAKING TESTS WITH CHECK FLOURS*

Brand	Made by	Flour Taken	Water Used	Weight of Loaf grms	Bread per 100 of flour	Volume of loaf	Volume per 100 grams of flour
Gold Medal	Washburn Crosby & Co.	400	257	603	151	2000	500
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	574	144	2055	514
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	572	143	1980	495
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	574	144	2000	500
Cream	Plainville, Kansas	400	250	588	147	1900	475
Cream	Plainville, Kansas 2d sample	400	250	602	151	2020	505
Cream	Plainville, Kansas 3d sample	400	247	594	149	1970	493
Cream	Plainville, Kansas 4th sample	400	267	593	148	1910	478
Jersey Cream	Kansas	400	230	574	144	2165	541
Prize Winner	Hays City, Kansas	400	255	600	150	2005	501
Prize Winner	Hays City, Kansas	400	255	576	144	1980	495

*These samples represent high grade, patent flours and are air-dried under our conditions.

DIFFERENCES PERSIST IN PROPERTIES OF FLOURS

The object in view in this part of our study has been to show by results obtained experimentally that the differences observed in the composition of the wheats grown with the different fertilizers persist in the properties of the corresponding flours. These may seem to be self evident facts. I was inclined to consider them such to so great an extent that I seriously considered the omission of all milling and baking experiments in connection with this work, but I was advised that it would be better to present these features in detail and not to assume a complete parallelism between the composition of the wheat and flour and a perfect correspondence between the composition and the baking qualities of the flours.

There were two considerations which inclined me to act on this advice in addition to my confidence in the advice itself. These were: First, that I am persuaded that there are other factors than the composition of a flour entering into its properties. Second, because no study of Colorado flours has been made previous to this time. Whatever the millers may know has not been made public. This feature is, it is true, only incidental to my main purpose but it seemed that it would be better to present it in connection with our work than to make it the object of a special investigation. This reason appealed more forcefully when we considered that, aside from the study of the definite question proposed, this station has no definite policy which would call for an extended study of the cereals. The principal reason for any hesitancy has been in the question in regard to the extent of the experiments, i.e., whether it represents a sufficient number of samples from the different sections of the State and has been extended over a sufficient lenght of time.

It would undoubtedly have been better from this standpoint if the number of general samples had been increased. On the other hand, the data presented in other portions of this account of our work show clearly that labor spent on a general sample when we know nothing of the conditions under which it has been produced is largely in vain because this knowledge is absolutely necessary to a correct interpretation of the results obtained, and it is very probable that the data obtained by the study of our own samples are of more value than those which we might have obtained from the study of any number of general samples collected over a period twice as long as we have continued this study.

Another question arises in this connection, i.e., Should not a greater number of varieties have been studied in considerable detail before the data presented and the inferences drawn from them should be accepted as of general applicability? The answer to this is that observation in the field and analyses of the wheat produced show that the general inferences drawn are justified and that a study of more varieties. and especially of general samples, would have a cumulative value only and in many cases would have no value at all due to the fact that it would be practically impossible, as we have unfortunately found to be the case, to obtain reliable information about the conditions under which the samples were produced, without which the results would have no value for our purpose, in fact would simply be results with no possible rational interpretation.

While we willingly admit the possible advisability of a more extended investigation of the features of our study which apply to those subjects which are incidentally applicable to the general questions pertaining to the properties of Colorado wheat, we are inclined to believe that the results presented would be supported even in detail by a more extended series of experiments.

The primary purpose of this study is to ascertain whether our wheats are soft, and if so to ascertain the causes. These questions have been answered in so far as they pertain to the plants and grain in the parts of this study previously published. In this part we have continued the study, extending it to the milling qualities of the wheat, also to the composition and baking qualities of the flour.

We found that the prevalent notion that irrigation influenced the composition and character of the wheat, causing softness or starchiness in the grain is not justified by the facts in the case, but that we can grow very hard, flinty wheat, applying at the same time an ample supply of water. On this subject we have confined ourselves to the grain produced and have not undertaken to find out whether there are any differences in the milling and baking qualities of irrigated wheat which can be attributed to this cause. We have assumed, and believe ourselves justified in doing so, that the effect of irrigating the plants will express itself upon these properties in the same sense and to a corresponding degree that it affcets the composition of the wheat.

This is not so much an assumption as a conclusion based on the results obtained, which show a very close relation between the composition of the wheat and the properties of the flour produced.

ONLY DIFFERENCE BETWEEN DRY-LAND AND IRRIGATED WHEAT IS IN BRAN YIELDED

We have analyzed dry-land wheat, milled it and baked bread from the flour. The only difference that we have been able to detect between it and wheat of the same grade grown under irrigation is in the amount of bran that it yields. Turkey Red, for instance, grown with irrigation yields around 25 percent of bran. Grown under dry-land conditions it yields 4 to 5 percent more. So far as the composition of the wheat or the baking qualities of the flour produced is concerned, we failed to observe any difference. The one is as good as the other provided they are of the same grade. These statements will of course not apply if a strongly yellow-berried or starchy wheat grown on dry land be compared with a flinty wheat grown under irrigation or vise versa. The flinty wheat would in each case be the better wheat or flour. Dry-land wheat is frequently grown after fallow cultivation. Sometimes, however, it is not. In this case the kernels will be small in size with probably a large percentage of mealy ones, in the former case they will be medium to small in size with but few or no mealy ones. We interpret the small size of the kernels and their high yield of bran in milling as characteristic effects of the dry-land conditions in which there is simply a lack of sufficient water to complete the proper or normal activities of the plant in filling out the grain. Otherwise they do not differ from wheat grown under irrigation.

APPLICATION OF NITRATES PRODUCES BETTER FLOUR

We present in the tables given in this bulletin the composition of the flour yielded by the crops of 1913. 1914, 1915 and 1917. The composition of the crops of 1913, 1914 and 1915 may be found in Bulletin No. 219, Colorado Experiment Station, while that of the crop of 1917 is given in this bulletin. These tables, giving the composition of the crops grown, show that under our soil conditions nitrate, in this case sodic nitrate, produces hard wheat rich in nitrogen. This is true in every case without regard to the variety used in the experiment. This is not to be understood as stating that one can convert a soft variety of wheat into a hard one by applying sodic nitrate to the soil. We cannot change the variety characteristics, but we can grow flinty berries of this variety which are richer in nitrogen than berries grown without it and to this extent we modify the wheat produced, and the flour obtained from this flinty wheat is better flour than such as is prepared from mealy berries of the same variety. This fact appears in every one of the tables giving the composition and baking qualities of the products from the wheats grown on our experimental plots.

MILLING AND BAKING TESTS MUST BE COMPARABLE

In this connection the manner of milling must be considered and the grades of flour compared must be as nearly alike as is possible to prepare, also the process of baking must be as nearly alike as is feasible to apply or the results will not be comparable. These facts are evident, especially to persons who have done any of this kind of work, but the necessity of keeping the conditions as nearly uniform as possible in order to obtain comparable results may be shown rather forcefully by the two following baking experiments:

The two flours were made from the same lot of wheat. One hundred grams of one sample ground in our routine way gave 147 grams of bread measuring 470 c. c. The same sample ground with a little change in the manner of milling gave for 100 grams of flour 154 grams of bread having a volume of 562 c.c. In this case we obtain a much larger yield by volume and 7.0 percent more by weight, or 13 one-pound loaves per barrel. We have made a straight flour throughout. The second-grade flour separated was small in quantity and was poor in quality. Our results do not represent the best flour that could be made from the wheats used, but we have aimed to make the results comparable with one another. The baking tests, however, compare fairly well the results obtained with well known brands of commercial flours which we used as standards for comparison. These best commercial brands represent the highest skill in blending the wheats and milling them, besides, their color is improved by bleaching. Only a few of our loaves were decidedly poor in color, the reason for which was not always clear.

NITRATES PRODUCE HIGHER GLUTEN CONTENT

An examination of the tables presented shows clearly that there are no great or consistent differences in the composition of the flours produced from the check, potash or phosphorus wheats. These are in every group nearly the same, but there is regularly a difference in favor of the nitrate wheat in gluten content which may be taken as the determinative feature. This advantage in favor of the nitrate wheat persists throughout all of our tests and finally appears in the volume of the baked loaf.

The figures of the table express only those differences which are shown by the balance, or the measuring cylinder, but there are other differences. The gluten is softer and darker, the texture of the loaf is better but I cannot say that I could detect any difference in the flavor of the loaves.

The flour made from the flinty samples of the respective varieties of wheat, the ones grown with the application of the nitrate, were really the best flours.

RESULTS ARE INDEPENDENT OF WEATHER

No one denies that the climate may have an influence upon the wheat produced in different countries or in the same locality in different years but the cause of hardness and softness is the supply of nitrate available to the plants or rather its ratio to the potassium. This has been insisted on in previous bulletins, particularly in Bulletin No.

219 of this station and we here have it expressing itself in the baking qualities of the flour.

These results are independent of the weather conditions. In 1914 we had an abundant crop of low quality of wheat, the cause of which was probably a spell of wet weather late in July which induced an abundant development of rust. I say probably because I cannot definitely assert that this was the cause. But all other conditions were so favorable throughout the season that the low quality of the wheat and, as we now see, of the flour too, is a matter of surprise. This wet spell, followed by the rusting of the plants, is the only untoward condition that we have to offer in explanation. In 1915 we can state with full confidence that much rainy weather and a very severe attack of rust practically ruined some of our plots and injured all of them. These are climatic effects that are evident but they are fortunate events instead of regrettable ones from the standpoint of our study, for while they injured our crops, this injury was concurrent with the development of the rust, as is shown in Bulletin No. 217, in which we discuss the development of the crop for 1915. They scarcely obscured the specific effects of the soil factors, i.e., those of the nitrate and potassium in any degree. The flintiness produced by the nitrate was characteristic in the one case and the mealiness in the other though some of the nitrate wheat was badly shrunken and most of the samples in a less degree. The flours made from these crops also show quite as pronouncedly as the better crops of 1913 and 1917 the effects of the nitrate upon the baking quality of the flour. This statement relative to the flour is true even in the case of the Defiance wheat grown with the application of nitrates, which was so shrunken that I could not sell it for milling purposes, but only as chicken feed.

SHRUNKEN GRAIN YIELDED AS MUCH FLOUR AS OTHER SAMPLES

Our experience with this excessively shrunken grain was a surprise to us in that it yielded as much flour as the other samples of the same variety per 100 pounds. In the second place, this flour showed the characteristic effects of the nitrate as markedly as other samples of nitrate flour and this was also true of its baking qualities. This flour gave a better loaf than that prepared from the check plot or from the one dressed with phosphorus but inferior to the one prepared from the plot receiving potassium. This is the only instance in which the nitrate flour did not yield the best loaf in every respect, but even in this worst case the climatic conditions, including the rust, did not conceal and scarcely modified in any degree the effects of the nitrate applied to the soil.

SERIES OF FACTS ESTABLISHED

We have established a series of facts pertaining to the effects of the soil conditions upon the composition of the plants and upon the grain produced, further we have shown that irrigation produces no effect upon the composition of the grain; further that when the plants are kept continuously wet the percentage of nitrogen in the plant is depressed, but we were not able to follow this effect upon the composition of the grain because of the development of rust, which apparently stops the transference of the material for the filling of the grain and causes shrinkage. In this connection we have shown that ripe grain is susceptible to the leaching action of water, giving up both nitrogen and potassium. We have not determined whether the composition and baking properties of the flour are affected by such washing or leaching or whether this effect is confined to the outer portions of the berry, or the bran. We have not considered any other portion of the berry than the flour produced and we find that the soil conditions produce distinctive characteristics of composition and properties in the flour similar to those produced in the grain, which express themselves in the baking qualities of the flour and the characteristics of the loaf.

MUCH DEPENDS ON THE MILLING OF WHEAT

While our climate is undoubtedly favorable to the production of good wheat, as has been repeatedly pointed out by writers on this subject, the quality of our wheat is after all determined by our soil conditions, especially by the relative supply of nitric nitrogen and potassium. The reputation of our flour has probably been earned by the general use of an inferior bread-making variety and the practice, especially in the past, of planting wheat after wheat till the crop was all yellow or mealy. This reputation is no longer deserved. With our climate and proper soil conditions we can produce first quality wheat as well as big crops. The question of producing good flour from such wheat is one of milling and it is difficult to lay too much stress on this process.

Through the courtesy of the Colorado Milling and Elevator Company and especially of Mr. G. B. Irwin, the manager of its mill at this place, we are able to present the baking results obtained with flours produced by different mills which we may take as representative of our wheats and the flours produced from them. These results are presented in the table under the caption of "Baking Tests of Flours from Some Colorado Mills". Some of these are straight flours, others are various grades of patent flours from 50 to 70 percent and grading into straight flours. The results of such tests can be considered as the basis of just comparisons only when they have been made under the same conditions throughout. It would be wholly inadmissible to compare baking results obtained by myself with those obtained by a skilful baker even though he used the same brand of flour. This principle is still more imperative when it concerns milling products as an expert miller might use my appliances and make an excellent flour but he certainly would be able to produce a much better flour in his own plant. For such reasons I have presented a separate table entitled "Baking Tests with Check Flours" which represents the best brands on our market in order to compare the results obtained with our Colorado flours. These check flours are, of course, high-grade patent flours, while the samples from the mills of this State are of various grades made from a variety of different wheats in some cases blended by chance mixing in the bins, in others with a definite purpose and wisely, and in others not blended at all. These facts should all be borne in mind in making any comparisons of the results.

An examination of these tables shows that with the check flour the lowest yield of bread from 100 grams or flour was 143 grams and that two other trials with this flour gave 144 grams. The smallest volume yielded by 100 grams of any of these samples was 475 c.c., other samples of the same brand yielded 478,493 and 505 c.c., showing fairly uniform results in this respect. The largest yield of bread from 100 grams of flour was 151 grams, and the largest volume was 541 c.c. All of these samples are supposed to have been made from hard wheats. We know that this is not the case with the samples from the Colorado mills. In a few instances we know of what wheats the flours were made. For instance, flour No. 4 was made from a mixture of Defiance wheat* and a soft Idaho wheat, probably Dicklow Spring wheat, also, No. 13 was made from a mixture which was very rich in Defiance, again, No. 23 "Silver Bell" brand was a 70-percent patent made from soft wheat. We find that the flour from the Defiance wheat requires the least water and yields the smallest weight of bread, and is always deficient in volume. Sample No. 13, which required only 53 percent of water to make a dough was flour from Defiance wheat. We see that the water required by these samples varies from 57 to 72 percent. The maximum that I have found required by a sample of Colorado flour was one of Mr. Hoffman's which required 88 percent. This sample is not given in the tables. The range in the water required by these samples is mostly from 57 to 62 percent, which is fully an average water requirement. The water content of these flours themselves, as we have shown in a separate table, is mostly a little less than 12.0 percent and the crude protein about 10.0 percent, except for flour made from distinctly soft wheats, in which it may fall materially below 10.0 percent.

The yield of bread per 100 lbs. of flour is from 144 to 154 lbs. or from 282 to 305 one-pound loaves per barrel of 196 pounds, except

*Defiance wheat is not to be confused with "Defiance" flour which is ground from blended wheats.

for the soft wheat flours, which fall below this yield. The minimum yield that we have found is 272 loaves. This result is in harmony with the statements often made relative to our flours, but it no longer represents the facts. The check flours that we used as criteria of excellence yielded from 280 to 296 loaves per barrel.

In volume, our flours yielded from 100 grams of flour, from 455 to 511 c.c. mostly, however, from 470 to 500 c.c. The samples prepared from soft wheats show their deficiency in this as well as in other respects. Our check samples ranged from 475 to 514 c.c. for each 100 grams of flour used. It is evident that our flours compare favorably with the best on the market and can be produced of uniform quality if the desire to do so is strong enough. This might be different in the case of small mills receiving all kinds of wheat, varying from good, hard wheat, either spring or winter wheat, to very soft, indifferent wheat.

We have given the results on such samples as we could obtain. They represent different localities, the products of different mills and the skill of different millers. These results are in harmony with the conclusions that we have elsewhere drawn based wholly upon analytical results, i.e., that our wheats are not inferior in composition or in bread-making qualities to the same varieties grown elsewhere, but that on the contrary our conditions produce excellent wheats when the soil is properly cultivated and advisedly fertilized.

SUMMARY

The character of the grain produced depends upon the relative supply of the respective plant foods.

The important factor in our conditions is the ratio of the nitric nitrogen to the available potassium.

Organic nitrogen, as in farmyard manure, is not nitrified rapidly enough to affect the composition and physical properties of wheat.

Phosphorus does not produce in our soils the effects usually ascribed to it.

Potassium in excessive ratio to nitric nitrogen produces meally wheat.

Excessive irrigation does not produce meally or soft wheat.

Frequent rainfall, accompanied by heavy dews, reduces the ash and nitrogen content of the plant.

Rainfall and dews sufficient to keep the plants wet, together with poor ventilation, are accompanied by a development of rust which seriously interferes with the maturation of the plant.

Fallowing the land has the effect of increasing the nitrates, and under normal conditions will produce hard wheat.

There is a close relation between the physical quantities of the wheat and its composition.

The milling qualities of the wheat are closely related to the physical and chemical qualities.

The baking qualities of the flour are related to the hardness or softness of the wheat.

The process of milling is of very great importance in determining the quality of the flour produced.

Colorado wheat is mostly hard enough to produce good breadmaking flour.

Flour produced in Colorado from Colorado wheat is usually good flour.

Some of the better grades of Colorado flours compare favorably with the best commercial flours.

Flour made from dry-land wheat is identical in quality with flour made from the same kind and quality of wheat grown with irrigation.

Dry-land wheat yields more bran than irrigated wheat.

Shrunken wheat yields more bran than plump wheat.

Flour made from shrunken wheat is not poorer in quality than that made from plump wheat. The quality of such flour depends upon the cause of the shrunkenness; if it be caused by the presence of nitrates the quality will be high, it may be higher than that of flour made from plump grain of the same variety.

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By ROBERT E. TRIMBLE

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COLORADO CLIMATOLOGY *

By ROBERT E. TRIMBLE

Nearly all the variations of a continental climate are to be found within the borders of the State of Colorado. The natural diversities which result from its location in latitude and the many variations caused by the difference in topography, and the effect of the Rocky Mountains extending through the State, are well defined in many cases and cause many complex conditions. Many important local features are not apparent in the averages of the principal atmospheric conditions which make up what is known as ''climate''. Two-fifths of the State is highly mountainous, and the rest of it plains and high mesas. About 40 percent of the area is above 7,000 feet in elevation. That portion of the State lying east of the mountains, or the plains region, is crossed by a ridge which forms the watershed between the South Platte and the Arkansas rivers. The lowest point in the State is where the Arkansas river leaves the State a few miles below Holly, at an altitude of 3,370 feet, while Julesburg, 3,460 feet, on the South Platte, is the lowest point in the northeastern portion of the State.

A prominent feature of the mountain region is the number of large upland parks. North, Middle and South Park, and the San Luis Valley in the southern part, a remarkably flat, immense basin, which at one time was evidently a lake or sea bed, are all 7,000 to 10,000 feet in elevation. The average height of timber line is about 11,500 feet, varying from 10,000 to 12,000 feet.

Some of the qualities of the climate of Colorado that make for health, comfort, and man's enjoyment of life are: Abundance of sunshine; a pure, dry air; clear skies giving a wide range of temperature; freedom from heat prostrations; a low humidity, making us exempt from the raw, chilly mornings or penetrating cold, giving in its place a dry, bracing cold, usually attended by sunshine; and a favorable sensible temperature, tending to modify the cold of winter as well as the heat of summer. In winter it is usually warm in the sunshine, and in summer it is always cool in the shade. There is seldom a night in the year when a blanket covering is not comfortable. The air is more healthful than at a lower altitude, because it is cleaner. Bacteria decrease rapidly as we rise in the air. Such

*Bulletin No. 182, "Colorado Climatology," is out of print. This bulletin is published to supply the demand for information on Colorado climate and to bring the records down to date.

a bracing, invigorating climate stimulates the people as a whole to their best efforts in any line of work or endeavor.

MEAN TEMPERATURE AND PRECIPITATION

The mean temperature of the State as a whole is 45 degrees. The precipitation varies. In the eastern counties it averages 17 to 18 inches, it diminishes gradually to a point somewhere east of the foothills, where the average is about 15 inches, and from this point it increases so that on some of the high mountain watersheds it will be considerably more. The high mountain parks are dependent upon the mountain barriers surrounding them for the rain they receive. In North Park the average is around 15 inches, while in the San Luis Valley it is only about 7 to 8 inches. On the Western Slope the location in respect to mountain ranges and prevailing winds causes considerable variation.

Our position, south of the track of the majority of the storms as they cross from north of Montana to the Great Lakes and beyond, and in the interior of the continent, remote from the ocean, with our differences in altitude and diversified topography, greatly modify the climate at different points. The usual track of storms being some distance northward, the State is generally dominated by the warm and dry quadrants of the low areas that move eastward with great regularity, and escapes in part the attendant precipitation of moisture, the high wind movement and the sharp fluctuations of temperature. Considering the great distance from the Pacific and the high mountain ranges which the westerly winds must cross, it is not surprising that the low humidity is attended by a great range of temperature.

Normal pressure distribution, with its effect on the resulting direction of the winds, causes an important effect on our climate. During the winter the high pressure of the Salt Lake region remains fairly constant, and the effect this has on any locality depends upon its location, whether east or west of the mountains. To the west is found persistent cold for the latitude and altitude, especially in some of the higher valleys. The clear skies and still atmosphere cause radiation to proceed rapidly, and the topography causes a steady flow of cold air from the higher points into the valleys. On the eastern slope at such times the resulting winds are westerly, coming over the mountains, the air being warmed by compression during the descent to the foothills and plains, the mean temperature is raised considerably, and the capacity of the air for moisture is increased, so that there prevails in the eastern half of the State a long succession of relatively dry, warm and bright sunshiny days. During the summer months a low pressure is prevalent over the Salt Lake region, causing little precipita tion, but this area of low pressure causes easterly winds east of the mountains and the air which is drawn up the slopes of the mountains becomes chilled by the elevation and causes precipitation during the warmer half of the year.

Though distant, the influence of the Gulf of Mexico is felt to a varying extent. During the summer months when there is a general stagnation in the movement of the northern low pressure areas, sufficient time is afforded for moisture to be brought to the eastern slope, which causes increased precipitation east of the mountains during the warmer half of the year. The difference in the temperature of the two slopes is quite marked in the winter months, when cold waves from north of Montana sweep southward along the eastern slope of the Rocky Mountains, but do not pass to the western slope, as the continental divide is an effective barrier. In the areas of high pressure or anti-cyclones, the greatest cold is generally confined to the lower stratum of air whose upper limit does not always reach as high as the mountain tops. As a matter of fact during these periods of low temperatures the adjacent high altitude stations experience relatively moderate temperatures, which condition, if not already in existence in the western valley, is soon in evidence. Cold waves are the result of the transferring of cold air from the north, often increased by the radiation in the clear dry air.

EFFECT OF CONTINENTAL DIVIDE

The continental divide is also effective in moderating the winter temperatures of the eastern slope. When the distribution of the pressure is favorable to westerly winds, remarkable rises of temperature occur. These are called ''chinook'' winds. That the ''chinook'', or warm winds, blowing from the snow-covered mountains should be so warm and dry is explained by the fact that the air as it is forced up the western slope, owing to the high elevation, is unable to hold the moisture it contains and precipitation occurs. Its latent heat is liberated, so that the air reaches the top of the mountains colder but relatively warmer than when it began its ascent, and when in descending it is compressed, it reaches us as a warm dry wind. Its effect in evaporating the snow on the plains has been the salvation of many herds of stock that must otherwise have perished. Locally these winds are accompanied by a low barometer, and soon a long wind cloud is seen like a banner lying close to the mountains, and later the wind springs up and the chinook is at hand. Chinooks are liable to occur at all seasons of the year, but the warmth is relatively greater in winter and therefore more noticeable when the mountain region is warmer in comparison with the plains than in summer, adding extra heat to the descending air.

RAPID EVAPORATION REDUCES EFFECT OF HIGH AND LOW TEMPERATURES

During the heated period in July and August, high temperatures often characterize the days. However, the periods of oppressive heat, sunstrokes and heat prostrations that occur in our eastern states, especially in the large cities, are practically unknown in Colorado, owing to the mild effect of our temperature, although the thermometer in this State often registers as high as in the eastern states. The prevailing lack of moisture in the air is favorable to increased intensity of the direct rays of the sun, but owing to the dry atmosphere, which is favorable to rapid cooling by radiation and evaporation, even the warmest days are comfortable in the shade, and are succeeded by cool nights, which prevent a tendency toward the debility incident to continued heat. Nowhere in Colorado is the air sultry or ''muggy'', the dryness being marked as shown by the low reading of the wet bulb thermometer, which gives the temperature of evaporation, or sensible temperature, or approximating that experienced by the body. In Colorado this temperature is not infrequently 20, 30 or 35 degrees lower than the air temperature during the hottest part of the day. The air temperature as it is commonly recorded does not necessarily indicate the sensation of heat experienced by a person, so that an estimation of the pleasantness of two locations, as judged by the air temperatures, may give an entirely erroneous impression. The term ''sensible temperature'' is used to describe the temperature felt on the surface of the body. The wet bulb thermometer as used indicates this. It is an ordinary thermometer covered with a piece of muslin and immersed in water. The dryness of the air takes up the water by evaporation, the greater the dryness the greater the evaporation, and since this is a cooling process, it affects the temperature shown by the thermometer. Evaporation thus affects, also, the temperature experienced by a person. The greater the humidity, or amount of moisture in the air, the less the evaporation, and therefore, less cooling effect. The wind is also an important factor in promoting evaporation, hence the effect of a light breeze is to make it seem cooler than the temperature of the air would indicate, especially on a cold day.

YEARS OF STUDY SHOWS CLIMATE NOT CHANGING

We often hear the statement made that the climate is changing, and the popular belief that such is the case can only be explained by the generally short and defective memories of people who through exposure to a few severe storms in the past, or inconvenience, or perhaps loss from a few of them, unintentionally exaggerate the severity and frequency of their occurrence. Although large fluctuations occur in different years with some indication of periodical terms, especially in Colorado, where the range of temperature is great, there seems to be no progressive change. These fluctuations are large and often in the same direction for several successive years.

In the meteorological data for the last one hundred years, the record of some places extending still further back, there is nothing to support the idea of any permanent change in the climate having taken place, or that any change is about to take place, and the mean temperature shows no indication of any permanent change either warmer or colder. The small modifications claimed by cultivation, the planting of trees, and the erection of buildings, even of a large city, are too small to alter the mean temperature of any section of the country.

Colorado being an arid state, the amount of precipitation is at all times a vital question. Liability to a marked deficiency in rainfall in any region is a matter of grave concern to those engaged in agriculture and other interests. We often hear it stated that the rainfall is changing, that the settling up of the country and the planting of trees and building of reservoirs, forming lakes and wet places throughout the country, is causing an increase in the amount of our precipitation, but long series of observations taken at different places over the world, do not bear out that claim.

That the forest that cover the sides of the mountains exert a retarding influence in the melting snow and the drainage of the water, thus prolonging the period in which the same may be made available in irrigation, is true. Complaints are heard that the snows do not lie as long in summer as they used to before so much of the forest cover was removed, but there is no reason to believe that the amount of snow falling on the high mountains, or plains either for that matter, is different from that of ages ago. In general, the precipitation seems to decrease with increase of altitude, as from the Missouri river west to near the base of the Rocky mountains, then there seems to be an increase in the amount to the tops of the higher mountains and on the crest of the range, especially on the windward side. There also seem to exist what have been termed islands of greater rainfall, where the precipitation, especially in winter, seems to be great deal more than on the lower levels. In our case the line of lowest rainfall seems to be some 30 or 40 miles east of the foothills, and to increase to the eastward as well as westward to the summit of the mountains. The existence of islands of greater rainfall has long been noticed, several of which are found in this State. The rainfall in some of the more favored localities is at least twice as much as it is only a short distance away. These islands aften occur at the sources of our larger streams, and since it is from the slowly melting snow on the high mountains that a fairly constant stream of water is available for the irrigation of the valley lands, the snowfall is very important to the well being of the people of the State, particularly those engaged in agriculture.

GREATEST RAINFALL IN APRIL, MAY, JUNE AND JULY

The months of greatest rainfall at the College are April, May, June, and July, which with that of the months of March and August, makes a total of 10.68 inches out of the total for the year, that falls during the growing season and is directly available to growing crops and ranges of the State. The rainfall of the State as a whole averages about 15 inches annually, the rainy season being in the spring and early summer months. The portion falling in the mountainous section is subject to a large run-off, and is gathered by the streams for use below, while the run-off on the plains is much smaller, being 10 to 15 percent but, falling on a comparatively flat surface, the moisture is absorbed by the soil and is directly available to the cultivated crops or natural stock range. An accurate knowledge of the rainfall or precipitation of this State is extremely desirable. All agricultural activities depend upon the amount and time of the year it is available, directly or through the aid of irrigation. Colorado, in common with a large part of the Rocky Mountain region is occasionally visited by long dry spells. Since the distribution of pressure which brings about this condition is generally wide-spread, the dry periods prevail at the same time over extensive areas. During the last few years, for instance in 1910, from January 4th to April 29th, only 0.28 inches of moisture fell at Fort Collins. In 1907-08, from October 1st to May 1st, the total precipitation was only 0.82 inches, .44 of which fell in one storm in November, but fortunately this period was followed by a wet May, 5.83 inches, which was followed by favorable rainfall, permitting good crops to be secured.

Absence of precipitation does not always mean drouth, especially when the soil is moist and evaporation is retarded by cloudiness and unfavorable wind conditions. Therefore, the maximum period without rainfall as a measure of the intensity of drouth must take into calculation the previous period and these other conditions. Then again the maximum period without rainfall often, in fact usually, occurs during the non-growing season, the autumn and early winter months having little or no effect on crops except that we need all the snow we can get on the high mountains for next season's supply. There is quite a wide range between the amount of precipitation in the wettest and driest years. For the wetter years the difference in amount may be two or three times the amount of the drier years. The snowfall for the winter months in Colorado is small, the average for November and December being the least in the year. However, on the crest of the range and on the high mountains, the snowfall is heavier and is stored there, especially in large drifts in the timber and gulches and north hillsides, for use in irrigation the following season.

STREAMS CARRY MOST IRRIGATION WATER IN MAY AND JUNE

While many of the streams of the State have a good flow during May and June, they fall short during the months of July and August, at a time when some of our most valuable crops are in need of water. During times when the flow is plentiful a supply of water that would otherwise go to waste and help increase the damage due to floods lower down, can be impounded in our reservoirs and put to a beneficial use to water our best paying crops later in the season. This condition arises almost every year, because our best months for rain are April, May and June, which is the time the melting snows cause the rivers and streams to be in a flood stage, and as the rains on the plains supply sufficient moisture for growing crops, the water then flowing in the streams is available for the reservoirs.

The storms during the summer months are local in character and vary considerably in the amount, from nothing to an inch or more, and in their frequency, sometimes one or more every day for ten days or two weeks, and then again they are entirely absent, no precipitation falling for three weeks or more. A general rain is not usual at this time of the year, the form being that of the thunder shower. These local storms are often so frequent that several may occur over the same valley or region on the same afternoon. The western part of the State and high mountain regions receive most of their percipitation from the westerly winds from the Pacific ocean, while east of the mountains the supply obtained from the Gulf of Mexico becomes important.

HEAVIEST PRECIPITATION DURING GROWING MONTHS

The precipitation during the growing months of the year is about two-thirds of that for the entire year, and this is a very important factor, since this distribution makes our small supply more effective than it otherwise would be. In the crop season when we are subject to a long continued drouth and many farmers are sometimes ruined and destruction is widespread, one cannot fail to see that the state which would fail to develop its irrigation possibilities and reclaim its arid lands would be making a great mistake. From the mountain peaks, which collect the snows of winter, flow the streams which make crop production a certainty. The original source of all our lakes and streams is precipitation in the form of rain or snow. This is the original water supply. The guarantee to the irrigator and farmer, to the irrigation enigneer and to the capitalist who finances some of our large enterprises, is the information furnished by the rainfall observers over the State that there is a sufficient and steady water supply that can be depended upon, that we shall know intelligently the amount of water available for the use of crops, and that the hydraulic engineer may have data to calculate the supply tributary to the storage reservoirs or the streams from which their canals are taken.

The normal barometer for the Station is 24.992 inches for the year. While the Station barometer has been moved two or three times, the change in elevation has been very slight and no correction has been applied for this. Only the correction for temperature has been applied. Our precipitation nearly always comes with a rising barometer. When the barometer is very low it is nearly always succeeded by wind. The precipitation is preceded by any barometer from the moderately low to the high.

LIKELY DATES OF LAST KILLING FROST

The average date at which the last killing frost is likely to occur in a locality as a normal event, must often determine the limit in latitude and altitude at which a fruit or certain kinds of crops can be grown. Even in the most favored fruit regions of the State the records bring out the fact that killing frosts may be expected and will occasionally do great damage, though the smudge pot is lessening the danger and making a certainty of many years that formerly would have proved a total loss of crop. At Fort Collins the average date is May 10 to May 15 and September 15 to 20. At Rocky Ford and Cheyenne Wells the season is a little longer.

In reporting the meteorological observations for the last twenty-five years it has been thought well to include, for purpose of comparison, the records taken for temperature and rainfall for our substations, and also the precipitation from a number of stations scattered over the State. Some of these observers reported to this Station during the early years, but during the last few years have reported altogether to the United States Weather Bureau office in Denver. They have been included here that they may be accessible to people who may be interested along with data from our Station.

LOCATION OF STATION

The Agricultural Experiment Station at Fort Collins is located at the base of the Rocky Mountains, about four miles from the lowest foothills, beyond which the mountains rise to the summit of the range about fifty miles westward. It is located in Larimer county, about seventy-five miles north of Denver, on bench land about one mile south of and 40 feet above Cache la Poudre river. The College is in an irrigated area which extends about three miles westward, while in all other directions there are irrigated lands for a number of miles. The nearness to the mountains affects the climate in the amount and character of the clouds, in the temperature and in the direction and character of the winds. The elevation is about 5,000 feet, the latitude 40° 34′, and the longitude 105° 6′ west of Greenwich.

EQUIPMENT USED

The maximum and minimum thermometers used are called self-registering, that is, the maximum thermometer registers the warmest temperature of the day and the minimum the coldest and the thermometers remain at the extreme point until read and reset. They are read each day so that a continuous record of the lowest and highest temperature for each day of the year is kept at each station. The difference between the maximum and minimum temperatures of the day constitutes the daily range of temperature. The average of the two gives the mean temperature. The difference between the highest and lowest temperature during the month gives the monthly range. At the end of the year we obtain the annual mean temperature, the monthly and daily means of temperature, the daily, monthly and yearly range of temperature.

The rain gage which is used to measure the precipitation has an inner receptacle that magnifies the amount ten to one, making it possible to read to one hundredth of an inch with accuracy, and though the different elements vary considerably from month to month and year to year, the averages of all the years and of all the separate months afford a fairly accurate estimate of what we may expect each year and each month. It is only from the average of a long series of observations that an accurate opinion may be formed of the temperature and precipitation of a locality, and also, what is of equal importance, the extremes that are liable to come. The records in this bulletin are brought up to the end of 1917 and extend far enough back to give the average results and a fairly good knowledge of the climate of those portions of the State reported upon. That it is possible to place before the public the data from these stations depends upon a great deal of patience, care and accuracy on the part of the observers, and much credit is due those observers whose only recompense has been in giving to the public a portion of their time and labor, in some cases twenty to thirty years, in order that we may have knowledge of the climatology of the State in which we live.

Throughout all tables, unless otherwise stated, Fahrenheit degrees have been used.

THE ARKANSAS VALLEY SUBSTATION

This station is located near Rocky Ford, Colorado, and was established by the Colorado Experiment Station in 1888, and records have been taken since that time. The elevation of the station is 4,180 feet. Mr. Frank L. Watrous was the observer at this station for a number of years and was succeeded by Mr. W. F. Crowley. Mr. H. H. Griffin was observer at that station from February, 1898, to February, 1903, and was succeeded by Mr. Philo K. Blinn, who is still in charge.

