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OF THE

## Colorado Agricultural College

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# HOME-MADE CIDER VINEGAR

*By* WALTER G. SACKETT

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FORT COLLINS, COLORADO
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# The Agricultural Experiment Station

FORT COLLINS, COLORADO

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# HOME-MADE CIDER VINEGAR

By Walter G. Sackett.

In driving through the fruit-growing sections of the United States, one cannot fail to be impressed with the fact that thousands of bushels of apples and other fruit are allowed to go to waste annually just because it is too much trouble to gather it up and make some use of it. This is particularly true during a season when prices are low owing to an overproduction. Such a practice would be condemned, most certainly, by any commercial firm, and rightfully so, as a most extravagant waste and far removed from any principle of scientific management. Talk with any captain of industry, and he will invariably tell you that the largest profits in his business accrue from the complete utilization of the waste products.

Indifference to the needs of others and ignorance of the latent possibilities in this second grade fruit are largely responsible for the fruit grower's short-sightedness. He is apt to forget that there are a few more than ninety-three million others in this country who are dependent upon him for orchard products such as cider, apple butter, jelly and vinegar, all of which could be made from this fruit which he permits to rot unnoticed under the trees. Could he only be shown the roll of greenbacks or catch the glitter of the gold which would represent his actual net return from the complete utilization of this unnecessary waste, rotten apples, wormy apples, green apples and everything would be cleaned up the next time we should pass by his orchard.

In spite of the fact that thousands of gallons of white wine vinegar, which has never been near a wine press, are produced yearly by a purely chemical process from alcohol, there is still a market for good, old-fashioned, apple cider vinegar. The genuine article will never be entirely replaced by the artificial product. But where is the public to obtain pure apple vinegar of acceptable quality? It is not for sale at the local groceries except in sealed bottles at twenty-five cents a quart. Beside it on the shelf may be found the distilled vinegar, artificially colored with caramel, and the white pickling vinegar at fifteen cents a bottle. In bulk the distilled vinegar can be bought for forty cents the gallon with a reliable guarantee behind it for strength and quality. But you say, "Surely you must be mistaken about not being able to get cider vinegar from your grocer in bulk." No, gentle reader, do not be deceived by the stencil mark on the end of the barrel. If, perchance, this particular lot came from a nearby ranch, the odds are in favor of its not being worth carrying home. Do not understand me to speak thus lightly of all home-made vinegar for there is some to be found of splendid quality, but it is the exception. As a rule the storekeeper will apologize to the customer for his farm vinegar, but with that which comes from the wholesale dealer it is different. Most certainly a sad condition, when the first and best vinegar that was ever made came from the farm home! What is more, it cannot be obtained from the farmer or apple grower today for most of them are buying all of the vinegar they use.

What has become of our apple vinegar industry, and why have the merchants turned their attention to the distilled article? The answer to this can be had without pursuing an extensive investigation into the economics of the question. It is simply this—the average run of farm vinegar is so inferior to the distilled product that the merchants cannot afford to handle it. The quality is so variable and the strength is so unreliable that the good housewife has learned through the repeated experience of having her pickles spoil not to ask for cider vinegar.

There is no good reason why this condition of affairs should exist which has resulted in placing a boycott on the farm product, but in the light of the facts as they actually exist, is not the consumer justified in taking this stand? There is no doubt that the synthetic article has come to stay, but this does not mean that genuine apple vinegar is a thing of the past. However, until we are able to produce as good or better vinegar on the farm and in the orchard and can guarantee its quality and strength to be reasonably constant, we have no right to ask or to expect the public to buy an inferior product or to help build up the industry by its patronage.

It is just as easy to make high-grade apple vinegar at home when one understands the different operations and principles involved as it is to make good butter or good bread. If the housewife knew as little about making butter and baking bread as the average farmer or orchardist knows about making vinegar, we should all forsake the staff of life and take refuge in the nearest sanitarium.

## *Selection of the Apples.*

What has been said above concerning second grade fruit for cider and vinegar is not to be construed as meaning rotten, wormy, dirty, or unripe fruit. Nothing is gained by such a practice and often all is lost. In the first place, it is impossible to cover up the flavor of the spoiled apples in the vinegar, and in the second place, when decayed and dirty fruit is employed, it is practically out of the question to control the fermentations in the cider upon which the quality of the finished product depends almost entirely.

There is no reason why apples which have merely been bruised should not be used, and where they are not too badly rotted, the soft portion can be cut out. Children are always glad to have a hand in cider making and this is just where their services will fit in nicely. Remember that many hands make light work and likewise clean, acceptable cider, and you will be surprised to see in how short a time the spoiled parts can be removed from the bushels of otherwise worthless apples.

The importance of washing the apples thoroughly with clean water before they go to the mill to be ground cannot be overestimated. There is bound to be a quantity of soil and dust clinging to the outside, particularly where the orchards lie along a public road and are clean cultivated so that the apples fall on plowed ground. This can be carried out very conveniently in an ordinary washtub, after which the apples should be allowed to drain before they are ground. One is always astonished at the amount of mud in the water after such an operation, even when relatively clean, hand-picked fruit is employed.

Let us see next whether all varieties of apples are equally well suited to cider vinegar making; whether a good cider apple is necessarily a good vinegar apple; and what constituent or constituents of the apple determine its usefulness for these different purposes.

In answer to the first question, it may be said that apples differ very widely in their adaptability to cider and vinegar making; some appear to have been created for this very purpose, while others would not do at all.

Concerning the second point, we find it is quite often the case that an apple which makes an excellent cider to drink would not make good vinegar. This is due to the fact that most tastes demand a cider that is not too sweet and with a slight acidity. Such apple juice would be very apt to make weak vinegar because of the relatively small amount of sugar present.

This reference to sugar brings us to the third item, namely, the important constituents of the apple so far as cider and vinegar are concerned. Several years ago, Dr. Van Slyke of the Geneva, N. Y., Experiment Station, reported a series of analyses of apple juices representing eighty-three different American-grown varieties. He gives the average composition of these juices as follows:

| | |
|---|---|
| Solids | 13.52 per cent |
| Total sugar as invert sugar | 10.91 per cent |
| Ash | .29 per cent |
| Fixed acid (malic) | .52 per cent |

The sugar is unquestionably the most important of these substances so far as the part which it plays in the making of cider vinegar since the degree of sourness due to the vinegar acid (acetic) is directly proportional to the fermentable sugar present; in other words, all of the acid which was not originally present in the cider as natural apple acid, or malic acid, is produced from the sugar by processes which are soon to be described. Therefore, since from a given amount of sugar just so much acid and no more can be made, we can understand quite readily that for a high grade vinegar of maximum acidity the apple juice containing the most sugar will be the most desirable. The amount of natural acid present in the juice plays an insignificant part in the final acidity of the vinegar, since the small quantity that is present in the apple juice practically all disappears during the change into vinegar. From this it is clear that it is the sugar and not the natural apple acid that is to be considered in cider for vinegar.

Now, as has been stated above, cider for table use is usually more pleasant to drink when it is not too heavy and when the sugar is lower and the acid somewhat higher than the standard for vinegar cider requires.

The composition of the juice of some of our common commercial varieties, especially the sugar content, may be of interest at this time in connection with what has been said with reference to the suitability of different ciders for vinegar making. The analyses which I am submitting are those given by Dr. Van Slyke* for eastern apples.

*Table I—Analyses of Apple Juice of Different Varieties of American Apples.*

| Variety of Apple. | Specific Gravity. | Solids. Per cent. | Equivalent of total sugar in form of invert sugar. Per cent. | Fixed acid as malic. Per cent. |
|---|---|---|---|---|
| Baldwin | 1.072 | 16.82 | 15.39 | .67 |
| Belleflower | 1,061 | 14.09 | 12.82 | .58 |
| Ben Davis | 1.052 | 12.77 | 10.60 | .46 |
| Ben Davis | 1.046 | 10.69 | 6.74 | .44 |
| Gano | 1.046 | 10.16 | 8.61 | .41 |
| Gano | 1.056 | 13.92 | 11.32 | .41 |
| Grimes Golden | 1.070 | 18.18 | 14.05 | .74 |
| Jonathan | 1.056 | 14.62 | 11.60 | .32 |
| Maiden Blush | 1.051 | 12.70 | 9.99 | .67 |
| Northern Spy | 1.052 | 13.77 | 9.77 | .69 |
| Red Siberian Crab | 1.070 | 17.34 | 11.83 | .97 |
| Rome Beauty | 1.048 | 11.37 | 8.70 | .37 |
| Wealthy | 1.057 | 15.26 | 11.64 | .66 |
| Whitney | 1.060 | 14.16 | 11.39 | .40 |
| Winesap | 1.065 | 16.45 | 13.34 | .58 |
| Yellow Transparent | 1.049 | 11.71 | 9.76 | .87 |

An examination of the above table shows us that there is a wide variation in the percentage of sugar in the apple juice of different varieties, varying from 6.74 per cent. in one sample of Ben Davis to 15.39 per cent. in the Baldwin; that the quantity of sugar in any given variety may vary as much as 4 per cent. (Ben Davis 6.74-10.60).

The amount of sugar depends upon a number of factors such as soil, climate, culture, variety, and ripeness, unripe and over-ripe apples containing less sugar than ripe ones.

†Browne has shown very clearly the changes that take place in the sugar content of apples at different periods of ripeness:

*Table II—Sugar in Baldwin Apple at Different Periods.*

| Date | Condition. | Equivalent of Total Sugar in Form of Invert Sugar. |
|---|---|---|
| Aug. 7, 1899 | Very green | 8.11 |
| Sept. 13, 1899 | Green | 10.72 |
| Nov. 15, 1899 | Ripe | 14.87 |
| Dec. 15, 1899 | Over-ripe | 14.85 |

The question is sometimes asked whether the so-called "sweet apples" will make as good vinegar as the tarter varieties. All things being equal, there is no reason why they should not, provided they contain as much sugar as the more acid kinds. This statement may seem somewhat paradoxical, but it should be remembered that

*Van Slyke, L. L., Bulletin 258, Geneva, N. Y., Exp. Sta. "A Study of the Chemistry of Home-Made Cider Vinegar," 1904.

† Browne. Annual Rept. Penn. Dept. Agr. 1899, p. 541.

it is the presence of acid rather than the absence of sugar that makes an apple taste sour. As a matter of fact, some of our very sourest sorts contain as much and more sugar than the sweetest sweet apples. Cider for vinegar should not contain less than 8.5 per cent. of sugar.

*Storage of the Cider.*

The most satisfactory containers for both cider and vinegar are whisky and brandy barrels. Molasses barrels and old vinegar barrels should be used only when no others are available, and then not until they have been very carefully and thoroughly cleaned. Too much stress cannot be laid upon the necessity of scalding old vinegar barrels with either live steam or boiling water to remove the last trace of the old vinegar. There is, perhaps, no one factor which is responsible for more failures in farm vinegar making than the time-honored but pernicious custom of using old vinegar barrels for sweet cider without even rinsing out the dregs of former years. Mere rinsing is not sufficient. They must be scalded to make them fit for use. If this is not done in such a manner as to kill all of the organisms in the barrel, the probability is that the sweet cider which is put in them subsequently will never make vinegar. The reason for this will be given a little later. In a recent number of a certain farm journal, the following is given under directions for making apple vinegar:

"Get a barrel in which good vinegar has been made and use it, or get some of the scum off of the top of good vinegar and rinse out the new barrels with this as soon as they cool after having been thoroughly washed out with boiling water. Put fresh cider into these barrels."

No procedure more absurd and dangerous to the success of apple vinegar could possibly be undertaken than is contained in this recommendation. In fact, it would be difficult to find a better recipe for vinegar failures than this. Never, under any consideration, put either "mother" or old vinegar into sweet cider. It is never safe to use metallic containers for holding cider even for an interval of a few hours, since the acid of the juice attacks the metal, dissolving a portion of it. Such cider, because of the metal in solution, might produce metallic poisoning in the person drinking it.

The sweet cider as it comes from the press may either be placed at once in barrels, which should not be filled more than two-thirds to three-fourths full, or if one has suitable wooden tubs or vats in a clean, cool place, it may be stored there for twelve to twenty-four hours to permit settling, after which it should be transferred to barrels. The bung should be left out and a loose stopper of cotton batting inserted in the hole to decrease evaporation and prevent dirt from falling in. The barrels should not be tightly stoppered until the vinegar contains at least 4.5 to 5.0 per cent. of acetic acid, at which time they should be filled entirely full and securely bunged. Throughout the entire period of vinegar making, the casks should be placed on their side and not on the end. This gives the cider a larger free surface exposed to the air, which is quite essential to rapid vinegar formation. It may be of some advantage in admitting air to bore a one and one-half inch hole in each end of the barrel along the upper edge. If this is done, the holes should be covered with fine wire gauze or two thicknesses of cheese cloth to exclude small vinegar flies.

*The Alcoholic Fermentation.*

A few days after the cider is put into the barrels, the characteristic frothing appears at the bung-hole. To use a common expression, "It is beginning to work." This indicates that the alcoholic fermentation, the first step in the vinegar making process, has begun, and the sugar of the apple juice is being converted into alcohol and carbon dioxide gas.

The first of these substances is too well known to need any further comment other than to state that it is this element of "hard" cider that gives it its intoxicating property. With carbon dioxide, many of us are not as well acquainted. It is this gas escaping from the fermenting cider that causes the frothing and likewise the foamy appearance of the bread sponge. It is this gas dissolved in the cider or in the carbonated drinks at the soda-water fountains that imparts to them the characteristic bite or tingle, and upon escaping from the stomach produces that peculiar sensation in the head and nose. Strangely enough, this same gas is the active principle of practically all chemical fire extinguishers.

Now, what is the exciting agent which starts up the fermentation in the bread sponge and in the sweet cider? In both cases it is the same: a microscopic organism, the yeast plant. In the one instance we add a yeast cake to the bread mixture; in the other we either trust to the wild yeasts of the air and the skin of the apples or following the more recent, approved method, we add a yeast cake or a pure culture of a yeast selected especially for this purpose.

To depend upon the wild yeasts of the air to accomplish the fermentation is too uncertain since many of them are able to convert only a small part of the sugar into alcohol, while others act so slowly that they are impracticable. Inasmuch as the percentage of acetic acid in the vinegar depends directly upon the amount of alcohol produced, it is very essential to secure as large a yield of alcohol as possible from the sugar present. This means converting all of the sugar into alcohol in the shortest time possible. The most satisfactory way of doing this is to add one cake of compressed yeast, stirred up in a little cooled, boiled water, to each five gallons of sweet cider. In place of this, one quart of liquid wine yeast, propagated from a pure culture, may be used for each thirty gallons of cider.

During the alcoholic fermentation, the cider should be kept at a temperature of 65 to 80 degrees F. Here is where many make the very serious mistake of putting their fresh cider into a cool cellar where the fermentation takes place entirely too slowly. If the cider is made in the fall, the barrels should be left out of doors for a while on the protected, sunny side of a building and kept warm, unless a regular vinegar-cellar, artificially heated, is at hand.

If yeast is added and the proper temperature is maintained, the alcoholic fermentation should be completed in six weeks to three months in place of seven to ten months as in the old-fashioned way. Experiments along this line have shown that when yeast is added and a temperature of 70 degrees F. is held, the cider at the end of one month contained 7.25 per cent. of alcohol as against .11 per cent. when no yeast was used and the temperature was between 45 and 55 degrees F. Cider kept in a cellar at 45 to 55 degrees with no yeast added required seven months to make 6.79 per cent. of alcohol.

Temperature, alone, is an important factor as shown by an experiment wherein cider to which no yeast was added was held for three months at 70 degrees F. and yielded 6.41 per cent. of alcohol.

There is no question but that the time required for completing the alcoholic fermentation can be reduced at least one-half by adding yeast and by maintaining the proper temperatures. By hastening this operation, the loss of alcohol by evaporation is reduced, and the acetic fermentation can be started that much sooner.

Theoretically, 100 parts of sugar should give 51 parts of alcohol and 49 parts of carbon dioxide gas. This figure has been shown by Browne to be a little high. In actual practice, 45-47 parts of alcohol from 100 parts of sugar is a fair average.

But why not add "mother" or vinegar to sweet cider or put sweet cider into an old vinegar barrel? Here is the reason: We have seen from what has gone before that alcohol is produced from the fermentation of the sugar. We shall soon learn that the acetic acid of the vinegar is formed from this alcohol. Now, in order to obtain the maximum amount of acetic acid, it is necessary to have as much alcohol as possible in the hard cider, and this can be obtained only by the complete conversion of all the sugar into alcohol and carbon dioxide gas. The complete destruction of the sugar can be accomplished only by the uninterrupted action of the yeast, and the presence of "mother" of vinegar by producing acetic acid interferes seriously with this fermentation. The yeast cells are either killed or their useful activity is checked long before all of the sugar has been changed into alcohol. This is the condition of a very large percentage of farm vinegar—just hard cider that will not and never will make vinegar. It means just this:

A small part of the sugar was made into alcohol and this alcohol was at once changed to acetic acid by the "mother" present; this acetic acid killed the yeast so that no more sugar could be changed to alcohol and no more alcohol being found, no more acetic acid could be made by the "mother." We have a weak, worthless something neither vinegar nor hard cider with considerable unfermented sugar still present and incapable of further fermentation because no yeast can develop in the weak acetic acid solution.