The season is some longer than in the northern part of the State, and the mean temperature a little higher, especially during the summer months. The climate, as well as the soil, has been found suitable to melon growing, and the Rocky Ford cantaloupe has a nation-wide reputation for quality, while the growth of wheat, alfalfa, sugar beets and other farm crops, make the Arkansas Valley famous throughout the West.

CHEYENNE WELLS STATION

This station was established by the Colorado Experiment Station in June, 1894. It is located at Cheyenne Wells, Cheyenne county, on the Union Pacific railroad near the eastern border of the State, at an elevation of 4,280 feet.

The records were taken by Mr. J. B. Robertson, the superintendent of the substation until April, 1896, when he was succeeded by Mr. J. E. Payne, a very capable and conscientious observer, who kept the records until September, 1901. Mr. L. M. Parker took the records from that date until June, 1902, at which time Mr. J. B. Robertson was again employed by the station and was the observer until March, 1910, when he resigned and was succeeded by Mr. J. W. Adams, who has continued the work until the present time.

Lying as it does in the eastern part of the state, with no running streams of any size, the crops grown will always be limited to the rainfall of that region, but by conservation of the water supply, aided by the proper methods of tillage, much may be accomplished.

LONG'S PEAK, ESTES PARK, COLORADO

This station was established by Mr. Carlyle Lamb, a well known guide in that region, in May, 1892, near the base of Long's Peak, and observations of precipitation and temperature were taken regularly until March, 1902, when Mr. Lamb left the Park and Mr. Enos A. Mills, the well known guide and lecturer, succeeded him, and the records have been continued by him to the present time.

The climate of Estes Park is typical of that found in this State in the high elevations, and the clear, sunshiny days and cool nights are making of the Park one of the greatest tourist resorts in the State.

The climate during the summer and fall months is delightful, and during the winter the brisk, dry cold, with plenty of sunshine, is found to have its charm to many. Often the cold wave surrounding the lower valleys is absent, owing to the fact that many of them do not extend upward to a sufficient height to affect many of the higher elevations of the

State. Nature has done much in giving to this western country such grand and beautiful scenery as may be found throughout the Rocky Mountain region, and in Estes Park may be found one of the most pleasant resorts in the State.

During the winter the snowfall was not always melted; in those cases ten inches of snowfall has been taken as the equivalent of one inch of water. In some cases at the College small amounts, when the weather was very cold, often take nearer 14 or 15 inches of snow to be equivalent to one inch of water.

COWDREY, NORTH PARK

In 1891 Miss Lucy Bell began taking observations at what was then Pinkhampton, but was soon succeeded by Mr. George A. Barnes, and records have been kept by him at the same place, continuously since that time until 1911, although the post office now used is Cowdrey.

The temperature seems to be a little colder than formerly, and the extrement temperature of December, 1910, given as—56, seems to indicate that possibly the thermometer is not altogether reliable at that extreme temperature. The thermometer at Kremmling on that same morning registered—44 degrees. During the winters the snowfall is measured but not melted. In the computations ten inches of snowfall have been used as an equivalent of one inch of water, although during some of the cold weather when the snowfall was light, this would be rather more than the actual amount.

A BRIEF HISTORY OF THE WORK AT THE COLLEGE

The Agricultural College has shown an active interest in meteorology from its very inception, and has maintained records since the opening of the institution. The work in this line was begun by Hon. F. J. Annis, then Professor of Chemistry, and kept up by him until he resigned his work as a professor at the College. The observations were then continued under Professor C. F. Davis and later by Professor A. E. Blount. These records are not all complete; but much credit is due these professors, pressed as they were with so many other duties, for having begun and carried on the observations under such difficulties. The rainfall records for the years 1873-74 were furnished by Mr. R. Q. Tenney, who, even at that early date, took an active interest in our climate.

In 1886 the work was put in the able hands of Dr. Elwood Mead, then a professor in the College, and since January, 1887, the records are fairly complete. Upon the resignation of Dr.

Mead in 1888, the observations were carried on by Professor V. E. Stolbrand until September 1 of that year, when Professor L. G. Carpenter was put in charge. Upon the organization of the Experiment Station, this work was transferred to it, and made a regular part of the investigations of the Section of Meteorology and Irrigation Engineering. Professor Carpenter remained in charge until January 1, 1911, and to his long continued plan and steadfastness of purpose must be given a great deal of credit for the value of this work. I wish also to express my thanks for the interest and co-operation of the Director of the Experiment Station, Professor C. P. Gillette, and of Mr. V. M. Cone, who had charge of the Section from April 1, 1911, at which time the work of the Section was merged into a co-operative agreement with the Division of Irrigation Investigations of the U. S. Department of Agriculture, until April 1, 1918, at which time he resigned and was succeeded by Mr. R. L. Parshall, who is now in charge of the work. The writer has served as an assistant in this Section since April 1, 1891, and upon him has devolved the taking of the observations and the computations of this and the substations.

Free use has been made of the previous publications of this Station in this line, also the publications of the Weather Bureau, which has been for several years under the charge of Mr. F. H. Brandenburg, and especially of the article on the Climate of Colorado, by Professor A. J. Henry, in Bulletin ''C'' of the U. S. Weather Bureau.

TABLE I—DAILY MINIMUM TEMPERATURES FOR NOVEMBER

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887	32	32	36	28	26	39	34	29	24	24	27	26	36	39	28	32	24	15	32	19	21	27	20	18	16	−12	**−13**	6	14	16	..
1888	42	29	27	35	29	32	31	16	..	..	..	..	..	..	..	..	..	19	22	**13**	16	20	21	16	18	26	33	30	28	15	..
1889	20	8	24	8	**1**	9	25	21	20	28	21	7	27	12	17	11	18	24	29	29	26	24	30	30	26	18	18	17	15	18	..
1890	27	36	23	27	36	20	20	24	**6**	20	20	19	17	35	14	11	19	21	19	18	34	18	20	21	26	12	19	21	16	20	..
1891	24	22	29	33	31	34	25	27	13	40	24	14	20	19	13	−1	**−6**	9	18	17	31	12	26	21	26	28	45	20	12	25	..
1892	32	32	21	29	27	32	16	20	16	16	28	28	34	15	31	13	22	26	17	25	13	28	20	20	26	**11**	14	16	32	26	..
1893	25	17	13	17	22	28	39	18	23	33	17	10	24	12	16	20	15	9	8	9	25	1	**−13**	3	14	10	21	37	30	19	..
1894	36	19	32	22	19	29	41	25	28	17	23	44	20	22	19	**−1**	0	22	18	35	19	24	14	24	25	30	31	21	19	21	..
1895	22	36	29	26	22	9	19	24	16	16	16	16	27	17	20	40	28	36	19	23	26	4	4	11	5	**−3**	13	20	14	16	..
1896	27	21	26	16	25	10	5	7	34	34	24	13	18	32	30	35	30	24	9	8	14	16	31	19	20	2	**−11**	−10	−8	−5	..
1897	22	24	29	30	13	20	28	27	18	38	22	33	37	26	8	1	17	24	31	30	25	24	25	20	22	**−3**	2	4	1	11	..
1898	32	20	17	46	26	18	26	16	−10	**−11**	8	4	10	4	8	20	18	38	27	16	11	7	5	16	9	13	22	24	25	19	..
1899	22	**15**	16	28	28	30	20	27	27	30	24	34	31	21	24	34	25	31	17	25	26	22	31	16	17	17	18	28	28	33	..
1900	21	26	29	31	21	28	33	23	17	21	13	18	32	17	22	26	30	10	16	13	**9**	35	28	26	13	24	30	13	13	12	..
1901	22	30	15	29	24	39	17	31	22	27	26	14	17	15	14	20	33	31	**12**	19	24	19	27	33	19	23	20	18	20	35	..
1902	36	20	32	30	24	15	22	28	34	32	29	38	23	18	26	14	22	20	24	23	19	23	19	23	24	16	15	18	8	**4**	..
1903	24	22	24	28	22	20	25	25	19	20	19	30	23	22	26	18	0	**−10**	−4	7	21	23	22	22	19	20	26	22	15	18	..
1904	21	18	36	22	17	18	20	22	29	18	**0**	12	14	15	18	33	22	18	29	11	27	20	15	16	11	12	21	39	20	19	..
1905	**3**	4	24	27	35	25	25	25	21	17	20	22	25	21	27	24	32	27	20	20	27	30	22	21	27	25	35	15	4	8	..
1906	37	30	29	27	31	33	22	30	27	28	34	26	40	27	33	34	21	11	−2	**−9**	11	12	17	−2	15	11	6	11	15	29	..
1907	38	22	23	24	22	25	29	20	18	25	3	**−1**	7	10	14	11	14	27	11	4	7	3	3	9	23	20	19	18	18	21	..
1908	30	23	22	21	20	22	22	21	22	15	−4	1	**−12**	−8	6	13	14	27	30	22	24	24	25	19	16	0	−1	10	19	15	..
1909	24	27	.30	28	27	29	36	21	24	27	21	25	24	17	11	**−3**	7	16	29	38	32	25	35	42	27	32	29	10	21	28	..
1910	37	27	24	33	18	24	29	32	17	28	29	34	32	34	30	28	20	20	32	[illegible]	23	32	23	27	24	31	**14**	14	32	27	..
1911	17	14	11	23	24	22	18	26	19	22	**−7**	−11	2	22	36	27	22	35	34	26	20	17	12	18	14	26	16	5	2	9	..
1912	12	19	19	26	34	20	28	26	23	35	33	29	23	23	26	14	17	19	21	28	16	30	23	22	20	21	**6**	22	16	14	..
1913	22	30	29	28	19	32	34	15	23	19	31	32	34	32	20	20	27	30	29	25	32	17	**11**	15	22	32	20	21	18	16	..
1914	31	36	30	26	24	29	26	16	24	24	20	26	25	28	15	**11**	**11**	13	18	27	22	16	18	19	20	20	19	16	22	27	..
1915	43	32	33	31	33	39	36	32	29	31	22	18	9	**3**	15	22	21	21	23	26	22	32	24	37	25	20	25	15	11	19	..
1916	30	27	31	27	25	26	23	13	22	24	9	4	**−21**	−13	1	14	24	23	24	23	−1	0	19	9	5	17	29	24	19	18	..
1917	22	25	27	25	29	24	28	25	28	23	20	20	20	26	25	32	32	27	20	25	34	26	28	28	30	21	29	18	29	29	..
Average .	27	24	25	27	24	25	29	23	20	23	18	20	21	19	20	19	19	21	20	20	21	20	20	20	19	17	18	18	17	19	..

NOTE—Extremes are printed in bold faced type.

TABLE II—DAILY MINIMUM TEMPERATURES FOR DECEMBER

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887	21	17	23	14	19	19	24	22	24	26	11	23	19	7	**0**	17	18	32	11	3	1	2	28	20	18	16	3	7	15	18	**10**
1888	11	32	12	26	19	18	27	15	18	19	20	18	18	21	32	28	26	16	13	22	23	18	23	19	19	11	**4**	4	9	6	5
1889	24	31	21	24	31	26	28	27	18	26	22	27	25	29	26	30	29	29	17	13	26	12	20	22	20	23	23	26	17	**3**	13
1890	24	25	29	16	23	20	12	**6**	15	23	24	13	20	19	18	9	11	10	17	26	10	14	12	21	11	34	12	13	24	26	32
1891	34	29	25	10	14	1	**−10**	14	18	32	17	16	19	33	23	19	18	16	17	18	20	13	15	7	−5	−9	25	28	8	15	17
1892	19	23	21	21	30	26	14	4	2	9	8	−0	5	−10	**−17**	5	−9	−3	6	4	**−17**	−15	17	17	28	17	16	14	17	22	15
1893	17	34	17	27	29	12	31	28	21	27	31	22	14	20	33	18	17	22	14	12	18	30	27	25	7	8	8	24	14	**2**	9
1894	28	21	−4	2	12	26	31	18	20	28	14	15	10	12	23	13	13	14	20	24	17	14	18	19	−5	−13	−16	**−24**	−3	−2	−6
1895	17	10	1	8	15	21	27	20	12	31	24	19	23	24	18	15	5	10	0	11	21	9	9	20	7	17	4	13	**−5**	20	7
1896	15	14	29	28	38	22	**0**	9	18	19	22	24	21	24	13	27	22	13	10	22	22	21	15	21	15	12	18	19	14	15	27
1897	11	3	−2	−8	7	27	19	27	28	17	18	25	22	17	3	**−11**	−10	−6	−2	−6	−6	6	16	13	15	12	20	25	40	29	14
1898	15	26	21	6	20	5	10	−1	−18	−11	1	27	3	6	8	9	13	10	16	29	21	8	12	8	13	16	20	17	13	−14	**−22**
1899	25	25	11	16	4	13	9	8	21	1	−3	19	8	**−9**	−6	13	17	17	4	4	7	12	21	20	26	21	22	21	13	16	21
1900	25	24	7	23	27	23	21	19	15	13	10	16	15	13	12	19	24	27	13	20	34	31	24	15	24	13	19	−3	1	−7	**−22**
1901	19	19	27	26	27	26	22	0	9	17	16	10	−15	**−31**	−12	14	5	18	22	9	18	24	41	29	22	15	26	11	18	15	23
1902	16	23	17	12	24	17	13	22	24	26	19	15	26	18	0	**−18**	−5	−1	25	33	13	6	21	15	10	13	21	17	7	6	8
1903	19	29	17	19	8	8	13	26	32	14	17	7	6	6	11	17	13	14	22	13	27	14	13	**5**	21	25	16	12	8	15	17
1904	29	24	26	17	7	8	14	11	16	18	24	8	17	12	12	26	10	22	11	29	12	25	25	13	15	7	2	**1**	8	17	27
1905	8	7	6	13	10	7	5	8	13	2	10	10	8	14	8	15	14	9	14	14	9	11	−1	15	4	18	10	15	**−4**	−3	6
1906	21	19	27	36	30	27	22	22	18	23	27	30	29	18	**7**	7	9	10	21	22	34	18	21	25	18	31	19	17	29	15	15
1907	20	18	17	15	18	28	20	33	18	15	15	33	14	28	4	10	9	**−5**	−3	−1	8	11	25	19	22	17	27	17	17	5	10
1908	0	−5	6	14	18	2	−1	5	13	17	19	25	25	18	23	25	16	**−13**	−3	−1	−3	5	9	18	18	18	24	19	25	16	16
1909	33	30	9	−15	**−19**	−6	−18	−9	8	6	25	4	19	22	16	14	3	−9	−2	1	−11	−10	−4	3	−4	7	15	23	9	16	21
1910	26	26	28	22	20	11	23	22	24	23	24	29	24	17	18	18	14	15	17	20	25	18	5	14	20	**3**	10	9	6	6	12
1911	14	18	11	11	21	17	12	11	9	21	16	5	12	−2	9	12	11	21	24	15	14	1	7	15	−2	−3	**−8**	−1	1	−6	5
1912	22	14	17	22	15	6	10	11	9	18	12	5	21	20	18	15	30	8	20	12	2	3	3	12	2	**−11**	4	14	11	27	9
1913	25	16	19	7	30	22	−2	2	−1	0	−6	−1	−1	−1	7	5	6	1	−2	−7	−12	**−13**	−4	−3	−10	4	4	−6	−5	−9	−2
1914	15	11	11	22	16	16	25	19	10	1	2	9	0	−2	7	−5	0	13	5	3	**−6**	−3	7	8	10	11	8	9	12	8	7
1915	10	13	18	22	28	22	21	21	22	27	16	29	19	18	24	10	−3	10	0	3	25	37	30	21	11	17	−6	−3	12	−7	**−10**
1916	25	27	32	28	29	23	8	3	9	15	−5	16	16	−1	8	16	6	4	26	5	−8	6	7	7	8	−7	−9	**−11**	−8	−5	6
1917	27	30	23	17	24	16	6	0	2	1	**−8**	1	0	6	15	11	21	25	31	28	26	20	30	22	17	22	24	15	9	34	23
Average .	20	20	17	16	19	16	14	14	14	16	14	16	14	12	12	13	11	11	12	13	12	11	16	16	12	12	12	11	11	10	10

NOTE—Extremes are printed in bold faced type.

TABLE III—DAILY MINIMUM TEMPERATURES FOR JANUARY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887	..	..	..	..	..	..	−9	**−19**	−18	−1	8	21	23	16	30	18	10	12	34	24	26	14	14	20	11	6	20	23	26	8	18
1888	10	26	23	28	18	16	−15	−12	−14	18	10	9	20	−16	**−28**	−17	0	2	13	−8	−6	13	18	22	19	35	26	26	28	20	26
1889	6	4	7	7	16	18	20	11	2	19	9	19	19	17	5	10	−2	**−4**	11	−3	12	8	0	3	11	1	30	28	10	16	15
1890	5	−2	4	8	8	8	2	9	15	21	15	**−13**	−7	−4	−6	−2	9	14	13	−12	−4	−1	10	9	43	42	28	16	18	16	16
1891	15	9	10	14	7	17	10	22	12	−13	12	−9	3	−2	9	3	0	5	4	14	33	30	11	9	13	20	24	21	−11	**−16**	2
1892	2	9	21	36	22	0	10	11	6	−4	**−28**	−11	−15	−6	8	10	−6	−24	−8	26	−7	2	5	11	15	15	18	21	24	31	23
1893	14	33	23	39	22	31	22	12	17	19	27	7	10	12	**−2**	−2	2	−1	13	4	7	12	15	28	22	4	14	34	10	18	25
1894	15	34	13	2	−8	−16	0	1	−12	5	17	14	16	24	24	25	26	−1	1	13	20	12	−14	**−22**	4	10	5	22	9	14	9
1895	−2	−3	0	−2	24	12	15	−3	20	22	23	18	27	32	8	−1	15	16	15	17	17	16	13	14	14	7	−4	**−10**	10	9	1
1896	26	13	**−8**	1	14	20	7	18	28	15	22	10	2	13	10	13	20	24	29	20	28	24	7	15	10	23	16	17	24	21	19
1897	28	15	9	6	11	16	14	12	14	16	13	20	13	24	10	19	23	7	9	12	20	26	20	−5	−7	−17	**−26**	−19	−9	8	8
1898	4	14	25	18	15	16	26	13	12	23	10	6	6	15	2	10	19	6	−1	13	15	−2	4	10	−2	**−12**	0	16	16	20	11
1899	−8	6	22	14	5	−2	7	5	3	2	13	22	11	7	13	27	22	7	25	22	21	27	18	22	11	19	6	0	−8	−2	**−17**
1900	10	9	23	24	16	10	14	9	25	10	11	19	25	25	31	29	27	14	18	20	13	15	15	28	5	9	10	**−6**	−2	6	11
1901	**−22**	−18	−4	11	13	18	14	21	13	2	−4	33	24	31	29	22	12	15	10	16	24	21	20	6	17	21	9	17	14	2	6
1902	19	27	15	15	23	19	24	24	27	19	14	17	18	19	17	8	20	24	17	28	6	7	2	−5	−11	**−31**	−19	−20	−18	−15	−7
1903	7	18	18	34	37	47	13	13	19	14	3	**1**	13	6	9	12	8	10	7	9	10	21	24	26	27	21	23	19	19	6	15
1904	12	6	7	6	13	0	9	13	13	5	18	23	10	14	3	13	15	13	17	4	10	4	3	7	10	1	0	−7	13	24	12
1905	24	4	16	26	11	20	0	10	9	3	−12	−16	**−22**	−5	4	14	29	30	16	22	18	19	19	24	22	19	18	25	18	17	8
1906	10	2	16	1	26	8	16	**−4**	5	9	6	20	21	8	15	10	21	18	30	23	5	−3	8	25	12	15	12	11	23	12	15
1907	25	−2	**−5**	10	23	20	15	12	12	14	18	20	19	11	5	11	7	13	13	6	22	20	13	8	8	4	3	12	14	14	19
1908	19	6	15	5	8	15	11	8	22	21	5	19	5	6	6	**−10**	21	5	15	7	20	20	5	17	18	31	10	17	19	7	−3
1909	11	17	24	27	3	**−3**	4	20	41	3	0	3	8	18	22	26	29	27	27	31	25	25	24	21	14	18	21	17	10	1	8
1910	21	9	2	−11	**−21**	−16	−6	−1	−4	2	4	6	−1	4	4	14	26	17	21	16	8	30	27	28	20	23	21	17	26	19	22
1911	−2	−13	**−18**	4	22	21	22	23	16	40	26	11	16	29	28	21	16	16	23	31	17	1	−5	7	24	27	30	21	28	32	45
1912	−4	−8	−2	7	−1	−5	−7	**−14**	5	29	−2	−7	23	28	20	31	19	2	7	12	12	18	16	25	27	18	24	18	17	13	26
1913	10	5	44	11	−8	−26	**−30**	−15	0	−3	−1	−7	11	9	30	14	17	16	21	4	6	11	19	13	24	24	11	12	26	25	21
1914	2	10	10	1	9	21	18	27	20	7	−1	**−5**	6	17	17	22	24	13	31	17	8	26	31	13	20	32	26	17	5	12	22
1915	15	16	9	14	18	2	4	3	13	24	7	14	15	14	25	15	0	9	28	15	9	−12	**−14**	−4	−10	1	2	−2	12	24	24
1916	9	−1	2	16	16	13	15	10	25	26	−1	−14	−9	6	1	−13	−18	5	2	13	4	9	24	25	28	4	−8	−3	**−24**	−5	−5
1917	11	14	11	11	7	17	19	11	20	24	16	9	−13	2	−1	−16	−13	4	13	21	1	−18	**−4**	−1	6	20	11	23	36	25	6
Average .	10	9	11	13	12	11	9	8	12	13	8	8	10	12	11	11	13	10	15	14	13	13	11	13	14	13	12	12	12	12	13

NOTE—Extremes are printed in bold faced type.

TABLE IV—DAILY MINIMUM TEMPERATURES FOR FEBRUARY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887	6	–5	0	–5	–4	10	14	18	12	5	–2	8	18	18	20	14	30	20	8	8	**–8**	14	11	8	8	20	20	22	..	..	..
1888	29	29	36	27	**14**	20	27	27	31	30	25	34	37	20	17	26	22	32	24	21	19	16	18	27	26	16	25	30	25	..	..
1889	6	9	14	38	16	11	15	9	8	28	29	10	37	24	12	2	**–16**	0	10	–14	10	7	–2	12	25	17	30	18	..	..	..
1890	12	33	33	38	31	26	15	14	19	19	16	6	14	14	13	16	41	16	14	13	23	18	16	8	0	–7	**–20**	–19	..	..	..
1891	–11	–12	**–15**	–2	4	5	5	6	–14	–4	1	1	5	7	25	24	21	18	22	10	5	16	22	33	21	9	14	2	..	..	..
1892	22	21	17	23	8	7	–1	**–9**	–8	18	24	8	22	19	7	9	19	18	20	24	25	25	29	13	17	27	28	21	23	..	..
1893	–2	**–10**	7	12	32	6	1	8	31	15	26	13	14	12	1	16	23	14	8	24	23	23	24	17	4	18	–3	**–10**	..	..	..
1894	0	16	–3	–10	–5	6	9	17	6	3	–12	**–15**	–7	0	–2	8	10	24	7	–4	0	1	–12	–11	11	15	33	20	..	..	..
1895	–8	6	8	13	9	–3	–14	1	2	–2	–14	**–28**	–24	–22	–23	–14	30	24	10	24	29	26	29	28	32	22	26	28	..	..	..
1896	**4**	15	23	14	11	25	6	21	10	16	8	15	9	25	25	21	22	14	19	17	19	27	29	11	20	20	33	18	19	..	..
1897	10	23	22	11	19	20	24	12	14	20	16	22	9	0	20	34	21	17	5	10	14	0	**–5**	5	13	11	8	23	..	..	..
1898	9	10	8	23	9	26	31	21	28	13	11	10	15	30	23	22	22	20	16	**7**	13	22	12	13	20	20	17	22	..	..	..
1899	–7	–16	–18	–31	–32	**–38**	–32	–17	–4	–5	–30	**–38**	–1	1	1	23	5	8	13	21	26	–4	–12	–1	17	–2	2	21	..	..	..
1900	11	14	29	14	15	15	9	–7	12	7	23	–2	–7	0	–17	**–23**	–18	5	17	18	26	22	28	19	31	29	20	10	..	..	..
1901	5	1	9	–1	–9	–5	5	–14	**–15**	–6	–2	–4	0	7	32	23	30	19	20	18	19	10	6	11	25	28	26	24	..	..	..
1902	–9	**–23**	0	10	18	22	16	14	18	18	28	22	28	6	19	27	25	30	30	14	23	25	20	12	31	28	35	29	..	..	..
1903	18	11	6	–20	–19	–9	–21	–13	1	11	13	5	–15	–23	**–28**	–20	–3	9	–3	5	5	8	15	20	18	5	10	11	..	..	..
1904	15	13	18	13	26	26	8	12	**3**	6	12	18	34	9	17	18	24	5	4	16	22	25	48	33	49	27	36	28	20	..	..
1905	0	–2	–5	–4	13	10	–2	–1	8	6	–14	–25	**–27**	9	3	23	–1	3	12	21	21	19	28	21	19	28	13	16	..	..	..
1906	17	14	18	3	**–5**	–2	3	7	6	2	10	11	15	12	14	33	7	13	15	14	24	26	15	10	11	25	14	25	..	..	..
1907	24	11	**–3**	3	11	26	19	24	35	15	17	21	22	16	21	18	19	38	27	25	26	21	21	35	17	21	20	9	..	..	..
1908	**–15**	–3	14	15	19	10	19	17	19	18	14	12	16	3	25	18	11	18	–2	5	6	2	11	30	26	23	19	26	18	..	..
1909	14	14	14	20	15	18	14	3	–6	19	18	22	9	–6	**–14**	17	22	29	25	27	15	23	16	–5	9	27	12	23	..	..	..
1910	21	17	5	5	9	9	10	20	1	7	14	19	13	23	10	–5	**–16**	2	2	10	6	0	4	26	26	24	18	20	..	..	..
1911	33	16	28	27	21	18	19	12	11	11	18	22	17	21	25	24	20	20	11	–3	–8	–7	**–9**	–2	14	15	11	5	..	..	..
1912	14	14	–2	**–16**	1	–2	12	25	21	24	23	21	15	17	31	23	26	29	26	18	6	7	22	22	15	–10	6	2	–14	..	..
1913	1	–4	1	6	2	7	3	–4	5	10	6	6	12	14	19	24	20	24	17	10	7	**–17**	–1	–8	2	14	–4	–8	..	..	..
1914	15	17	4	13	7	**–18**	–11	–7	7	12	13	16	15	18	16	19	27	30	27	27	27	8	–4	3	18	28	17	30	..	..	..
1915	19	14	17	32	18	11	18	14	19	19	18	20	24	22	7	15	22	23	20	28	28	21	**3**	9	22	22	24	13	..	..	..
1916	**–18**	–14	0	–8	10	14	11	35	30	27	29	30	18	25	22	25	26	25	22	21	21	23	23	20	17	18	17	1	16	..	..
1917	**–6**	3	28	24	15	28	12	20	21	22	24	19	24	24	14	14	20	8	**–2**	–4	20	27	30	25	42	34	10	8	..	..	..
Average .	7	7	10	9	9	10	8	9	10	12	12	9	12	11	11	15	16	18	14	14	16	14	14	14	20	18	17	15	..	..	..

NOTE—Extremes are printed in bold faced type.

TABLE V—DAILY MINIMUM TEMPERATURES FOR MARCH

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887	26	27	13	12	**8**	26	25	24	26	26	30	35	24	36	28	36	28	36	25	14	18	20	25	34	28	20	15	30	32	30	20
1888	13	11	9	4	**3**	11	15	22	20	13	19	26	30	32	28	28	29	30	18	18	20	19	32	30	14	12	8	21	32	39	35
1889	21	**17**	31	**17**	20	23	25	20	19	**17**	29	28	28	37	30	34	40	42	30	39	31	33	21	19	18	29	30	32	32	35	32
1890	**-9**	17	18	29	33	22	24	20	23	22	19	16	12	18	16	21	34	34	28	33	28	33	28	40	20	20	36	20	23	26	18
1891	26	34	3	10	14	4	**-4**	5	16	34	8	1	14	18	25	25	36	26	22	37	24	30	31	19	14	6	24	28	32	25	26
1892	24	26	32	33	33	34	28	27	26	17	20	30	25	26	19	8	**-20**	-3	19	16	14	7	21	29	33	28	18	24	33	21	28
1893	**-2**	12	20	4	18	16	23	36	19	29	13	16	24	6	12	18	10	15	16	29	23	28	27	12	18	21	36	18	25	33	48
1894	18	20	19	27	15	14	18	19	28	28	19	42	28	32	24	35	31	34	21	21	14	19	13	20	**10**	18	20	13	14	34	32
1895	15	24	14	16	20	15	21	26	21	23	18	16	4	-9	**-18**	-5	11	24	26	21	26	26	29	30	23	28	36	40	34	32	28
1896	13	7	5	2	14	12	18	16	31	17	22	27	18	7	**-7**	15	20	10	22	27	45	34	32	33	47	27	40	39	28	27	24
1897	21	19	20	17	22	21	24	33	20	15	22	15	4	7	14	18	32	24	23	16	25	15	**-7**	6	19	27	30	29	29	30	25
1898	33	13	16	25	19	15	17	24	18	24	19	18	20	29	20	17	13	19	26	20	9	-2	**-6**	16	21	22	9	20	19	12	18
1899	28	33	25	18	14	11	28	32	31	22	17	17	20	30	12	22	21	16	22	22	28	27	23	31	26	9	**-24**	-17	10	12	-9
1900	30	27	29	26	22	21	21	26	33	33	30	27	28	25	22	21	16	20	24	25	20	21	27	29	23	26	30	**10**	22	18	23
1901	34	32	35	3	-4	10	19	31	26	14	28	34	27	19	19	20	20	19	24	17	29	29	33	25	33	20	28	20	14	**-8**	8
1902	29	17	27	24	8	23	27	20	24	33	18	17	14	20	20	12	**2**	18	24	33	32	29	32	32	31	34	26	23	19	16	14
1903	**-10**	6	9	17	22	24	4	7	23	19	21	28	29	28	30	28	34	19	4	-3	7	16	-8	6	18	29	28	29	37	36	33
1904	22	23	11	19	31	20	32	23	37	21	25	21	13	24	22	29	21	34	32	30	28	19	18	34	15	**10**	21	25	30	33	32
1905	37	18	31	28	36	20	27	**12**	22	28	21	23	26	26	40	36	36	42	30	29	28	34	32	25	32	34	35	32	20	27	37
1906	15	12	3	14	18	25	17	30	27	11	6	2	9	6	2	-19	-19	9	**-25**	0	15	5	22	24	27	27	32	33	32	26	31
1907	5	33	27	25	23	25	28	21	33	28	27	27	**3**	13	21	29	28	33	49	34	44	41	25	33	34	28	24	30	31	28	18
1908	23	10	11	21	33	20	11	20	**8**	10	15	26	29	42	33	46	44	33	26	11	26	18	29	42	34	16	29	24	11	21	30
1909	27	31	26	31	29	25	23	11	15	19	16	**-12**	15	21	26	20	28	26	31	26	31	36	19	34	15	**10**	21	25	30	33	32
1910	36	42	24	28	27	29	22	35	29	**12**	21	20	23	30	21	24	28	27	29	31	32	32	36	34	29	38	37	30	33	28	19
1911	**-2**	8	14	17	27	26	26	45	33	33	35	28	23	21	24	25	33	24	22	27	44	33	25	27	29	29	13	28	44	22	28
1912	**-13**	9	10	6	-7	7	16	1	-10	4	20	7	13	3	-8	10	18	15	27	2	-12	2	13	9	9	26	29	21	27	26	22
1913	5	-1	23	20	23	28	27	25	26	26	27	27	27	21	14	19	31	30	28	7	1	14	22	2	4	**-2**	8	23	29	42	27
1914	25	28	26	25	23	21	20	21	26	27	16	20	20	31	32	24	32	24	12	18	**2**	11	27	25	21	23	25	29	35	37	31
1915	17	28	22	**5**	**5**	12	7	20	11	18	19	22	25	29	27	31	27	31	20	19	23	18	24	30	14	12	23	31	33	25	30
1916	12	**5**	12	28	26	27	23	24	27	45	26	32	32	27	14	38	32	39	37	37	41	32	36	27	25	21	28	29	33	25	15
1917	2	-2	0	**-13**	9	20	19	20	25	26	26	13	-6	4	19	16	8	7	23	24	23	28	22	30	30	19	15	33	28	33	24
Average	17	19	18	17	19	20	20	22	23	22	21	21	19	21	19	22	23	24	23	22	23	23	23	25	23	22	24	25	27	27	25

NOTE—Extremes are printed in bold faced type.

TABLE VI—DAILY MINIMUM TEMPERATURES FOR APRIL

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887 ..	40	18	26	**16**	34	34	32	40	45	30	30	25	34	34	30	34	33	31	30	30	34	26	30	24	28	28	40	44	40	43	..
1888 ..	49	45	**30**	35	46	33	37	48	44	31	**30**	**30**	36	41	50	43	42	32	40	36	42	48	53	53	46	48	38	37	38	37	..
1889 ..	32	46	25	28	34	35	44	38	39	43	42	32	31	36	44	39	41	38	**24**	27	37	35	47	29	36	45	35	38	31	31	..
1890 ..	**14**	17	32	26	46	38	41	29	19	29	33	35	32	32	33	27	28	30	38	43	41	35	42	41	32	31	32	38	36	42	..
1891 ..	25	**13**	18	23	17	27	29	39	33	21	30	33	35	29	31	31	31	39	37	41	34	37	34	38	39	39	33	36	47	38	..
1892 ..	33	23	30	31	25	24	37	24	21	34	25	36	22	20	28	30	32	36	29	27	**19**	22	27	33	36	43	25	36	33	42	..
1893 ..	30	36	39	32	28	42	33	22	21	21	39	31	19	**8**	26	20	24	29	24	28	25	30	35	44	30	26	26	34	25	22	..
1894 ..	25	29	32	22	22	26	37	38	**16**	27	33	38	34	25	31	34	31	31	35	28	30	39	37	38	33	39	34	36	42	40	..
1895 ..	27	**17**	30	27	28	30	38	19	27	39	26	29	27	33	38	24	25	37	31	36	32	27	32	34	35	35	44	45	50	39	..
1896 ..	**7**	7	21	30	26	30	34	41	26	30	36	35	25	39	36	31	23	14	26	30	33	35	37	34	40	37	36	41	40	37	..
1897 ..	29	28	**20**	23	27	33	31	**20**	23	33	36	37	23	25	35	34	31	38	35	37	39	33	39	44	31	35	40	38	32	32	..
1898 ..	21	18	32	29	**14**	27	25	25	27	29	35	35	26	33	30	39	42	23	38	36	39	32	36	25	29	31	50	21	37	42	..
1899 ..	14	13	**8**	21	29	14	26	24	27	35	33	32	51	28	24	27	36	24	39	25	22	28	29	44	37	48	31	30	31	37	..
1900 ..	27	29	30	32	32	29	31	32	36	24	**5**	23	31	33	35	39	32	12	32	34	38	41	31	36	35	30	42	43	32	32	..
1901 ..	16	20	32	30	24	23	29	33	32	17	32	29	27	30	27	22	**9**	29	31	32	34	47	43	36	38	40	38	42	50	41	..
1902 ..	20	25	21	24	33	38	35	46	37	23	26	34	32	**18**	24	29	30	30	34	35	38	30	23	28	41	30	29	33	33	34	..
1903 ..	37	33	26	24	33	27	29	34	31	38	39	27	18	24	30	30	28	39	41	27	40	30	37	43	33	37	35	30	23	**13**	..
1904 ..	27	21	32	26	38	27	30	28	14	38	39	21	30	30	26	23	25	25	39	41	31	35	29	38	29	36	37	43	43	39	..
1905 ..	38	32	30	29	29	26	29	36	44	28	22	**12**	31	32	23	27	30	33	34	29	21	34	39	32	33	35	41	44	34	35	..
1906 ..	30	31	**22**	30	25	26	36	37	33	43	38	39	35	27	32	33	32	39	37	30	39	38	39	43	40	33	36	28	39	38	..
1907 ..	34	40	34	41	29	34	30	32	37	39	38	22	28	33	42	36	21	32	24	23	**6**	20	37	25	22	23	32	30	22	**6**	..
1908 ..	18	**10**	16	30	21	28	31	31	24	33	25	32	35	35	42	39	35	47	36	33	33	34	37	39	32	27	30	30	20	36	..
1909 ..	29	32	31	30	27	**9**	23	14	23	27	30	26	35	32	32	36	36	34	29	32	28	28	25	38	27	38	28	40	29	21	..
1910 ..	31	25	40	29	**18**	23	51	28	37	38	44	35	40	36	31	21	33	28	25	36	43	28	27	25	27	30	32	39	50	42	..
1911 ..	29	42	29	32	31	23	28	24	33	33	34	36	21	24	16	**24**	30	36	27	40	33	35	44	40	39	33	42	44	33	30	..
1912 ..	23	26	28	36	35	29	**21**	25	27	27	28	30	32	34	29	30	27	32	26	27	32	26	25	28	34	37	38	38	31	40	..
1913 ..	31	33	28	**18**	28	30	33	28	26	26	**18**	27	28	27	34	42	39	42	39	33	39	35	31	23	32	29	32	33	33	39	..
1914 ..	34	31	31	29	33	38	24	**16**	18	32	29	25	32	38	32	47	41	33	34	33	36	39	33	38	35	42	38	35	41	38	..
1915 ..	30	35	31	37	30	39	36	35	38	**26**	30	34	33	40	44	43	39	37	39	35	36	46	40	36	39	45	37	45	51	43	..
1916 ..	19	23	24	23	23	30	22	**17**	26	46	37	41	32	27	36	35	35	34	39	37	24	36	40	33	39	34	28	34	33	30	..
1917 ..	**17**	22	30	**17**	32	34	30	19	33	39	35	30	40	37	36	28	34	31	33	28	31	34	36	44	30	32	26	24	25	20	..
Avr. ..	27	26	28	28	29	29	32	30	30	32	32	31	31	30	32	32	31	32	33	33	33	34	35	36	34	35	35	36	36	34	..

NOTE—Extremes are printed in bold faced type.

TABLE VII—DAILY MAXIMUM TEMPERATURES FOR JUNE

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887 ..	88	82	68	74	88	92	79	72	78	87	89	92	89	90	90	88	90	91	94	82	83	83	87	90	**96**	93	93	79	73	80	..
1888 ..	67	74	81	78	73	78	88	73	76	79	88	..	..	..	..	..	..	..	79	69	71	74	75	75	85	83	89	**97**	94	89	..
1889 ..	62	68	65	68	85	82	70	49	54	61	74	82	86	74	68	77	81	82	82	64	73	80	83	84	86	81	86	**90**	85	**90**	..
1890 ..	85	84	74	65	71	63	67	75	77	81	82	86	73	72	85	78	85	88	86	89	85	88	**92**	**92**	**92**	86	84	82	84	85	..
1891 ..	65	71	65	58	62	72	83	84	81	68	78	78	80	77	71	59	73	78	77	79	72	**87**	79	74	76	78	77	77	71	80	..
1892 ..	71	82	77	50	65	74	81	85	84	81	78	69	68	81	77	67	74	82	83	**86**	81	77	77	69	83	78	**86**	85	78	76	..
1893 ..	71	74	64	55	60	73	93	87	77	91	**95**	93	89	80	82	85	91	94	94	92	87	91	91	80	88	85	88	92	74	84	..
1894 ..	71	75	76	85	59	75	76	65	70	84	87	87	85	78	74	72	86	89	83	79	81	82	81	77	80	86	72	83	89	**91**	..
1895 ..	66	55	55	66	77	80	80	71	60	66	77	79	81	85	86	81	67	68	73	78	77	86	**89**	85	67	77	64	61	76	76	..
1896 ..	64	79	87	71	71	69	76	84	88	90	77	84	89	**91**	90	90	84	85	89	82	80	80	78	79	62	81	85	76	83	85	..
1897 ..	..	..	..	63	61	66	68	78	74	74	73	84	80	81	88	77	78	76	85	85	87	**90**	84	69	69	76	78	85	80	85	..
1898 ..	84	88	66	54	66	65	72	67	69	72	72	76	80	73	83	88	88	85	86	83	90	92	88	88	90	76	89	**97**	80	87	..
1899 ..	73	72	67	70	83	63	74	64	67	82	89	72	69	69	78	84	90	**96**	89	85	83	74	85	77	88	82	88	92	95	95	..
1900 ..	66	77	78	72	79	86	90	85	84	61	76	81	74	77	82	88	80	84	85	91	93	90	87	89	91	**94**	89	**94**	88	93	..
1901 ..	70	72	71	73	70	73	86	85	73	67	71	77	82	61	62	74	78	69	74	84	80	84	90	92	**94**	85	84	90	89	89	..
1902 ..	83	74	79	85	84	86	55	80	94	94	77	79	85	88	62	80	77	74	77	54	77	87	90	**96**	83	92	72	61	68	75	..
1903 ..	61	62	61	62	60	70	70	70	49	53	67	70	74	64	70	71	85	84	83	69	71	67	81	64	76	82	87	**92**	86	86	..
1904 ..	67	69	54	59	65	77	83	65	64	78	74	73	66	76	74	76	82	79	79	73	69	76	80	73	64	74	81	**87**	83	85	..
1905 ..	79	79	85	85	78	74	78	82	76	75	77	84	85	83	83	66	77	74	69	80	67	87	81	80	73	86	**92**	89	78	83	..
1906 ..	66	70	66	76	80	64	62	76	82	83	80	80	82	80	85	**90**	69	75	76	70	85	82	53	64	76	82	83	84	83	87	..
1907 ..	72	70	74	70	76	72	76	70	69	75	82	86	80	84	86	72	78	75	76	75	77	82	74	77	68	67	81	86	**88**	84	..
1908 ..	68	68	82	71	74	73	70	75	77	78	86	76	65	74	57	78	71	69	81	87	**92**	82	74	83	80	88	83	71	79	80	..
1909 ..	63	72	80	88	90	70	69	76	69	68	73	72	74	61	72	83	82	85	84	81	79	83	88	89	81	88	**94**	**94**	86	83	..
1910 ..	79	85	54	71	75	73	85	83	76	74	77	71	78	85	86	77	85	86	**90**	**90**	89	87	**90**	68	78	82	84	85	82	78	..
1911 ..	83	81	80	83	82	81	86	82	82	78	81	84	85	84	72	62	72	76	84	87	81	78	86	85	79	74	86	**92**	89	83	..
1912 ..	74	74	73	78	82	54	64	71	70	76	66	72	76	69	59	58	50	64	70	75	78	72	75	81	83	82	83	**86**	**86**	79	..
1913 ..	71	81	75	80	80	71	61	68	63	70	72	65	77	82	85	88	86	85	84	80	77	82	87	82	84	86	**90**	88	82	83	..
1914 ..	66	75	77	75	75	77	73	70	76	84	78	79	89	76	64	70	77	85	**90**	86	87	80	89	85	83	80	80	82	86	68	..
1915 ..	71	69	54	66	63	50	69	67	80	74	**83**	68	56	70	80	78	77	79	74	76	77	70	73	74	81	81	80	69	76	78	..
1916 ..	68	69	72	73	74	57	66	73	77	71	71	75	72	77	75	79	81	78	77	80	84	79	77	85	87	80	91	**93**	**93**	88	..
1917 ..	57	69	77	69	64	68	75	73	85	86	79	73	67	77	82	82	88	74	82	80	76	89	85	92	83	85	84	90	**94**	**94**	..
Avr. ..	71	74	71	71	73	72	75	74	74	76	78	78	78	77	77	77	79	80	82	80	80	83	82	81	81	82	84	85	83	84	..

NOTE—Extremes are printed in bold faced type.

TABLE VIII—DAILY MAXIMUM TEMPERATURES FOR JULY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887 ..	80	79	79	88	94	**97**	91	82	88	90	79	94	94	92	78	64	72	85	89	76	83	82	85	88	86	84	79	92	78	77	84
1888 ..	84	87	89	94	90	97	83	79	87	95	**99**	95	90	89	89	87	69	80	89	87	89	83	79	78	86	..	87	92	90	92	81
1889 ..	92	70	78	91	95	95	84	75	66	78	88	89	81	81	86	89	90	84	84	91	92	80	79	80	83	94	95	84	72	87	**97**
1890 ..	85	86	80	86	88	92	90	90	89	85	86	90	**93**	78	89	91	86	85	89	**93**	86	80	87	84	89	90	92	93	85	77	86
1891 ..	88	78	87	81	83	74	68	78	88	81	88	85	75	79	82	81	83	86	84	**89**	89	82	83	86	82	87	86	81	80	66	80
1892 ..	87	76	74	84	90	91	71	69	79	89	85	85	86	**93**	75	85	84	90	92	91	90	89	86	87	89	87	64	64	77	87	90
1893 ..	91	83	94	93	93	93	85	84	91	89	**95**	91	91	87	84	90	88	86	90	89	89	90	90	90	76	80	88	85	87	85	81
1894 ..	83	90	79	71	73	73	80	89	91	**94**	**94**	82	74	80	86	90	89	80	78	83	88	89	93	92	93	**94**	87	85	88	90	89
1895 ..	78	78	86	91	79	87	79	65	69	56	55	69	71	86	89	87	81	82	81	74	70	69	74	84	92	**93**	92	**93**	87	76	84
1896 ..	91	89	79	83	89	92	81	85	89	91	93	93	**96**	90	89	74	81	84	86	85	82	75	80	75	81	82	76	81	88	83	85
1897 ..	89	86	73	76	90	91	**95**	89	67	74	82	84	93	77	84	82	85	75	62	77	85	84	83	76	87	87	89	94	91	85	89
1898 ..	71	69	76	85	86	88	90	85	85	84	87	79	83	85	84	84	92	91	88	84	91	93	91	81	89	**97**	**97**	93	78	86	67
1899 ..	72	81	70	83	89	78	78	87	87	87	91	81	78	76	75	71	76	74	81	86	90	91	82	90	**94**	80	82	79	64	82	87
1900 ..	80	87	85	74	84	91	82	83	92	91	92	**93**	90	**93**	74	73	90	82	60	79	88	88	78	74	78	80	90	76	86	89	**93**
1901 ..	72	86	92	91	86	91	94	95	89	89	92	93	92	**97**	93	93	84	89	95	96	93	92	90	90	82	84	87	91	85	94	94
1902 ..	76	86	79	72	71	78	82	79	63	76	86	88	85	94	**98**	89	69	69	74	79	85	86	87	92	81	75	89	94	94	88	95
1903 ..	91	82	55	72	86	92	86	85	90	86	82	86	83	92	88	86	75	76	86	90	90	90	85	86	**95**	92	91	88	85	78	80
1904 ..	79	73	73	77	71	56	70	80	86	84	86	86	82	85	**91**	88	90	82	84	81	79	78	84	74	81	81	80	84	88	82	80
1905 ..	80	70	78	87	78	80	79	69	74	83	89	87	84	89	87	89	**91**	78	85	79	82	83	76	81	81	80	74	74	75	74	74
1906 ..	81	62	70	76	79	75	69	66	74	76	75	80	76	74	66	78	85	80	85	**93**	85	81	78	86	87	91	84	80	83	83	88
1907 ..	85	89	**94**	**94**	88	85	81	87	79	80	81	84	85	75	84	74	88	90	84	90	87	88	93	87	80	63	73	75	79	81	77
1908 ..	64	73	83	**93**	78	66	81	89	92	92	85	76	82	78	81	87	81	77	76	85	83	80	80	87	89	91	88	92	89	77	76
1909 ..	88	93	88	83	89	85	88	87	85	84	89	83	80	74	81	87	92	**94**	93	88	81	75	76	85	86	84	86	88	81	90	93
1910 ..	83	80	86	89	78	83	91	88	61	79	74	80	82	93	92	92	92	93	92	88	85	92	96	94	96	**100**	94	82	82	80	85
1911 ..	78	69	78	86	76	73	83	83	78	85	87	**88**	76	83	79	76	77	78	68	82	84	84	77	68	77	81	87	83	86	87	80
1912 ..	78	80	76	70	73	82	82	**89**	74	82	85	74	82	82	72	83	61	60	82	85	85	86	81	82	76	86	76	80	83	77	75
1913 ..	80	**94**	87	86	88	90	**94**	86	84	88	81	83	93	82	83	83	82	74	77	72	82	70	61	72	78	79	67	79	85	87	78
1914 ..	74	79	82	75	79	83	84	88	85	86	81	**89**	85	83	84	74	78	77	75	87	78	68	84	85	86	87	88	**89**	88	85	82
1915 ..	79	61	61	67	77	81	76	80	85	77	**91**	85	82	88	81	83	89	75	56	67	77	82	86	73	77	75	70	77	80	78	74
1916 ..	88	**91**	89	84	**91**	90	90	89	88	69	72	78	82	91	88	84	88	86	78	86	85	87	84	87	87	86	**91**	86	85	65	74
1917 ..	75	84	82	89	86	88	84	87	84	91	80	87	90	75	80	83	88	88	86	88	88	88	87	91	91	86	**92**	90	86	83	85
Avr. ..	81	80	80	83	84	84	83	83	82	84	85	85	84	85	84	83	83	82	82	85	85	83	83	83	85	82	85	85	83	82	83

NOTE—Extremes are printed in bold faced type.

TABLE IX—DAILY MAXIMUM TEMPERATURES FOR AUGUST

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1887 ..	90	92	95	89	75	82	**97**	84	86	87	83	83	87	84	86	86	90	87	85	80	85	88	59	59	73	77	83	85	73	85	77
1888 ..	85	83	84	**88**	86	85	77	73	85	82	78	83	**88**	84	72	68	72	83	80	81	77	80	85	86	**88**	83	81	78	82	85	83
1889 ..	78	86	84	88	94	**97**	90	89	70	79	84	89	81	84	88	82	90	89	90	78	82	84	89	93	84	90	92	90	85	83	90
1890 ..	90	89	87	79	89	**95**	92	78	86	84	84	82	77	76	86	67	80	68	56	79	81	80	84	74	76	76	82	82	85	88	78
1891 ..	81	78	87	90	88	90	89	88	84	90	83	92	**93**	83	83	86	84	84	84	83	66	74	80	88	83	63	65	80	82	83	88
1892 ..	96	98	**99**	97	87	90	90	84	81	86	92	92	94	96	96	97	88	76	82	77	80	71	78	83	86	86	85	58	73	84	87
1893 ..	79	79	87	85	87	88	87	77	82	79	88	88	**92**	86	82	83	87	89	90	76	86	84	80	80	88	81	72	77	84	82	70
1894 ..	82	72	76	85	84	82	87	84	87	86	84	92	89	83	89	88	**91**	87	85	84	85	80	89	83	83	82	84	89	87	88	88
1895 ..	83	81	82	87	84	82	87	89	76	83	90	93	86	73	90	93	**94**	74	78	88	93	87	83	85	90	91	67	67	81	86	76
1896 ..	88	92	92	90	85	88	93	89	91	93	78	90	92	**94**	92	84	85	80	84	90	74	60	74	83	79	79	86	86	85	79	83
1897 ..	86	82	74	69	82	87	86	80	81	77	86	89	87	79	76	85	81	77	79	83	77	83	81	91	**94**	77	83	84	79	88	91
1898 ..	79	76	90	95	80	76	79	83	86	79	89	91	91	90	95	82	86	92	92	93	**96**	91	77	89	93	91	93	83	96	94	90
1899 ..	79	88	74	70	81	83	86	86	88	88	85	85	79	87	91	80	82	84	82	86	91	85	78	84	91	92	89	**95**	87	71	85
1900 ..	**94**	93	90	87	87	83	92	89	90	87	88	89	85	85	84	88	87	87	87	86	84	82	78	71	81	86	84	89	91	91	86
1901 ..	**97**	81	77	76	85	83	80	87	88	90	78	89	88	89	88	82	89	86	86	80	84	87	86	88	89	89	87	84	85	75	84
1902 ..	**100**	92	92	95	64	84	84	87	93	72	76	89	87	88	92	92	93	88	91	88	85	86	70	84	84	77	81	80	82	80	82
1903 ..	82	88	94	**95**	82	81	91	90	76	78	76	78	86	87	82	87	88	85	88	91	92	85	87	82	78	85	79	79	82	88	94
1904 ..	85	86	86	76	88	87	71	90	81	**91**	85	90	87	85	87	83	79	80	87	85	62	79	87	87	72	86	86	80	79	80	83
1905 ..	80	83	84	88	78	80	85	86	87	87	74	75	85	83	87	79	**93**	83	84	91	90	91	88	84	87	90	90	91	90	84	89
1906 ..	75	86	81	78	79	78	81	85	89	87	85	85	87	86	89	**92**	90	91	91	85	86	87	74	81	75	70	82	86	85	77	78
1907 ..	78	78	80	84	88	91	90	91	**92**	90	80	87	87	88	87	87	90	82	64	69	74	86	86	87	84	83	76	82	75	77	75
1908 ..	86	85	**93**	88	88	79	72	87	82	72	64	78	73	80	78	79	76	79	65	71	75	61	76	83	86	77	80	87	87	87	72
1909 ..	89	84	85	89	**93**	88	87	83	88	88	86	89	88	88	**93**	92	77	78	83	82	90	89	92	78	92	89	86	67	78	82	85
1910 ..	84	89	87	80	76	84	80	78	77	85	89	81	74	79	85	75	61	81	**93**	90	92	92	87	84	64	85	89	88	92	69	83
1911 ..	80	80	78	78	82	83	87	**95**	85	77	76	82	88	89	93	85	82	88	84	87	74	65	72	64	78	86	68	81	86	89	91
1912 ..	74	80	79	82	80	82	71	71	75	87	87	86	85	76	77	83	78	82	80	74	82	81	89	88	81	**90**	85	84	86	74	76
1913 ..	88	**92**	**92**	90	87	80	87	91	77	87	78	87	85	88	83	88	86	86	86	87	87	82	84	84	88	90	90	74	85	84	82
1914 ..	89	83	83	89	88	89	86	88	79	82	76	89	83	86	89	**95**	88	83	78	84	84	80	76	83	69	72	76	77	78	80	79
1915 ..	72	73	81	84	88	77	71	67	79	82	78	82	79	77	78	78	79	76	79	77	73	76	68	63	60	66	78	77	72	77	**92**
1916 ..	83	86	89	85	87	75	82	86	79	77	81	**90**	67	81	84	84	82	84	78	74	71	73	80	81	78	66	72	83	78	70	79
1917 ..	86	87	**92**	88	77	82	87	80	73	88	73	71	79	79	82	78	80	82	78	80	84	84	75	80	87	88	60	70	76	84	81
Avr. ..	84	85	86	85	84	84	85	84	83	84	82	86	85	84	86	84	84	83	82	83	82	81	80	82	82	82	81	81	83	82	83

NOTE—Extremes are printed in bold faced type.

TABLE X—MONTHLY MEAN DRY BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December		Year	
	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm
1888........	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	51.2	....	40.0	....	23.6	....	20.4	....	....	....
1889........	11.7	....	15.2	....	30.9	....	44.5	....	48.5	....	58.9	....	63.4	72.9	61.1	72.1	47.9	60.0	38.7	49.5	23.8	30.2	29.4	34.7	39.5	....
1890........	15.8	25.7	18.8	31.0	30.4	41.6	40.8	49.8	51.1	59.7	60.0	67.0	66.8	73.0	60.6	66.6	51.8	60.3	36.2	47.4	25.8	35.8	23.2	31.2	40.1	49.1
1891........	13.6	21.6	14.8	19.5	23.4	29.6	40.5	49.6	52.5	55.3	59.0	63.4	63.7	68.2	62.2	66.7	52.6	60.3	37.5	48.1	27.6	34.2	21.1	26.5	39.0	45.3
1892........	13.3	20.2	21.2	27.2	27.0	34.8	39.7	44.6	47.1	51.4	59.6	64.4	65.5	68.9	62.7	67.4	54.5	62.5	37.8	45.6	28.2	36.8	16.0	22.3	39.4	45.5
1893........	22.4	30.9	17.4	27.4	26.3	37.3	38.4	44.9	49.2	54.7	62.4	69.1	66.3	73.0	60.7	67.7	53.0	60.5	37.9	47.1	24.2	32.4	24.8	31.4	40.2	48.0
1894........	14.3	24.6	9.0	18.8	28.2	37.8	42.7	51.4	53.3	57.0	60.3	66.2	65.5	70.3	62.5	67.8	50.7	58.3	41.9	49.5	28.5	38.9	16.1	22.4	39.4	46.9
1895........	16.2	22.9	11.8	21.8	25.8	34.6	44.2	51.4	50.8	56.4	57.5	60.8	61.7	65.4	61.6	66.4	52.2	60.0	37.1	45.3	23.2	32.4	18.0	27.3	38.3	45.4
1896........	20.4	29.1	23.2	32.6	27.2	34.6	41.4	49.1	54.0	58.9	62.3	67.3	66.7	70.1	63.6	68.6	52.3	56.5	38.3	46.0	19.9	30.0	21.0	32.3	40.9	47.9
1897........	12.0	22.4	16.9	28.1	25.3	32.6	41.9	46.8	56.2	59.5	60.4	63.9	62.9	66.9	60.9	65.3	56.1	61.8	38.5	45.4	26.2	33.4	17.5	23.7	39.6	45.8
1898........	13.8	23.4	21.8	32.0	24.5	32.8	43.3	50.6	48.8	53.0	60.4	66.7	64.2	71.8	62.5	71.2	47.5	57.1	37.7	44.5	23.6	27.8	13.2	19.6	38.4	45.9
1899........	16.6	24.3	1.6	10.6	24.2	29.9	40.3	47.8	49.7	56.8	60.0	66.8	63.0	67.2	62.3	67.0	52.8	59.3	37.3	43.4	29.1	37.4	19.8	24.3	38.1	44.6
1900........	19.7	28.7	15.2	23.6	29.0	39.6	39.5	44.2	54.5	60.0	63.4	69.1	62.6	69.7	61.6	68.6	51.0	58.2	39.5	48.6	26.7	35.9	20.2	28.9	40.2	47.9
1901........	16.9	27.6	13.9	24.2	28.9	35.8	39.5	45.9	54.0	59.3	60.1	66.5	68.3	74.0	64.2	68.3	50.6	58.3	39.0	46.8	27.7	36.5	20.2	28.0	40.3	47.6
1902........	12.2	20.6	22.4	31.2	28.6	35.6	40.8	48.2	52.9	59.2	59.5	67.1	62.4	68.2	63.7	68.3	47.8	56.9	38.1	47.3	25.1	34.8	18.8	24.3	39.4	46.8
1903........	20.8	28.8	5.7	11.0	23.2	31.7	41.1	46.9	49.1	56.2	57.8	62.4	64.2	69.8	61.8	68.9	47.0	55.8	37.4	49.1	24.4	33.4	23.0	29.9	38.0	45.3
1904........	15.5	29.4	24.5	37.4	30.5	42.0	40.4	49.8	51.2	56.4	58.2	62.8	63.6	67.2	61.1	67.5	50.5	58.0	35.3	45.4	24.0	33.2	23.3	30.0	39.8	48.3
1905........	19.5	24.6	10.6	22.2	33.6	42.4	37.5	44.8	48.1	53.7	60.2	66.7	63.1	66.8	61.9	67.8	49.1	58.3	30.7	40.6	25.8	37.3	13.3	23.6	37.8	45.7
1906........	18.8	29.2	16.5	29.6	18.9	25.8	42.4	49.5	51.1	57.4	58.1	64.0	62.4	66.5	61.3	65.3	51.5	57.7	37.0	44.2	25.5	33.0	25.3	32.1	39.1	46.2
1907........	18.2	25.1	24.9	35.6	33.8	46.4	37.1	44.4	46.6	50.6	58.5	63.8	64.0	68.4	61.8	67.0	51.3	58.0	37.2	47.8	20.4	30.3	22.8	27.5	39.7	47.1
1908........	18.8	26.5	19.3	31.0	33.3	41.8	44.4	53.1	48.8	55.2	57.8	64.6	63.4	67.5	61.1	64.1	52.6	59.7	37.5	45.7	22.6	27.6	18.2	22.8	39.8	46.6
1909........	22.1	28.0	19.5	26.5	29.0	35.2	37.7	43.8	49.2	54.5	60.2	65.3	64.3	71.0	64.2	69.2	51.3	56.7	40.4	47.8	30.4	35.3	12.6	17.6	40.1	45.9
1910........	16.6	23.3	15.0	27.7	35.4	50.0	46.1	55.5	50.8	56.2	61.8	68.1	68.3	72.3	61.8	67.5	53.2	60.6	40.2	48.1	30.7	38.7	22.2	31.2	41.8	49.9
1911........	21.9	32.5	17.4	25.8	33.0	44.6	41.1	48.9	51.9	60.3	64.3	69.4	62.9	69.2	60.4	68.8	54.6	62.2	38.3	45.4	24.6	30.7	13.1	21.7	40.3	48.3
1912........	17.4	25.3	20.0	26.5	18.6	23.8	41.1	46.6	50.8	57.7	59.6	62.8	62.8	67.4	61.9	68.2	44.8	51.2	36.4	46.3	27.2	35.9	17.6	27.0	38.2	44.9
1913........	15.8	24.4	11.3	20.7	26.9	35.2	40.3	49.6	52.8	59.3	60.2	67.6	64.3	68.4	66.1	70.2	50.3	56.3	38.6	46.4	28.7	38.4	8.2	14.9	38.6	45.9
1914........	24.4	28.3	17.8	24.6	29.6	38.8	41.5	46.4	51.8	57.6	62.9	69.6	67.2	71.5	62.1	68.4	52.6	61.2	41.6	49.7	25.7	38.7	12.4	21.3	40.8	48.0
1915........	16.1	24.2	22.9	32.8	26.7	33.0	45.3	51.6	47.8	53.0	56.5	62.2	61.8	66.8	60.1	62.8	50.6	57.5	38.9	48.7	32.2	37.6	22.2	27.9	40.1	46.5
1916........	13.7	18.1	20.6	33.6	34.5	45.9	40.0	47.5	50.6	56.3	59.6	67.2	68.0	72.5	61.4	66.6	51.3	57.3	38.5	45.3	22.1	29.3	14.0	20.5	39.5	46.7
1917........	15.3	23.3	22.2	31.4	24.4	30.9	37.2	44.6	44.9	49.5	59.6	66.2	66.6	71.4	59.9	64.3	52.4	58.4	36.4	45.3	29.8	38.2	23.5	29.6	39.4	46.1
Average....	17.4	25.5	16.9	26.6	28.0	36.6	41.1	48.1	50.3	56.3	60.0	65.8	64.5	69.5	62.0	67.5	51.2	58.6	38.0	46.6	25.9	34.3	19.1	26.0	39.5	46.8
Maximum ..	24.4	32.5	24.9	37.4	35.4	50.0	46.1	55.5	56.2	60.3	64.3	69.6	68.3	74.0	64.2	72.1	56.1	62.5	41.9	49.7	32.2	38.9	29.4	34.7	41.8	49.9
Minimum...	11.7	18.1	1.6	10.6	18.6	23.8	37.1	44.2	44.9	49.5	56.5	60.8	61.7	65.4	59.9	62.8	44.8	51.2	30.7	40.6	19.9	27.6	8.2	14.9	37.8	44.6

TABLE XI—MONTHLY MEAN WET BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December		Year	
	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm	7 am	7 pm
1888	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	46.6	....	35.7	....	22.6	....	18.6	....	....	....
1889	9.9	....	13.4	....	28.7	....	39.1	....	43.3	....	53.0	....	57.7	61.3	55.4	58.5	41.6	46.8	34.9	41.2	21.3	27.2	25.9	29.3	35.4	....
1890	13.9	21.5	16.8	25.0	26.2	32.4	36.4	40.8	45.5	48.0	51.8	53.3	59.5	61.6	55.5	57.7	44.4	48.3	32.5	38.8	23.4	30.1	20.6	26.7	35.5	40.3
1891	12.4	19.3	12.9	17.8	21.9	26.6	35.7	40.4	47.6	48.0	53.8	55.9	57.9	60.3	56.8	57.9	48.0	51.0	32.6	38.0	23.8	28.5	18.6	22.6	35.2	38.9
1892	11.5	17.6	19.8	24.9	24.4	29.9	34.7	36.5	42.4	44.4	53.3	56.3	59.1	60.1	55.1	56.0	47.0	49.1	34.1	38.6	24.6	30.1	14.0	19.6	35.0	38.6
1893	18.1	24.8	14.7	22.3	22.7	30.2	32.3	34.7	42.2	44.8	52.6	55.1	59.0	58.4	54.6	56.5	45.3	47.6	32.4	37.2	20.7	26.4	21.2	26.9	34.6	38.7
1894	12.0	19.7	7.0	15.5	24.4	29.8	36.2	39.9	45.6	48.0	52.6	53.2	57.6	59.2	56.2	57.5	45.0	48.2	35.5	39.2	24.8	31.4	14.3	19.5	34.3	38.4
1895	14.6	19.6	10.0	18.2	22.8	27.9	37.3	39.8	44.4	45.9	52.1	52.8	56.2	57.6	56.0	57.9	46.1	48.4	33.6	37.8	20.6	26.3	15.4	22.5	34.1	37.9
1896	17.5	23.1	20.0	25.7	24.0	28.9	35.3	38.8	44.7	45.5	55.4	56.9	60.7	60.8	56.8	57.8	48.7	50.8	34.8	38.8	17.4	24.0	19.0	26.8	36.2	39.8
1897	10.5	17.7	15.6	24.0	23.6	27.8	37.1	38.3	49.9	51.0	54.9	55.4	57.0	58.3	56.6	57.8	51.5	53.5	35.4	39.3	23.8	28.9	15.4	20.0	35.9	39.3
1898	12.4	20.2	19.6	26.7	21.9	26.4	36.8	39.7	44.7	45.9	53.9	55.9	57.2	59.7	56.0	57.9	42.2	46.8	31.9	36.1	20.5	24.2	11.4	16.6	34.1	38.0
1899	14.1	20.8	0.8	9.1	21.9	26.4	34.2	37.4	43.4	45.1	51.8	53.7	57.5	59.6	55.4	57.0	46.5	49.8	34.2	38.0	26.5	31.9	17.3	20.9	33.6	36.8
1900	17.8	24.6	13.4	20.5	27.1	33.4	37.0	39.9	48.4	50.6	56.2	57.8	56.4	59.4	54.3	56.6	46.4	49.8	35.0	40.4	23.2	29.1	17.2	23.1	36.0	40.4
1901	14.4	22.6	12.6	20.6	25.0	29.6	35.7	37.9	48.0	50.3	53.9	56.6	61.6	62.0	58.1	59.6	46.3	48.5	35.5	39.9	24.6	30.4	17.9	24.5	36.1	40.2
1902	11.0	17.7	20.2	26.4	25.5	29.4	36.0	39.1	47.0	49.1	53.8	55.0	56.1	58.7	56.3	57.2	42.9	47.8	35.4	41.6	23.4	29.6	16.9	21.9	35.4	39.5
1903	18.0	24.9	4.9	9.7	22.0	29.0	35.9	38.6	44.2	46.2	53.5	55.8	58.1	60.2	57.3	59.5	43.4	48.4	34.4	40.6	22.7	30.0	19.5	24.9	34.5	39.0
1904	13.5	24.0	20.7	30.0	26.8	34.4	34.9	39.6	45.5	48.7	53.6	55.1	57.8	59.4	55.8	59.2	46.3	51.7	32.7	40.0	20.5	27.4	20.7	26.1	35.7	41.3
1905	18.3	22.4	9.9	19.4	31.0	36.6	34.8	39.2	43.9	47.0	54.8	58.6	57.4	58.4	56.7	59.5	44.7	50.4	28.2	35.3	23.9	31.8	11.8	19.2	34.6	39.8
1906	16.2	23.3	14.2	23.7	17.6	22.8	37.8	40.9	45.0	47.9	51.6	55.1	56.7	58.9	55.6	58.1	48.6	52.6	33.5	38.7	23.5	29.4	23.2	28.1	35.3	40.0
1907	16.6	22.2	22.3	29.0	29.4	35.6	32.4	36.5	42.0	43.7	51.0	53.3	58.4	60.6	56.2	57.9	46.7	49.8	34.8	42.2	19.0	26.1	19.8	23.3	35.7	40.0
1908	15.8	21.6	16.2	25.1	27.4	32.2	35.9	39.8	42.8	45.0	51.2	53.8	57.6	59.6	56.5	59.2	47.4	51.6	33.7	38.8	20.8	24.6	16.5	20.7	35.2	39.3
1909	19.9	24.6	17.1	22.9	26.7	32.0	32.8	36.0	42.1	43.6	54.4	56.9	59.3	62.9	59.2	61.1	46.8	51.7	35.1	39.4	27.5	31.0	11.1	15.3	36.0	39.8
1910	14.1	19.3	12.8	21.9	29.2	37.0	37.0	41.0	44.8	47.4	54.2	55.4	58.9	60.0	55.5	57.6	49.2	51.8	35.3	41.2	28.1	33.5	20.0	26.6	36.6	41.1
1911	19.0	26.5	15.6	21.2	28.6	35.2	35.2	38.4	44.2	47.5	55.2	57.5	56.5	58.8	54.0	57.0	48.2	51.2	34.2	38.4	21.2	25.9	12.0	18.4	35.3	39.7
1912	15.2	21.4	17.8	24.0	17.8	22.3	36.5	38.8	43.8	46.6	53.4	54.4	58.6	60.8	57.3	59.9	42.3	47.2	34.8	41.4	25.5	32.1	16.1	23.0	34.9	39.3
1913	13.7	20.4	10.0	18.1	24.4	30.0	37.0	40.6	47.3	51.1	54.4	56.5	58.4	59.5	59.6	61.2	47.6	51.7	35.3	39.4	26.4	33.9	7.7	14.2	35.1	39.7
1914	21.4	24.3	16.8	22.4	26.8	32.3	37.2	39.7	47.6	50.5	57.2	60.0	61.7	64.0	57.7	60.3	49.1	53.0	39.6	44.2	23.2	32.1	11.5	18.9	37.5	41.8
1915	13.6	19.8	20.5	27.5	24.8	29.7	41.8	45.0	43.3	46.1	51.3	54.0	57.6	59.6	56.9	58.0	48.1	51.9	36.6	42.6	28.2	31.4	19.4	23.6	36.8	39.6
1916	11.8	15.8	18.8	29.0	29.9	37.7	37.0	42.2	47.6	52.6	55.7	59.9	59.9	61.4	57.1	58.8	47.2	51.3	36.1	41.0	19.8	25.3	12.1	17.9	36.1	41.1
1917	12.6	19.8	20.0	27.9	22.4	27.1	35.4	39.4	43.7	46.8	55.4	59.2	60.9	62.0	54.6	56.9	49.2	52.2	32.7	37.0	27.2	33.3	20.6	25.2	36.2	40.6
Average	14.8	21.4	15.0	22.4	25.0	30.4	36.0	39.2	45.0	47.4	53.7	55.8	58.3	60.1	56.3	58.3	46.4	50.1	34.3	39.5	23.3	29.9	16.9	22.3	35.4	39.7
Maximum	21.4	24.9	22.3	30.0	31.0	37.0	41.8	45.0	49.9	52.6	57.2	60.0	61.7	62.9	59.6	61.2	51.5	53.5	39.6	44.2	28.2	33.9	25.9	29.3	37.5	41.8
Minimum	9.9	15.8	0.8	9.1	17.6	22.3	32.3	34.7	42.0	43.6	51.0	52.8	56.1	57.6	54.0	56.0	41.6	46.8	28.2	35.3	17.4	24.0	7.7	14.2	33.6	36.8