*The Acetic Acid Fermentation.*

The second step in vinegar making is the change of the alcohol of the hard cider into the acetic acid of the finished product. This is accomplished by the acetic acid germ, another microscopic plant still smaller than the yeast. In some peculiar way it is able to bring about a union between the alcohol of the hard cider and the oxygen of the air so that the alcohol is transformed into acetic acid and water.

As soon as the alcoholic fermentation, described in the preceding section, is completed, draw off the clear liquid, being very careful not to disturb the sediment in the barrel. Wash out the barrel thoroughly and replace the hard cider. It is believed that removing this sediment permits the acetic acid to form somewhat more quickly, and furthermore, the sediment may undergo decomposition and impart a disagreeable flavor to the cider. Again, these dregs may harbor living bacteria which either destroy acetic acid or interfere with its formation.

This done, we are now ready to introduce the acetic acid germs. This may be carried out in a number of different ways, but preferably by means of a pure culture of a desirable organism which has been selected because of its ability to produce strong acetic acid and to impart an agreeable flavor to the vinegar. In place of the pure culture starter, one may add two to four quarts of good cider vinegar containing more or less "mother" for each barrel. The introduction of a desirable organism is left to chance in this case. A serious objection to this latter method is that sometimes one introduces foreign organisms with the "mother" which may prove detrimental to the vinegar. The pure culture starter is free from this objection. On the whole, the indiscriminate use of "mother" alone is to be discouraged, since the popular idea of what constitutes "mother" is apt to be wrong. Pure "mother" is made up exclusively of acetic acid bacteria and is recognized as the thin, white, glistening, gelatinous membrane that forms on the surface of vinegar. It seldom becomes one sixteenth of an inch in thickness and should be translucent or white in color. It is entirely distinct from the thick, tough, dark brown, slipping, leathery masses which form in vinegar and are usually regarded as "mothy of vinegar." Such accumulations contain the acetic acid germ, in all probability, but in an impure state. In addition to this organism there may be present yeast cells and numerous bacteria which are positively harmful to the vinegar. Often these growths undergo decomposition and give the vinegar a flavor of rotten oranges. Again the germs present may cause the partial or complete loss of the acid, particularly if the barrels are not full and tightly stoppered. All things taken into consideration, the use of this sort of "mother" is a rather dangerous procedure.

With the acetic fermentation, as with the alcoholic, the higher temperatures favor the changes. Experimental work shows that hard cider to which no acetic acid bacteria were added other than those that came from the air, and kept at 65 degrees F., when six months old, contained 7.03 per cent. of acetic acid, while that held at 55 degrees F. showed only 3.63 per cent.

The addition of some kind of an acetic acid starter, either as a pure culture of the acetic organism or as good vinegar, hastens the fermentation and reduces appreciably the time required for making marketable vinegar.

For most satisfactory results we would recommend using the pure cultures and holding the vinegar at a temperature of 65 to 75 degrees F. Under these conditions, salable vinegar can be obtained in three to six months in place of two to three years, as is often the case. Theoretically, 100 parts of alcohol should give about 130 parts of acetic acid, but in actual practice this will probably fall below 120.

When the acetic acid has reached 4.5 to 5 per cent., fill the barrels as full as possible and cork tightly. In this way, contact of the air with the vinegar is cut off and the acetic acid organisms soon cease their activity. If this is not done and the acetic and other bacteria are allowed to develop indefinitely, there is apt to be a reverse reaction resulting in a partial or complete loss of the acetic acid. Such vinegar is, of course, worthless.

### *Clarification of Vinegar.*

For those who desire an extra fancy product of extraordinary brightness, suitable for bottling, it will be necessary to subject the vinegar to a special process of clarification known as fining. According to Bioletti*, the best results are obtained by using isinglass. This is employed at the rate of from one-half to three-fourths of an ounce of isinglass to each one hundred gallons of vinegar.

"The isinglass is cut into small pieces and soaked for twelve to twenty-four hours in a little water containing acetic or tartaric acid equal in weight to the isinglass used. When thoroughly soft it is then rubbed several times through a fine sieve, gradually adding a little more water until a perfectly fluid liquid is obtained. This fluid is then well mixed with a little vinegar and thoroughly stirred into the cask. With some vinegars it is necessary to add a little tannin, from one-half to one-seventh the amount of the isinglass used. This tannin should be added at least twenty-four hours before the finings.

When the finings have settled and the vinegar is perfectly bright it is ready for bottling."

### *Pure Cultures for Vinegar Making.*

Reference has been made above to the use of pure cultures, both yeast and acetic acid bacteria, for vinegar making. For a little more than one year, the Bacteriological Laboratory of the Colorado Experiment Station has been supplying these at fifty cents (50c) per set, post paid, sufficient for one barrel, to those who care to give them a trial. Full printed directions for their use are included. These cultures have been selected because of certain properties which they possess which make them especially suited to the vinegar industry. No guarantee, either expressed or

* Bioletti, Frederic T., Grape Vinegar, Bull. 227, California Exp. Sta., 1912.

implied, goes with the cultures, since it is not the purpose of the Experiment Station to exploit these products, but rather to distribute them at the cost of production for experimental purposes. Inasmuch as one of the cultures is to be added to the sweet cider, the set should be obtained a few days, not longer, before the cider is to be made.

Requests for cultures should be addressed to the Bacteriological Laboratory, Colorado Experiment Station, Fort Collins, Colorado, and should be accompanied by a remittance of fifty cents (50c).

*Directions For Using Pure Cultures in Making Vinegar*

*Preparation of Yeast Culture.*

1. For each barrel of sweet cider, sterilize one two-quart Mason jar by washing thoroughly and boiling for five minutes in clean water.
2. Cover the top of the jar with a single layer of clean muslin or cheese cloth just removed from boiling water and secure it in place by a string tied about the neck of the can.
3. Select 6 or 8 medium sized *ripe* apples; pare and quarter or slice them; add one quart of water and boil till soft; strain liquid through clean cloth while hot into Mason jar, first removing the cloth covering from the top.
4. Make up the volume of liquid to approximately one quart with boiling water; add 4 tablespoonfuls of sugar and replace the cloth immediately.
5. When the liquid has cooled thoroughly, partly remove the cloth covering and add the contents of the culture bottle marked "Yeast." Replace the cloth. Just previous to opening the culture bottle, shake thoroughly and immerse the lip and cork only, ten second in boiling water. Do not touch the lip while removing cork.
6. Keep the jar in subdued light at a temperature of 75 degrees F. to 90 degrees F. After two to four days the foaming characteristic of alcoholic fermentation should appear.
7. After four to six days, add the entire contents of the *yeast* jar to the barrel of freshly made *sweet* cider. *The barrel must not be more than two-thirds full;* it should be placed on its side, and the bung-hole be left open, or, better, plugged loosely with a tuft of clean cotton batting.
8. Keep the barrel at 75 degrees F. to 85 degrees F.

*Preparation of Acetic Culture.*

1. Three to four weeks after the yeast culture has been added to the cider prepare the Acetic Culture in precisely the same manner as described for the yeast in paragraphs 1 to 6 above. See that all of the culture is removed from the bottle; rinse with a little cooled boiled water if necessary. Do not shake the jar while the culture is developing.
2. By the end of one to two weeks, a white, gelatinous film or membrane should be visible on the surface of the liquid. This is a growth of acetic acid bacteria and constitutes the "Mother of Vinegar."
3. When this acetic membrane is well formed, which will require about two weeks, with a clean sliver of wood, previously dipped into boiling water, remove the membrane from the jar, but do not lay it down; pour the contents of the jar into the barrel of cider, now fermented, to which the yeast was added some five or six weeks before; next drop the sliver with the attached acetic film into the barrel through the bung-hole. The wood will serve to float the acetic membrane on the surface of the hard cider and thereby hasten its development by keeping it in contact with the air.
4. Keep the barrel at 65 degrees F. to 75 degrees F. till the vinegar has formed.
5. When vinegar of satisfactory quality has been obtained, in three to six months, draw off and store at a cool, even temperature in casks which are kept full and tightly bunged.
6. Both of these cultures can be propagated indefinitely by employing a small portion of the jar cultures in the same manner as the original bottle starters.

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## THE NITRIFYING EFFICIENCY OF CERTAIN COLORADO SOILS

BY

WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station

FORT COLLINS, COLORADO

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# *THE NITRIFYING EFFICIENCY OF CERTAIN COLORADO SOILS.*

By Walter G. Sackett

## Introduction

When our bacteriological studies of Colorado soils were begun some three years ago, the chief interest in the investigation centered about the occurrence and origin of certain "brown spots" in the soil. These had been observed as early as 1892, and by this time, 1910, they were becoming so common as to be identified readily by mere mention of their physical characters.