TABLE XII——MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December		Year	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1887........	34.0	10.8	41.8	10.3	60.4	25.1	60.7	32.1	75.3	42.6	85.3	52.3	84.2	54.4	83.0	51.3	79.6	46.7	64.9	31.4	54.0	23.2	43.4	15.7	64.3	33.0
1888........	42.7	10.0	52.6	25.2	52.0	20.7	73.3	40.6	66.2	41.6	79.4	51.3	87.4	58.2	81.4	51.7	78.9	43.0	64.4	36.4	48.6	24.7	48.8	17.8	64.6	35.1
1889........	38.7	10.5	40.2	13.0	56.6	27.7	63.5	36.0	65.7	40.5	75.6	46.1	84.8	51.7	86.4	52.2	74.7	39.8	64.8	36.1	44.8	19.4	51.4	22.8	62.3	33.0
1890........	39.8	9.6	45.0	15.0	52.9	23.2	60.0	33.1	71.2	41.0	81.2	46.8	87.1	55.2	80.9	51.2	77.0	39.6	63.8	31.0	54.9	21.3	49.6	18.3	63.6	32.1
1891........	35.4	8.9	31.8	7.7	41.2	19.7	61.4	31.9	68.6	41.1	74.4	47.5	82.0	51.9	83.0	49.6	78.0	44.2	67.1	30.3	48.5	21.7	41.3	16.0	59.4	30.9
1892........	35.1	7.1	39.2	16.4	45.5	21.9	58.6	29.4	61.1	38.9	76.4	46.5	83.4	53.0	86.2	48.4	82.7	42.1	63.9	31.5	52.0	22.9	36.8	9.3	60.1	30.6
1893........	49.4	15.8	41.5	12.3	50.2	20.1	57.0	28.3	66.8	37.8	83.3	47.2	88.0	53.4	83.0	50.5	78.7	41.3	65.7	31.7	49.7	17.4	47.2	20.0	63.4	31.3
1894........	39.4	8.4	33.7	3.7	52.4	22.5	64.6	32.1	71.6	42.8	79.3	47.1	85.4	52.8	85.0	51.6	76.3	41.5	68.5	34.2	57.8	23.3	40.4	10.9	62.9	30.9
1895........	37.0	10.9	35.2	7.0	48.6	19.9	66.2	32.1	68.3	38.9	73.6	44.9	79.2	51.4	83.8	51.3	80.1	41.9	63.9	29.8	48.4	19.0	43.2	14.0	60.6	29.3
1896........	49.0	16.1	49.2	17.7	46.3	21.8	62.8	30.5	72.8	41.2	81.0	49.6	84.8	55.6	85.1	53.0	72.8	44.8	64.6	31.4	45.1	16.6	49.1	19.0	63.6	33.1
1897........	40.2	9.3	40.9	14.2	44.8	19.9	59.5	32.0	73.6	42.7	77.6	48.2	83.2	50.4	82.3	51.4	80.0	47.4	64.8	32.2	51.0	20.2	39.0	11.8	61.4	31.6
1898........	40.7	10.6	50.6	17.6	47.9	17.5	64.5	30.8	62.7	40.4	79.8	48.2	85.1	53.0	87.6	52.2	78.3	38.8	61.0	31.5	44.5	16.1	37.9	9.3	61.7	30.5
1899........	39.0	10.4	25.3	–5.4	41.6	17.9	60.5	28.9	69.5	38.0	79.8	47.4	81.3	52.6	84.2	51.9	80.3	42.4	60.2	31.9	56.6	24.9	42.6	12.7	60.1	29.5
1900........	46.7	15.2	37.8	10.7	53.9	24.3	54.5	31.3	72.4	43.2	83.4	50.7	83.7	52.1	86.4	49.5	73.9	43.2	67.6	32.8	53.1	21.6	47.3	16.0	63.4	32.6
1901........	43.8	12.6	38.4	9.4	48.1	21.2	56.9	31.1	71.1	42.8	78.3	48.3	90.1	54.9	85.0	52.9	75.4	42.7	66.6	32.9	56.8	23.1	40.4	15.1	62.6	32.2
1902........	39.2	9.1	45.5	18.5	48.0	22.5	61.0	30.4	70.5	41.7	79.0	48.2	82.5	49.5	85.1	52.3	74.1	39.5	64.5	33.2	49.6	22.6	39.8	14.3	61.6	31.8
1903........	44.2	16.4	28.2	–0.1	42.8	18.4	59.4	31.2	68.0	36.6	71.6	47.0	84.8	52.1	85.0	51.2	74.2	39.4	67.2	31.9	53.2	19.0	49.0	15.6	60.6	29.9
1904........	42.7	9.4	50.4	20.2	54.7	24.4	61.0	31.3	66.2	41.2	73.5	46.4	80.5	50.8	82.8	51.2	76.1	42.4	66.4	31.3	59.7	19.8	47.9	15.9	63.5	32.0
1905........	37.9	12.6	36.0	6.8	55.2	29.2	55.4	31.5	63.7	40.5	79.5	50.0	80.3	51.0	85.3	51.2	79.1	41.8	60.3	26.8	53.7	22.0	45.1	8.9	61.0	31.0
1906........	49.0	12.8	48.2	12.7	36.5	13.5	60.0	34.2	69.0	40.9	76.4	47.2	78.9	51.0	83.3	51.0	73.0	44.3	62.1	30.5	46.0	21.1	48.1	21.5	60.9	31.7
1907........	39.3	12.4	50.9	20.0	59.2	27.3	56.0	29.1	60.8	37.0	76.7	45.2	83.2	52.4	82.8	51.0	75.2	42.2	67.6	32.2	49.6	16.2	45.3	15.6	62.2	31.7
1908........	44.4	12.0	49.0	13.3	56.4	24.2	65.1	30.6	65.5	38.3	76.4	46.5	82.3	52.8	78.9	52.0	79.3	44.4	61.3	31.6	49.0	15.2	37.7	11.9	62.1	31.1
1909........	42.2	16.8	43.7	14.0	45.6	23.9	54.6	28.9	65.7	37.9	79.3	49.4	85.7	55.0	85.6	54.7	73.7	44.0	66.5	32.2	50.9	24.6	30.6	5.6	60.3	32.2
1910........	40.0	10.5	42.3	10.7	65.6	28.5	67.3	33.1	66.8	40.6	80.0	49.0	86.6	55.0	82.4	52.0	76.8	46.3	69.0	33.9	54.0	26.4	44.6	17.7	64.6	33.6
1911........	45.0	18.0	39.3	13.9	57.1	26.1	60.5	32.2	70.7	41.2	81.3	51.0	79.9	52.8	81.7	50.7	77.4	46.2	59.3	31.4	47.0	17.4	37.8	9.4	61.4	32.5
1912........	39.8	11.2	38.7	13.0	35.3	9.7	57.8	30.0	67.2	39.0	72.6	45.3	78.6	52.7	80.8	50.9	64.1	38.3	60.4	28.9	51.8	22.1	41.0	12.2	57.3	29.4
1913........	37.3	9.5	32.6	5.9	46.7	19.5	61.0	31.2	68.2	41.4	78.8	47.7	81.4	52.2	85.7	53.9	69.9	42.2	58.5	30.6	54.3	24.5	31.2	2.1	58.8	30.1
1914........	41.5	15.4	35.4	13.3	50.8	23.8	55.9	33.6	67.3	42.0	78.7	48.4	82.2	54.4	82.6	51.3	77.3	43.9	65.1	35.2	57.8	22.0	34.4	8.0	60.8	32.6
1915........	38.9	9.3	45.4	18.6	41.0	21.2	62.4	37.6	63.1	37.6	72.0	47.2	77.1	52.4	76.1	49.4	71.0	43.2	65.4	33.1	52.0	25.0	42.2	14.7	58.9	32.5
1916........	31.0	5.0	46.4	16.8	58.4	27.6	58.1	31.2	66.6	37.2	77.3	46.4	84.4	54.4	79.5	51.6	73.6	41.5	59.6	31.4	43.6	15.8	33.4	9.0	59.3	30.6
1917........	35.2	8.8	41.4	18.0	41.0	16.8	53.9	30.2	57.3	36.6	79.3	45.7	86.0	54.4	80.4	49.9	75.9	43.8	63.2	29.1	58.9	25.8	47.7	16.8	60.0	31.3
Average....	40.6	11.5	41.2	12.6	49.6	21.9	60.4	31.8	67.5	40.1	78.1	47.8	83.4	53.0	83.3	51.4	76.0	42.7	64.5	31.9	51.5	21.1	42.4	13.8	61.5	31.6
Maximum ..	49.4	18.0	52.6	25.2	65.6	29.2	73.3	40.6	75.3	43.2	85.3	52.3	90.1	58.2	87.6	54.7	82.7	47.4	69.0	36.4	59.7	26.4	51.4	22.8	64.6	35.1
Minimum...	31.0	5.0	25.3	–5.4	35.3	9.7	53.9	28.3	57.3	36.6	71.6	44.9	77.1	49.5	76.1	48.4	64.1	38.3	58.5	26.8	43.6	15.2	30.6	2.1	58.8	29.3

TABLE XIII—NORMAL DAILY TEMPERATURES FOR THIRTY-ONE YEARS, 1887-1917

At the Colorado Experiment Station, Fort Collins, Colorado.

Date	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	24.9	21.8	29.8	41.2	47.7	58.0	66.5	68.2	65.7	57.2	42.0	33.8
2	22.9	22.4	33.0	42.0	46.6	59.4	65.7	68.6	63.3	55.5	40.6	31.9
3	26.3	23.4	30.7	41.3	47.6	58.4	65.5	69.0	64.5	54.0	42.4	30.0
4	27.9	22.8	30.4	42.5	50.1	58.1	66.2	69.3	64.1	52.1	42.7	31.4
5	27.1	24.5	30.7	43.9	58.0	59.1	67.8	68.6	63.5	50.8	41.7	32.2
6	24.4	23.5	33.6	44.3	49.9	58.3	68.0	68.4	63.6	51.9	41.1	30.1
7	24.6	23.6	35.3	44.5	52.0	60.2	68.0	68.0	63.5	51.8	40.1	28.0
8	24.7	24.2	37.5	43.1	53.6	61.0	68.2	68.5	62.2	49.5	38.0	28.8
9	26.9	25.5	36.3	45.7	54.1	60.5	67.4	67.8	61.0	51.0	37.4	29.2
10	25.7	26.5	34.5	47.5	53.2	60.6	68.0	68.0	60.2	50.2	38.9	30.0
11	22.3	25.9	35.7	46.3	53.2	62.8	69.0	67.1	59.1	48.8	33.3	28.3
12	23.0	25.5	35.1	44.6	52.2	62.4	69.5	68.7	59.8	48.9	35.1	29.8
13	25.3	26.7	33.8	44.9	52.8	62.4	69.0	69.0	59.5	49.4	35.4	27.4
14	27.1	25.6	33.4	46.1	53.8	62.6	70.1	68.8	58.4	49.9	35.2	26.4
15	24.6	27.2	33.2	45.5	54.8	62.2	68.9	69.9	58.7	49.7	34.5	26.6
16	25.1	31.2	37.1	46.8	53.7	61.9	68.4	68.4	58.0	48.1	33.3	26.9
17	25.5	30.1	37.6	45.2	55.2	63.5	68.6	68.3	58.6	47.6	34.8	26.1
18	27.1	29.8	39.5	45.3	55.4	63.3	67.6	68.0	59.1	46.3	35.6	26.4
19	30.3	28.0	36.9	46.4	54.8	65.3	67.5	67.0	58.4	44.2	35.9	26.8
20	28.3	28.4	36.1	47.5	54.2	64.7	68.1	66.5	58.8	44.5	36.6	28.0
21	27.9	29.4	36.3	46.9	54.5	65.2	68.4	66.4	57.4	45.3	36.0	26.4
22	27.5	27.4	36.3	49.2	54.8	65.3	68.1	65.5	58.1	46.1	33.2	27.7
23	26.0	27.9	39.1	49.2	57.0	66.0	68.8	65.3	57.6	45.0	34.6	30.4
24	27.6	30.0	38.6	49.3	57.2	65.4	69.1	65.2	57.1	46.4	35.0	28.0
25	27.2	32.7	37.1	49.1	56.4	65.6	69.1	65.3	56.2	44.7	33.3	25.7
26	27.3	30.0	35.6	50.8	56.4	66.6	69.5	64.9	54.5	43.3	32.4	26.8
27	26.3	30.4	37.8	50.5	56.5	67.0	69.4	65.3	54.4	44.3	30.9	26.3
28	27.3	29.9	39.2	50.4	57.2	67.6	68.2	65.7	54.8	44.3	31.6	25.5
29	27.9	29.8	40.5	47.5	57.7	67.3	68.4	65.4	54.9	42.9	32.0	25.1
30	27.3	...	39.2	46.8	57.4	68.1	68.2	65.4	56.1	42.9	34.4	24.7
31	26.9	...	38.5	...	57.5	...	68.1	66.0	...	42.3	...	25.8
Averages	26.2	27.0	35.8	46.1	53.8	63.0	68.2	67.3	59.4	48.0	36.3	28.1

TABLE XIV—MONTHLY MEAN TEMPERATURE
At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	25.7	23.7	39.8	45.2	57.7	68.1	68.4	65.6	60.4	46.0	38.2	29.7	47.1
1888	22.2	37.1	37.4	55.3	54.4	68.1	72.8	66.6	61.4	49.2	33.0	31.3	49.0
1889	22.2	25.6	41.6	50.6	54.1	63.5	68.1	66.6	53.9	44.1	27.0	32.1	45.8
1890	24.7	40.0	38.0	46.5	58.0	64.0	71.1	66.1	58.3	47.4	38.1	37.8	49.1
1891	22.2	19.8	30.5	46.6	54.8	60.9	66.9	66.3	61.1	48.7	35.1	28.7	45.1
1892	21.1	27.8	33.7	44.0	50.0	61.7	68.2	67.3	62.4	47.7	37.4	23.0	45.4
1893	32.6	26.9	35.2	42.7	52.3	65.3	70.7	66.8	60.0	48.7	33.6	33.6	47.3
1894	23.9	18.7	37.4	48.3	57.2	63.2	69.1	68.3	48.9	51.3	40.5	25.6	46.9
1895	23.9	21.1	34.2	49.2	53.6	59.2	65.3	67.6	61.0	46.9	33.7	28.6	45.4
1896	32.6	33.4	34.0	46.6	57.0	65.3	70.2	69.0	58.8	48.0	30.8	34.0	48.3
1897	24.8	27.6	32.3	45.8	58.1	63.1	66.8	66.8	63.7	48.5	35.6	25.4	46.6
1898	25.6	34.1	32.7	47.7	51.6	64.0	69.0	69.9	58.6	46.3	30.3	23.6	46.1
1899	24.7	9.9	29.7	44.7	53.8	63.6	67.0	67.6	61.4	46.1	40.8	27.7	44.7
1900	30.9	24.2	39.1	42.9	57.8	67.1	67.9	68.0	58.6	50.2	37.4	31.6	48.0
1901	28.2	23.9	34.7	44.0	57.0	63.3	72.5	69.0	59.0	49.7	40.0	27.7	47.4
1902	24.2	32.0	35.3	45.7	56.1	63.6	66.0	68.7	56.8	48.8	36.1	27.1	46.7
1903	30.3	14.0	30.6	45.3	52.2	59.3	68.5	68.1	56.8	49.6	36.1	32.3	45.3
1904	26.1	35.3	39.6	46.2	53.7	59.9	65.6	67.0	59.2	48.9	39.7	31.9	47.8
1905	25.2	21.4	42.2	43.4	52.1	64.8	65.7	68.2	60.5	43.6	37.8	27.0	46.0
1906	30.9	30.5	25.0	47.1	55.0	61.8	64.9	67.2	58.7	46.3	33.6	34.8	46.3
1907	25.9	35.4	43.3	42.5	48.9	60.9	67.8	66.9	58.7	49.9	32.9	30.5	47.0
1908	28.2	31.1	40.3	47.8	51.9	61.4	67.6	65.5	61.8	46.4	32.1	24.8	46.6
1909	29.5	28.8	34.8	41.8	51.8	64.3	70.4	70.2	58.9	49.4	37.8	18.1	46.3
1910	25.3	26.5	47.1	50.2	53.7	64.6	70.8	67.2	61.5	51.5	40.2	31.2	49.1
1911	31.5	26.6	41.6	46.3	55.6	66.2	66.3	66.2	61.8	45.3	32.2	23.6	47.0
1912	25.5	25.8	22.5	43.9	53.1	59.0	65.7	65.8	51.2	44.6	36.9	26.6	43.4
1913	23.4	19.3	33.1	46.1	54.8	63.2	66.8	69.8	56.0	44.6	39.4	16.9	44.5
1914	28.5	24.4	37.3	44.8	54.6	63.6	68.3	67.0	60.6	50.2	39.9	21.2	46.7
1915	24.1	32.0	31.1	50.0	50.4	59.6	64.7	62.8	57.1	49.2	38.5	28.4	45.7
1916	18.0	31.6	43.0	44.7	51.9	61.8	69.4	65.6	57.5	45.5	29.7	21.2	45.0
1917	22.0	29.6	29.0	42.1	47.0	62.5	70.2	65.1	59.8	46.2	42.3	32.3	45.7
Average	25.9	26.7	35.7	46.1	53.9	63.1	68.1	67.2	59.2	47.7	36.0	28.0	46.5
Maximum	32.6	37.1	47.1	55.3	58.1	68.1	72.8	70.2	63.7	51.5	42.3	37.8	49.1
Minimum	18.0	9.9	22.5	42.1	47.0	59.0	64.7	62.8	51.2	43.6	27.0	16.9	43.4

TABLE XV—EXTREME MONTHLY MAXIMUM AND MINIMUM TEMPERATURES

At the Colorado Experiment Station, Fort Collins, Colorado.

YEAR.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1887	58.0	**−19.0**	70.0	−8.0	80.0	8.0	83.0	16.0	90.0	24.0	96.0	45.0	**97.0**	50.0	97.0	44.0	91.0	32.0	88.0	11.0	78.0	−13.0	61.0	0.0
1888	71.0	−28.0	68.0	14.0	79.0	3.0	91.0	30.0	84.0	30.0	97.0	42.0	**99.0**	51.0	88.0	44.0	89.0	32.0	75.0	20.0	64.0	16.0	68.0	4.0
1889	58.0	−3.5	62.0	−16.0	67.8	**−17.0**	79.0	24.0	81.0	31.0	90.5	35.0	**97.0**	37.5	97.0	41.3	93.0	23.0	85.2	24.9	61.0	1.0	66.5	3.0
1890	65.6	−13.0	68.3	**−20.0**	70.1	−9.0	78.0	13.8	85.0	29.1	92.2	32.7	93.4	46.9	**95.3**	39.5	85.3	28.0	77.0	15.7	75.7	6.5	62.9	5.8
1891	48.9	**−16.3**	46.5	−15.0	66.0	−4.1	81.9	12.9	84.6	21.3	86.9	37.9	89.4	41.2	**93.1**	36.7	88.8	34.3	79.8	19.5	75.9	−6.2	60.0	−10.0
1892	61.2	**−28.4**	55.1	−15.0	66.0	−4.1	81.9	12.9	84.6	31.2	86.5	35.4	92.7	45.3	**99.2**	33.9	89.3	27.5	87.0	18.7	67.2	10.6	65.6	−17.4
1893	67.3	−2.2	66.7	−10.0	78.3	−1.9	78.9	7.6	88.7	23.1	**95.0**	31.3	94.9	44.2	91.7	38.3	90.0	25.7	82.0	11.8	70.7	**−12.8**	60.4	2.5
1894	63.3	−22.0	54.6	−15.3	73.0	9.9	79.0	16.4	85.9	27.1	91.0	37.9	**94.4**	46.0	92.2	39.5	88.6	30.9	80.7	19.3	78.0	−1.1	64.7	**−24.0**
1895	57.2	−9.6	62.2	**−27.8**	80.2	−18.0	78.7	17.0	90.0	28.6	88.7	33.0	93.2	44.9	93.7	42.3	**95.0**	23.2	79.7	14.8	73.7	−2.9	66.7	−5.0
1896	67.8	−7.6	68.1	3.9	75.8	−6.8	80.0	7.0	88.3	31.0	91.2	39.3	**95.8**	48.8	93.8	40.2	90.0	31.8	84.2	21.0	74.7	**−11.3**	66.1	0.5
1897	64.0	**−26.0**	59.5	−5.3	65.3	−7.0	77.2	20.0	82.3	31.6	90.1	35.3	**94.8**	38.9	93.5	42.7	89.8	33.8	81.7	21.5	75.6	−3.0	63.0	−10.8
1898	61.5	−11.8	63.7	6.7	66.3	−6.2	86.2	14.5	81.8	29.6	**97.2**	36.0	97.0	44.3	95.6	43.1	90.2	29.7	85.7	16.2	71.3	−11.3	55.0	**−22.3**
1899	55.0	−16.8	50.8	**−38.4**	65.7	−24.5	78.0	8.0	82.5	23.4	**96.1**	36.4	94.0	44.6	95.2	39.7	94.6	29.0	86.7	23.7	69.5	15.0	63.7	−9.3
1900	63.0	−6.0	58.0	**−23.4**	76.9	9.7	73.9	5.1	84.7	29.8	**94.4**	40.7	92.9	40.2	94.0	41.2	88.2	29.7	83.0	12.5	74.0	8.7	62.9	−22.0
1901	61.8	−21.7	63.0	−14.7	71.9	−7.5	81.8	8.7	82.9	31.1	94.4	38.2	**96.7**	47.9	96.7	43.6	86.6	29.4	82.0	25.0	69.6	12.0	64.6	**−31.0**
1902	62.2	**−31.4**	63.0	−23.0	63.9	2.0	79.8	18.0	85.9	29.6	96.0	37.0	98.0	38.8	**99.6**	42.3	89.8	22.0	80.0	25.5	69.2	3.8	58.2	−17.6
1903	61.3	1.0	46.0	**−28.0**	66.2	−10.0	78.2	12.8	85.1	27.4	92.5	37.0	**95.0**	36.0	94.6	41.9	92.5	26.0	81.0	20.0	71.0	−10.0	61.0	5.0
1904	65.0	**−7.0**	69.0	3.0	70.0	10.0	79.8	14.1	82.0	28.2	87.2	38.4	90.7	40.3	**91.0**	33.0	90.0	29.6	80.1	17.8	75.4	0.5	65.7	1.0
1905	63.5	−22.3	66.2	**−26.8**	70.3	12.4	78.0	12.0	76.3	29.5	92.3	40.0	91.0	42.3	**93.2**	44.8	90.5	30.8	85.3	−8.0	74.0	3.4	62.2	−4.0
1906	67.8	−3.5	67.0	−5.0	69.9	**−24.6**	80.1	22.1	82.9	33.0	89.9	37.2	**92.6**	41.0	92.0	39.2	86.9	37.3	83.2	19.4	70.2	−9.3	64.5	7.0
1907	62.6	−4.7	68.8	−2.8	80.3	2.8	80.0	5.7	83.0	19.2	87.7	33.9	**94.4**	44.6	91.6	45.0	85.6	31.0	81.8	22.4	70.0	−1.2	61.7	**−5.4**
1908	57.1	−9.8	68.0	**−15.0**	75.7	8.0	80.2	9.8	86.6	22.2	91.8	37.6	**93.1**	43.6	92.8	42.5	91.9	23.4	81.0	13.5	72.2	−12.0	54.0	−13.4
1909	63.8	−3.2	66.3	−14.2	60.1	−11.6	73.2	9.2	81.0	23.6	**94.5**	41.3	94.3	48.0	92.6	46.9	84.2	30.2	81.5	16.3	76.2	−3.1	61.0	**−19.1**
1910	64.1	**−20.8**	66.2	−15.8	79.9	11.5	86.4	17.8	87.0	28.4	90.3	38.9	**99.9**	47.0	92.6	31.7	92.0	34.5	84.7	16.1	70.0	13.6	59.7	3.4
1911	65.8	**−18.0**	62.3	−8.8	69.1	−2.2	75.8	16.0	83.8	26.6	92.0	41.2	88.0	45.1	**95.4**	37.1	89.1	32.1	80.2	14.6	66.9	−11.0	62.9	−8.0
1912	63.6	−14.0	56.0	**−16.0**	55.4	−12.8	72.3	20.7	81.0	22.3	86.1	33.8	89.2	43.0	**89.8**	44.0	84.0	23.0	78.0	11.0	65.0	5.5	59.2	−11.2
1913	58.0	**−29.5**	62.0	−17.3	72.0	−2.0	78.8	18.0	83.0	28.1	90.4	41.2	**94.0**	42.0	92.0	47.0	85.3	27.4	77.1	13.2	70.5	11.0	40.6	−12.6
1914	56.6	−4.8	55.2	**−17.8**	68.4	2.1	73.5	16.3	81.2	32.3	89.7	40.1	89.2	47.1	**94.7**	43.1	87.4	26.1	76.5	23.2	69.8	10.9	52.9	−5.8
1915	60.2	**−14.1**	67.0	2.6	63.9	4.6	75.8	25.7	82.3	27.0	82.8	33.1	90.7	46.2	**92.0**	42.2	87.5	32.7	80.3	24.2	72.4	3.0	61.9	−9.9
1916	61.0	**−24.2**	66.2	−18.3	74.9	5.3	78.0	16.7	87.8	19.2	**92.7**	31.6	90.9	47.0	89.6	41.2	86.8	26.5	75.7	18.2	69.7	−21.1	58.4	−10.8
1917	55.7	**−18.4**	59.7	−5.8	71.6	−13.1	73.3	17.3	79.4	12.1	**94.2**	31.2	92.3	44.2	92.2	41.1	88.8	30.7	83.3	−7.4	71.2	18.2	67.0	−7.8
Extreme	71.0	−31.4	70.0	−38.4	80.3	−24.6	91.0	5.1	90.0	12.1	94.2	31.2	99.9	36.0	99.6	31.7	95.0	22.0	88.0	−8.0	78.0	−21.1	68.0	−31.0

NOTE—Extremes are printed in bold faced type.

TABLE XVI—MONTHLY MEAN DEW POINT ½ (7A+7P)
At the Colorado Experiment Station, Fort Collins. Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	...	...	...	...	28.0	...	...	55.2	...	33.4	23.4	12.3	...
1888	28.2	24.5	21.8	42.0	40.2	48.4	54.6	51.3	45.7	32.9	25.7	15.7	36.0
1889	9.6	14.7	28.4	34.1	39.2	49.1	54.5	51.1	34.2	30.9	19.9	20.1	32.2
1890	11.2	13.0	17.7	30.3	39.0	44.2	55.4	52.2	37.5	26.2	20.2	15.6	30.2
1891	12.2	10.9	20.9	29.7	42.6	50.7	55.2	53.0	44.1	25.0	18.4	14.1	31.4
1892	10.1	19.2	21.3	25.4	37.6	49.8	55.2	49.2	38.6	30.0	18.5	12.3	30.6
1893	10.0	9.7	17.2	20.8	34.6	45.5	51.8	49.7	37.0	24.3	15.2	16.6	27.7
1894	7.4	4.8	16.5	25.9	37.6	44.7	52.6	51.6	39.6	26.6	19.1	12.2	28.2
1895	11.7	9.0	17.3	26.6	37.2	47.5	52.7	52.6	39.9	27.9	15.5	10.2	29.0
1896	10.4	12.0	19.8	26.5	32.5	50.5	56.6	51.5	46.2	30.4	12.5	15.7	30.4
1897	6.6	14.1	19.8	29.5	44.6	50.5	53.3	53.6	48.0	32.3	21.3	12.1	32.1
1898	11.0	16.2	15.2	27.3	40.4	49.1	52.2	50.6	37.0	24.0	16.5	8.4	29.0
1899	10.6	2.4	18.8	24.6	34.6	44.6	54.8	50.3	41.6	30.7	23.1	13.1	29.1
1900	15.5	11.6	24.2	34.8	43.4	51.3	51.3	49.0	42.4	30.3	17.4	10.9	31.8
1901	10.7	12.2	18.8	30.0	42.8	49.8	56.7	54.6	40.5	31.6	20.4	16.5	32.0
1902	9.9	17.0	18.3	29.0	40.8	48.2	52.6	50.7	38.9	34.3	20.9	14.0	31.2
1903	15.5	4.5	22.6	29.0	38.1	51.3	54.2	54.2	41.1	30.8	22.4	13.6	31.4
1904	10.2	15.6	21.9	27.1	41.1	50.4	54.6	53.5	45.0	31.4	15.1	17.8	32.0
1905	17.5	11.9	28.2	32.3	40.2	52.4	53.6	54.1	42.4	26.4	21.9	7.9	32.4
1906	10.3	10.2	16.6	31.7	39.2	47.7	53.9	52.9	47.8	30.8	22.6	20.4	32.0
1907	15.0	18.0	21.3	28.6	37.4	45.4	55.7	52.3	42.8	34.3	17.4	14.7	31.9
1908	9.5	12.0	17.0	23.7	35.6	45.7	54.7	55.0	44.3	30.1	18.4	14.7	30.1
1909	17.2	13.9	25.4	25.9	32.7	51.2	57.6	56.6	46.9	28.5	24.2	9.1	32.4
1910	9.9	8.6	18.3	23.2	39.2	47.5	52.7	51.2	45.3	31.5	25.4	16.7	30.8
1911	15.3	11.5	21.4	25.4	35.2	49.2	52.2	49.6	42.2	29.2	16.2	9.8	29.8
1912	12.6	15.4	17.8	30.0	36.9	49.0	56.9	54.9	41.9	34.8	24.8	13.8	32.4
1913	11.2	10.0	21.3	31.9	43.8	50.1	54.6	56.3	47.0	31.3	25.4	8.5	32.6
1914	16.5	16.4	22.2	32.3	44.3	54.2	59.7	55.6	46.3	38.3	20.3	11.4	34.8
1915	8.7	15.9	23.2	38.7	38.4	47.8	55.4	55.1	46.9	35.2	21.7	15.0	33.5
1916	8.9	18.7	25.8	35.4	48.0	54.2	55.3	54.4	45.5	34.9	17.0	10.0	34.0
1917	9.9	19.0	20.4	33.6	43.8	54.4	57.6	51.7	47.6	27.3	24.8	16.8	33.9
Average	11.6	12.7	20.6	29.1	39.3	49.2	54.6	52.7	42.7	30.3	18.6	13.5	31.2
Maximum	28.2	24.5	28.4	42.0	48.0	54.4	59.7	56.6	48.0	38.3	25.7	20.4	36.0
Minimum	6.6	2.4	15.2	20.8	32.5	44.2	51.3	49.0	34.2	24.0	12.5	7.9	27.7

XVII—MONTHLY MEAN RELATIVE HUMIDITY ½ (7A+7P) IN PER CENT OF SATURATION

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	56.6	65.8	44.4	51.4	70.0	79.9	69.0	57.7	59.3	70.0	62.7	55.4	61.8
1888	44.6	61.5	59.7	62.6	62.2	52.5	55.8	60.2	59.7	56.2	71.2	60.5	58.9
1889	65.6	66.6	63.6	58.9	62.8	63.2	64.3	60.8	53.1	64.5	78.9	64.4	63.9
1890	75.4	68.0	52.9	63.5	59.1	51.4	61.8	69.0	52.9	60.7	70.0	65.4	62.5
1891	89.3	78.3	82.5	58.8	68.9	69.9	69.2	68.1	66.6	53.6	64.2	69.7	69.9
1892	80.0	82.6	73.2	56.2	69.1	66.2	67.4	58.9	51.6	66.1	61.3	78.1	67.6
1893	56.1	64.7	60.7	51.0	57.5	51.9	56.3	62.0	51.4	51.7	62.6	67.1	57.7
1894	63.8	70.6	56.6	48.1	55.5	54.8	60.6	63.2	61.0	50.5	62.2	76.7	60.3
1895	75.7	76.4	64.3	47.3	59.0	67.7	71.0	68.3	57.6	64.2	68.0	65.3	65.4
1896	62.1	58.6	69.7	54.6	46.6	52.6	67.7	62.8	76.1	65.7	65.1	67.2	63.2
1897	68.4	74.7	72.6	61.0	63.0	69.0	68.0	73.0	69.2	71.1	75.0	75.1	70.0
1898	75.2	67.5	62.6	52.4	71.4	62.7	60.9	59.0	60.1	55.6	72.4	73.6	64.4
1899	70.2	87.2	73.7	53.2	53.2	54.5	70.8	63.1	60.8	72.7	69.2	74.1	66.9
1900	73.3	76.4	70.6	78.8	62.6	60.5	64.5	57.8	67.6	61.9	61.0	61.0	66.3
1901	66.0	78.9	62.9	65.4	62.6	64.0	62.6	67.7	64.1	66.7	64.9	76.4	66.9
1902	78.2	70.8	61.8	58.8	61.2	62.0	65.1	60.1	64.5	74.4	72.4	75.0	67.0
1903	73.0	86.0	83.6	60.2	61.5	74.5	65.9	69.3	70.8	66.0	78.7	61.5	70.9
1904	65.5	59.5	60.3	53.5	64.9	70.5	70.1	69.3	73.2	74.0	60.2	73.6	66.2
1905	85.5	86.8	71.1	74.0	70.0	69.0	68.6	69.7	67.7	73.0	72.0	66.3	72.7
1906	60.0	63.3	81.5	61.0	60.7	63.7	70.1	70.2	79.3	71.2	80.6	74.2	69.6
1907	79.2	66.8	54.9	61.8	68.8	58.4	71.0	67.4	67.5	75.1	76.0	68.3	67.9
1908	63.4	62.8	51.3	42.4	59.2	60.0	69.7	77.4	66.8	68.0	77.9	81.2	65.0
1909	75.8	70.6	78.3	60.1	51.9	68.0	71.7	71.2	78.2	58.1	73.7	79.2	69.7
1910	70.0	62.8	41.0	37.6	62.5	56.9	56.7	64.8	69.3	63.7	71.8	68.8	60.5
1911	66.2	71.5	55.5	52.4	52.8	55.7	63.8	60.4	58.7	64.9	65.7	75.6	61.9
1912	73.6	76.6	88.4	62.8	56.4	66.5	75.6	71.7	81.2	79.8	78.3	73.7	73.5
1913	74.2	80.7	77.2	65.2	67.5	62.6	68.6	66.8	80.6	68.0	73.3	89.1	72.4
1914	69.2	83.3	65.0	67.7	70.3	67.0	72.2	72.6	69.5	77.9	64.8	81.5	71.8
1915	65.1	65.8	78.5	72.1	66.7	68.1	74.1	80.2	78.4	78.8	61.8	68.6	71.5
1916	77.0	72.5	59.2	74.1	82.4	76.0	60.9	72.3	73.9	78.2	72.2	75.7	72.9
1917	71.4	74.6	77.5	78.6	89.7	75.3	68.0	70.6	76.3	63.6	71.4	71.3	74.0
Average	71.3	72.5	67.1	59.7	63.4	63.9	66.8	67.2	67.2	67.9	69.8	72.3	67.4
Maximum	89.3	87.2	88.4	78.8	89.7	79.9	75.6	80.2	81.2	79.8	80.6	89.1	74.0
Minimum	44.6	58.6	41.0	37.6	46.6	51.4	55.8	57.7	51.4	50.5	60.2	55.4	57.7

TABLE XVIII—MONTHLY MEAN TERRESTRIAL RADIATION

At the Colorado Experiment Station, Fort Collins, Colorado.

(Difference between Monthly Minimum and Terrestrial 6 Inches from Ground.)

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889	9.9	9.1	8.6	5.5	7.6	7.1	6.3	7.2	7.3	5.9	6.8	6.2	7.3
1890	4.2	5.1	4.8	3.9	7.2	9.5	9.0	9.7	4.2	4.8	8.5	9.9	6.7
1891	6.5	3.6	5.3	6.8	7.4	5.3	4.4	4.2	5.4	6.0	5.5	5.0	5.4
1892	3.9	3.8	4.0	4.8	5.3	6.5	5.7	6.0	6.5	5.7	5.9	5.0	5.3
1893	5.5	5.0	3.9	4.5	5.1	7.6	5.3	4.6	6.0	5.5	4.9	4.8	5.2
1894	5.1	4.3	4.0	3.9	5.7	6.0	5.2	5.0	5.6	7.0	4.9	4.6	5.1
1895	4.5	4.1	3.9	4.9	5.6	4.2	4.3	4.1	4.3	5.1	5.4	5.9	4.7
1896	5.3	5.2	3.4	4.5	6.3	3.8	4.0	5.6	5.1	6.9	6.4	5.3	5.2
1897	4.4	4.1	3.8	4.0	5.4	4.7	5.2	4.7	4.2	4.1	4.0	4.8	4.5
1898	5.0	5.2	5.6	4.4	2.8	2.9	2.9	2.9	3.1	3.4	3.3	4.0	3.8
1899	4.2	3.3	2.4	3.3	3.7	3.8	3.6	4.9	4.7	3.6	4.6	4.5	3.9
1900	4.0	3.9	2.9	2.9	5.4	6.5	5.5	6.1	5.8	6.0	5.9	6.3	5.1
1901	5 8	5.2	4.2	4.6	7.6	7.1	7.0	5.4	6.2	6.0	7.1	3.8	5.8
1902	3.7	3.6	4.4	4.8	5.4	5.4	5.1	5.1	4.6	3.4	4.7	4.0	4.5
1903	3.8	4.5	2.4	4.7	5.2	4.3	7.5	...	5.7	5.0	4.2	...	...
1904	...	4.3	3.3	3.1	3.7	4.3	6.0	7.4	8.0	6.8	...	...	...
1905	5.0	5.3	5.2	4.2	6.3	9.3	...	...	...	...	...	...	...
1906	7.7	5.4	2.8	5.3	6.9	6.0	6.3	5.8	4.4	4.0	4.0	4.8	5.3
1907	2.8	3.9	4.7	3.9	5.8	8.4	7.8	6.5	6.0	5.4	5.4	5.7	5.5
1908	5.6	5.0	5.2	5.9	4.9	7.2	5.2	4.4	6.2	3.8	4.2	3.8	5.1
1909	2.7	3.9	2.7	2.6	6.8	7.4	5.0	4.0	3.8	4.9	3.9	3.6	4.3
1910	3.9	4.4	5.4	4.7	4.7	3.3	4.0	3.4	3.6	4.2	3.4	3.9	4.1
1911	3.6	3.2	3.1	3.2	3.6	4.1	3.4	4.5	4.3	3.3	2.9	4.1	3.6
1912	3.0	3.8	3.2	2.8	4.2	4.6	4.4	3.9	4.6	1.9	3.7	4.0	3.7
1913	3.2	2.5	2.3	2.7	3.7	4.6	4.7	4.8	4.1	3.7	3.8	2.4	3.5
1914	3.8	1.8	3.1	2.8	3.6	4.6	4.6	3.6	4.0	3.3	4.1	3.3	3.5
1915	3.3	3.1	2.4	2.8	3.2	3.5	3.8	4.8	4.1	4.2	4.7	2.6	3.5
1916	4.0	4.2	4.0	4.4	7.4	4.7	4.7	4.1	4.7	3.7	3.5	4.1	4.5
1917	4.1	3.7	3.4	3.4	2.9	5.7	5.4	4.5	4.9	3.8	4.9	3.4	4.2
Average	4.6	4.3	4.2	4.1	5.4	5.9	5.6	5.1	5.4	5.1	5.1	4.9	5.0
Maximum	9.9	9.1	8.6	6.8	7.6	9.5	9.0	9.7	8.0	7.0	8.5	9.9	7.3
Minimum	2.7	1.8	2.3	2.6	2.8	2.9	2.9	2.9	3.1	1.9	2.9	2.4	3.5

TABLE XIX—MONTHLY MEAN TERRESTRIAL RADIATION THERMOMETER

At the Colorado Experiment Station, Fort Collins, Colorado.

6 Inches from the Ground.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889	...	...	...	...	...	...	...	...	...	...	...	...	...
1890	4.4	9.9	18.4	29.2	33.8	37.3	46.2	41.5	35.2	26.3	12.8	8.4	25.3
1891	2.5	4.3	14.4	25.1	33.8	42.1	47.4	45.5	38.8	20.4	16.3	11.3	25.2
1892	3.4	13.5	17.9	24.7	33.6	40.0	47.3	42.4	35.6	25.9	17.3	4.3	25.5
1893	10.3	7.3	16.2	23.8	32.7	39.6	48.1	45.9	32.8	26.2	12.5	15.2	25.9
1894	3.3	-0.6	18.4	28.2	37.0	41.0	47.6	46.5	35.9	27.1	18.4	6.2	25.8
1895	6.4	2.8	16.0	27.2	33.2	40.7	47.1	47.2	37.6	24.7	13.6	8.1	25.4
1896	10.8	12.4	18.4	26.0	35.0	45.7	51.7	47.3	40.0	24.5	10.2	13.7	28.0
1897	4.9	10.2	16.1	28.0	37.3	43.5	44.7	46.7	43.1	28.3	16.2	7.6	27.2
1898	5.6	12.4	11.9	26.4	37.6	45.3	50.1	49.3	35.8	28.0	12.8	5.3	26.7
1899	6.2	-8.8	15.6	25.6	34.3	43.6	49.0	46.9	37.4	28.4	20.3	8.2	25.6
1900	11.2	6.8	21.4	28.4	37.8	44.2	46.8	43.4	37.5	26.8	15.7	9.7	27.5
1901	6.8	4.6	18.5	26.4	35.2	41.2	48.2	48.0	34.4	26.8	16.2	11.6	26.5
1902	5.4	9.8	17.9	25.7	36.3	42.8	44.2	47.2	35.4	29.7	17.9	10.3	26.9
1903	12.6	-4.6	15.9	26.5	31.3	42.7	44.6	...	33.6	26.6	14.7	...	...
1904	...	18.2	21.0	28.2	37.5	42.0	44.7	43.8	34.4	24.6	17.4	...	...
1905	7.6	1.5	24.0	27.3	34.2	40.7	...	...	...	...	...	...	...
1906	5.6	7.3	10.8	29.0	34.8	41.2	44.7	45.2	39.9	26.5	17.1	16.7	26.6
1907	9.6	16.0	22.6	25.2	31.2	36.8	44.6	44.4	36.2	26.7	10.8	9.9	26.2
1908	6.3	8.2	19.1	24.7	33.4	39.3	47.7	47.6	38.1	27.8	11.0	8.1	25.9
1909	14.1	10.1	21.2	26.4	31.1	41.8	50.0	50.8	40.2	27.3	21.0	2.0	28.0
1910	6.6	6.2	23.2	28.3	35.9	45.7	51.0	48.6	42.8	29.7	23.3	13.8	29.6
1911	14.5	10.7	23.0	29.0	37.6	47.0	49.4	46.2	41.9	28.1	14.5	5.3	28.9
1912	8.2	9.7	6.5	27.2	34.8	40.6	48.4	47.0	33.8	27.0	18.4	8.2	25.8
1913	6.4	3.4	17.2	28.5	37.7	43.1	47.5	49.2	38.2	27.0	20.6	-0.4	26.5
1914	11.7	12.5	20.7	30.8	38.4	43.9	49.9	47.8	39.9	32.0	17.9	4.8	29.2
1915	6.0	15.6	18.9	34.9	34.4	43.7	48.6	44.6	39.1	28.9	20.3	12.7	29.0
1916	1.0	12.5	23.6	26.8	32.7	39.0	49.7	48.0	36.8	27.7	12.3	4.9	26.2
1917	4.4	14.2	13.4	26.8	33.7	40.0	49.0	45.3	38.9	25.3	20.8	13.4	27.1
Average	7.2	8.1	17.9	27.3	34.9	41.9	47.7	46.4	37.5	27.0	16.3	8.8	26.8
Maximum	14.5	18.2	24.0	34.9	38.4	47.0	51.7	50.8	43.1	32.0	23.3	16.7	29.6
Minimum	1.0	-8.8	6.5	23.8	31.1	36.8	44.2	41.5	32.8	20.4	10.2	-0.4	25.2

TABLE XX—MONTHLY MEAN AND NORMAL BAROMETER

At the Colorado Experiment Station, Fort Collins, Colorado.

½ (7A+7P)

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	24.778	25.090	24.994	24.913	24.994	24.912	25.052	25.073	25.043	24.932	24.956	24.853	24.964
1888	14.818	24.793	24.805	24.944	24.835	24.827	25.075	25.102	25.126	24.988	25.031	24.985	24.944
1889	24.933	24.973	24.992	25.000	24.953	25.041	25.054	25.071	25.047	25.084	25.064	24.921	25.011
1890	24.906	24.889	24.918	24.998	24.942	24.965	25.065	25.188	25.074	25.014	25.130	25.034	25.010
1891	24.999	24.972	24.874	24.953	25.005	24.918	25.075	25.092	25.043	25.103	24.968	24.869	24.974
1892	24.979	24.936	24.909	24.886	24.953	24.965	25.085	25.069	25.086	25.042	24.959	24.939	24.981
1893	24.927	24.897	24.867	24.875	24.923	24.962	25.036	25.058	24.973	25.006	24.976	24.977	24.984
1894	24.875	24.939	24.886	24.921	24.978	24.956	25.133	25.130	25.012	24.975	25.084	25.025	24.956
1895	24.859	25.014	24.918	24.964	24.951	25.065	25.084	25.074	25.019	25.113	24.979	24.934	24.998
1896	24.964	24.956	24.911	24.858	24.887	25.054	25.104	25.110	25.060	25.037	24.954	25.052	24.996
1897	24.985	24.853	24.806	25.006	25.035	24.964	25.061	25.123	25.124	25.042	24.990	24.993	24.999
1898	24.917	24.995	24.878	25.002	24.940	25.006	25.064	25.057	25.027	25.039	24.927	25.039	24.991
1899	24.884	24.862	24.853	24.933	24.885	25.003	25.096	25.005	25.120	25.008	25.019	24.995	24.972
1900	25.019	24.892	24.987	24.910	24.989	25.006	25.009	24.995	25.035	25.015	25.048	25.037	24.995
1901	24.965	24.976	24.871	24.975	24.949	24.926	25.040	25.119	24.989	25.111	25.086	24.966	24.998
1902	25.026	24.888	24.836	24.923	24.920	24.952	25.036	25.058	25.040	25.054	24.936	24.954	24.970
1903	24.919	24.971	24.966	24.925	24.964	25.005	25.025	25.055	25.041	25.111	25.033	25.022	25.011
1904	24.920	24.867	24.821	24.990	24.962	25.040	25.070	25.130	25.123	25.089	25.113	24.974	25.008
1905	25.086	25.011	24.927	24.935	24.920	24.965	25.087	25.094	25.042	25.068	24.983	25.031	25.012
1906	24.973	25.003	24.982	24.983	24.919	24.962	25.129	25.066	25.083	25.068	25.020	25.007	25.016
1907	24.912	25.019	24.907	24.957	24.945	24.953	25.067	25.063	25.057	25.117	25.086	24.930	25.001
1908	25.003	24.951	24.946	24.949	24.851	24.955	25.139	25.086	25.096	25.021	25.064	24.992	25.004
1909	24.922	24.855	24.905	24.912	24.898	25.040	25.046	25.092	25.106	25.064	25.003	24.931	24.981
1910	24.977	24.960	25.030	25.003	25.037	24.990	25.064	25.080	25.085	25.044	24.978	24.977	25.019
1911	24.951	24.993	24.997	24.919	24.938	25.007	25.096	25.064	25.042	25.051	24.966	24.915	24.995
1912	24.932	24.965	24.959	24.918	24.979	25.108	25.115	25.064	25.082	25.035	25.089	24.988	25.020
1913	24.910	24.940	24.918	24.982	24.992	25.008	25.102	25.105	25.087	25.029	25.010	25.043	25.010
1914	24.968	24.962	25.016	24.972	25.030	24.985	25.097	25.056	25.039	25.034	25.060	24.968	25.011
1915	24.861	24.908	24.993	24.932	24.889	24.979	25.023	25.117	24.987	25.056	24.946	24.920	24.968
1916	24.857	25.025	24.917	24.962	24.877	24.950	25.045	25.061	25.033	25.021	25.047	24.803	24.966
1917	24.891	24.930	24.907	24.924	24.924	25.028	25.063	25.108	25.096	25.047	25.123	24.970	25.001
Normal	24.931	24.939	24.920	24.946	24.944	24.984	25.072	25.083	25.059	25.049	25.020	24.969	24.992
Maximum	25.086	25.090	25.030	25.006	25.037	25.108	25.139	25.188	25.126	25.117	25.130	25.052	25.020
Minimum	24.778	24.792	24.905	24.858	24.877	24.827	25.023	24.995	24.973	24.932	24.927	24.803	24.944

TABLE XXI—MONTHLY PRECIPITATION

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1872	...	...	...	...	...	...	...	...	...	...	0.02	0.20	...
1873	0.25	0.16	0.00	1.20	2.30	1.50	1.30	0.85	0.75	0.42	0.20	0.17	9.10
1874	0.06	0.43	1.29	0.77	2.95	0.65	3.15	0.25	0.00	1.00	0.02	0.00	10.57
1879	...	...	...	...	...	...	...	...	...	1.75	0.15	0.60	...
1880	0.72	1.09	0.38	0.94	0.60	0.86	1.80	0.37	1.47	2.07	1.10	0.10	11.50
1881	1.10	0.55	1.45	...	...	...	...	...	...	...	...	...	...
1882	...	...	0.17	...	4.67	3.07	1.76	0.89	2.51	0.82	0.29	...	...
1883	1.00	1.50	0.68	...	2.51	3.18	...	1.78	1.00	1.29	T	1.33	...
1884	1.10	0.70	1.15	3.94	4.84	...	...	...	...	0.10	1.80	0.35	...
1885	1.77	...	...	...	...	...	...	...	...	...	...	...	...
1886	...	...	...	...	...	...	...	...	...	0.69	1.18	0.33	...
1887	0.86	0.23	0.45	1.10	1.23	1.96	3.05	2.12	0.54	0.43	0.15	0.00	12.12
1888	0.29	0.36	0.73	1.23	3.39	0.47	0.60	1.01	0.29	0.88	0.38	0.16	9.79
1889	0.21	0.34	0.65	2.07	3.39	2.06	0.79	0.95	0.42	3.16	0.42	0.02	14.48
1890	0.13	0.21	0.22	3.92	1.19	0.12	1.27	3.14	0.07	0.70	0.32	0.12	11.41
1891	2.32	0.15	1.21	2.14	4.07	1.30	0.17	2.06	1.02	0.20	0.60	0.46	15.70
1892	0.60	1.29	1.52	1.60	4.83	2.42	1.32	0.22	0.14	0.93	0.23	0.35	15.45
1893	0.02	0.54	0.14	1.66	1.92	0.26	0.64	0.92	0.18	0.16	0.55	0.12	7.11
1894	0.25	0.60	0.67	0.89	3.09	0.42	1.72	1.53	2.29	T	0.14	0.76	12.36
1895	0.24	1.52	0.54	1.36	3.62	3.65	3.75	1.45	0.47	1.06	0.40	0.01	18.07
1896	0.43	0.03	1.73	1.26	1.68	3.05	3.05	2.20	1.55	0.49	0.05	0.24	15.76
1897	0.18	0.54	2.15	1.39	2.06	1.69	2.65	1.74	0.75	0.75	0.67	0.67	15.24
1898	0.14	0.08	0.50	1.08	3.65	1.37	0.50	0.98	0.50	0.82	1.24	0.17	11.03
1899	0.66	1.04	1.50	1.10	1.01	1.03	4.95	0.99	0.21	3.23	T	0.47	16.19
1900	0.25	1.12	1.07	10.56	1.75	0.82	1.14	0.16	1.92	0.24	0.07	0.11	19.21
1901	0.19	0.38	1.88	3.62	7.47	2.35	0.71	0.72	2.10	0.36	0.02	1.37	21.17
1902	0.32	0.15	1.50	0.61	2.13	2.43	1.31	0.67	7.12	1.15	0.27	0.77	18.43
1903	0.16	1.60	1.03	1.50	0.63	2.23	1.06	0.86	0.87	1.70	0.18	0.07	11.89
1904	0.04	0.34	0.51	0.89	5.37	1.68	1.99	0.71	1.09	0.39	0.00	0.12	13.13
1905	0.29	0.35	1.75	6.32	4.13	0.64	2.18	1.25	0.28	2.60	0.07	T	19.86
1906	0.01	0.03	2.44	4.30	2.40	1.80	1.96	0.80	3.08	1.59	1.35	0.12	19.88
1907	0.23	0.36	0.69	2.80	2.44	0 44	2.28	1.27	0.58	0.08	0.44	0.03	11.64

TABLE XXI—MONTHLY PRECIPITATION—Continued
At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1908	0.11	0.03	0.28	0.05	5.83	1.16	3.66	2.12	0.54	1.78	1.06	0.60	17.22
1909	0.02	0.90	3.35	1.34	1.06	2.59	1.98	1.45	2.10	0.08	0.79	0.58	16.24
1910	0.29	0.16	0.06	0.42	4.75	1.04	0.87	1.92	1.79	1.03	0.11	0.48	12.92
1911	0.34	1.52	0.05	1.89	0.72	1.78	1.47	0.59	0.80	0.93	0.43	0.37	10.89
1912	0.37	1.65	1.79	0.90	2.84	2.43	2.93	1.26	2.66	2.03	0.59	0.21	19.66
1913	0.30	0.94	0.20	1.49	2.09	0.15	2.63	0.41	2.39	1.00	0.17	4.08	15.85
1914	0.35	0.30	0.87	3.23	2.73	2.01	1.68	1.27	0.02	1.58	0.12	0.15	14.31
1915	0.12	1.41	1.73	4.01	3.78	1.90	2.12	1.56	2.97	1.97	0.10	0.82	22.49
1916	0.84	0.11	0.31	0.86	3.85	0.60	0.65	0.71	0.70	2.92	0.98	0.62	13.15
1917	0.40	1.04	0.99	1.22	5.86	0.03	1.19	1.21	0.45	0.62	0.40	0.31	13.72
Normal	0.45	0.64	0.98	2.10	3.05	1.53	1.84	1.18	1.27	1.10	0.43	0.45	15.02
Average 31 years	0.35	0.62	1.05	2.16	30.6	1.48	1.82	1.23	1.29	1.12	0.40	0.46	15.04
Maximum	2.32	1.65	3.35	10.56	7.47	3.65	4.95	3.14	3.08	3.23	1.80	4.08	22.49
Minimum	0.01	0 03	0.00	0.05	0.60	0.03	0.17	0.16	0.00	T	0.00	0.00	7.11

TABLE XXII—NUMBER OF STORMY DAYS (.01 OR MORE PRECIPITATION)
At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	6	2	1	4	6	10	11	8	3	3	1	0	55
1888	3	2	6	2	10	2	6	4	5	4	5	3	52
1889	2	3	3	8	14	7	8	6	3	8	3	1	66
1890	2	1	3	9	8	3	10	13	2	2	2	1	57
1891	5	5	12	4	13	10	4	16	11	2	6	3	91
1892	6	7	7	6	15	8	14	5	1	4	2	6	81
1893	1	5	1	6	11	4	5	10	1	3	4	3	54
1894	5	8	6	4	10	6	6	7	6	0	2	5	65
1895	4	8	4	4	11	12	14	11	3	4	7	1	83
1896	2	2	10	5	5	9	12	9	11	5	2	2	74
1897	2	6	9	7	13	12	9	12	6	6	4	5	91
1898	3	2	8	8	22	7	8	7	4	4	4	2	80
1899	6	11	11	6	8	9	13	7	3	10	0	3	87
1900	3	8	5	11	7	7	9	4	8	2	1	1	66
1901	3	7	7	7	11	8	3	12	3	2	1	8	72
1902	4	2	8	5	12	8	8	3	4	6	1	4	65
1903	3	12	2	9	7	9	6	2	6	4	2	1	63
1904	3	3	7	5	13	10	5	3	5	3	0	3	60
1905	8	7	5	10	16	10	12	6	2	7	3	0	86
1906	1	2	14	7	8	6	11	9	13	4	6	1	82
1907	4	5	4	12	15	6	13	8	4	2	1	3	77
1908	2	2	3	3	12	11	7	13	3	5	7	4	72
1909	2	4	10	11	3	13	10	9	8	3	6	6	85
1910	4	4	2	2	12	7	4	12	9	2	2	4	64
1911	2	9	3	10	7	7	8	4	3	7	6	5	71
1912	5	8	12	3	6	11	9	10	9	8	2	3	86
1913	4	10	7	8	11	4	12	3	10	7	2	7	85
1914	2	3	7	11	13	8	6	11	1	5	1	3	71
1915	1	4	13	13	10	10	11	8	13	3	4	5	95
1916	8	2	3	7	7	3	4	12	4	4	6	9	69
1917	4	5	5	9	16	3	8	8	10	3	4	3	78
Average	3.5	5.1	6.4	7.0	10.7	7.7	8.6	8.1	5.6	4.3	3.1	3.4	73.6
Maximum	8	12	14	13	22	13	14	16	13	10	7	9	95
Minimum	1	1	1	2	3	2	3	2	1	0	0	0	52

TABLE XXIII—MONTHLY AVERAGE WIND IN MILES PER DAY

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888	96	180	130	198	136	232	110	98	85	123	113	125	136
1889	128	162	160	184	154	108	101	92	119	115	132	148	134
1890	140	158	170	152	124	...	...	...	...	90	68	91	...
1891	96	140	150	216	171	154	145	126	137	132	188	181	145
1892	121	125	178	224	218	130	76	75	163	187	212	189	158
1893	243	251	287	297	263	186	168	153	174	196	225	246	224
1894	227	179	280	290	222	191	150	147	163	219	205	162	203
1895	202	188	255	265	203	179	146	136	160	146	175	234	191
1896	181	236	253	249	247	154	134	143	142	153	196	158	187
1897	163	201	227	220	160	143	138	114	116	152	167	178	165
1898	147	187	214	219	161	135	142	125	137	203	176	170	168
1899	213	165	198	236	182	153	113	127	123	169	147	169	166
1900	160	199	164	172	147	131	119	113	123	150	156	184	143
1901	181	153	248	178	165	127	115	110	127	124	160	183	156
1902	107	164	205	180	130	117	98	116	129	95	140	154	136
1903	192	120	114	185	167	113	109	101	102	124	156	183	139
1904	188	231	216	217	168	173	115	113	104	122	138	182	164
1905	134	129	171	169	156	161	120	98	108	114	142	129	136
1906	144	161	139	188	136	141	87	96	93	137	131	129	128
1907	119	150	172	175	146	151	91	93	106	90	96	166	130
1908	176	144	208	201	166	171	86	88	96	119	80	105	137
1909	149	177	143	192	215	108	92	98	96	147	95	117	136
1910	108	187	177	220	130	113	99	92	102	122	139	141	136
1911	170	121	174	182	153	115	144	144	156	151	220	135	155
1912	181	187	140	227	162	...	...	...	...	...	107	167	...
1913	192	107	165	145	132	136	117	106	116	133	110	105	130
1914	144	113	136	152	112	116	109	110	117	98	84	81	114
1915	144	133	130	143	135	142	123	99	90	79	142	174	128
1916	133	140	283	200	213	130	104	105	123	121	124	152	152
1917	170	176	190	178	137	128	74	107	116	171	107	168	144
Average	159	165	189	202	167	144	115	112	122	138	144	157	151
Maximum	243	251	287	297	263	232	168	153	174	219	225	246	224
Minimum	96	107	114	143	112	108	74	75	85	79	68	81	114

TABLE XXIV—EVAPORATION FROM WATER SURFACE
At the Colorado Experiment Station, Fort Collins, Colorado.
(From Tank 3 ft. x 3 ft. About 2 Inches Above Ground Surface.) Inches.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887	2.46	3.23	4.60	5.55	5.19	5.75	5.23	4.24	4.12	3.26	1.48	1.60	46.71
1888	...	...	...	...	4.45	7.70	7.00	4.06	3.94	2.17	1.35	0.99	....
1889	1.08	1.03	2.75	4.06	3.72	4.34	5.20	5.15	5.19	3.28	0.62	1.42	37.84
1890	0.86	2.36	3.58	3.50	4.32	5.71	5.44	5.76	3.69	2.71	1.32	1.10	40.25
1891	1.89	1.90	2.23	2.24	5.03	4.97	5.72	4.91	4.12	3.62	1.74	0.75	39.12
1892	2.51	2.15	2.78	3.58	3.49	4.20	4.69	5.64	5.11	3.33	1.93	1.13	40.54
1893	...	1.52	3.79	5.40	5.12	6.12	6.41	4.73	5.04	3.79	1.05	1.88	....
1894	1.14	1.15	1.95	4.61	4.66	5.01	4.74	4.88	3.77	3.75	1.64	1.22	39.52
1895	1.19	1.19	...	4.91	4.27	4.13	4.57	4.52	4.06	2.24	1.53	1.68	....
1896	2.64	2.25	2.39	4.71	5.91	5.09	5.23	5.80	3.34	2.94	1.62	1.25	43.17
1897	1.80	2.20	...	3.33	4.13	4.26	4.64	4.76	3.97	2.88	1.47	0.94	....
1898	1.12	1.31	2.53	4.65	3.90	5.67	7.33	6.57	5.57	4.64	1.36	0.67	45.32
1899	1.51	1.39	1.54	3.79	5.35	6.37	5.38	5.86	5.04	2.87	1.86	1.15	42.11
1900	0.96	1.55	2.32	3.12	4.53	5.51	6.26	5.43	4.55	3.74	2.10	1.54	41.61
1901	1.19	0.84	2.79	3.54	5.25	5.16	6.96	5.46	5.01	3.55	2.81	1.03	43.59
1902	0.91	1.25	1.58	4.08	5.06	5.73	5.49	6.20	4.41	2.89	1.81	0.85	40.26
1903	1.66	2.22	1.82	4.05	4.38	4.81	5.60	4.53	4.12	4.12	1.29	1.56	40.12
1904	0.91	2.74	3.32	5.64	4.04	5.72	5.13	4.08	3.27	2.77	1.57	1.24	40.43
1905	0.64	0.58	2.40	3.17	3.99	4.60	5.32	4.12	3.66	3.11	1.59	1.38	34.56
1906	1.55	1.09	4.14	3.64	4.37	5.49	4.26	4.62	3.33	3.74	1.36	0.72	38.31
1907	0.89	0.80	4.42	4.56	3.49	5.47	5.60	4.62	4.14	2.77	1.08	1.05	38.89
1908	1.04	1.60	3.96	6.17	4.70	5.01	4.52	3.79	5.03	3.18	0.89	0.26	40.15
1909	0.66	0.66	2.32	3.20	4.92	3.97	5.32	4.56	3.14	3.58	1.26	0.65	34.24
1910	0.73	2.02	...	5.29	4.54	6.46	6.59	5.15	4.49	4.38	2.05	1.54	....
1911	0.64	1.21	3.35	5.39	6.58	6.94	5.86	5.61	5.42	3.62	1.70	0.98	47.30
1912	0.92	0.68	0.73	4.43	6.63	5.09	5.15	5.71	4.36	3.00	1.52	1.66	39.88
1913	0.81	0.71	1.35	4.24	4.14	5.26	6.01	5.88	4.10	2.74	...	...	....
1914	0.68	0.62	2.37	3.26	4.23	5.86	5.81	5.49	4.96	3.22	1.93	1.36	39.79
1915	1.36	1.32	0.57	4.10	4.62	5.04	5.07	4.18	3.74	3.17	2.18	0.84	36.19
1916	0.84	0.87	4.29	4.24	6.06	6.37	6.60	5.63	4.60	2.79	1.20	1.10	44.59
1917	1.10	0.99	1.10	3.80	4.08	6.26	6.30	5.19	4.05	3.88	1.61	1.51	39.87
Average	1.23	1.45	2.63	4.21	4.68	5.42	5.59	5.07	4.30	3.28	1.56	1.17	40.59
Maximum	2.64	3.23	4.60	6.17	6.63	7.70	7.32	6.57	5.57	4.64	2.81	1.88	....
Minimum	0.68	0.58	0.57	2.24	3.49	3.97	4.26	3.79	3.14	2.17	0.62	0.26	....

TABLE XXV—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Arkansas Valley Sub-Station, Near Rocky Ford, Colorado.

DATE.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December		Year	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1888........	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	80.4	66.2	....	....	....	....	....	....	....	....
1889........	....	....	....	....	....	....	69.9	38.1	76.0	45.7	86.1	....	93.8	....	93.6	....	81.4	....	70.4	37.3	44.5	20.3	57.5	....	....	....
1890........	47.7	....	54.5	...	62.6	....	68.1	....	78.0	....	89.2	53.2	94.6	61.2	91.1	55.1	83.1	44.6	72.1	29.7	60.0	21.5	54.4	16.9	....	....
1891........	38.5	8.6	46.4	15.4	58.4	21.0	68.0	33.8	76.0	45.3	82.1	54.8	89.2	58.2	91.4	55.8	85.0	50.1	73.8	32.2	56.5	20.6	43.4	18.0	....	....
1892........	40.0	12.6	50.1	20.7	50.9	23.2	68.9	32.4	72.7	42.3	84.2	52.1	91.7	58.4	91.2	56.9	89.8	47.8	70.1	35.4	56.4	23.8	40.0	12.1	....	....
1893........	53.7	17.0	50.4	16.1	61.4	22.0	68.4	32.7	77.3	40.9	91.9	55.6	92.4	58.4	86.1	57.7	83.0	47.7	72.9	33.2	55.4	21.3	49.9	19.3	....	....
1894........	48.1	14.5	39.0	10.0	59.8	26.8	70.7	36.2	81.1	46.9	86.8	52.2	92.4	57.6	90.5	55.6	82.4	46.3	74.9	33.5	60.9	21.2	46.7	15.5	....	....
1895........	40.2	13.3	39.6	9.1	56.5	22.5	71.4	35.5	77.0	44.0	84.0	52.6	84.2	56.4	87.1	56.5	88.0	48.1	69.9	33.0	54.7	18.7	44.6	15.4	....	....
1896........	52.6	18.2	52.9	18.4	57.6	21.3	73.3	35.2	81.4	45.0	91.1	55.2	90.9	59.6	91.9	58.4	80.6	51.7	66.5	34.7	52.5	20.1	55.4	16.9	....	....
1897........	38.4	13.3	48.1	21.4	56.0	23.5	67.1	33.2	....	....	....	....	....	....	87.5	52.8	85.6	53.0	68.9	39.1	59.5	23.9	41.3	12.1	....	....
1898........	42.6	12.7	55.9	21.1	57.5	22.6	69.4	37.6	70.6	43.6	83.7	55.3	88.9	59.4	91.3	57.4	79.3	42.9	65.7	32.9	54.0	20.8	38.8	9.4	66.5	34.6
1899........	42.6	12.1	33.1	0.6	57.6	22.7	71.3	34.1	79.0	45.0	88.2	53.6	87.0	58.0	90.8	56.6	83.8	47.8	71.8	36.0	59.3	28.5	41.6	12.6	67.2	34.0
1900........	48.8	20.2	47.4	14.2	63.9	26.4	61.8	35.7	76.5	46.9	88.8	55.1	90.8	58.0	92.6	54.9	81.6	48.7	73.9	37.4	59.3	22.0	51.6	13.4	69.8	36.1
1901........	50.3	11.9	44.0	13.2	57.3	24.4	67.8	35.8	75.8	46.9	89.7	54.0	97.0	61.8	91.7	58.7	83.5	47.8	73.3	37.6	63.3	24.9	46.4	13.6	70.0	35.9
1902........	46.5	13.1	55.4	20.3	58.1	26.0	70.0	37.7	80.0	47.8	87.0	55.0	91.4	56.7	92.3	58.7	80.1	43.9	72.5	35.6	58.0	25.4	45.6	15.1	69.7	36.3
1903........	50.7	18.6	38.7	10.9	56.9	25.4	68.4	36.9	75.7	42.6	78.2	52.1	92.2	58.8	89.9	58.6	82.1	45.7	71.1	32.2	55.7	22.3	50.4	15.7	67.5	35.0
1904........	45.2	12.0	58.2	18.8	63.1	27.4	67.1	35.3	73.8	44.9	81.8	51.0	89.3	56.4	87.0	56.4	82.7	49.2	70.0	38.6	62.9	20.7	50.4	14.7	69.3	35.5
1905........	39.8	15.0	38.2	10.0	59.0	31.2	63.6	34.5	74.2	44.5	88.0	57.1	88.3	56.7	91.4	57.8	84.2	49.4	69.8	29.9	62.1	26.3	46.4	9.4	67.1	35.2
1906........	52.9	16.7	56.0	15.7	48.5	21.0	68.1	34.9	77.3	44.6	86.8	53.0	86.6	57.1	89.3	56.7	80.5	48.9	69.1	33.0	55.8	22.7	54.2	18.9	68.8	35.3
1907........	49.8	14.2	58.8	19.2	68.1	29.2	62.8	34.0	68.1	41.8	82.9	52.2	89.8	59.0	87.9	58.8	84.2	48.9	73.6	35.6	58.3	22.2	48.0	15.7	69.4	35.9
1908........	50.5	13.6	49.6	19.7	66.4	28.2	70.4	33.6	76.1	40.9	87.7	56.4	89.6	58.6	88.6	58.7	85.7	46.4	68.0	34.0	52.5	21.6	43.1	18.1	69.0	35.8
1909........	50.9	17.7	51.6	16.9	57.7	19.6	64.2	33.0	73.0	41.2	85.0	53.7	92.7	60.5	91.1	60.3	80.5	48.2	71.6	35.4	56.8	25.9	34.8	8.7	67.5	35.1
1910........	48.0	15.2	49.4	13.5	72.6	30.9	72.2	35.9	74.7	44.1	88.0	54.5	90.6	59.6	88.6	56.6	86.6	49.8	77.5	33.8	62.6	26.1	51.2	15.3	71.8	36.3
1911........	56.5	19.4	47.2	15.8	64.3	28.6	69.2	35.8	79.9	49.2	89.6	56.8	88.1	60.7	89.2	57.0	86.0	52.4	66.6	35.4	52.4	19.0	39.2	6.1	69.0	36.4
1912........	34.9	5.0	43.1	20.6	43.7	21.2	66.3	35.4	76.1	45.4	81.9	51.1	89.2	59.0	88.1	56.9	76.6	46.4	70.2	34.7	61.0	21.8	47.6	13.3	65.5	34.2
1913........	45.7	10.5	36.8	11.5	55.2	24.1	67.7	35.2	80.7	47.2	83.3	55.8	90.5	59.8	93.2	57.4	76.9	48.3	65.0	33.8	58.2	27.5	32.8	8.6	65.5	35.0
1914........	46.9	21.6	47.5	15.2	59.1	24.5	66.8	36.2	75.7	47.6	86.9	57.3	87.1	60.5	89.4	57.1	84.3	50.4	71.3	38.1	62.3	24.1	36.3	11.5	67.8	37.0
1915........	45.6	12.0	52.9	21.3	47.6	21.9	68.2	41.4	70.5	42.1	82.1	54.0	84.9	58.2	82.8	55.2	80.5	49.9	74.3	33.6	63.4	23.9	47.5	16.0	66.7	35.8
1916........	40.0	13.3	57.7	18.9	66.2	30.1	65.4	35.4	77.7	44.3	87.6	54.4	94.1	61.6	86.8	59.6	80.0	46.8	70.5	36.3	54.7	22.0	44.9	12.6	68.8	36.3
1917........	46.8	10.9	52.1	19.3	58.2	20.6	65.6	33.3	69.2	42.0	87.0	51.4	92.8	61.6	86.9	56.4	81.8	50.5	67.9	33.5	64.3	26.7	51.6	14.5	68.7	35.1
Average....	46.2	14.2	48.4	15.8	58.7	24.7	68.0	35.3	75.9	44.5	86.1	54.1	90.4	59.0	89.6	57.1	82.7	48.9	70.8	34.7	57.8	23.0	46.1	13.9	68.4	35.4
Maximum ..	56.5	21.6	58.8	21.4	72.6	31.2	73.3	41.4	81.4	49.2	91.9	57.3	97.0	61.8	93.6	60.3	89.8	66.2	74.9	39.1	64.3	28.5	57.5	19.3	....	....
Minimum...	34.9	5.0	33.1	0.6	43.7	19.6	61.8	32.4	68.1	40.9	78.2	51.0	84.2	56.4	86.1	52.8	76.6	42.9	65.0	29.7	44.5	18.7	32.8	6.1	....	....