One not familiar with their appearance might easily mistake the smaller areas for spots where crude oil had been spilled, especially if this material had been used for heating purposes in the orchard where they occurred. Sometimes the spots are sharp in outline and are limited to a space of three to five feet in diameter; again, tracts of one to five acres and more exist, which present an unbroken expanse of dark brown, wet-appearing waste land. A well defined crust is usually present, and while the surface appears wet to the eye, it is not necessarily so; in fact, we often find it to be hard and dry. Beneath this crust, which may be one-half an inch in thickness, the soil is frequently mealy in texture. The same characteristic greasy, brownish-black color exists along the ditch banks, on the sides of the irrigating furrows and for miles in more or less broken stretches along the road-sides.

The first complaint of serious damage to agriculture from this cause was received by Dr. Headden in 1905, who, two years later, began his studies of the niter soils of Colorado. The universal grievance of those who are attempting to cultivate land of this character is that nothing will grow on the brown areas; it matters not whether the crop is sugar-beets, alfalfa, small grains, or fruit, all suffer alike. In looking over a field of oats or sugar-beets, one cannot fail to be impressed with the dark green color and rank growth of the plants which border the barren areas. This would seem to indicate the presence of a zone where conditions for plant growth are particularly favorable, beyond which they become almost intolerable. That such is the case has been demonstrated repeatedly by Dr. Headden. It suggests that where the growth is vigorous, the soil contains the optimum amount of nitrates for vegetative development; and where nothing can live, that the nitrates are in excess. Apple trees appear to have suffered more than any other of our fruit trees. In the fruit-growing sections of the state, these have died by the thousands, and acres of once valuable and profitable land are now worthless. Heavy manuring, additional draining, excessive irrigation and more thorough cultivation, all have been tried with the hope of ameliorating the pending conditions. Little or no benefit has accrued from these efforts, and up to the present time, we have observed nothing which seems to indicate a positive recovery, although, now and then, our attention has been called to cases where the intensity of the attack, as measured by the time required to accomplish the destruction of the crop, appears to have been lessened somewhat.

A full description of the characteristic appearance and manner in which fruit trees and cultivated crops succumb to the trouble, here referred to, has been given elsewhere (1) and a further elaboration of this feature is unnecessary at this time.

This condition of the soil which has resulted so seriously to the agricultural and horticultural interests of the state has been shown by Dr. Headden to be due to the presence of large quantities of nitrates. To one who is accustomed to think of these salts in thousandths and ten-thousandths of a per cent., as they occur in the east and south, the quantities which we find in our niter sections must seem preposterous. However, one visit to the troubled districts is usually sufficient to convince the most skeptical. It is not uncommon to find the nitrates in some of the brown spots making up from two to six per cent. of the weight of the air dried soil. From this, it will be seen at a glance that our problem is not one involving pounds but rather tons of nitrates. For example, we have the analysis of the soil from an orchard where the samples were taken to a depth of one foot; it carried 2.873 per cent. of nitrates, corresponding to 113,480 pounds or 56.74 tons per acre foot. This does not represent an isolated brown spot a few feet in diameter but an area of ten to twelve acres, being a portion of a forty acre tract; again, in another sample, taken to a depth of five inches, the area involved being about eight acres, sodic nitrate corresponding to 344,000 pounds or 172 tons was found; in the top five inches of another eight acre tract the equivalent of 189,971 pounds or 95 tons was present. Dr. Headden has examined sample after sample from the affected districts and all his analysis tell essentially the same story—excessive nitrates.

The difference which we find between the niter content of the brown spots and that of the adjoining apparently normal soil is rather striking. A sample of the brown crust from the side of an irrigating furrow in an apple orchard contained 640 parts per million of nitrate nitrogen, while two and one-half feet away, the surface four-inches of normal soil gave 34 parts. The surface half-inch from the top of the ridge of an irrigating furrow in a deserted oat field including the brown crust showed 1360 parts per million of nitrate nitrogen, while six feet from the edge of the mottled brown area, the normal soil contained but 46 parts. To the writer, this seems to suggest rather strongly the probability that the brown patches are purely local surface-formations, which are actively engaged in building up nitrates *in situ*, especially since the areas are increasing daily both in number and in size. Furthermore, we are now in position to present a complete chain of experimental evidence to show beyond all reasonable doubt that these niter areas in the incipient stage of their formation, if not in the later stages as well, contain within themselves all the agents necessary to bring about their existence.

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(1) Bakteriologische Untersuchungen uber die Stickstoffbindung in gewissen Bodenarten von Colorado. Cent. f. Bakt., II Abt., Bd. 34, No. 4-7. S. 81-114, 1912.

Bacteriological Studies of the Fixation of Nitrogen in Certain Colorado Soils, Bul. 179, Colorado Experiment Station, 1911.

There is no need of attempting to trace the origin of these accumulations to the concentration at the surface of the salts in the ground waters containing a hypothetical nitrate; moreover, granted that a ground water could be found independent of a niter area, which was rich in nitrates and which underlay the tract in question, why should we not find the nitrate and the brown color, as well as the sulfates and chlorides, distributed uniformally over the hundreds of square miles which are involved in this trouble? This is not the case.

In this connection, it may be said that Dr. Headden had made a very careful study of the ground-waters of Colorado previous to the appearance of the niter trouble and had failed to find more than a mere trace of nitrates. Since then, he has followed up this phase of the question, and except where the ground-water flows under a niter area, from which it unquestionably receives the salt by leaching from above, he finds the nitrates present only in negligible quantities. In order to obtain the quantity of nitrates from our ground-waters which we meet in the brown spots, the evaporation of many acre feet of water and many years of time would be required. Furthermore, the chlorides and sulphates which would come from the evaporation of this immense amount of ground-water would be sufficient to cover the land with a white deposit many feet deep. Illustrative of the case, Dr. Headden (1.) gives the following:

"We will not consider any greater depth of soil than is represented by our samples, i. e., two inches, but we will calculate how much of this drain water would be required to furnish the nitrate which we actually find in these two inches of soil, and we take this as 2,150 pounds. The samples of soil and drain water were taken in May, 1911. The drain water contains 0.1 part per million of nitric nitrogen, equivalent to 0.6 parts per million sodic nitrate; taking an acre foot at 2.7 million pounds it gives us 1.62 pounds of nitrates per acre foot of water and we would have to evaporate 1,327 acre-feet of this drain water to obtain this 2,150 pounds of nitrates which we find present at this time. The evaporation of this amount of water would require, assuming that the annual evaporation amounted to sixty inches (At Fort Collins it is only 41 inches) two hundred and sixty-five years. This drain water carries 8,489 parts of total solids per million which, calculated on the 1,327 acre-feet of water necessary to yield the 2,150 pounds of nitrates, would yield 30,414,840 pounds of salts, a quantity sufficient to cover the land more than seven feet deep, if we suppose them to have the same density as the soil itself."

"The changes in the conditions of these soils have taken place within the past few, say six, years and these conclusions to which we are forced, if we suppose that these nitrates have their origin in the ground-waters, are evidently false. We know that no 1,327 acre-feet of water have evaporated to dryness on this land in this time and it is evident that our country is not covered nearly eight feet deep with

(1) Fixation of Nitrogen in Some Colorado Soils, Wm. P. Headden, Bul. 178, Colo. Exp. Sta., p. 28, 43, 1912.

calcic chlorid and other salts and we are likewise quite as sure that land which up to six years ago was good, and this assumed period is from three to six times as long as the facts indicate, has not been two hundred and sixty-five years in going to the bad."

That these spots are the remains of great herds of extinct animals which perished from some unknown cause is highly improbable: First, because the areas involved are too great; second, as mentioned before, the present spots are increasing in size; and, third, spots are appearing today in localities where the trouble has never been reported before.

For the same reasons, there is no ground for believing that these areas are niter beds related to any established geological horizon.

Having failed to find a satisfactory explanation for these brown areas in any of the foregoing hypotheses, we ventured the assumption that the nitrates were and are being formed *in situ* and proceeded with the hypothesis that they owe their origin to the activity of microorganisms.

To assume that ammonifying and nitrifying bacteria alone were responsible for the formation of the nitrates was to assume the existence of large quantities of organic matter in the soil, which, as a matter of fact, is quite deficient. This condition obtaining, we were obliged to begin our investigation one step farther back and to find some adequate supply of organic nitrogen which could furnish protein for the ammonifying organisms.