TABLE XXVI—EXTREME MONTHLY TEMPERATURES
At Arkansas Valley Sub-Station, Rocky Ford, Colorado.

YEAR.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1888	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	83	31	74	18	62	13
1889	52	**-11**	54	-3	73	20	83	31	90	32	98	49	**104**	62	102	62	98	32	89	24	60	10	70	8
1890	74	**-10**	79	-8	80	3	86	19	91	42	102	39	**104**	55	103	47	96	31	83	22	80	13	70	6
1891	54	**-8**	72	-8	72	-6	90	15	89	31	95	43	98	50	**100**	45	95	34	82	24	76	4	69	-4
1892	68	-8	60	-5	75	-10	90	21	90	31	97	36	102	50	**104**	43	98	36	89	25	77	14	73	**-14**
1893	71	5	71	**-1**	88	4	85	17	94	19	**102**	41	101	45	92	47	94	39	86	22	77	5	66	7
1894	71	-6	59	-13	80	9	87	24	93	30	**101**	40	100	51	100	42	93	32	87	15	79	7	75	**-23**
1895	65	-11	71	**-23**	83	-3	85	19	96	31	97	42	98	46	97	48	**100**	28	82	16	76	-3	68	-10
1896	67	4	72	1	84	-2	87	15	94	33	**101**	41	98	54	100	49	97	38	85	14	81	**-5**	72	10
1897	54	**-15**	65	0	74	7	85	20	..	..	..	..	..	..	99	46	98	42	88	24	80	10	74	-8
1898	61	-10	74	12	74	2	86	23	90	30	99	41	99	53	**100**	52	96	32	90	20	80	2	64	**-17**
1899	61	-20	60	**-32**	82	2	87	18	94	32	**105**	43	102	53	99	45	99	35	92	22	74	19	66	-20
1900	67	2	67	-10	82	19	79	17	90	38	101	48	**103**	52	96	44	95	30	88	26	77	9	70	**-21**
1901	70	**-22**	69	-5	83	10	86	16	88	37	**105**	43	103	57	100	53	93	33	84	28	76	15	75	-16
1902	68	**-10**	72	-9	74	8	89	25	89	35	103	48	102	44	**104**	50	95	30	86	25	77	9	71	-7
1903	70	5	61	**-15**	77	-2	85	20	87	32	97	39	**101**	41	**101**	49	96	29	89	22	76	-12	68	3
1904	66	0	81	5	81	15	88	24	88	32	94	45	**99**	49	95	44	94	40	89	21	75	5	68	**-12**
1905	64	-13	67	**-24**	77	18	84	19	87	32	**100**	50	96	48	**100**	51	91	36	90	16	78	7	60	-4
1906	67	3	78	0	74	1	84	15	89	35	**99**	39	98	49	98	47	90	41	88	13	78	**-1**	75	5
1907	72	7	78	5	92	10	88	21	90	27	94	38	**97**	51	96	52	96	36	89	26	74	9	68	**-5**
1908	64	**-7**	72	-4	86	17	86	18	92	30	101	43	**102**	51	98	50	97	27	90	20	77	6	63	4
1909	69	**-18**	66	-9	74	-8	85	17	87	18	99	44	**102**	55	98	54	93	35	89	24	78	-1	64	-13
1910	74	-6	72	**-17**	85	15	91	22	92	31	100	41	**101**	54	98	39	95	37	90	13	81	16	67	4
1911	77	-15	72	-16	77	3	82	23	93	29	99	45	95	54	**100**	47	99	36	90	14	72	-16	64	**-26**
1912	58	**-19**	63	1	71	6	85	25	91	29	94	36	**98**	46	97	50	92	31	84	23	78	11	64	1
1913	65	**-21**	68	-12	77	0	84	21	93	33	95	43	**102**	51	101	49	93	32	85	13	77	15	46	-10
1914	66	9	70	-6	75	12	89	21	90	37	**98**	45	96	52	**98**	50	94	38	85	27	78	15	50	**-14**
1915	65	-2	74	-1	74	3	84	27	92	30	94	37	**97**	49	92	47	92	40	86	25	83	4	73	**-13**
1916	67	**-10**	72	-4	83	11	86	19	96	30	100	45	**101**	55	99	49	91	30	89	19	84	-6	69	-4
1917	68	**-9**	72	-8	82	-1	88	22	86	30	**101**	35	100	53	96	47	94	38	89	0	78	14	75	-1
Extreme	77	-22	81	-32	92	-10	91	15	96	18	105	35	104	41	104	39	100	27	92	0	84	-16	75	-26

NOTE—Extremes are printed in bold faced type.

TABLE XXVII—MONTHLY MEAN TEMPERATURE

At Arkansas Valley Sub-Station, Rocky Ford, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888	...	...	...	...	...	...	...	...	73.3	56.4	38.8	35.0	...
1889	20.2	29.1	45.6	54.0	60.8	72.4	74.7	73.4	60.2	50.6	32.4	35.0	50.7
1890	21.4	30.0	38.7	48.9	56.7	71.2	77.8	73.1	63.8	50.6	40.7	35.6	50.7
1891	23.6	31.0	39.7	50.9	60.6	68.4	73.7	73.3	67.6	53.0	38.5	30.7	50.9
1892	26.3	35.4	37.0	50.7	57.5	68.1	75.1	74.1	68.8	52.7	40.1	26.0	51.0
1893	35.3	33.2	41.7	50.6	59.1	73.8	75.4	71.9	65.4	53.0	38.3	34.6	52.7
1894	31.3	24.5	43.3	53.4	64.0	69.5	75.0	73.1	64.4	54.2	41.1	31.1	52.1
1895	26.7	24.4	39.5	53.5	60.5	68.3	70.3	71.8	68.0	51.5	36.7	30.0	50.1
1896	35.4	35.7	39.4	54.2	63.2	73.2	75.2	75.2	66.3	50.6	36.3	36.2	...
1897	25.9	34.8	39.8	50.2	...	...	...	70.2	69.3	54.0	41.7	26.7	...
1898	27.6	38.5	40.1	53.5	57.6	69.5	74.2	74.4	61.1	49.3	37.4	24.1	50.6
1899	27.4	16.9	40.2	52.7	62.0	70.9	72.5	73.7	65.8	53.9	43.9	27.1	50.6
1900	34.5	30.8	45.2	48.7	61.7	72.0	74.4	73.7	65.2	55.6	40.7	32.5	52.9
1901	31.1	28.6	40.8	51.8	61.4	71.8	79.4	75.2	65.7	55.4	44.1	30.0	52.9
1902	29.8	37.8	42.1	53.6	63.9	71.3	74.1	75.6	62.0	53.7	41.7	30.5	53.0
1903	34.6	24.8	41.2	52.6	59.2	65.1	75.5	74.2	63.9	51.6	39.0	33.0	51.2
1904	28.6	38.5	45.3	51.2	59.4	66.4	72.9	71.7	66.0	54.3	41.8	32.5	52.4
1905	27.4	24.1	45.1	49.0	59.3	72.5	72.5	74.6	66.8	49.8	44.3	27.9	51.1
1906	34.8	36.0	34.8	51.5	61.0	69.9	71.9	73.0	64.7	51.0	39.2	36.5	52.0
1907	32.0	39.0	48.6	48.4	55.0	67.6	74.4	73.4	66.6	54.6	40.3	31.9	52.6
1908	32.1	34.6	47.5	52.0	58.5	72.0	74.1	73.7	66.0	51.0	37.0	30.6	52.4
1909	34.3	34.2	38.7	48.6	57.1	69.4	76.6	75.7	64.3	53.5	41.4	21.8	51.3
1910	31.3	31.4	51.7	54.1	59.4	71.2	75.1	72.6	68.2	55.7	44.4	33.3	54.0
1911	38.0	31.5	46.5	52.5	64.5	73.2	74.4	73.1	69.2	51.0	35.7	22.7	52.7
1912	19.9	31.8	32.5	50.9	60.7	66.5	74.1	72.5	61.5	52.4	41.4	30.7	49.6
1913	28.1	24.1	39.6	51.5	64.0	69.5	75.2	75.3	62.6	49.4	42.9	20.7	50.2
1914	34.3	31.4	41.8	51.5	61.6	72.1	73.8	73.3	67.4	54.7	43.2	23.9	52.4
1915	28.8	37.1	34.8	54.8	56.3	68.1	71.5	69.0	65.2	54.0	43.6	31.8	51.2
1916	26.7	38.3	48.2	50.4	61.0	71.0	77.9	73.2	63.4	53.4	38.3	28.8	52.6
1917	28.9	35.7	39.4	49.4	55.6	69.2	77.2	71.6	66.2	50.7	45.5	33.1	51.5
Average	29.5	31.8	41.7	51.6	60.1	70.1	74.6	73.3	65.6	52.7	40.3	30.1	51.8
Maximum	38.0	39.0	51.7	54.8	64.5	73.8	79.4	75.7	73.3	56.4	45.5	36.5	50.4
Minimum	20.2	16.9	32.5	48.4	55.0	65.1	70.3	69.0	60.2	49.3	32.4	20.7	50.1

TABLE XXVIII—MONTHLY PRECIPITATION

At Arkansas Valley Sub-Station, Rocky Ford, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888	...	...	...	...	...	...	...	...	...	...	...	...	....
1889	0.36	0.12	0.67	2.12	1.75	0.75	4.50	1.28	0.26	1.68	0.77	0.04	14.30
1890	0.34	0.15	0.15	2.97	0.29	0.77	1.14	0.74	0.08	0.00	0.30	0.00	6.93
1891	1.50	0.00	1.80	0.43	3.52	2.31	0.74	0.73	1.75	0.21	0.20	1.77	14.96
1892	0.50	0.80	1.50	0.73	3.26	3.31	1.99	3.10	0.00	0.95	0.50	0.46	17.10
1893	0.02	0.08	0.80	0.25	0.70	0.40	10.26	3.20	0.30	0.25	T	0.50	16.76
1894	0.10	0.95	0.45	0.60	4.25	0.70	1.40	0.25	0.80	0.00	0.04	0.65	10.19
1895	0.27	0.65	0.07	0.35	1.90	0.52	4.37	1.86	T	0.85	0.20	0.57	12.11
1896	0.32	0.18	0.23	0.55	1.12	0.47	2.09	0.47	1.85	1.96	0.00	0.70	9.94
1897	0.75	0.37	0.20	0.44	...	...	...	0.73	0.79	2.64	0.19	1.06	....
1898	0.40	0.00	0.16	1.06	2.71	3.16	3.52	0.92	1.55	1.36	0.37	0.96	16.17
1899	0.98	0.55	0.32	0.28	0.99	0.78	7.00	2.22	1.43	0.63	2.40	0.98	18.56
1900	T	0.52	0.37	7.15	2.28	1.47	1.77	1.05	0.08	0.60	0.06	0.24	15.59
1901	0.20	0.10	1.00	2.36	1.34	0.23	1.48	0.74	0.48	0.25	0.00	0.50	8.68
1902	0.18	0.57	1.78	0.18	4.02	0.60	0 72	2.72	0.46	0.80	0.41	0.33	12.77
1903	T	1.05	0.18	0.56	0.28	3.94	0.42	0.87	T	1.62	0.26	0.22	9.40
1904	T	T	0.77	0.81	2.03	2 20	1.75	0.33	2.34	0.50	0.00	0.31	11.04
1905	0.05	0.11	2.11	4.67	2.13	1.56	1.30	0.45	1.48	0.10	0.41	0.02	14.39
1906	0.23	0.10	0.92	5.59	0.59	0.54	2.05	1.21	1.64	1.57	0.22	T	14.66
1907	T	T	0.00	1.84	1.85	0.69	4.96	0.78	0.33	0.88	2.00	0.26	13.59
1908	0.18	0.35	T	0.14	0.89	1.16	2.65	2.89	0.00	1.96	0.86	0.04	11.12
1909	0.15	0.15	0.65	0.95	0.75	1.21	0.65	2.53	1.72	0.90	1.07	0.14	10.87
1910	T	0.17	0.35	2.40	2.00	0 27	3.58	1.57	0.00	T	0.43	T	10.77
1911	T	0.65	0.05	0.60	0.65	0.67	1.51	0.69	0.12	1.25	0.20	1.16	7.55
1912	0.16	0.75	0.16	0.65	1.70	1.57	1.22	0.82	1.77	0.40	0.00	0.00	9.20
1913	0.17	0.62	T	1.65	0.42	2.87	2.82	0.00	0.54	0.77	0.67	2.32	12.85
1914	0.00	0.14	0.35	2.92	3.38	2.68	3.09	0.87	1.18	1.68	T	0.30	16.59
1915	0.10	0.91	0.51	3.64	4.55	1.10	3.36	3.22	0.69	0.22	0.15	0.30	18.75
1916	T	T	0.32	1.78	0.80	0.88	0.45	4.52	1.01	0.16	0.10	0.31	10.33
1917	0.17	0.22	0.35	0.99	1.62	0.25	1.60	1.18	2.45	0.12	0.00	T	8.95
Average	0.25	0.35	0.56	1.68	1.85	1.32	2.60	1.45	0.87	0.84	0.41	0.49	12.67
Maximum	1.50	0.95	2.11	7.15	4.55	3.94	10.26	4.52	2.45	2.64	2.40	2.32	18.75
Minimum	0.00	0.00	0.00	0.14	0.28	0.23	0.42	0.00	0.00	0.00	0.00	0.00	6.93

TABLE XXIX—MONTHLY MEAN TEMPERATURE

At Plains Sub-Station, Cheyenne Wells, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1894	...	...	...	...	...	70.7	74.4	72.5	64.5	54.8	42.9	30.0	...
1895	24.3	23.2	38.2	52.3	59.7	65.9	69.0	71.6	67.6	50.6	34.8	26.7	47.8
1896	33.2	36.0	36.2	52.7	62.1	70.8	74.3	74.3	62.2	49.7	33.2	37.8	51.9
1897	25.9	31.7	35.2	48.0	62.0	68.9	74.1	70.0	69.0	53.6	39.8	26.6	50.4
1898	28.9	35.0	35.7	49.1	55.3	67.8	72.8	73.7	62.2	47.0	33.4	26.1	48.9
1899	26.4	14.9	34.9	49.8	59.5	68.8	71.8	75.6	66.3	53.4	43.4	28.1	49.4
1900	34.5	28.6	41.2	48.4	60.1	70.7	74.2	75 2	64.2	54.9	43.9	31.4	52.3
1901	30.2	24.7	36.0	47.8	58.7	71.6	78.9	74.3	64.0	54.0	43.4	29.5	51.1
1902	28.9	33.6	39.6	49.9	62.7	66.6	72.0	73.6	59.4	54.4	40.0	27.6	50.7
1903	32.0	20.9	36.2	48.5	56.0	62.0	73.4	72.4	64.0	53.0	41.3	34.1	49.5
1904	26.9	34.7	42.4	48.2	57.6	65.9	72 3	70.5	64.8	54.0	43.6	32.8	51.1
1905	27.3	18.8	44.9	47.6	55.0	69.7	69.8	74 5	67.4	48.7	43.5	30.3	49.8
1906	33.8	34.9	28.8	51.2	57.7	65.9	68.7	71.8	63.5	51.5	39.6	38.0	50.4
1907	30.1	36.5	46.8	47.8	53.4	66.4	74.5	74.1	64.8	54.8	40.4	43.0	52.8
1908	30.9	32.6	41.5	50.6	57.2	68.5	71.8	70.4	67.5	50.6	40.5	25.6	50.6
1909	26.4	33.2	35.9	45.7	55.6	66.4	74.6	74.3	63.0	50.9	40.4	18.0	48.7
1910	27.2	...	51.2	50.8	56.4	70.1	75.7	72.0	67.0	56.4	43.3	34.4	...
1911	33.8	29.2	44.6	49.2	60.9	73.3	73.5	73.0	68.7	48.5	34.7	24.7	51.2
1912	21.4	29.7	26.7	47.6	59.3	65.0	72.8	70.5	58.6	51.0	40.9	29.7	47.8
1913	27.0	22.5	36.0	51.0	59.7	68.4	75.6	76.8	61.6	49.0	43.6	24.9	49.7
1914	33.2	28.4	40.0	50.0	59.0	71.8	73.3	73.9	67.7	54.4	46.5	22.8	51.8
1915	26.2	35.1	30.3	52.1	54.6	63.7	69.3	66.4	63.0	54.5	43.2	32.0	49.2
1916	22.6	34.3	45.8	45.3	59.1	68.6	78.4	73.4	63.4	49.6	38.2	24.2	50.2
1917	27.6	32.2	34.9	45.4	51.8	68.0	76.2	70.8	66.4	48.6	46.0	30.2	49.8
Average	28.6	29.6	38.4	49.1	58.0	68.1	73.4	72.7	64.6	52.0	40.9	29.5	50.4
Maximum	34.5	36.5	51.2	52.7	62.7	73.3	78.9	76.8	69.0	56.4	46.5	43.0	52.8
Minimum	21.4	14.9	26.7	45.3	51.8	62.0	68.7	66.4	58.6	47.0	33.2	18.0	47.8

November, 1900, 14 days; December, 21 days.

December, 1907, 15 days.

TABLE XXX—MONTHLY PRECIPITATION

At Plains Sub-Station, Cheyenne Wells, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1894	...	...	...	...	...	0.48	1.99	1.03	0.14	0.14	T	0.55	...
1895	0.67	0.27	0.16	1.67	1.49	3.00	6.38	1.22	T	0.21	0.30	0.42	15.79
1896	0.45	T	0.71	3.41	2.28	3.03	2.27	3.07	0.84	0.78	T	0.60	17.44
1897	0.26	0.10	1.58	1.20	1.44	2.22	4.19	3.24	0.92	2.73	0.10	0.20	18.18
1898	0.03	0.00	0.61	1.10	5.56	3.95	2.09	1.33	2.00	0.48	0.50	0.48	18.13
1899	0.47	0.36	0.39	0.03	2.88	1.89	3.67	0.55	0.78	T	2.49	0.55	14.06
1900	0.03	0.67	0.56	9.95	0.80	2.47	2.02	0.30	1.31	0.22	T	0.18	18.53
1901	0.15	0.38	0.71	4.02	1.18	0.90	2.63	2.59	1.12	0.49	0.02	0.25	14.44
1902	T	0.25	1.92	0.78	3.12	2.53	1.42	6.06	0.20	1.32	0.00	0.75	18.35
1903	0.34	0.79	0.23	0.94	3.71	2.63	1.87	1.89	T	T	0.75	0.13	13.28
1904	T	T	0.11	1.59	2.51	4.78	3.39	4.89	4.26	0.99	0.00	0.29	22.81
1905	0.14	0.35	2.00	5.16	2.13	2.58	2.02	1.12	2.41	0.40	0.00	T	18.31
1906	0.21	0.24	0.89	3.77	1.24	3.00	4.26	2.39	2.36	0.90	0.20	T	19.46
1907	T	T	0.13	0.72	1.10	2.86	1.98	0.95	1.28	0.25	0.25	0.20	9.72
1908	T	0 57	T	0.02	2.06	1.50	4.88	2.72	T	4.75	1.25	0.70	18.45
1909	0.42	0.16	1.85	0.45	1.96	8.62	3.63	0.78	2.93	1.15	1.43	0.27	24.82
1910	T	..	0.09	1.15	2.54	0.88	2.76	3.10	1.53	T	T	T	...
1911	T	1.34	T	1.10	0.99	1.23	2.87	2.36	0.44	1.14	0.25	2.10	13.82
1912	T	1.53	1.42	0.63	0.34	3.30	3.20	2.77	2.16	0.42	0.10	0.05	15.92
1913	0.60	1.73	1.00	1.93	1.14	2.93	0.99	0.69	1.23	0.54	0.21	2.72	15.71
1914	0.19	0.10	T	1.70	4.09	1.15	2.16	1.00	0.04	2.96	0.00	0.50	13.89
1915	0.88	1.17	1.03	2.77	4.85	2.19	5.09	5.60	0.82	T	0.41	0.55	25.36
1916	0.44	T	0.32	2.93	1.47	2.04	1.01	4.14	0.68	0.15	0.57	0.64	14.39
1917	0.21	0.50	0.77	1.53	2.59	1.33	1.28	1.74	2.74	0.35	0.25	0.30	13.59
Average	0.26	0.48	0.67	2.11	2.24	2.56	2.84	2.31	1.26	0.85	0.38	0.52	16.46
Maximum	0.88	1.73	2.00	9.95	5.56	8.62	6.38	6.06	4.26	4.75	2.49	2.72	25.36
Minimum	T	0.00	T	0.02	0.34	0.48	0.99	0.30	T	T	0.00	T	0.72

TABLE XXXI—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURE

At Plains Sub-Station, Cheyenne Wells, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1894	....	....	....	....	....	....	....	....	....	....	87.9	53.5
1895	36.2	12.4	37.0	9.4	54.3	22.0	69.4	36.4	75.2	44.2	80.2	51.6
1896	47.1	19.2	50.5	21.4	50.3	22.0	69.8	35.5	76.1	48.2	87.4	54.2
1897	38.2	13.7	45.8	17.6	48.5	22.0	61.9	34.1	76.8	47.2	84.7	53.2
1898	43.3	14.5	52.2	17.8	52.9	18.5	64.2	34.0	67.3	43.4	80.9	54.6
1899	42.0	10.7	28.5	1.3	50.1	19.9	67.4	32.2	75.8	43.3	85.0	52.6
1900	47.9	21.4	42.3	14.8	56.4	26.1	59.2	37.6	74.1	46.1	85.0	56.4
1901	44.6	15.7	37.0	12.4	50.0	21.9	62.5	33.2	72.9	44.4	89.2	54.2
1902	44.1	13.7	49.0	18.1	53.1	26.0	65.6	34.2	78.1	47.2	78.7	51.5
1903	44.8	19.2	31.0	10.7	48.9	23.5	64.2	32.8	69.8	42.2	73.6	50.3
1904	43.3	10.5	53 3	16.0	60.1	24.8	65.0	31.5	70.8	44.4	80.2	51.6
1905	39.4	15.3	32.7	4.8	57.8	32.0	61.7	33.4	68.4	41.6	84.0	55.5
1906	48.4	19.3	51.6	18.2	39.4	18.2	68.1	34.3	73.5	41.9	82.6	49.3
1907	46.1	14.2	52.3	20.7	65.2	28.4	65.5	30.1	67.9	38.9	84.0	48.7
1908	45.8	15.9	47.7	17.6	58.1	24.9	70.1	31.1	74.0	40.4	85.6	51.4
1909	36.3	16.5	47.5	18.9	48.5	23.3	60.7	30.6	72.2	38.9	81.7	51.1
1910	38.5	15.9	....	....	70.6	31.8	68.1	33.3	70.0	42.9	86.4	53.8
1911	52.2	18.0	42.9	15.4	60.9	28.3	65.3	33.0	78.0	43.9	90.5	56.2
1912	33.5	9.4	40.5	18.9	35.7	17.8	62.2	32.9	74.9	43.6	80.1	49.8
1913	40.7	13.4	35.1	9.9	51.2	20.7	67.3	34.7	75.5	43.8	82.2	54.6
1914	42.2	24.3	43.0	13.9	55.9	24.2	64.9	35.0	72.1	45.9	87.2	56.3
1915	39.7	12.8	48.1	22.2	40.4	20.3	64.5	39.8	67.8	41.4	75.8	51.7
1916	36.2	9.0	50.1	18.5	64.2	27.3	59.7	31.0	75.4	42.8	84.2	52.8
1917	43.7	11.5	48.6	15.9	51.5	18.3	59.7	31.1	65.2	38.4	85.8	50.3
Average	42.4	15.1	43.9	15.2	53.2	23.6	64.7	33.6	72.7	43.3	83.5	52.7
Maximum	52.2	24.3	53 3	24.1	70.6	32 0	70.1	39.8	78.1	48.2	90.5	56.4
Minimum	33.5	9.0	28.5	1.3	35.7	17.8	59.2	30.1	65.2	38.4	73.6	48.7

DATE.	July		August		Septemb'r		October		November		December		Year	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1894	90.2	58.7	87.2	57.7	80.8	48.3	73.4	36.2	62.0	23.9	44.6	15.3	....	....
1895	81.2	56.7	86.1	57.2	85.1	50.2	66.3	34.9	49.0	20.7	39.2	14.2	63.3	34.2
1896	88.4	60.2	88.9	59.7	76.0	48.4	64.4	35.1	47.3	19.1	53.6	22.0	66.6	37.1
1897	89.8	58.4	83.2	56.7	84.2	53.8	67.4	39.8	56.0	23.6	38.9	14.3	64.6	36.2
1898	86.7	59.0	89.2	58.2	78.4	45.9	62.6	31.4	49.2	17.6	40.4	11.8	63.9	33.9
1899	85.1	58.6	91.5	59.8	83.0	49.6	69.1	37.2	57.9	28.9	38.3	17.9	64.5	34.3
1900	88.9	59.4	91.8	58.6	78.3	50.1	71.1	38.7	61.4	24.0	47.0	18.1	67.0	37.6
1901	95.6	62.2	89.3	59.4	79.1	48.8	69.7	38.2	59.5	27.2	43.6	15.4	66.1	36.1
1902	87.9	55.6	88.7	58.6	74.6	44.3	69.3	39.4	54.0	26.0	40.3	14.8	65.3	35.8
1903	88.0	58.8	86.8	58.1	80.7	47.3	70.8	35.2	56.7	25.9	50.7	17.5	63.8	35.1
1904	86.5	58.1	86.5	56.4	79.9	49 7	68.3	39.7	60.3	26.9	46.6	19.0	66.7	35.7
1905	84.6	54.9	91.0	57.9	84.2	50.7	66.9	30.5	58.2	28.9	46.2	14.3	64.6	35.0
1906	82.4	55.0	88.3	55.3	78.1	49.0	68.9	34.1	56.8	22.5	53.3	22.8	66.0	35.0
1907	90.5	58.4	89.5	58.8	82.3	47 2	71.8	37.9	55.6	25.2	58.8	27.2	69.1	36.3
1908	86.0	57.5	84.9	55.8	84.8	50.2	66.4	34.9	55.1	25.9	37.8	13.5	66.4	34.9
1909	89.0	60.1	89.8	58.8	78.0	47.9	68.8	33.0	53.1	27.6	28.7	7.4	62.9	34.5
1910	91.8	59.6	86.5	57.5	81.4	52.6	72.8	40.0	59.2	27.4	49.3	19.5	....	....
1911	87.5	59.4	88.4	57.5	84.8	52.6	61.9	35.2	50.1	19.3	37.8	11.6	66.7	35.9
1912	86.8	58.8	84.5	56.6	72.0	45.2	66.7	35.3	56.6	25.3	43.9	15.5	61.4	34.1
1913	91.3	59.8	94.1	59.4	75.9	47.2	63.4	34.7	57.6	29.5	32.6	17.1	63.9	35.4
1914	86.8	59.8	89.3	58.5	83.7	51.6	69.6	39.1	61.3	31.6	33.3	12.2	65.8	37.7
1915	81.9	56.7	78.5	54.2	76.6	49.4	71.8	37.2	59.5	26.8	46.8	17.2	62.6	35.8
1916	95.1	61.7	88.5	58.3	80.3	46.5	65.3	33.9	52.8	22.0	38.7	9.8	65.3	34.5
1917	92.4	60.1	85.9	55.8	80.4	52.3	65.2	32.0	60.7	31.3	46.8	13.6	65.5	34.2
Average	88.1	58.6	87.8	57.7	80.1	49.1	68.0	36.0	56.2	25.3	43.2	15.9	65.3	35.5
Maximum	95.6	62.2	94.1	59.8	85.1	53.8	73.4	40.0	62.0	31.6	58.8	27.2	69.1	37.7
Minimum	81.2	54.9	78.5	54.2	72.0	44.3	62.6	30.5	47.3	17.6	28.7	7.4	61.4	33.9

TABLE XXXII—EXTREME MONTHLY TEMPERATURES

At Plains Sub-Station, Cheyenne Wells, Colorado.

YEAR.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1894	..	..	..	..	..	..	..	..	..	..	100	45	101	48	96	50	91	36	85	22	76	9	73	–14
1895	56	–3	68	**–15**	79	–9	84	19	96	30	96	38	97	50	97	48	**104**	25	79	17	70	4	62	–2
1896	61	–6	69	7	75	6	85	10	90	34	98	42	95	55	**101**	41	95	35	85	23	79	**–11**	66	12
1897	61	**–12**	63	9	70	7	82	26	92	37	98	43	**103**	48	96	51	96	37	88	21	79	3	64	–10
1898	69	0	70	4	72	–12	84	19	89	31	97	39	97	52	**98**	52	95	32	89	19	76	–12	68	**–17**
1899	61	–17	59	**–26**	76	6	83	15	91	26	102	39	99	52	101	50	**102**	32	93	26	71	4	63	1
1900	63	–6	62	–7	83	14	79	20	87	38	98	49	**100**	51	**100**	45	93	34	86	23	76	12	66	**–16**
1901	64	–17	63	–14	79	3	83	9	84	30	103	38	103	58	**109**	54	90	30	83	26	76	16	72	**–21**
1902	68	**–14**	67	–11	70	1	87	21	92	35	103	39	101	41	**104**	45	91	29	90	32	77	9	65	0
1903	70	3	53	**–10**	72	–2	79	14	84	30	94	36	97	48	**100**	47	96	27	87	24	77	–6	70	1
1904	65	**–11**	77	–4	76	–1	79	19	88	31	94	43	**96**	51	94	41	92	32	81	18	72	12	69	–2
1905	69	–14	82	**–17**	72	18	85	18	83	28	97	44	97	40	**100**	54	91	39	89	13	73	10	59	5
1906	67	**0**	70	2	68	0	83	25	89	34	92	34	93	45	**96**	44	90	38	87	20	75	8	70	6
1907	65	0	74	0	91	10	86	14	92	20	99	38	**100**	51	**100**	49	98	32	89	30	76	**–3**	72	15
1908	61	0	71	**–12**	80	10	85	12	92	30	**100**	40	97	48	97	50	97	24	86	23	76	7	47	–2
1909	54	**–11**	72	–6	63	2	84	21	89	18	96	42	95	53	**97**	46	94	35	91	23	77	8	54	–11
1910	64	–5	..	..	89	14	91	21	88	29	99	40	**101**	43	95	39	94	40	89	16	80	11	65	9
1911	71	**–18**	70	–5	74	4	81	21	95	27	100	50	97	55	**101**	34	97	50	86	13	63	–7	65	–18
1912	61	**–21**	55	–2	60	–6	77	21	95	31	94	36	**99**	48	96	50	93	29	85	21	76	5	60	4
1913	62	**–12**	64	–10	77	–1	85	17	94	32	101	42	**104**	49	101	51	94	28	83	12	76	18	50	4
1914	60	9	69	**–12**	73	8	87	13	89	31	100	41	99	50	**101**	49	96	40	85	23	75	19	52	–4
1915	55	**–11**	72	10	64	–1	82	29	94	28	91	35	**96**	46	89	44	87	37	85	26	80	2	70	–5
1916	66	**–15**	69	–13	80	–4	81	8	96	30	100	44	**101**	56	100	42	97	32	87	18	80	–5	72	**–15**
1917	66	**–8**	73	**–8**	80	–2	80	14	87	23	**101**	35	**101**	54	99	46	96	38	88	1	77	18	70	–6
Extreme	71	–21	82	–26	91	–12	91	8	96	18	103	34	104	40	109	34	104	24	93	1	80	–12	73	–21

NOTE—Extremes are printed in bold faced type.