## Fixation of Nitrogen

In Bulletin 179, we have shown that our niter soils are abundantly stocked with *Azotobacter chroococcum* by virtue of which they are able to build up large quantities of proteid nitrogen from atmospheric nitrogen. Not only have we demonstrated the almost universal occurrence of the nitrogen fixing organisms, but we have also been able to obtain a positive increase in the total nitrogen content of the soil itself by merely keeping the soil moistened and holding it at 28 degrees C. Without any inoculation other than that which the soil already contained and without the addition of any carbohydrate to supply energy, we were able to secure in thirty days an increase in the total nitrogen of 11.12 per cent. with one sample and 9.83 per cent. with another.

So far as a supply of carbon in the soil with which to furnish Azotobacter with the necessary energy for nitrogen fixation is concerned, I may say that Professor Robbins (1) has reported to date the occurrence of some twenty-four species of algae. All but two of these belong to the blue-green algae (Cyanophyceae), the family Nostocaceae being best represented.

## Brown Color

The brown color of the niter soils has been discussed quite fully in

(1) Algae in Some Colorado Soils, W. W. Robbins, Bul. 184, Part II, Colo. Exp. Sta., 1912.

Bulletin 179 so that mere reference to it will suffice at this time. In the light of our experiments, we have little hesitancy in saying that this is due in a large measure to the pigment of Azotobacter chroococcum. Even the colorless varieties in the presence of .05 per cent. of sodium nitrate produce a dark chocolate brown pigment. This experiment has been carried out repeatedly on the ordinary solid media, ground quartz, sand and an assortment of soils. Given a source of energy, the nitrate appears to be the limiting factor in the formation of the brown color by the nitrogen fixing organisms.

## Ammonification

In Part I of Bulletin 184, we have taken up a study of the ammonifying efficiency of this same class of soils, and we have been able to show that so far as the presence of an active, ammonifying microbial flora, as well as suitable medium for their development for converting the protein of the azotobacter cells into ammonia, our soils are all that could be desired. The results of our experiments, based upon the change of the protein of alfalfa-meal, cotton-seed-meal, flaxseed-meal, and dried blood into ammonia led us to believe that this is a property common to many cultivated Colorado soils; that soils in the incipient stage of niter trouble surpass our normal soils in ammonifying efficiency; also that compared with the soils from other localities our niter soils excel in this function to a very marked degree. The maximum per cent. of ammonia produced in seven days by any soil from 100 m. g. of nitrogen as cotton-seed-meal was 51.98 per cent.; as dried blood 52.64 per cent.; as alfalfa-meal 34.85 per cent.; as flax-seed-meal 12.15 per cent.

## Nitrification

Having shown that the niter soils could transform atmospheric nitrogen into ammonia salts by the two processes just outlined, we had yet to demonstrate their ability to change the ammonia compounds into nitrates before we could assert definitely that the atmosphere is in all probability contributing the nitrogen for the excessive nitrates. In the pages which follow, will be found a detailed discussion of our studies upon the nitrifying efficiency of these soils,—nitrification being the third and final step in the transformation of the atmospheric nitrogen into nitrates. I use the term *nitrifying efficiency,* rather than *nitrifying power,* in the sense in which it has been employed by Stevens and Withers (1) to denote not only the presence of the nitrifying organisms in the soil which are capable of exercising their specific function under favorable conditions (nitrifying power) but also the suitability of the soil as a medium in which the process of nitrification may proceed advantageously (nitrifying capacity).

## Soil Samples

We have not confined the investigation to Colorado soils alone,

(1) Studies in Soil Bacteriology III. Concerning methods for the determination of nitrifying and ammonifying powers, Stevens, F. L. and Withers, W. A., Cent. f. Bakt., Abt. II., Bd. 25, No. 1-4, p. 64, 1909.

but have extended it to include samples from widely separated and distant localities in the United States. These have been designated as "foreign" merely to distinguish them from the local collection. With but two or three exceptions, as hereinafter noted, they have been gathered from cultivated land and represent cotton, tobacco, melon and orchard soils of the South, general farming and sugar-beet land of the East, Central and Middle West, the citrus and viniferous districts of the Southern Pacific Coast, and the orchard section of the Northwest.

Their distribution was as follows: Two samples from Georgia, three from North Carolina, one from Virginia, one from Ohio, one from Arkansas, one from Kansas, two from Oklahoma, one from Texas, nine from California, and one from Washington.

The samples from our own state have been taken from different localities over a continuous area of approximately six hundred square miles. Much of this is still good farm and orchard land but no small portion has been rendered worthless during the past five years by excessive nitrates. The soils which we have selected are fair representatives of orchard land, sugar beet, oat and alfalfa fields, barren wastes and raw land in the afflicted district. A few samples from apparently normal localities have been introduced for comparison.

## METHODS

*Nitrifiable Substances Employed*:

Ammoniacal nitrogen for our experiments was supplied to the soils in three forms: Ammonium sulphate, ammonium carbonate and ammonium chlorid. An additional series was prepared with dried blood in order to determine whether the ammoniacal nitrogen made from proteid nitrogen by the ammonifying bacteria would respond to the nitrifying agents to a greater or less degree than the above mentioned compounds of ammonium. The ammonium sulphate, ammonium chlorid and ammonium carbonate were added to the soils in the form of solutions so prepared that 10 c. cm. of each solution contained its respective salt in quantity sufficient to furnish 100 m. g. of nitrogen.

*Collection of Samples.*—With respect to the collection of the foreign samples, it was practically impossible either to expect or to secure any uniformity since the majority of the samples were taken by persons wholly unfamiliar with the technique of sampling, to say nothing of bacteriological precautions. To have imposed upon them the burden of sterilizing spatulas and containers would have meant not getting the soils; consequently, the only instructions which accompanied the requests were that the samples be taken to a depth of four inches and that about as much soil be sent as would go into an ordinary sized cigar box. The majority of collectors lined the boxes with paper before putting in the soil, but some failed to do even this. Occasionally, a sample came to the laboratory in a heavy, paper sugar sack, and one was received in a cloth bag.

For the benefit of any who may take exception to the results of our comparative studies on the ground that the foreign series was not collected according to the usual methods employed by soil bacteriologists, I may say that no one recognizes the value of using standard methods, wherever possible, more than we do, and we have the greatest respect for the investigator who holds firmly to this position. However, for our purpose, I believe that our soils were just as nearly representative of their respective localities as if they had been taken by an experienced person under aseptic conditions.

In Colorado where we could give our personal supervision to collecting the samples, we have exercised every precaution to prevent exterior contamination. All of the surface litter was removed before opening up the ground. Except where otherwise stated in the descriptions which follow, the samples were taken to a depth of six inches, i. e., they included the surface six inches; the soil was removed with sterilized spatulas and placed immediately in double. sterilized, paper sugar sacks; each sample contained approximately five pounds of the moist soil. All of the samples were shipped by express, as soon after collection as possible. to the bacteriological laboratory of the Experiment Station at Fort Collins in order to minimize the time in transit, during which, if unduly prolonged, the soil flora might undergo changes. This statement is deemed necessary since many of the samples were taken more than five hundred miles from Fort Collins. As a result of our nitrogen fixing and ammonifying studies, we have made it a point in collecting samples where the brown color is present, to avoid getting this portion of the soil since experience has taught us that the nitrates are apt to be so high that they interfere with the normal development of the microorganisms present.

*Preparation of Samples.*—From this point, both the Colorado and the foreign soils were handled alike. As soon as they reached the laboratory, each was emptied on a sheet of heavy, sterilized manilla paper and thoroughly mixed. It was next divided into two unequal portions, the larger being spread out in the air to dry in diffused light, while the smaller was transferred in its original moist condition to a sterilized Mason fruit jar and sealed. As soon as air dry, which seldom requires more than twenty-four hours in our atmosphere, each soil was again mixed and pulverized in a glass mortar. Both the mortar and pestle were sterilized carefully between each two different samples with a 5 per cent. solution of lysol. They were subsequently rinsed with hot, boiled water and allowed to dry before the next sample was treated. The soils were next passed through a thirty mesh wire sieve which was washed between the different samples and sterilized by dry heat.

As containers for the prepared soil, we have used the same style of deep culture dish as in our previous experiments. These are similar in shape to the ordinary Petri dish except that they are deeper, measuring 10 cm. in diameter and 4 cm. in depth.

100 grams of soil, prepared as described above, were used for each dish. The ammonium sulphate, ammonium chlorid and ammonium car-

bonate were mixed with this by adding the respective solutions drop by drop to a portion of the 100 grams, and then more of the soil was added and more solution, and so on until 10 c. cm. of solution corresponding to 100 m. g. of nitrogen had been used with the whole sample. For the organic nitrogen, dried blood (1) corresponding to 100 m. g. total nitrogen was added to like portions of soil and was thoroughly incorporated by stirring the mixture for five minutes with a sterile glass rod. Five cultures were prepared from each of the Colorado soils. Three received the ammonia salts, one the dried blood, and one to which no form of nitrogen was added, was kept as a control. The ammonium chlorid series was omitted from the foreign soils.

*Inoculation of Soils.*—Each culture mixture was inoculated with 10 c. cm. of soil infusion prepared from fresh soil of the same source as that already in the dish and corresponded to 5 grams of the undried material. These infusions were made by shaking 100 g. of undried soil with 200 c. cm .of sterile distilled water for five minutes. They were allowed to stand thirty minutes for the coarser particles to settle after which 10 c. cm. of the turbid suspension were drawn off with a sterile pipette and distributed uniformly over the surface of the soil in the culture dish. In order that the dried blood and control series might have the same moisture content as the other three, sufficient sterile distilled water was added to make the moisture approximately 22 per cent. Additional water was used for the dried blood at the rate of 1.5 c. cm. for each gram of material.

The weight of each culture was determined at the beginning of the experiment and the loss of water by evaporation was restored every ten days with sterile, distilled water.

*Incubation of Samples.*—All of the cultures were kept in the incubator at a temperature of 28 - 30 degrees C. throughout the experimental period of six weeks. At the end of this time quantitative determinations were made for nitrites and nitrates.

*Chemical Methods.*—10 grams of each sample, air dried and pulverized, were used in the chemical determinations. This was extracted with hot water and washed free from chlorides and nitrates on a Buchner funnel containing asbestos. The resulting extracts were rendered colorless by means of carbon black. That portion of the extract which was used for the determination of nitrites and nitrates was freed from chlorides by the use of silver sulphate. The loss of nitrous and nitric acid during the evaporation and concentration of the extracts on the water bath was prevented by the addition of milk of lime in excess.

The nitrates were determined by the phenoldisulfonic acid method; the nitrites by Ilsovay's modification of Griess's test (sulfanilic acid and naphthylamine acetate); the chlorids, volumetrically, by titration with silver nitrate.

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(1) The dried blood contained 13.0503 per cent. total nitrogen.

## DESCRIPTION OF THE SOILS

### COLORADO SOILS

*Sample No. 75.*—The first soil that we shall consider was collected at Fort Collins April 29, 1913. The land had been in barley the preceding year and in sugar-beets the year before that. It is what would be considered a normal clay soil for this section of the state; level, well drained, and free from any trace of white alkali and brown discoloration. In 1913, it produced an average of 45 bu. of wheat to the acre and in 1911, 24 tons of sugar-beets per acre. This sample was composed of twenty sub-samples taken to a depth of six inches over an area of one-half acre. The nitric nitrogen amounted to 7 p. p. m. and the chlorin to 500 p. p. m.

*Sample No. 76.*—For the next sample, we went to an altitude of almost 9000 feet to a truck patch nestled in a gulch on the outskirts of a mining town. This is the only tract of its kind which Nature has allowed in the vicinity and which, I should judge, has an area of less than twenty acres. It is more than 3000 feet above and 36 miles from any known niter area, and, so far as could be learned, it is perfectly normal. However, it has an an added interest from the fact that previous to its present ownership it was held as a placer gold claim. The soil is a deep river-bottom silt loam and has been maintained in a very productive condition in recent years by the heavy application of stable manure. In 1911, the owner harvested 240 sacks (over 450 bushels) of potatoes to the acre. All kinds of vegetables and small fruits, especially strawberries, are grown here very successfully. At the time this sample was collected, May 11, 1913, nothing had been planted, and the ground was covered with a very liberal dressing of manure. This was removed as far as possible before taking the sample, but the heavy snows of the preceding winter and spring must have caused some leaching. Just how much this had affected the nitrates of the surface-layers, we have no means of knowing, but it undoubtedly contributed something. The nitric nitrogen amounted to 54 p. p. m. and the chlorin to 400 p. p. m.

*Sample No. 77.*—This soil came from a tract that we have had under observation since 1908. At that time it was planted to oats, but the stand was very spotted. Throughout the field barren patches were developing, brown in color and mealy in texture. Alfalfa growing had been abandoned in previous years because it was believed that the water table was getting so close to the surface that this crop could not succeed. In the light of our present knowledge, it is possible that it was the excessive nitrates rather than too much water that was injuring the alfalfa. In 1909 sugar-beets were planted, but with no better results. The brown areas kept increasing in number and size until there were patches of half an acre in extent where nothing would grow. That fall it was planted to winter wheat, but before the harvest of 1910, the whole twenty-five acres had died. I visited the place in 1911 and found that Russian thistles and salt bush had taken possession of practically the entire area. Evidently the nitrates had been reduced by the heavy rains of the preceding winter and spring to a point of tolerance for these weeds since in other years nothing of this kind had occurred. I do not know what crop, if any, occupied the land in 1912, but when the present sample was collected in May, 1913, it had been sown to oats. The stand was exceedingly thin and the bulk of the growth was confined to the narrow zone adjacant to the irrigating furrows. Between these, the plants were very scattering. There was considerable white alkali in evidence, and the sides of the irrigating furrows bore a slight crust beneath which the soil was mealy. There were no well defined brown or chocolate colored areas as in previous years, but the whole field presented a marked brownish aspect. The soil is a clay loam and contained nitric nitrogen at the rate of 26 p. p. m. and chlorin 4,500 p. p. m.

*Sample No. 78.*—While our chief interest in this investigation attached itself to cultivated soils, we have selected, nevertheless, one sample from the side of an adobe hill where the soil was just being formed from the weathering shales. This was raw land, of course, if it could be styled land at all, and there was no evidence that anything had ever grown upon it. The overlying mesa was in cultivation, and judging from the water erosion of the hillside, it had received some of the leachings from above during heavy rains. Such formations as this, by gradual weathering, are contributing quite extensively to the formation of our heavy adobe clay soils and it was of considerable interest to learn whether the ancestors of these soils were as active biologically as their cultivated offspring. There was no white alkali visible on the surface and no seep from the side of the hill at the time the sample was taken, May 13, 1913. The nitric nitrogen was higher than I should have expected had it not been for the wash from above; it amounted to 140 p. p. m. and the chlorin to 700 p. p. m.

*Sample No. 79.*—The next sample came from a well drained orchard where there was never any white alkali to be seen, but where the niter trouble has been manifesting itself to a greater or less degree for the past four years. When it first made its appearance it was confined to a few rows of trees on the west side of the orchard; today, it extends up and down both sides of the main highway for several miles, easily recognized by the dark brown, greasy appearance of the soil. That section of the orchard from which this sample was taken is a red clay loam, and owing to this color it has always been difficult to discern any decided brown discoloration, although in another part where the formation is different, the brown color is strongly developed.

In 1910, the burning was very moderate and there seemed little reason for anticipating any grave danger from this cause. A few trees had died, but most of those affected appeared to be dying slowly rather than to be going in one season as is often the case. The next year, the number involved was considerably greater and the burning continued to be relatively mild, but by 1913, although the disaster had been moving slowly, it had been accomplishing its work just as surely, and nearly every third tree in the twenty acres had been killed and removed. When I visited here in May, 1913, young apple trees had been set out where the old trees were missing. I have not been back since to see if they survived the summer, but I should be surprised if they did. Red clover had been sown between the trees as a shade crop, but the stand was very scattering.

My sample was collected about two feet from a hole where a dead tree, presumably killed by niter, had been taken out. When the nitric nitrogen was determined, I was very much surprised to find that it contained but 5 p. p. m. with 1000 p. p. m. of chlorin. That the nitrates in this soil had been considerably above normal in 1910, there is no question, for at that time Dr. Headden found in the surface-three inches 4.902 per cent. of water soluble salts to be nitrates, the water soluble amounting to 2.92 per cent. of the air-dried soil. I am at a loss to explain the low figure that I obtained unless it is that I was misled by the hole where the tree was missing into thinking that it was a niter tree when, in reality, it had died from another cause, or else, I just happened to take the sample from a spot where the excessive nitrates had not yet developed. As mentioned before, there was no brown color apparent on this red soil, to guide one either in picking out or in avoiding the bad places.

*Sample No. 80.*—In our study of this question we are continually meeting land-owners who believe that the difficulty can be remedied by proper drainage. The present case is only one of several that could be cited to show that little relief follows the installation of a drainage system. It is difficult to see how it could be otherwise, since the accumulation of nitrates does not appear to be a question of drainage; again, it has been found to be practically impossible to drain the heavier niter soils because of their sticky, gumbo character; and furthermore, in the majority of instances, draining is not indicated and is unnecessary. However, in the case at hand, the owner employed an experienced engineer to put in the necessary amount of tile at the proper depth and with the correct fall and distribution.