TABLE XXXIII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

DATE.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December		Year	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1892	....	....	....	....	....	....	....	....	48.6	28.6	65.1	37.9	70.1	42.9	....	....	....	....	....	....	....	....	....	....	....	....
1893	....	....	27.4	9.0	36.3	14.3	40.8	19.9	53.7	27.8	69.5	37.3	74.3	39.9	68.1	40.6	64.8	34.4	49.2	26.5	38.7	18.5	33.7	18.7	....	....
1894	28.4	9.4	29.0	5.1	37.4	17.4	48.2	26.1	58.6	32.3	65.6	35.8	71.4	41.4	70.3	40.6	61.2	34.2	51.5	29.8	44.9	25.4	33.1	13.3	50.0	25.9
1895	27.7	11.0	30.0	7.1	35.6	14.3	50.6	23.5	54.9	29.9	62.6	35.2	67.6	40.4	69.8	41.0	64.3	35.5	50.6	24.2	37.4	16.4	28.5	13.5	48.3	24.3
1896	38.8	19.6	41.5	14.8	37.2	17.2	38.4	24.7	60.8	33.9	71.2	38.2	68.3	41.1	70.4	41.2	61.2	34.9	53.2	26.3	37.1	18.9	43.1	18.3	51.8	27.4
1897	35.4	12.3	29.7	8.6	33.0	12.3	43.1	21.9	57.9	32.2	62.5	36.7	67.7	41.6	63.5	43.6	66.2	34.8	53.2	26.1	44.7	23.7	33.1	12.0	49.2	25.5
1898	32.3	7.7	38.4	15.3	35.1	12.0	49.3	23.3	49.7	27.2	64.2	36.7	65.4	41.3	71.8	41.5	66.0	35.2	50.3	26.6	36.8	16.9	31.7	8.4	49.2	24.3
1899	30.9	12.6	23.9	7.0	33.6	14.0	46.6	24.3	54.6	29.2	64.3	36.0	68.7	40.6	69.9	42.0	67.6	35.4	49.1	25.5	47.2	23.0	37.2	13.8	49.5	25.3
1900	38.6	12.9	31.1	12.1	42.0	19.3	43.4	19.7	57.9	31.8	68.2	41.0	69.5	40.0	71.2	41.3	60.7	33.3	53.4	27.5	44.3	22.6	36.4	16.0	51.4	26.5
1901	34.4	12.4	31.8	10.2	33.6	14.2	43.3	20.8	55.3	32.5	64.3	37.9	74.3	42.7	69.3	42.3	61.9	32.9	54.6	28.2	46.8	22.7	33.6	13.5	50.3	25.9
1902	34.9	10.8	35.8	18.1	33.3	12.2	46.9	24.3	55.3	30.4	65.1	35.7	67.7	36.9	70.1	39.0	63.5	30.7	52.7	26.1	41.9	16.4	37.8	14.4	50.4	24.6
1903	35.3	13.7	22.4	-0.1	39.4	13.4	43.1	21.1	50.8	25.8	59.2	35.9	70.4	40.5	71.9	38.7	62.1	31.6	53.5	25.5	43.4	19.9	37.4	15.9	49.1	23.5
1904	30.0	8.6	36.7	16.9	40.9	22.1	47.0	21.7	51.4	29.4	60.4	34.8	67.6	35.6	69.2	39.9	66.9	33.7	53.1	25.3	49.1	19.9	35.6	13.6	50.7	25.1
1905	32.6	10.7	31.6	7.2	41.5	17.4	40.9	19.5	51.8	26.6	68.6	37.2	66.8	37.2	71.0	38.8	61.5	33.1	42.4	19.1	42.7	16.3	33.6	5.7	48.8	22.4
1906	36.2	11.6	38.0	8.9	34.3	8.1	44.9	21.2	54.6	29.2	63.8	32.6	65.5	36.2	69.0	35.7	60.6	33.4	51.4	22.6	39.7	14.4	40.3	16.7	49.9	22.6
1907	37.3	14.5	41.2	18.7	43.4	22.1	44.8	20.9	48.7	24.0	62.6	32.4	71.7	38.0	69.8	38.0	66.4	34.0	60.7	36.8	48.1	28.8	41.6	24.0	53.0	27.7
1908	44.1	20.2	39.7	15.7	41.0	19.7	49.1	23.6	52.7	27.5	61.7	33.6	66.5	38.0	65.9	40.8	64.0	34.1	49.0	23.5	41.5	14.6	37.0	12.1	51.0	25.3
1909	36.2	16.8	31.3	10.3	35.5	13.1	39.3	19.0	49.9	28.6	64.9	37.5	74.2	42.5	71.6	43.0	62.5	34.6	58.2	29.3	49.3	17.9	30.2	8.4	50.3	25.1
1910	36.8	14.4	36.3	9.6	52.3	23.1	48.7	22.7	56.5	28.1	68.2	34.4	73.2	35.9	71.5	36.2	64.5	34.8	59.9	24.4	50.5	12.9	44.1	7.3	55.2	23.7
1911	41.1	10.0	35.8	10.4	45.0	14.9	47.4	19.4	58.3	26.5	68.4	35.8	67.9	39.0	70.5	38.0	65.6	35.1	52.2	19.8	41.4	11.3	35.3	4.2	52.4	22.0
1912	33.4	8.5	28.5	3.0	36.2	5.2	42.5	15.2	53.4	24.7	62.9	47.6	68.5	38.7	69.3	39.2	55.3	28.0	50.9	23.5	47.9	17.0	39.3	11.0	49.0	21.8
1913	34.4	7.4	28.5	5.0	36.1	11.5	49.2	22.7	58.3	31.2	65.2	37.0	68.9	41.0	73.1	41.0	64.7	32.5	47.3	24.2	47.1	22.8	35.6	3.4	50.7	23.3
1914	37.6	16.9	32.9	10.0	42.1	14.9	46.7	24.1	57.3	32.6	70.1	38.6	71.1	41.2	74.5	40.0	68.1	34.1	55.6	27.1	48.8	20.6	31.8	-0.1	53.0	25.0
1915	29.9	8.4	36.2	13.4	35.2	11.4	49.5	27.1	51.6	26.5	61.1	34.2	68.6	39.1	66.9	36.1	61.4	33.0	56.8	27.4	40.7	21.1	36.6	13.5	49.5	24.3
1916	31.5	10.4	39.3	13.6	44.5	21.7	48.5	21.4	54.9	28.0	67.6	33.7	73.0	41.6	68.5	38.3	63.0	32.4	48.0	25.1	37.2	12.9	24.2	5.1	50.0	23.7
1917	28.6	6.0	32.3	10.5	31.1	7.1	41.4	17.5	45.8	23.9	66.4	33.9	70.7	39.0	69.5	37.5	66.5	31.9	55.5	22.7	48.9	21.0	37.6	19.5	49.5	22.5
Average	34.4	12.0	33.2	10.4	38.2	14.9	45.3	21.8	54.0	28.8	65.1	36.4	69.6	39.7	69.9	39.8	63.6	33.5	52.5	25.7	43.8	19.0	35.5	12.1	50.4	24.5
Maximum	44.1	20.2	41.5	18.7	52.3	23.1	50.6	27.1	60.8	33.9	71.2	47.6	74.3	42.9	74.5	43.6	68.1	35.5	60.7	36.8	50.5	28.8	44.1	24.0	55.2	27.7
Minimum	27.7	6.0	22.4	-0.1	31.1	5.2	38.4	15.2	45.8	23.9	59.2	32.4	65.4	35.6	63.5	35.7	55.3	28.0	42.4	19.1	36.8	11.3	24.2	-0.1	48.3	21.8

TABLE XXXIV—EXTREME MONTHLY TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

YEAR.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1892	..	..	..	..	..	..	..	..	..	..	..	..	77	35	..	..	..	..	..	..	..	..	..	..
1893	42	**-10**	42	-9	58	-6	60	-2	70	9	**81**	22	80	31	78	30	75	19	63	14	51	-6	45	-8
1894	47	-14	45	**-21**	51	-10	64	10	72	19	75	29	**80**	35	75	32	70	21	62	15	57	-9	51	-19
1895	45	-12	49	**-23**	59	-6	62	4	69	12	76	22	**79**	32	77	35	76	17	64	12	56	-6	52	-16
1896	50	1	50	-7	56	-8	68	-8	78	19	**85**	29	78	36	78	28	74	15	67	15	62	**-9**	60	1
1897	54	**-14**	48	-10	53	-11	60	1	68	23	74	26	**78**	32	75	22	75	28	67	2	72	-4	48	-9
1898	56	-21	52	0	52	-14	67	0	64	8	79	23	73	34	**81**	33	78	21	65	13	57	-12	51	**-24**
1899	46	-7	43	**-31**	54	-22	60	-1	65	17	79	22	78	37	79	32	**82**	20	69	8	59	6	55	-9
1900	53	-12	41	-9	60	8	63	-9	70	19	**81**	32	78	27	79	33	72	23	64	11	55	13	50	**-27**
1901	48	**-20**	45	-13	48	-6	63	-8	67	24	79	29	**82**	35	80	37	70	19	67	21	59	6	51	-14
1902	51	**-15**	49	-5	45	0	63	5	67	15	77	26	81	27	**83**	33	74	13	65	10	60	-6	52	-2
1903	48	-7	40	**-22**	53	-8	57	-4	62	3	**76**	19	76	31	75	29	75	12	65	4	55	-14	49	-4
1904	45	-11	48	**-13**	52	8	61	1	65	20	70	26	**76**	28	75	24	73	22	67	9	56	-2	52	-6
1905	42	-13	52	**-28**	54	-4	61	4	**79**	13	76	29	76	27	77	32	70	25	55	-5	55	-4	58	-13
1906	53	-12	54	-6	52	**-23**	61	2	69	18	**78**	25	78	27	75	27	73	26	67	3	53	-17	59	-7
1907	51	**-12**	49	1	59	5	60	-9	68	3	71	23	**80**	31	78	29	73	17	73	*31	65	10	62	0
1908	55	6	55	-5	53	-6	63	0	70	11	72	26	**80**	26	76	32	76	7	65	1	60	-8	56	**-13**
1909	52	**-14**	50	-8	53	-12	54	-4	72	12	78	31	**81**	36	79	33	74	20	70	16	64	-4	48	†-11
1910	51	-9	60	**-20**	62	0	69	10	73	14	76	23	**82**	29	78	25	80	29	76	-10	56	1	58	0
1911	48	0	47	2	70	0	61	-2	70	14	**80**	29	74	28	79	25	78	22	64	-9	53	-7	61	**-14**
1912	55	-11	41	**-23**	51	-14	60	1	70	7	74	15	75	31	**78**	32	70	11	64	8	59	-1	48	0
1913	47	**-25**	45	-13	51	-16	62	0	72	13	74	29	**81**	29	79	34	78	11	65	-1	62	-2	55	-12
1914	55	-6	52	-6	52	-20	60	5	70	21	78	30	79	33	**82**	31	**82**	22	63	12	61	2	57	**-25**
1915	50	**-19**	52	-4	46	12	60	13	69	5	75	16	**90**	30	76	30	76	26	69	13	63	2	51	-17
1916	52	-8	59	**-22**	57	1	63	-1	70	1	**79**	22	78	32	76	30	72	17	65	2	58	**-22**	44	-15
1917	42	**-18**	44	-15	52	-16	57	-15	65	**-3**	79	21	78	30	**80**	29	77	24	71	-15	60	7	50	-1
Extreme	56	-25	60	-31	70	-23	69	-15	79	-3	85	15	90	26	83	22	82	7	76	-15	72	-22	62	-27

NOTE—Extremes are printed in bold faced type. *18 days. †14 days.

TABLE XXXV—MONTHLY MEAN TEMPERATURE

Near Long's Peak, Estes Park, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1892	...	...	...	...	38.5	51.5	56.5	...	...	...	...	...	...
1893	...	18.2	25.3	30.4	40.7	53.4	57.1	54.4	49.6	37.8	28.6	26.2	...
1894	18.9	17.0	27.4	37.2	45.4	50.7	56.4	55.4	47.7	40.6	35.2	23.2	37.9
1895	19.3	18.5	25.0	37.0	42.4	48.9	54.0	55.4	49.9	37.4	26.9	21.0	36.3
1896	29.2	28.2	27.2	31.6	47.3	54.7	54.7	55.8	48.0	39.7	28.0	30.7	39.6
1897	23.8	19.1	22.6	32.5	45.0	49.6	54.7	53.5	50.5	39.6	34.2	22.6	37.3
1898	20.0	26.8	23.6	36.3	38.4	50.5	53.4	56.6	50.4	38.5	27.2	20.0	36.8
1899	21.7	15.4	23.8	35.4	41.9	50.2	54.6	56.0	51.5	37.3	35.1	25.5	37.4
1900	25.8	21.6	30.6	31.6	44.9	54.6	54.8	56.2	47.0	40.5	33.4	26.2	38.9
1901	23.4	21.0	23.9	32.0	43.9	51.1	58.5	55.8	47.4	41.4	35.1	23.6	38.1
1902	22.8	26.9	22.8	35.6	42.8	50.4	52.3	54.5	47.1	39.4	29.2	26.1	37.5
1903	24.5	11.2	26.4	32.1	38.3	47.5	55.5	55.3	46.9	39.5	31.7	26.6	36.3
1904	19.3	26.8	31.5	34.4	40.4	47.6	51.6	54.6	50.3	39.2	34.5	24.6	37.9
1905	21.6	19.4	29.4	30.2	39.2	52.9	52.0	54.9	47.3	30.7	29.5	19.6	35.6
1906	23.9	23.5	21.2	33.0	41.9	48.2	50.8	52.4	47.0	37.0	27.1	28.5	36.2
1907	25.9	29.9	32.7	32.8	36.3	47.5	54.9	53.9	50.2	*48.8	38.4	32.8	40.3
1908	32.1	27.7	30.4	36.3	40.1	47.6	52.2	53.3	49.4	36.2	28.8	24.5	38.2
1909	26.5	20.8	24.3	29.2	39.3	51.2	58.3	57.3	48.6	43.7	33.6	†19.3	37.7
1910	25.6	22.9	37.7	35.7	42.3	51.9	54.5	53.9	49.6	42.4	31.7	25.7	39.5
1911	25.5	23.1	29.9	33.4	42.4	52.1	53.4	54.2	50.4	36.0	26.4	19.8	37.2
1912	20.9	15.7	20.7	28.9	39.1	47.6	53.5	54.2	41.6	37.2	32.5	25.2	34.8
1913	20.9	16.8	23.8	36.0	44.7	51.1	55.0	57.1	48.6	35.7	35.0	19.5	37.0
1914	27.3	21.4	28.5	35.4	45.0	54.3	56.2	57.2	51.1	41.3	34.7	15.8	39.0
1915	19.1	24.8	23.3	38.3	39.1	47.6	53.8	51.5	46.9	42.1	30.9	25.1	36.9
1916	21.0	26.4	33.1	35.0	41.5	50.7	57.3	53.4	47.7	36.6	25.0	14.6	36.9
1917	17.3	21.4	19.1	29.5	34.9	50.1	54.8	53.5	49.2	39.1	34.9	28.5	36.0
Average	23.2	21.8	26.6	33.6	41.4	50.5	54.6	54.8	48.2	39.1	31.5	23.8	37.4
Maximum	29.2	29.9	37.7	38.3	47.3	54.7	58.5	57.3	51.5	48.8	38.4	32.8	40.3
Minimum	17.3	11.2	19.1	28.9	34.9	47.5	50.8	51.5	41.6	35.7	25.0	14.6	34.8

*18 days. †14 days.

TABLE XXXVI—MONTHLY PRECIPITATION

Near Long's Peak, Estes Park, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891	...	...	...	1.80	...	...	...	...	...	...	...	1.00	...
1892	0.55	1.35	1.20	2.02	3.40	1.90	3.65	0.67	0.08	0.55	0.85	0.42	16.64
1893	1.00	1.90	0.92	1.60	2.50	0.50	1.00	2.05	1.00	0.40	1.40	0.62	14.89
1894	0.40	0.65	1.40	1.65	8.90	0.45	4.10	2.90	2.47	0.35	0.82	0.97	25.06
1895	0.75	1.85	1.55	1.47	4.95	2.70	4.61	1.52	1.10	2.60	0.50	0.18	23.78
1896	0.62	0.55	2.40	1.35	1.16	0.65	3.60	2.95	1.95	1.05	0.38	0.15	16.81
1897	1.55	1.20	1.96	1.35	1.60	1.50	1.85	1.29	0.95	1.10	0.55	0.25	15.15
1898	0.40	0.45	0.59	1.73	1.82	2.06	2.94	1.53	0.81	0.60	1.60	0.60	15.13
1899	0.52	1.05	2.97	1.10	0.38	1.09	3.32	1.73	0.11	2.31	0.03	0.62	15.23
1900	0.18	0.82	0.35	6.34	0.55	0.80	0.48	0.17	1.83	1.04	0.32	0.62	13.50
1901	0.69	0.40	1.00	1.80	1.73	1.47	0.85	2.22	1.59	0.95	0.18	0.91	13.79
1902	0.35	1.00	1.36	1.32	2.90	1.40	2.40	2.79	4.42	1.60	1.00	0.75	21.29
1903	0.15	1.70	1.65	2.55	0.80	3.54	2.00	0.85	2.33	2.38	0.70	0.20	18.85
1904	0.26	0.91	1.45	0.87	5.30	2.75	1.96	6.49	1.45	2.40	T	0.94	24.78
1905	1.87	1.23	3.70	6.20	3.43	0.47	1.95	1.75	0.46	5.31	0.20	0.00	26.57
1906	0.40	0.20	4.80	4.86	1.45	0.41	3.28	1.75	2.18	2.20	1.50	0.20	23.23
1907	0.90	2.30	3.40	5.20	5.39	0.86	3.50	1.65	0.70	0.70	0.80	1.60	27.00
1908	0.71	0.30	1.30	0.70	1.95	1.75	3.69	4.00	0.90	1.41	1.70	1.40	20.29
1909	1.80	1.85	5.40	6.00	1.94	1.18	3.99	2.99	1.70	0.10	1.76	T	28.71
1910	1.00	0.30	0.80	1.66	5.10	2.61	4.59	1.75	0.15	1.45	0.30	0.70	20.41
1911	1.60	1.10	1.40	3.30	0.73	1.72	3.12	1.75	0.96	2.63	3.00	0.80	22.11
1912	1.60	3.60	4.80	4.10	4.95	1.81	4.39	1.66	2.64	3.02	1.15	0.45	34.17
1913	1.10	1.60	1.00	2.30	0.80	2.30	2.90	0.65	3.80	2.10	1.50	6.90	26.95
1914	2.70	1.80	1.45	5.20	0.90	2.20	6.20	2.57	1.49	0.30	0.30	1.40	26.51
1915	2.30	2.70	5.10	4.78	2.99	1.94	1.61	4.51	2.97	1.27	0.30	1.80	32.27
1916	2.25	0.80	2.70	3.50	2.84	0.12	4.10	2.01	0.80	3.78	1.50	1.00	25.40
1917	1.00	3.70	3.60	2.50	3.29	0.00	4.40	1.65	0.43	0.16	0.11	1.20	22.04
Average	1.02	1.36	2.24	2.86	2.76	1.47	3.10	2.15	1.51	1.61	0.86	0.99	21.93
Maximum	2.70	3.60	5.40	6.34	8.90	3.41	6.20	6.49	4.42	5.31	3.00	6.90	...
Minimum	0.15	0.20	0.35	0.70	0.38	0.00	0.48	0.17	0.08	0.10	T	0.00	...

TABLE XXXVII—MONTHLY MEAN TEMPERATURE ½ (12M+7A)

At Cowdrey, North Park, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1893	19.6	19.0	29.9	33.6	...	...	...	...	...	...	...	...	...
1894	...	...	...	...	...	...	...	...	...	...	...	...	...
1895	19.6	19.4	28.0	...	...	...	60.2	62.0	54.9	42.3	28.4	17.4	...
1896	25.4	23.1	28.2	38.6	48.0	58.6	63.8	61.5	52.3	43.7	27.4	28.3	41.6
1897	18.2	23.5	27.3	40.2	53.4	56.5	61.2	61.9	57.7	43.6	35.7	20.0	41.6
1898	16.8	27.5	26.2	42.5	47.5	60.4	65.8	64.0	53.4	38.2	26.4	13.2	38.7
1899	21.8	19.1	30.8	40.1	46.7	56.6	64.3	60.4	54.6	41.3	36.4	19.1	40.9
1900	22.9	22.8	35.4	43.4	52.4	62.9	63.5	60.7	54.6	43.3	34.0	22.2	43.2
1901	23.0	24.5	29.7	40.4	53.1	58.4	70.5	63.3	51.0	44.1	34.3	22.8	42.9
1902	20.5	28.9	28.7	39.8	51.2	59.4	59.9	61.4	51.2	42.0	31.2	22.9	41.4
1903	20.8	14.1	31.3	39.9	46.0	58.3	61.7	60.6	49.4	42.2	34.1	24.5	40.2
1904	19.5	28.3	32.4	42.2	49.5	54.5	60.4	61.2	52.0	41.1	33.3	23.8	41.5
1905	26.1	20.2	36.2	40.2	46.9	59.7	61.7	62.7	54.8	38.1	34.9	14.7	41.4
1906	21.0	26.6	30.6	41.7	48.6	53.6	56.9	54.5	48.2	35.4	26.1	24.1	38.9
1907	21.9	25.3	31.2	34.5	37.8	47.2	55.0	52.6	45.7	38.9	23.8	17.1	35.9
1908	13.0	14.9	25.9	33.9	38.3	45.5	54.3	52.3	45.9	31.3	20.2	16.1	32.6
1909	20.8	18.6	24.7	30.4	37.5	49.3	56.4	55.2	45.0	35.2	26.3	7.5	33.9
1910	12.1	12.4	32.0	34.6	40.7	50.3	55.8	53.3	47.9	35.4	30.3	13.4	34.8
1911	17.5	13.2	26.9	32.3	41.2	51.0	53.1	50.8	46.1	32.4	18.4	7.4	32.5
Average	20.0	21.2	29.7	38.1	46.2	55.1	60.3	58.7	50.9	39.3	29.5	18.5	39.0
Max.....	26.1	28.9	36.2	43.4	53.4	62.9	70.5	64.0	57.7	44.1	36.4	28.3	43.2
Min.	12.1	12.4	24.7	30.4	37.5	45.5	53.1	50.8	45.0	31.3	18.4	7.4	32.5

TABLE XXXVIII—MONTHLY PRECIPITATION

At Cowdrey, North Park, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1890	...	...	...	...	...	...	...	...	...	0.43	0.23	0.27	...
1891	...	...	...	...	26.7	0.63	1.61	1.37	1.54	0.78	1.35	...	...
1892	...	...	...	...	...	...	...	...	...	...	0.55	1.82	...
1893	0.60	0.90	1.20	2.20	1.15	0.80	1.18	2.16	0.21	2.38	0.75	2.15	15.68
1894	1.30	1.20	3.10	3.80	0.37	0.43	1.33	0.88	1.24	0.63	0.60	0.50	15.38
1895	1.40	0.65	2.40	1.59	1.73	1.67	1.02	1.58	0.41	0.67	1.65	0.70	15.47
1896	0.37	0.55	1.05	1.95	1.52	0.70	1.81	2.28	2.02	0.52	0.60	0.30	13.67
1897	1.50	1.35	2.20	1.95	2.06	2.62	2.41	1.38	0.35	0.45	1.10	2.00	19.37
1898	0.45	0.52	1.30	0.33	2.10	0.66	0.50	0.82	0.15	1.51	2.10	1.50	11.94
1899	3.33	3.60	2.60	1.60	0.27	0.60	1.18	0.91	0.30	3.09	T	1.17	18.65
1900	1.00	3.00	1.20	4.65	0.79	0.85	0.09	0.43	0.71	0.69	0.84	0.80	14.65
1901	0.55	1.65	3.25	3.25	1.07	1.05	0.20	2.58	0.17	1.07	0.60	2.10	17.54
1902	1.00	1.20	2.40	0.85	0.63	0.16	1.29	0.81	1.11	0.62	0.10	1.75	11.92
1903	1.80	1.10	0.70	2.12	1.83	0.72	0.79	0.43	2.68	1.00	1.30	0.75	15.22
1904	1.50	0.95	1.70	1.40	0.75	1.74	1.18	2.64	0.80	0.60	0.00	1.20	14.46
1905	1.45	1.70	1.90	3.00	0.90	0.36	1.66	0.15	1.48	1.35	0.90	1.50	16.35
1906	2.20	0.40	1.90	3.20	0.91	0.85	1.90	0.72	1.52	0.90	0.50	0.00	15.00
1907	0.30	1.35	1.70	1.66	1.37	0.00	1.79	1.11	1.48	0.23	0.00	1.90	12.89
1908	0.70	0.00	1.50	0.39	1.68	0.45	0.70	1.30	1.16	0.81	0.45	1.90	11.04
1909	2.60	1.80	4.20	2.50	1.38	1.15	1.56	2.27	1.00	0.36	1.05	1.40	21.27
1910	0.75	0.20	0.20	0.90	0.90	0.40	1.27	1.01	2.20	0.43	0.55	1.20	10.01
1911	1.15	1.20	0.90	1.20	0.29	1.78	1.30	1.48	1.24	0.83	1.50	0.65	13.52
Average	1.26	1.23	1.86	2.03	1.14	0.89	1.22	1.31	1.06	0.95	0.77	1.24	14.96
Max.....	3.33	3.60	4.20	4.65	2.67	2.62	2.41	2.64	2.68	3.09	2.10	2.15	21.27
Min.	0.30	0.00	0.20	0.33	0.27	0.00	0.09	0.15	0.15	0.23	0.00	0.00	10.01

TABLE XXXIX—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Cowdrey, North Park, Colorado.

DATE.	January		February		March		April		May		June		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1893........	30.2	8.9	29.4	8.5	43.8								....	....	....	....	....	....	....	....	....	....	....	....	....	....
1894........	....	....	....	....	....	16.0	42.7	24.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1895........	29.1	10.1	30.4	8.3	41.1	....	....	....	....	....	....	....	74.0	46.3	78.2	45.9	71.2	38.6	59.1	25.5	39.5	17.3	27.4	7.3	....	....
1896........	34.4	16.4	36.2	10.0	38.6	15.0	....	....	....	....	....	....	78.1	49.5	76.6	46.4	66.4	38.2	60.1	27.3	35.4	19.3	39.2	17.4	54.1	29.1
1897........	29.7	6.8	34.5	12.5	39.3	17.7	50.3	26.9	59.8	36.3	73.8	43.4	75.9	46.6	79.2	44.6	73.2	42.2	57.0	30.3	44.8	26.6	27.5	12.6	54.4	28.9
1898........	29.8	3.9	38.8	16.2	37.1	15.3	53.8	26.5	68.4	38.5	69.1	43.9	81.6	49.9	81.5	46.4	73.6	33.3	49.6	26.8	37.2	15.6	24.7	1.7	53.8	26.5
1899........	30.0	13.6	29.7	8.6	41.6	15.3	56.2	28.8	58.6	36.3	76.8	44.0	79.7	48.8	77.2	43.5	74.2	34.9	53.2	29.4	48.5	24.3	28.7	9.4	54.0	27.9
1900........	36.1	9.7	33.1	12.5	49.3	20.0	56.1	24.2	58.0	35.4	71.1	42.0	81.1	46.0	78.6	42.7	71.3	37.9	57.6	28.9	45.8	22.2	33.6	10.8	57.7	28.6
1901........	33.8	11.9	36.7	12.3	42.2	21.5	59.0	27.8	67.0	37.7	80.0	45.8	90.7	49.4	78.3	48.3	67.7	34.3	59.2	29.0	45.9	22.8	31.3	14.3	56.8	28.9
1902........	34.4	6.7	40.0	17.9	42.0	16.6	55.1	25.8	67.6	38.5	73.1	43.7	76.5	43.3	77.9	44.9	66.2	36.1	55.3	28.6	41.1	21.4	32.2	13.6	54.9	27.9
1903........	32.2	9.3	27.6	0.5	45.4	15.4	52.4	27.3	66.2	36.3	75.1	43.7	76.8	46.6	78.2	43.0	63.8	35.0	58.0	26.4	46.0	21.7	34.7	14.3	53.8	26.7
1904........	28.9	10.2	36.8	19.8	42.0	17.3	52.2	27.6	57.9	34.1	72.6	49.1	75.9	44.6	76.3	46.1	67.7	36.2	55.7	26.5	49.7	17.0	33.8	13.8	54.4	28.7
1905........	35.7	16.6	36.2	5.1	48.1	22.8	54.4	30.0	62.6	36.4	68.4	40.5	77.6	45.8	79.7	45.7	72.0	37.5	51.8	24.3	49.0	20.7	29.3	0.0	55.3	27.3
1906........	35.9	6.1	42.6	10.6	45.9	24.3	50.8	29.6	58.9	34.9	75.9	43.6	74.4	39.5	73.2	35.7	64.6	31.8	50.5	20.4	39.0	13.1	35.0	13.2	54.4	23.5
1907........	31.8	12.0	37.9	12.8	41.7	15.2	57.1	26.3	63.9	33.3	70.6	36.6	72.9	37.1	70.3	34.9	63.8	27.6	57.1	20.7	40.0	7.5	29.8	4.4	50.6	21.3
1908........	27.5	–1.5	31.0	–1.2	38.3	20.7	46.1	23.0	51.9	23.6	63.5	30.9	73.1	35.5	69.1	35.5	64.2	27.7	46.3	16.3	35.7	4.8	26.4	5.8	48.1	17.2
1909........	31.5	10.0	34.2	2.9	43.6	13.5	49.9	17.9	52.7	23.8	63.0	28.0	77.1	35.7	73.6	36.8	62.1	27.9	56.8	13.6	41.9	10.7	21.4	–6.5	50.5	17.3
1910........	25.2	–0.9	26.6	–1.8	49.8	5.8	45.9	14.8	52.1	22.8	66.0	32.7	76.8	34.8	74.2	32.4	66.3	29.5	54.1	16.8	42.9	17.7	27.7	–0.9	52.4	17.3
1911........	28.8	6.2	29.6	–3.2	40.8	14.2	53.9	15.3	58.8	22.5	72.3	28.3	71.0	35.1	71.0	30.6	64.9	27.3	48.6	16.1	30.8	6.1	24.3	–9.6	49.0	16.1
						13.0	48.1	16.5	60.4	22.0	69.4	32.6														
Average....	31.4	8.7	33.9	8.5	42.8	16.7	52.0	24.3	60.3	32.0	71.3	39.0	77.2	43.2	76.1	41.4	67.8	33.9	54.7	23.9	42.0	17.0	29.8	7.2	53.3	24.6
Maximum ..	36.1	16.6	42.6	19.8	49.8	24.3	59.0	30.0	68.4	38.5	80.0	45.8	90.7	49.9	81.5	48.3	74.2	42.2	60.1	30.3	49.7	26.6	39.2	17.4	57.7	29.1
Minimum...	25.2	-1.5	26.6	–3.2	37.1	5.8	42.7	14.8	51.9	22.0	63.0	28.0	71.0	34.8	69.1	30.6	62.1	27.3	46.3	13.6	30.8	4.8	21.4	–9.6	48.1	16.1

*These temperatures are read at about the time of the maximum and minimum of the day.

TABLE XL—EXTREME MONTHLY TEMPERATURES

At Cowdrey, North Park, Colorado.

YEAR.	January		February		March		April		May		June		July		August		Septemb'r		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1893	45	−20	48	−20	60	−18	58	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1894	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1895	48	−24	54	**−33**	70	−12	..	..	..	..	..	..	84	38	88	36	86	16	72	2	68	−4	55	−20
1896	45	−6	48	−11	52	**−18**	66	−2	74	20	86	34	**88**	39	86	30	78	24	77	13	56	−6	48	5
1897	50	−17	52	−7	65	−9	81	2	82	29	83	33	86	37	**87**	36	84	28	78	5	68	10	59	**−24**
1898	48	−25	54	−4	55	−10	75	8	78	16	90	32	**94**	40	90	37	92	20	72	8	70	−12	54	**−27**
1899	46	−12	53	**−42**	62	−15	76	4	72	16	90	30	**91**	40	86	28	88	26	76	16	64	7	44	−28
1900	48	−19	51	−23	74	9	78	2	82	29	**94**	37	**94**	32	88	34	92	25	69	14	61	−2	50	**−30**
1901	50	−16	56	**−21**	64	−4	76	−7	84	22	98	32	**100**	36	98	39	82	22	74	22	60	10	46	−13
1902	50	**−17**	58	−4	62	−10	74	6	82	18	86	28	**92**	32	**92**	36	78	18	76	18	62	−2	52	−14
1903	44	−12	48	**−24**	71	−21	68	12	78	24	86	30	**94**	33	90	32	82	20	74	4	62	−3	48	−4
1904	46	−4	52	**−24**	55	−4	70	13	76	24	81	32	**89**	34	**89**	24	84	24	74	12	66	−4	50	−14
1905	50	−8	54	**−40**	63	−2	66	9	80	22	88	32	**90**	32	89	37	84	30	76	8	66	−4	49	−18
1906	54	**−20**	58	−8	70	−18	74	9	80	18	82	25	**86**	30	**86**	20	77	21	68	6	54	−19	48	−14
1907	44	−3	42	−10	60	−2	64	4	68	9	72	24	**80**	30	**80**	26	78	13	68	10	54	−14	46	**−30**
1908	42	**−28**	40	−23	54	−12	67	3	67	8	71	20	84	22	**85**	15	78	9	64	−9	50	−16	39	−27
1909	46	−28	46	−18	62	−25	59	−19	66	4	80	26	**90**	26	84	28	76	11	72	−6	62	−10	36	**−56**
1910	44	**−34**	38	−31	62	−4	70	5	78	8	86	18	**87**	24	80	14	76	11	76	−1	54	−4	46	−31
1911	45	−34	44	−35	50	−16	64	−1	72	10	80	20	79	19	**80**	20	78	12	64	−6	44	−30	37	**−42**
Extreme	54	−34	58	−42	74	−25	81	−19	84	4	98	18	100	19	98	14	92	9	78	−9	70	−30	55	−56

NOTE—Extremes are printed in bold faced type.

TABLE XLI—MONTHLY PRECIPITATION

At Denver, Colorado. U. S. Weather Bureau. Elevation 5,272 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1870	1.80	1.70	0.70	2.80	0.34	0.52	0.51	0.12	2.85	0.68	0.54	0.73	13.29
1871	0.46	0.23	1.81	1.01	2.56	0.05	0.51	0.27	1.18	0.40	3.10	0.77	12.35
1872	0.55	0.22	1.71	2.09	3.74	2.07	2.69	1.75	1.57	0.68	0.69	0.29	18.05
1873	0.13	0.24	0.22	2.43	0.75	2.24	2.00	1.41	0.89	0.73	0.16	0.61	11.81
1874	0.84	0.53	0.49	1.70	2.43	1.21	3.35	0.68	1.34	0.64	0.08	0.17	13.46
1875	0.38	0.60	0.39	2.24	1.94	0.43	4.32	1.97	2.89	0.22	1.28	0.59	17.25
1876	0.21	0.11	1.80	1.22	8.57	1.10	1.16	2.03	0.60	0.12	1.50	1.70	20.12
1877	1.90	0.40	1.40	2.77	2.30	1.93	0.23	1.30	0.38	2.15	0.73	0.79	16.28
1878	0.10	0.48	1.82	0.05	2.90	2.78	1.38	2.25	1.23	0.80	0.67	1.05	15.51
1879	0.40	0.39	1.00	2.62	3.36	0.32	0.64	1.38	0.02	0.19	0.21	0.33	10.86
1880	0.38	0.32	0.21	0.31	1.11	1.22	1.38	1.46	0.89	1.37	0.83	0.10	9.58
1881	0.49	1.22	0.87	0.50	2.21	0.09	2.50	2.33	0.57	0.32	1.68	0.00	12.78
1882	0.57	0.20	0.20	1.47	2.98	4.96	0.66	1.20	0.06	0.75	0.71	0.73	14.49
1883	2.35	0.45	0.21	3.10	4.30	0.85	2.27	0.75	1.08	1.49	0.32	2.32	19.49
1884	0.22	0.86	0.93	3.33	4.61	1.47	0.65	1.71	0.13	0.21	0.19	0.76	15.07
1885	0.41	0.75	0.97	4.94	2.13	0.66	1.33	1.18	1.22	0.73	0.55	1.08	15.95
1886	0.62	0.72	2.36	2.79	0.09	2.26	0.50	1.62	0.98	0.33	1.93	0.87	15.07
1887	0.67	0.30	0.23	2.16	1.13	0.53	2.49	2.68	0.97	0.97	0.22	0.14	12.49
1888	0.11	0.37	1.15	1.71	2.66	0.29	0.41	1.51	0.11	0.77	0.33	0.09	9.51
1889	0.50	0.70	0.40	1.34	3.44	1.88	2.94	0.33	0.28	2.11	0.53	0.30	14.75
1890	0.18	0.46	0.35	2.50	2.01	T	0.79	1.89	0.17	0.64	0.30	0.04	9.33
1891	1.60	0.27	3.10	2.49	4.15	2.93	0.59	2.84	0.73	0.48	0.69	1.56	21.43
1892	0.40	0.75	1.20	1.75	2.14	1.33	1.19	0.58	T	3.92	0.44	1.32	15.02
1893	0.05	0.83	0.23	0.87	3.09	0.13	1.14	0.35	0.05	0.84	0.55	0.35	8.48
1894	0.18	0.90	0.70	3.30	3.00	0.39	2.11	1.86	1.55	0.19	0.22	0.69	15.09
1895	0.32	0.48	1.19	1.19	2.86	2.65	4.28	0.76	0.98	1.13	0.27	0.01	16.12
1896	0.25	0.24	1.43	0.93	1.27	0.89	2.80	0.97	1.81	0.84	0.10	0.31	11.84
1897	0.58	0.82	0.90	1.31	3.15	2.16	2.06	1.44	0.44	1.64	0.24	0.63	15.37
1898	0.20	0.68	0.28	1.20	4.88	0.94	0.67	0.96	0.28	1.05	0.85	0.99	12.98
1899	0.65	0.58	1.10	0.75	0.15	0.47	1.92	1.78	0.20	1.01	T	0.72	9.33
1900	0.13	0.55	0.63	8.24	0.53	1.87	1.30	0.05	0.87	0.33	0.37	0.42	15.29
1901	0.05	0.06	0.88	1.96	1.18	2.09	0.01	1.30	0.22	0.46	T	0.89	9.10
1902	0.17	0.38	0.63	0.60	1.98	1.89	1.24	0.76	3.70	0.80	0.61	0.59	13.35
1903	0.12	0.42	0.87	0.81	0.75	1.62	1.36	1.35	0.56	1.34	0.07	0.23	9.50

TABLE XLI—MONTHLY PRECIPITATION—Continued

At Denver, Colorado. U. S. Weather Bureau. Elevation 5,272 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1904	0.04	0.17	0.94	0.74	3.27	3.54	2.13	0.60	1.77	0.40	0.04	0.41	14.05
1905	0.99	0.35	3.07	4.95	2.65	0.61	1.55	0.67	0.49	2.31	0.04	T	17.68
1906	0.17	0.06	1.88	3.67	1.45	1.51	1.21	0.88	2.72	1.98	1.30	0.01	16.84
1907	0.46	0.33	0.54	2.91	2.93	1.15	1.52	0.23	0.74	0.17	0.40	0.45	11.83
1908	0.53	0.04	0.11	0.39	2.82	1 68	2.09	3.19	0.80	1.90	1.74	0.63	15.92
1909	0.21	1.35	3.03	2.59	1.74	1.70	4.17	2.13	3 78	0.28	1.10	0.88	22.96
1910	0.16	0.35	0.96	1.38	2.50	0.20	3.47	1.79	1.00	0.21	0.16	0.71	12.89
1911	0.12	0.68	0.28	1.41	0.52	0.56	1.31	1.08	0.75	0.33	0.37	0.34	7.75
1912	0.12	1.34	0.87	0.89	4.18	2.27	2.90	1.07	2.01	1.69	1.14	0.45	18.93
1913	0.36	0.96	0.59	1.66	1.68	1.10	1.76	0.85	2.64	1.17	0.38	5.21	18.36
1914	0.03	0.39	2.02	3.75	3.55	1.67	1.49	2.43	0.21	3.05	0.30	0.72	19.61
1915	0.38	1.19	0.91	3.66	2.99	1.70	1.28	1.92	1.69	1.25	0.24	0.63	17.83
1916	0.53	0.03	0.52	1.93	1.49	0.08	1.44	1.74	0.80	1.92	0.66	1.09	12.23
1917	0.20	0.46	0.95	0.75	3.80	0.41	0.31	0.05	0.60	1.41	0.03	0.27	9.24
Normal	0.46	0.54	1.02	2.07	2.51	1.34	1.67	1.32	1.06	1.01	0.60	0.71	14.30
Average last 31 yrs.	0.34	0.53	1.03	2.06	2.39	1.30	1.70	1.29	1.06	1.18	0.44	0.68	14.04
Maximum	2.35	1.70	3.10	8.24	8.57	4.96	4.32	3.19	3.78	3.92	3.10	5.21	22.96
Minimum	0.03	0.03	0.11	0.05	0.09	T	0.01	0.05	T	0.12	T	0.00	7.75

TABLE XLII—MONTHLY PRECIPITATION

At Hamps, Elbert County, Colorado. Elevation 5,500 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1893	0.02	0.08	0.02	0.24	1.60	0.70	3.07	1.23	0.27	0.16	0.04	0.19	7.62
1894	0.07	0.29	0.54	1.11	4.10	0.51	1.65	1.23	1.19	0.05	0.02	0.17	10.93
1895	0.15	0.42	0.28	0.85	2.05	3.79	4.07	2.08	0.12	0.15	0.10	0.11	14.70
1896	0.52	0.30	1.25	1.22	1.05	0.70	3.42	2.80	0.65	0.57	0.02	0.28	12.78
1897	0.14	...	...	0.49	0.70	1.68	1.35	6.21	0.42	0.96	T	0.22	....
1898	0.04	0.02	0.20	0.96	3.80	1.03	1.84	1.61	1.17	0.90	0.28	0.72	12.57
1899	0.90	0.19	2.26	1.30	0.30	1.13	2.50	2.19	0.19	0.49	0.51	0.71	12.67
1900	0.09	0.60	0.86	11.30	1.25	2.20	1.94	0.91	0.65	0.09	0.25	1.03	21.17
1901	0.34	0.07	1.50	4.24	0.83	0.98	0.38	2.58	0.52	0.81	T	0.69	12.89
1902	0.23	0.13	1.37	1.03	4.97	2.52	0.62	2.68	1.37	0.91	0.22	0.98	17.03
1903	0.20	0.76	0.21	0.53	0.75	3.73	1.90	1.40	0.44	0.53	0.09	0.14	10.77
1904	0.03	0.07	0.06	0.71	3.08	2.70	2.69	3.09	2.37	0.62	T	0.09	15.51
1905	0.08	0.58	3.48	4.86	3.98	2.04	4.72	1.27	2.23	0.23	0.13	T	23.60
1906	0.38	0.90	2.25	4.17	0.98	1.44	3.09	2.56	2.23	0.64	0.38	0.05	19.07
1907	0.15	T	0.27	2.38	1.85	0.65	2.59	1.06	0.74	0.02	0.20	0.65	10.56
1908	0.14	0.45	0.02	0.03	1.32	1.03	1.55	1.44	0.05	2.36	0.84	0.14	9.37
1909	0.41	0.56	1.24	1.52	1.77	6.20	3.94	0.82	2.34	0.85	1.15	0.78	21.58
1910	0.16	0.18	0.50	1.25	1.12	0.13	2.31	2.35	0.98	T	0.11	0.27	9.36
1911	0.12	0.82	T	1.06	2.17	0.58	4.35	4.22	0.38	1.55	0.21	0.65	16.11
1912	0.02	0.92	0.48	1.13	1.59	2.30	2.20	1.50	0.76	0.54	0.12	0.07	....
1913	0.29	0.79	0.35	1.46	0.87	1.23	2.27	0.57	0.41	0.11	0.18	2.15	10.68
1914	0.35	0.60	0.90	2.85	2.51	0.66	5.40	0.45	0.34	0.78	0.00	0.42	15.26
1915	0.94	0.88	1.61	3.61	1.39	3.15	4.93	4.90	1.82	0.23	0.20	0.49	24.15
1916	0.06	T	0.09	1.83	1.64	0.68	2.24	6.00	T	0.42	0.42	0.28	13.66
1917	0.18	0.78	0.72	0.72	3.57	1.53	0.73	1.89	3.37	0.53	T	0.15	14.17
Average	0.24	0.43	0.85	2.03	1.97	1.73	2.63	2.28	1.00	0.58	0.22	0.46	14.42
Max.....	0.94	0.92	3.48	11.30	4.97	6.20	5.40	6.21	3.37	2.36	0.51	2.15	....
Min.	0.02	T	T	0.03	0.30	0.13	0.38	0.45	T	T	0.00	T	....