A part of the orchard was manifestly seeped as indicated by the white alkali on the surface, and this condition was remedied considerably by the drain, but so far as checking the progress of the niter destruction, nothing had been accomplished.

When I collected my sample, on the thirteenth of May, 1913, about one-third of the trees were dead and the barren spots had been reset with young stock. The soil is a clay loam and where the sample was taken the surface was very fine and mealy. Because of this condition, the surface-inch was removed and the second to fifth inch used. The nitric nitrogen present amounted to 13 p. p. m. and the chlorin to 10,400 p. p. m. As in the preceding orchard, we have observed here also in previous years that the burning was moderate and that the trees were succumbing slowly. This was probably due to the fact that the nitrates were accumulating more gradually than in other localities where damage had been more acute.

*Sample No. 81.*—This soil came from a field which had been in cultivation at one time, but which has been abandoned for the past two years, at least, for some unknown reason. The tract is situated well above the surrounding country on an imposing mesa, but in spite of its favorable location and elevation, it is a matter of common observation that much of the land is too wet for successful farming without a great deal of draining. Why this condition should exist where every advantage appears to be offered for natural drainage has been some what of a quandary. During recent years, very extensive ditches and drains have been put through this section and incidentally we observed while the trenches were still open that the underlying shales present at their upper limit a series of basins, filled with coarse gravel, which appear to retain the irrigating waters and in this way interfere with natural drainage.

The field in question was barren for the most part, although clumps of Russian thistles occurred here and there. The ground was wet in places from an over-flowing ditch and there was a very decided development of large brown areas. Everything indicated that these were niter spots. Accordingly, I took a composite sample of the brown surface-inch from a number of dark brown patches on the ridge of what looked to be an old sugar-beet row.

The soil is a clay and the surface color varied from a yellowish brown to chocolate. A determination of the nitric nitrogen showed it to contain 1360 p. p. m. with 32,400 p. p. m. of chlorin.

*Sample No. 82.*—This sample was taken exactly six feet from the brown area described in No. 81 and consisted of the second to fifth inches. The soil was very dry and rather mealy on the surface, but there was no indication whatever of any brown color. Russian thistles had grown on this particular spot luxuriantly and had to be removed before securing the sample. This soil, from just beyond the limits of the brown areas, together with No. 81 from the brown crust gave me an excellent opportunity to compare the microbic activities under two such different soil conditions where the two samples occurred less than seven feet from one another. The soil contained 46 p. p. m. of nitric nitrogen as compared with 1,360 in the brown crust. The chlorin present amounted to 9.800 p. p. m.

*Sample No. 83.*—This soil came from an orchard in prime bearing condition where seven trees had been killed by niter in 1911. These trees were all in one row, although not adjacent. They were cut down in the fall of 1911 and when I visited the orchard in September, 1912, the water sprouts from these stumps showed very severe nitre burning. My sample was taken between two of the stumps and consisted of the surface-three inches. The soil is a very heavy clay. No new cases of burning had been observed in the orchard that summer and there was no indication of the trouble spreading to adjacent rows. Seven of the trees in another row bore rather scant foliage and small fruit but this condition might have been due to a variety of causes. This soil contained 6 p. p. m. of nitric nitrogen and 58 p. p. m. of chlorin. I should consider this orchard in the incipient stage of the trouble.

*Sample No.* 84.—Another bearing orchard, probably fifteen to eighteen years old, in the same neighborhood as No. 83 gave us the next sample. The soil here is a heavy clay. When I visited the ranch in September, 1912, fifteen trees, all within a circular area in one corner of the orchard, were burning very badly. The foliage was practically all brown but the apples showed no signs of any injury and unless some very rapid change for the worse took place, they gave promise of maturing. In a remote corner of the orchard, three more trees were found to be buring. The soil between the trees showed no brown spots as yet, but the sides of the main ditch were brown four or five feet up from the water. My sample was taken near a burning tree and contained only a trace of nitric nitrogen and 128 p. p. m. of chlorin. Here also this orchard is to be looked upon as being in the incipient stage of the trouble.

*Sample No. 85.*—We have here another old orchard where the burning from excessive nitrates has been present to our knowledge for four years. In 1910, the attack was very acute and about two and one-half acres of bearing trees were destroyed. Strangely enough, since then the onslaught has abated, and while a large number of the trees show the typical burning of the foliage, but few more have died. A considerable number are making practically no growth and are struggling along stunted and half leaved out. The soil is a clay loam and shortly after it is irrigated, the brown color can be seen very readily, developing along the irrigating furrows. The sample was taken in September, 1912, near an affected tree and contained 6 p. p. m. of nitric nitrogen and 1000 p. p. m. of chlorin. The soil was very dry and hard at that time and no brown color was in evidence near where the sample was collected, although it had been seen in great abundance on other occasions.

*Sample No. 86.*—Sample No. 86 is a sandy loam and came from the mealy ridge of an irrigating furrow in an orchard where high nitrates have made their appearance within the past three years. While collecting samples in this vicinity in former years, I had passed by this place many times but never until 1911 had I observed anything unusual about either the trees or the soil. The area of the orchard is about four acres, and in Ocober, 1911, every tree on the two acres was seriously affected, in fact, they were as good as dead. When I saw the place again in September, 1912, all of these trees had been grubbed out, and the two acres had been planted to oats and alfalfa. It goes without saying that the experiment had been disappointing. At least three-fifths of the trees on the remaining two acres were burning. A well defined crust had formed on a portion of the ground, and this was dark chocolate brown to black in color, all the darker because of its moist condition due to the presence of quantities of deliquescent magnesium nitrate. sample contained 130 p. p. m. of nitric nitrogen and 6400 p. p. m. of chlorin.

*Sample 87.*—This soil came from an orchard which was among the first to be called to our attention because of the heavy losses from high nitrates. The area of the original tract was forty acres and previous to 1911, from seven to eight acres had died and the trees had been taken out. In 1911, this part was sown to oats, but the stand was very unsatisfactory. The mealy ridges of the irrigating furrows were barren, and what little growth occurred took place in the bottom of the furrows where the water appeared to have reduced the nitrates to a point of partial tolerance. Nothing was planted here the next year. The burning was general over the remainder of the orchard in 1912, but the attack seemed to have been concentrated upon two rows of trees next to the outside row on the east side. Practically every one of these was so badly burned that no green color was left to the foliage and the apples in September were not more than two-thirds grown and badly shriveled. Judging from the hardness of the ground and the aspect of the orchard as a whole, it had been neither irrigated nor cultivated that season and was suffering from general neglect. My sample consisted of the surface-four inches taken between two burning trees. The soil is a clay loam and was very hard and dry. There was no brown color visible, due, presumably, to the fact that the ground was too dry for the development of the Azotobacter pigment. It contained 6 p. p. m. of nitric nitrogen and 202 p. p. m. of chlorin.

*Sample No. 88.*—Of all the soils which we have had under observation, none has offered a better opportunity for watching the development and lateral movement of the high nitrates than this one. The wiiter's acquaintance with the area dates from 1909 when all that was left of a twenty acre orchard was parts of six rows of trees on one side next to a ditch. The whole tract involved is forty acres, twenty of which was in alfalfa prior to 1907 and the balance in bearing apple trees. In 1907, barren spots began to appear in the alfalfa and brown patches to develop in the orchard. Soon the trees began to show the burned leaf margins which we have come to associate positively with excessive nitre, and a large number died. Here, as is so often the case, a few trees in the interior of the orchard succumbed first, and from these as a focal center, the destruction spread rapidly in all directions. The attack was so severe and the progress so rapid that by the spring of 1909, all of the alfalfa had been killed and at least fifty per cent. of the trees. During 1909, the remainder of the trees died except parts of six rows. During 1910, the three inside rows of these were killed. In 1911, the two inside rows of the remaining three travelled the road of their fellows, and the lone outside row bade fair to follow, for several of its members were burning. When I next visited the place to take the present sample in the fall of 1912, not one tree was standing. All had died save three, which the owner had taken pity on and cut down. These three were still green; the foliage was not burned, but the leaves were small and scattering. I first saw the orchard in 1909, and at that time the whole central portion from which the trees had been removed was as brown as could be; in fact, almost black. This color did not extend into the six rows which were still alive beyond the very inside row. The next year it moved in four rows, but beyond this, the color and physical condition of the soil were normal to all appearances. By

1912, when the last trees died, the brown color covered the entire area, spreading, in more or less broken stretches, over the ground occupied by the very outside tree-row. The soil in the beginning was a rather heavy clay loam; now it is quite mealy and ashy in character.

I do not know where we could find a better illustration of the formation and spread of nitrates from a central point than is given in this case by the regular succession in which row after row of trees went down before the approaching niter wave.