TABLE XLIII—MONTHLY PRECIPITATION

At Le Roy, Logan County, Colorado. Elevation 4,380 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889	...	...	...	4.40	2.09	3.38	0.36	2.56	0.83	0.37	0.60	0.10	....
1890	0.30	0.48	0.01	2.80	1.03	1.96	0.47	1.41	T	0.98	0.48	0.01	9.93
1891	1.70	1.00	1.99	1.35	5.02	4.84	4.69	2.89	0.67	0.14	0.37	0.94	25.60
1892	0.89	2.24	0.80	4.02	2.53	1.48	3.07	1.83	0.84	1.66	0.10	0.65	20.11
1893	0.05	1.20	0.87	0.46	2.73	1.25	1.75	0.61	0.41	0.41	0.48	0.94	11.16
1894	0.35	0.46	0.95	0.98	0.17	0.75	1.16	0.47	1.06	0.08	0.26	0.65	7.34
1895	0.73	0.88	0.40	2.43	2.05	2.94	2.56	0.79	0.42	0.11	0.47	0.12	13.90
1896	0.53	0.24	1.20	1.91	2.36	3.77	1.33	0.87	0.86	0.90	0.20	0.01	14.18
1897	0.60	0.72	1.66	1.77	3.08	2.24	1.39	2.79	0.41	2.61	0.40	0.81	18.48
1898	0.38	0.26	0.67	1.07	4.60	1.31	2.83	1.13	1.27	0.54	0.65	0.27	14.95
1899	0.50	0.33	1.21	1.57	2.93	0.28	2.17	2.38	0.88	0.30	0.23	0.44	13.22
1900	0.10	0.96	0.12	7.27	2.10	0.78	1.68	0.99	0.35	0.07	0.12	0.20	14.74
1901	0.06	0.49	1.60	2.92	0.72	2.52	0.97	4.03	0.27	0.47	T	0.89	14.94
1902	0.12	0.72	1.23	1.28	3.16	1.82	0.98	3.70	3.46	0.78	0.09	0.99	18.33
1903	0.18	1.50	0.26	1.12	0.80	1.07	1.71	3.44	0.62	0.29	0.06	0.03	11.08
1904	0.10	0.26	0.35	1.99	3.97	4.39	3.46	1.17	2.96	1.55	0.04	0.05	20.29
1905	0.17	0.30	3.28	4.70	3.88	2.48	2.56	1.96	0.78	1.93	0.12	0.02	22.18
1906	0.23	0.43	1.38	4.53	1.96	1.35	1.88	2.83	2.70	2.69	1.29	0.53	21.80
1907	0.12	0.05	0.25	0.97	2.85	2.67	2.24	4.19	1.88	T	0.66	0.69	16.57
1908	0.08	0.23	0.18	1.68	4.34	3.52	5.72	3.65	0.16	3.76	1.86	0.05	25.23
1909	0.01	1.30	1.80	1.01	1.67	4.15	1.05	2.14	2.81	0.56	0.91	1.08	18.49
1910	0.04	0.04	0.62	1.96	2.34	2.06	1.53	1.95	1.72	0.13	0.13	0.36	12.88
1911	0.32	0.24	0.10	3.13	1.74	2.21	2.50	1.68	...	...	...	0.92	....
1912	0.26	1.16	0.65	2.62	2.58	3.32	1.84	1.60	2.31	2.52	0.42	0.16	19.44
1913	0.21	0.96	0.77	2.01	2.54	0.52	2.96	1.62	1.08	1.17	T	3.54	17.38
1914	0.03	0.35	0.09	3.45	0.79	3.17	2.85	3.54	0.04	1.71	0.02	0.58	16.62
1915	0.85	0.63	2.09	4.66	4.98	4.45	1.07	5.13	1.63	0.62	0.24	0.76	27.11
1916	0.40	0.06	0.05	1.54	2.03	1.45	1.54	2.67	0.55	1.91	0.38	0.69	13.27
1917	0.36	0.20	1.30	1.21	5.95	0.94	1.83	2.35	0.86	0.49	0.33	0.72	16.54
Average	0.35	0.63	0.93	2.44	2.65	2.31	2.07	2.29	1.14	1.06	0.39	0.59	16.85
Max.....	1.70	2.24	3.28	7.27	5.95	4.84	5.72	5.13	3.46	3.76	1.86	3.54	....
Min.	0.01	0.04	0.01	0.46	0.17	0.28	0.36	0.47	T	T	T	0.01	....

TABLE XLIV—MONTHLY PRECIPITATION

At Yuma, Yuma County, Colorado. Elevation 4,128 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891	2.35	0.50	3.63	2.90	4.21	5.23	2.98	0.75	0.64	0.05	0.13	1.25	24.62
1892	0.80	1.55	0.80	3.20	3.46	1.20	4.44	1.05	0.35	1.00	T	0.62	18.92
1893	T	0.90	0.70	0.38	2.57	1.30	2.10	0.95	T	0.40	0.41	0.55	10.26
1894	0.50	0.90	1.10	0.68	0.04	1.85	0.80	0.70	2.85	0.00	0.22	0.70	10.34
1895	1.20	1.70	0.50	1.10	2.76	2.73	3.22	1.77	0.55	0.10	0.60	0.10	16.33
1896	0.60	0.20	1.25	1.82	2.06	3.98	2.59	1.04	1.02	0.78	0.30	0.20	15.84
1897	0.37	0.40	2.80	0.80	1.62	4.44	1.78	2.44	T	2.55	0.10	1.00	18.30
1898	0.30	0.20	0.31	1.55	5.80	2.70	1.86	3.62	1.00	1.50	1.45	1.10	20.39
1899	1.38	0.60	1.18	0.97	1.23	3.03	2.63	2.22	0.17	0.03	0.90	0.27	14.61
1900	0.14	1.55	0.61	8.67	1.39	0.72	1.81	2.22	0.16	0.03	0.17	0.51	17.98
1901	T	1.11	2.44	3.90	0.31	3.51	1.61	6.53	0.36	0.39	T	0.57	20.73
1902	0.07	0.56	0.95	0.67	3.76	1.91	2.70	3.33	1.68	0.78	0.20	0.73	17.34
1903	0.14	1.88	0.20	0.40	1.00	2.10	2.65	3.12	0.35	0.10	0.36	0.09	12.39
1904	T	0.70	0.25	3.37	4.26	4.98	1.65	1.28	2.92	1.07	T	0.27	20.75
1905	0.31	0.13	4.47	4.27	3.64	3.16	4.45	0.73	1.91	1.64	0.05	0.00	23.76
1906	0.38	0.51	2.36	4.45	2.01	1.98	2.44	1.23	1.19	2.92	1.17	0.12	20.76
1907	0.28	0.02	0.33	0.94	1.43	2.44	3.44	2.58	1.44	0.04	0.24	0.35	13.53
1908	0.02	0.08	0.02	1.16	2.21	3.96	5.64	3.51	0.15	5.00	2.02	T	23.77
1909	0.02	0.51	2.10	0.54	1.79	4.50	5.72	1.26	1.78	0.76	0.92	0.93	20.83
1910	T	0.04	0.45	1.16	2.38	...	...	...	...	0.23	0.02	...	....
1911	0.05	0.21	0.10	2.47	1.02	1.15	1.00	2.82	1.30	1.69	0.06	0.43	12.30
1912	0.05	0.86	1.10	0.86	1.84	3.83	4.86	4.51	1.37	1.44	0.03	0.05	20.80
1913	0.15	0.12	0.35	0.39	1.30	1.45	1.30	1.05	2.44	0.46	T	2.40	11.41
1914	0.00	0.02	0.07	2.38	2.67	3.52	3.51	1.37	T	1.78	T	0.42	15.74
1915	0.18	0.65	1.66	5.12	5.44	4.17	3.57	6.33	1.11	0.50	0.10	0.46	29.29
1916	0.25	T	T	0.87	1.70	3.54	1.19	4.08	0.18	0.76	0.71	0.12	14.01
1917	0.37	0.27	...	1.09	6.32	1.77	0.56	2.06	1.53	0.39	0.12	0.40	....
Average	0.37	0.60	1.14	2.08	2.53	2.89	2.71	2.41	1.02	0.98	0.38	0.52	17.63
Max.....	2.35	1.88	4.47	8.67	6.32	5.23	5.72	6.53	2.92	5.00	2.02	2.40	....
Min.....	0.00	T	T	0.38	0.04	0.72	0.56	0.70	T	0.00	T	0.00	....

TABLE XLV—MONTHLY PRECIPITATION

At Garnett, Costilla County, Colorado. Elevation 7,700 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1892	...	0.32	0.34	0.44	1.01	0.35	0.76	0.11	0.00	0.91	0.00	0.13	...
1893	T	0.63	0.06	T	0.41	T	0.62	1.80	0.94	0.00	T	0.00	4.46
1894	T	0.80	0.02	0.02	1.07	0.34	1.22	2.07	0.79	0.00	0.00	T	6.33
1895	T	0.22	0.03	0.03	2.49	0.66	3.21	1.98	T	1.10	0.10	T	9.82
1896	0.12	T	0.45	0.10	0.02	T	1.32	0.90	0.39	T	0.00	0.20	3.50
1897	0.26	0.23	0.26	0.10	1.14	0.24	0.90	0.86	0.86	1.08	0.00	0.32	6.25
1898	0.01	0.05	0.35	0.09	0.51	0.65	1.48	0.32	T	0.15	0.50	0.49	4.60
1899	T	0.06	0.03	0.00	0.07	0.18	2.32	0.93	1.91	0.82	0.38	0.26	6.96
1900	0.00	0.06	0.01	1.24	1.17	0.13	0.33	...	...	...	...	...	...
1901	...	...	...	...	...	...	...	...	...	...	...	...	...
1902	0.15	0.00	T	0.07	1.18	0.85	0.63	3.20	0.37	0.16	0.54	1.03	8.18
1903	0.01	0.28	0.23	0.59	T	2.15	0.62	0.48	0.58	0.19	T	0.05	5.18
1904	0.05	0.15	0.40	0.15	0.16	1.68	0.96	2.99	1.95	0.51	0.00	0.51	9.51
1905	0.40	0.35	0.90	0.46	0.34	0.33	1.03	1.44	0.96	T	0.87	0.00	7.08
1906	0.07	0.05	0.49	1.06	0.38	0.21	1.78	0.34	1.45	2.37	0.31	0.54	9.05
1907	0.17	T	0.00	0.79	1.57	0.45	1.23	1.98	0.31	0.63	0.35	0.14	7.62
1908	0.19	0.35	0.20	0.24	0.79	0.58	0.23	0.94	0.10	0.30	0.87	0.10	4.89
1909	0.41	0.01	0.55	0.46	0.75	0.61	0.95	1.47	1.62	1.60	0.69	0.32	9.44
1910	0.07	0.33	0.27	1.05	0.46	0.06	0.12	1.07	0.69	0.64	0.35	0.00	5.11
1911	0.03	0.50	0.04	0.46	1.00	0.55	2.39	0.88	1.56	1.12	0.37	0.18	9.08
1912	0.13	0.13	0.29	0.05	0.02	1.63	0.65	1.25	0.04	0.39	T	0.18	4.76
1913	0.54	0.06	T	0.95	0.08	2.23	1.34	0.56	1.14	0.29	0.53	0.71	8.43
1914	0.16	0.03	0.10	0.81	0.95	1.59	1.98	1.78	1.30	T	0.00	0.20	8.90
1915	0.13	0.30	0.45	2.61	0.79	T	1.54	0.25	0.90	0.05	0.35	0.54	7.91
1916	0.12	T	0.15	1.12	0.30	0.00	0.95	0.92	0.41	1.78	T	0.05	5.80
1917	0.34	0.15	0.05	0.16	1.18	0.14	1.93	1.05	0.64	T	T	0.00	5.64
Average	0.13	0.20	0.23	0.52	0.71	0.62	1.22	1.23	0.79	0.59	0.26	0.25	6.75
Max.....	0.54	0.80	0.90	2.61	2.49	2.23	3.21	3.20	1.95	2.37	0.87	1.03	...
Min.....	0.00	0.00	0.00	0.00	T	0.00	0.12	0.11	0.00	0.00	0.00	0.00	...

TABLE XLVI—MONTHLY PRECIPITATION

At Durango, La Plata County, Colorado. Elevation 6,530 Feet

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1886	...	...	...	...	...	...	...	...	4.20	2.29	1.44	...	...
1887	0.46	...	...	...	...	...	...	...	...	...	...	...	...
1889	1.70	1.60	2.30	1.00	0.60	1.30	1.90	1.40	1.30	3.10	1.97	4.18	22.35
1890	1.90	0.46	1.80	2.30	0.00	0.40	0.30	...	...	...	...	...	...
1894	...	...	...	...	...	...	...	...	...	0.78	0.00	3.45	...
1895	2.10	1.38	T	T	0.99	0.37	1.78	2.81	0.92	...	2.22	1.20	...
1896	0.50	0.55	0.53	0.55	0.05	...	1.30	1.76	3.59	3.61	1.08	0.86	...
1897	2.61	3.70	2.72	0.45	3.22	0.40	1.38	0.93	3.55	3.89	0.09	1.99	24.93
1898	2.21	0.45	1.17	1.67	1.33	0.62	3.46	0.89	0.30	0.07	0.88	3.22	16.27
1899	1.63	0.97	0.91	0.00	0.01	1.58	1.91	2.85	0.60	2.22	0.93	0.88	14.49
1900	0.29	0.42	0.18	2.15	0.82	0.13	0.02	0.48	2.60	0.55	2.22	T	9.86
1901	0.44	0.80	0.04	0.55	2.05	0.35	0.95	2.05	0.33	1.24	T	0.10	8.90
1902	0.70	0.84	0.68	0.20	0.99	0.16	0.91	2.19	1.02	0.92	0.92	2.69	13.22
1903	0.35	1.24	3.90	2.60	1.25	2.02	2.82	1.87	2.15	0.13	0.00	0.04	18.37
1904	0.13	0.31	1.77	0.56	1.06	0.47	0.78	3.13	2.14	3.39	0.00	1.17	14.91
1905	2.96	4.38	3.31	3.93	1.28	1.21	1.41	1.23	2.76	0.12	3.26	0.45	26.03
1906	1.99	0.24	4.83	1.79	1.16	0.08	2.03	1.33	2.73	0.89	2.66	3.06	22.85
1907	2.15	1.22	1.73	2.42	1.94	1.08	1.40	3.62	0.99	0.99	1.08	2.04	20.66
1908	1.48	3.98	1.15	1.90	1.68	0.24	2.39	3.99	0.77	1.65	1.13	3.64	24.00
1909	2.59	2.97	1.27	0.79	0.62	0.27	2.20	3.54	3.63	0.44	1.81	3.81	23.94
1910	1.53	0.98	0.64	0.55	0.09	0.72	0.95	1.28	0.33	2.91	1.92	0.94	12.84
1911	3.48	7.02	3.14	1.50	0.59	1.09	5.21	2.89	2.82	5.07	0.94	0.54	34.29
1912	0.21	0.47	4.51	1.58	0.08	0.89	2.29	2.57	0.04	2.70	0.40	0.44	16.18
1913	0.78	2.75	2.45	0.77	0.74	1.69	2.47	1.07	2.40	1.59	3.36	2.67	22.74
1914	4.74	1.46	0.63	0.77	1.62	1.72	3.03	1.80	0.39	5.55	T	1.92	23.63
1915	1.80	3.91	0.26	3.84	1.64	0.62	3.03	1.02	2.32	T	1.47	1.84	21.75
1916	6.94	1.00	2.94	1.80	0.14	T	3.30	4.80	1.98	6.99	0.20	1.40	31.49
1917	2.12	1.20	0.63	2.58	1.96	0.14	2.62	1.19	0.70	0.12	0.06	T	13.32
Average	1.84	1.77	1.74	1.45	1.04	0.73	1.99	2.11	1.82	2.05	1.16	1.70	19.40
Maximum	6.94	7.02	4.83	3.93	3.22	2.02	5.21	4.80	4.20	6.99	3.36	4.18	...
Minimum	0.13	0.24	T	0.00	0.00	T	0.02	0.48	0.04	T	0.00	T	...

TABLE XLVII—MONTHLY PRECIPITATION

At Grand Junction, Colorado. Elevation 4,608 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1885	...	...	...	1.74	...	...	1.25	1.62	0.18	...	...	...	...
1887	...	...	...	...	0.34	0.20	1.60	1.48	1.93	1.13	1.09	0.88	...
1888	0.98	0.39	0.87	0.58	...	...	...	...	...	...	...	...	...
1891	...	...	...	...	...	...	0.95	...	...	...	T	...	...
1892	...	...	1.42	1.37	0.65	0.06	0.71	0.10	0.00	1.05	0.38	0.10	...
1893	0.22	1.77	0.63	0.30	0.79	0.09	0.11	1.20	0.87	0.80	0.92	0.51	8.21
1894	0.08	0.47	0.97	0.15	0.56	0.07	0.57	0.64	0.62	0.97	0.16	0.78	6.04
1895	1.24	0.80	0.62	0.14	0.35	0.37	1.43	2.24	0.25	0.92	2.39	0.10	10.85
1896	0.37	0.05	0.27	0.18	0.51	0.01	0.43	1.01	3.78	0.79	0.49	0.33	8.22
1897	1.00	0.80	1.05	1.12	0.62	0.40	0.98	1.05	1.53	1.82	0.33	0.40	11.10
1898	0.55	T	1.05	0.92	1.40	0.05	T	0.57	0.10	0.25	0.25	0.31	5.45
1899	0.42	0.45	0.59	1.11	0.14	1.74	0.18	2.42	0.31	2.67	0.08	0.76	10.87
1900	0.14	0.14	0.13	1.26	0.06	0.04	0.09	0.19	1.18	0.14	0.27	T	3.64
1901	0.45	0.25	0.98	1.65	1.29	0.50	0.13	2.36	T	0.35	0.02	0.21	8.19
1902	0.37	0.44	0.45	0.13	0.37	0.04	0.81	0.77	0.85	0.43	1.10	0.50	6.26
1903	0.15	1.05	0.73	0.78	1.21	1.22	0.67	0.02	0.69	0.07	0.01	0.02	6.62
1904	0.33	0.71	0.64	0.26	1.39	0.25	0.54	1.00	0.65	0.49	0.00	0.37	6.63
1905	1.01	1.37	1.18	1.24	1.98	0.04	0.16	0.33	1.71	0.27	0.75	0.23	10.27
1906	0.40	0.40	1.45	1.78	2.74	0.04	0.34	0.56	1.43	0.50	1.23	0.74	11.61
1907	0.44	1.06	1.14	0.34	1.21	0.60	0.62	1.62	0.45	1.48	0.10	0.35	9.41
1908	0.43	0.71	0.14	0.48	0.56	0.62	0.87	0.86	0.65	3.43	0.27	1.21	10.23
1909	0.66	0.34	0.02	1.14	0.45	0.10	0.50	0.86	1.13	0.04	1.05	0.67	6.96
1910	0.38	0.14	0.11	0.32	0.26	0.25	0.96	0.60	0.92	1.26	1.30	1.11	7.61
1911	0.48	1.29	0.54	0.62	0.03	0.64	0.84	0.35	1.30	1.53	0.60	0.20	8.42
1912	0.44	0.10	2.36	0.36	0.38	1.37	0.78	1.35	0.03	1.24	0.46	0.17	9.04
1913	0.62	1.22	0.37	0.23	0.12	0.37	0.31	0.22	1.70	0.22	1.15	0.75	7.28
1914	1.13	0.49	0.46	0.92	0.62	1.10	0.86	1.74	0.30	1.89	0.02	0.26	9.79
1915	0.77	0.53	0.10	1.41	1.23	0.92	0.16	0.51	0.95	0.01	0.71	1.15	8.45
1916	1.18	0.45	0.71	0.20	1.05	T	0.76	2.16	0.50	2.12	0.34	0.27	9.74
1917	0.73	0.10	0.32	1.59	1.45	0.01	0.28	0.38	1.00	T	0.02	0.12	6.00
Average	0.58	0.60	0.71	0.80	0.81	0.41	0.62	1.03	0.89	0.96	0.55	0.46	8.42
Maximum	1.24	1.77	2.36	1.78	2.74	1.74	1.60	2.42	3.78	3.43	2.39	1.21	...
Minimum	0.08	T	0.02	0.13	0.06	T	T	0.02	0.00	T	0.00	T	...

TABLE XLVIII—MONTHLY PRECIPITATION

At Meeker, Rio Blanca County, Colorado. Elevation 6,182 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891	0.55	1.21	1.73	1.22	1.90	0.20	2.27	1.66	2.04	0.11	1.23	2.10	16.22
1892	3.08	1.30	...	...	...	...	0.00	0.44	T	1.22	1.97	1.30	....
1893	0.30	1.30	4.25	0.45	0.30	...	...	...	...	...	...	...	....
1894	1.86	1.45	0 69	1.99	0.39	0.86	...	0.04	2.35	1.97	0.14	1.34	....
1895	1.66	1.07	1.22	0.98	1.79	1.50	2.13	1.88	0.72	1.48	1.56	0.75	16.74
1896	1.24	1.37	1.83	0.39	0.54	0.16	3.56	1.35	3.66	0.28	1.43	0.47	16.28
1897	1.38	2.33	3.11	2.19	1.64	1.17	3.71	2.04	2.33	1.19	1.02	2.19	24.30
1898	0.67	0.34	0.73	0.79	2.15	0.40	1.85	2.14	0.03	2.15	1.57	0.52	13.34
1899	0.90	1.94	2.50	1.45	0.24	3.26	1.10	2.13	0.35	4.60	0.12	1.46	20.05
1900	0.54	1.03	0.26	2.14	0.69	0.49	0.45	0.91	1.50	...	...	...	....
1901	0.81	0.75	2.09	1.86	2.52	1.44	0.56	2.05	0.28	0.53	0.28	1.92	15.09
1902	0.50	0.78	1.20	0.69	0.65	0.60	1.47	0.32	1.43	0.99	1.10	1.15	10.88
1903	0.77	1.77	0.80	2.46	1.66	0.68	1.40	1.11	4.42	0.92	0.47	0.41	16.87
1904	0.90	0.86	1.81	0.75	1.88	2.23	0.43	1.56	1.21	0.77	T	0.58	12.98
1905	0.93	1.55	2.58	2.04	1.78	0.08	0.77	1.01	2.47	0.46	0.73	0.56	14.96
1906	0.81	0.66	2.86	4.12	2.43	0.34	0.97	1.17	2.98	1.35	1.74	0.92	20.35
1907	1.21	0.60	0.98	0.99	2.55	1.04	2.41	2.57	3.12	0.60	0.22	1.64	17.93
1908	0.59	0.56	0.82	1.01	1.69	1.07	1.90	1.55	1.33	3.02	0.78	1.98	16.30
1909	0.66	1.03	0.79	2.62	0.97	0.90	0.59	2.91	1.95	0.61	2.53	1.04	16.60
1910	0.90	0.78	0.24	1.08	1.36	0.60	1.00	1.89	1.95	1.98	1.34	1.24	14.36
1911	1.45	1.36	0.91	0.97	0.25	1.38	0.97	1.67	1.74	2.14	1.38	0.89	15.11
1912	0.52	0.60	1.79	1.15	1.00	2.01	3.59	1.75	0.94	1.76	0.84	0.67	16.62
1913	0.78	0.67	0.11	0.79	0.46	0.85	1.10	0.66	1.71	1.73	1.80	0.78	11.44
1914	1.22	1.01	0.86	2.21	2.20	1.71	1.67	1.49	1.67	2.56	0.06	0.32	16.98
1915	0.65	0.84	0.40	1.82	0.62	1.18	0.12	0.61	2.63	0.25	2.28	1.27	12.67
1916	2.78	0.44	0.68	1.06	2.73	T	2.19	3.71	0.80	4.42	0.37	1.44	20.62
1917	1.78	0.63	0.75	2.41	3.03	0.12	1.02	1.21	1.27	0.28	0.45	0.10	13.05
Average	1.09	1.05	1.38	1.52	1.44	0.97	1.49	1.53	1.73	1.49	1.02	1.04	15.75
Max....	3.08	2.33	4.25	4.12	3.03	3.26	3.71	3.71	4.42	4.60	2.53	2.19	....
Min.	0.30	0.34	0.11	0.39	0.24	T	0.12	0.04	T	0.11	T	0.10	....

TABLE XLIX—MONTHLY PRECIPITATION

At Wray, Yuma County, Colorado. Elevation 3,512 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1890	...	...	T	T	4.44	1.42	0.62	0.25	1.09	0.45	0.25	T	....
1891	1.80	0.50	1.90	4.68	2.02	4.55	2.52	0.45	1.24	0.00	0.20	0.83	20.69
1893	...	...	...	6.03	2.12	1.00	...	...	...	...	...	...	....
1895	...	...	...	...	...	...	...	...	...	T	0.12	0.32	....
1896	0.47	0.02	0.66	4.83	1.64	3.77	1.13	1.47	1.01	1.37	0.06	0.20	16.63
1897	0.28	0.26	1.79	1.64	3.34	4.79	1.79	2.27	0.73	2.92	0.07	0.31	20.19
1898	0.06	0.07	0.83	1.73	5.47	2.98	1.88	2.56	2.33	0.25	0.26	0.29	18.71
1899	0.63	0.07	0.50	0.62	1.96	1.83	2.18	1.38	0.08	T	1.16	0.33	10.74
1900	0.16	0.90	0.33	6.00	0.61	2.35	4.57	2.60	0.15	0.03	0.20	0.34	18.24
1901	T	1.37	2.51	4.02	0.28	3.40	2.05	5.36	2.11	0.43	T	0.91	22.44
1902	0.20	0.74	1.05	0.74	7.00	5.69	3.33	2.71	3.73	1.05	0.16	0.59	26.99
1903	0.25	1.98	0.16	0.54	1.95	1.55	5.16	1.48	0.69	0.34	0.25	T	14.35
1904	T	0.58	0.04	2.46	2.02	6.25	2.00	1.26	1.74	1.19	0.05	0.20	17.79
1905	0.04	0.05	3.10	5.12	2.59	3.19	2.98	0.93	2.19	1.64	0.60	T	22.43
1906	0.55	0.62	1.88	4.82	3.20	2.57	1.62	3.57	1.71	1.43	0.83	0.29	23.09
1907	0.12	0.02	0.24	0.94	2.17	1.53	3.39	3.80	1.27	0.08	0.14	0.58	14.23
1908	0.13	0.52	0.06	0.30	3.37	3.52	3.39	2.14	0.28	4.53	1.89	T	20.03
1909	0.07	0.60	2.34	0.53	1.06	6.40	1.75	0.30	0.95	1.11	1.92	0.63	17.66
1010	0.15	0.22	0.38	1.21	3.32	0.96	1.17	3.51	1.73	0.05	T	0.11	12.71
1911	0.29	0.77	0.03	4.65	2.50	1.16	0.63	0.87	0.91	2.10	0.23	1.04	15.18
1912	0.19	1.20	1.53	1.52	1.60	5.25	5.88	5.16	1.38	1.37	0.16	0.17	25.41
1913	0.41	0.54	0.88	1.88	1.38	2.40	1.35	0.90	1.08	0.73	0.09	3.73	15.37
1914	0.05	0.35	0.08	2.55	3.35	1.05	4.20	3.41	0.05	1.70	0.00	0.60	17.39
1915	0.32	0.90	...	...	6.83	3.30	1.97	5.86	1.42	0.60	0.28	0.53	....
1916	...	...	...	...	...	...	...	...	0.27	0.90	0.30	...	....
1917	...	...	...	2.35	4.77	1.70	2.57	3.75	1.45	0.48	0.00	0.45	....
Average	0.29	0.58	0.97	2.31	2.87	3.03	2.53	2.43	1.23	1.03	0.37	0.52	18.16
Max....	1.80	1.98	3.10	6.00	7.00	6.40	5.88	5.86	3.73	4.53	1.92	1.04	....
Min.	T	0.02	T	T	0.28	0.96	0.62	0.25	0.05	T	0.00	T	....

TABLE L—MONTHLY PRECIPITATION

At (Near) Hoehne, Las Animas County, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1897	1.10	0.30	0.20	0.96	1.65	0.95	2.05	1.62	0.47	2.20	0.01	0.29	11.80
1898	0.52	1.01	0.34	1.25	2.41	1.66	1.36	1.59	1.02	0.82	0.74	1.35	14.07
1899	0.26	0.11	0.80	0.08	0.22	0.59	3.75	0.94	1.14	2.01	1.90	0.56	12.36
1900	0.01	0.48	0.22	3.78	1.89	1.99	1.10	1.04	0.59	1.71	0.02	0.47	13.30
1901	0.13	0.15	0.80	1.40	2.30	0.56	0.10	0.93	0.29	0.46	0.58	0.66	8.36
1902	0.15	0.41	0.50	0.28	4.43	0.35	0.72	2.64	0.63	0.56	0.23	0.52	11.48
1903	0.14	0.97	0.12	0.85	0.22	4.28	0.83	1.44	0.08	0.83	0.27	0.20	10.23
1904	.035	0.30	0.33	1.50	0.54	1.71	1.20	3.05	5.37	0.87	T	0.43	16.65
1905	0.55	0.19	2.21	5.00	1.42	0.45	3.89	3.78	0.84	0.47	0.58	0.10	19.48
1906	0.29	0.50	1.19	2.26	1.61	2.65	5.28	0.84	2.17	2.16	0.70	0.66	20.31
1907	0.20	0.40	T	1.86	2.72	1.18	2.22	1.83	0.06	0.55	0.48	0.60	12.10
1908	0.30	1.55	0.35	1.41	0.55	0.21	2.66	1.62	0.29	1.12	1.11	0.05	11.22
1909	0.40	0.24	0.93	2.53	1.56	1.49	2.10	1.31	3.12	0.25	2.10	0.73	16.76
1910	...	...	0.30	3.17	2.02	0.51	2.25	3.22	0.05	0.66	0.22	0.02	....
1911	0.22	1.63	0.10	0.54	0.81	0.14	3.20	1.11	1.32	1.41	0.55	0.20	11.23
1912	0.10	2.00	0.85	1.40	1.73	3.21	2.01	1.25	1.01	0.46	0.38	0.31	14.71
1913	0.41	2.56	0.29	1.13	0.43	2.58	1.48	0.79	1.66	0.94	0.47	4.10	16.84
1914	0.38	0.33	0.84	3.26	3.47	2.22	5.04	3.00	0.21	1.99	0.00	0.22	20.96
1915	0.55	0.55	0.76	5.75	2.97	1.68	4.05	2.27	1.18	0.45	0.10	1.12	21.43
1916	0.10	0.00	0.68	2.10	0.23	0.56	1.98	1.95	0.49	...	...	0.42	....
1917	0.02	0.35	0.09	1.72	2 16	0.51	0.95	...	0.80	0.31	0.20	T	....
Average	0.31	0.70	0.57	2.01	1.68	1.40	2.30	1.81	1.09	1.01	0.53	0.62	14.03
Max.....	1.10	2.56	2.21	5.75	4.43	4.28	5.28	3.78	5.37	2.20	2.10	4.10	....
Min.	0.01	0.00	T	0.08	0.22	0.14	0.10	0.79	0.05	0.25	T	0.02	....

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