One rather interesting thing that occurred in connection with this soil was the very luxuriant growth of salt bush which took place in the summer of 1911. With the exception of a few barren spots, here and there, where the nitrates were evidently too concentrated, the whole forty acres were covered with this weed, waist high. During the preceding three years, nothing had grown there, but the winter and spring of 1911-1912, were very wet for this locality and it is possible that the nitrates were washed out sufficiently to allow the Atriplex to become established. While there were some weeds here in 1912, the vigor of the growth and the area covered were nothing compared with that of the preceding year. The tract was entirely barren in 1913.

My sample was taken between the two living trees that had just been cut, where the soil was beginning to get rather mealy. It consisted of the surface-three inches and contained 70 p. p. m. of nitric nitrogen and 8300 p. p. m. of chlorin.

*Sample No. 89.*—The sample was collected from an orchard where the trees have been dying since 1908. The owner believed that the cause of the trouble was starvation so he gave the soil a heavy dressing of stable manure, thereby, in all probability, aggravating the attack. At any rate, no benefit whatsoever resulted, and year after year more and more trees have succumbed until about three and one-half acres died and were grubbed out. One year the land was planted to spring wheat where the trees were removed, but practically none of it ever came through the ground. When I last saw the place in the fall of 1912, the burning had extended north and west into the good part of the orchard five more rows, but there was almost none to be found in the remaining five or six acres. The ground appeared to have been heavily manured quite recently. The soil was a coffee-brown color where the trees had been taken out, and no attempt was being made to use the land. It was not wet and there was no water in a test well at a depth of 6 feet, although spots of white alkali were showing up here and there. The soil is a sandy loam, not particularly mealy. The brown color had not yet developed, at least it was not visible at that time, where the trees were then burning and where I took my sample. Nitric nitrogen amounting to 180 p. p. m. and chlorin to 1600 p. p. m. were found.

*Sample No. 90.*—We have next the case of a ninety acre apple orchard where the trees commenced dying from too much nitrate in 1908. At this time the brown stain was most conspicuous on the sides of the irrigating furrows, but more recently it has spread over the entire surface in some parts of the orchard. During 1910-1911 the violence of the attack centered in one corner and resulted in the death of every tree on two and one-half acres save a few in the outside fence-row along an irrigating ditch. This meant the loss of approximately two hundred and fifty bearing trees. During the last two seasons, the trouble has become generally distributed over the south half, but it appears to be very much less active than in the preceding years. The trees exhibit some burning, and the leaves and fruit are undersized, with a suggestion of premature ripening, but the death rate does not begin to be as high as in 1910-1911. My sample consisted of the surface four inches of sandy loam taken between two burning trees on the edge of the two and one-half acres where everything had died. No brown color was in evidence, although the soil was moist. The nitric nitrogen present amounted to 13 p. p. m. and the chlorin to 140 p. p. m.

*Sample No. 91.*—During the summer of 1910, while looking over a large orchard for indications of niter, I came upon three trees near to one another whose leaves were considerably burned. The inference was that the same causal factors were operative here as elsewhere, although no nitrate determinations were made at the time. A sample of the soil was taken for my nitrogen fixation experiments, and better than 11.00 m. g. of nitrogen were fixed with 1.5 g. of mannite. I did not see the orchard again until the fall of 1912, and I must confess that I was very much surprised to be unable to find a single tree affected where I had noted them before. In place of the dwarfed, sickly growth with many brown leaves, I found the trees unusually vigorous and free from burning. Many had sent out new shoots over three feet long; the foliage was fully developed and of an excellent color. Confronted with such an unexpected condition of affairs, I set out at once to find the manager and to ascertain, if possible, an explanation of this remarkable rejuvenation. According to the owner's statements, one hundred and fifty-six trees were in a serious condition with niter symptoms in 1911, and realizing the immediate need of some extreme measures to save the trees, he plowed the whole orchard twelve to fourteen inches deep that fall, and in the spring of 1912, he dynamited the two acres where the trouble seemed to be localized using one-half stick of dynamite placed midway of the rows for each four trees. Following this, he turned on a big head of water and washed out the soil as thoroughly as can be accomplished by such a procedure. The blasting had loosened the soil to a considerable depth so that the water penetrated it very readily, and any nitrates that had accumulated in the surface layers were doubtless reduced very materially. Added to the benefit derived from this source was the greatly improved physical condition of the soil, which must have encouraged new root development. This last factor was undoubtedly responsible for the thriving condition of the orchard. Although I did not locate any burning trees myself, Mr.———— stated that there were a few, not to exceed six, whereas in 1911 there had been one hunded and fifty-six. He told me that the results of his blasting experiment had been so gratifying that it was his purpose to apply the same treatment to the remainder of the orchard before another season.

At no time have I observed any brown color on this soil. The present sample, a heavy clay, was taken from the two and a half acres described above and contained only a trace of nitric nitrogen and 60 p. p. m. of chlorin.

*Sample No. 92.*—This soil came from an orchard which is very favorably located for securing the best possible natural drainage. It borders on a river and is about twelve feet above the normal level of the stream. The soil is a light sandy loam and is underlaid at five to eight feet with coarse gravel. When the river is at flood, the level of the ground-water has been within ten inches of the surface and in the depressions the water has stood two inches deep so there can be no question about the openness of the soil. It has been frequently observed on this place that the ground water rises and falls regularly with any appreciable change in the level of the river.

The orchard is about twenty years old and until 1909 it had been very productive. During that year, the brown color became very conspicuous on the surface and the nitrates developed very rapidly. Approximately three hundred apple trees were killed, and in the spring of 1910, they were removed. The entire surface of four and one-half acres from which the trees had been taken was covered with a hard brown crust beneath which the soil was mealy and ashy. Corn was planted here, but it amounted to nothing since much of it never came up, and what little succeeded in getting through the ground turned yellow and died when it was 8 to 10 inches high. Not despairing of all hope, the owner planted it to cantaloupes in 1911. Here and there a plant got established and produced very well, but the crop as a whole was a dismal failure. The tract was sown to oats in 1912 but only those plants that were next to the water in the irrigating furrows survived. A good many got to be six to eight inches tall and then burned. In some places weeds were growing in the furrows, but in many others neither weeds nor oats could endure the nitrates and the stand was so poor that it was not considered worth irrigating. When I visited the ranch in the fall of 1912, the burning had extended no farther into the orchard than in 1911 and had stopped abruptly almost to the row. Strangely enough, there were a few scattering trees next to the river that were badly burned. One tree in particular attracted my attention, since it was not to exceed ten feet from the edge of the river bank and twelve feet above the water, yet it was as brown as could be from niter injury. Most certainly the burned condition of the leaves could not be attributed to poor drainage in this case.

My sample was collected from the barren area and contained 320 p. p. m. of nitric nitrogen with 7800 p. p. m. of chlorin.

*Sample No. 93.*—Thus far, all of the orchards which we have described have been apple, but we come now to a section of the country where peaches and apples are grown in alternate rows, the peaches being used as fillers. I first became interested in this orchard in 1910, not because of the niter but because of a peculiar physiological condition of some apricot trees. While looking about for some explanation of this trouble I noticed the same brown color on the sides of the irrigating furrows. A short distance away I found about a dozen apple trees badly burned so that my diagnosis of the condition of the soil was confirmed.

In 1911 I visited the orchard and again in the fall of 1912, but on both occasions I failed to find either the brown color on the soil or burning of the apple foliage. The peach trees were yielding well and everything seemed to be normal. I took a sample of the soil, a heavy clay, however, as typical of our best peach land and have regarded it as a normal soil. It contained 4 p. p. m. of nitric nitrogen and 120 p. p. m. of chlorin.

*Sample No. 94.*—A short distance from the orchard described as No. 93 is a large apple orchard where in 1910 six acres of bearing trees were killed and in 1911 ten acres more were so nearly exterminated that the owner grubbed out all of the sixteen acres. Peaches were set out where the apples were removed and when I saw them in September of 1912 they seemed to be thriving. At this time the soil was moist from a recent irrigation and it was brown everywhere, particularly on the sides and crests of the irrigating furrows. Although this condition prevailed in the remainder of the apple orchard, I was able to find only one tree that was burning. In all probability the nitrates either had not become sufficiently concentrated as yet or they had not been washed down to the zone of the feeding roots. My sample was taken from the ridges of three irrigating furrows and included the top four inches. It contained 34 p. p. m. of nitric nitrogen and 420 p. p. m. of chlorin.

*Sample No. 95.*—This sample consisted of the brown surface half-inch form the irrigating furrows described in the preceding sample. The color varied from the brown of iron rust to dark chocolate. The soil was quite moist and there was no mealy condition beneath the surface crust. It contained 600 p. p. m. of nitric nitrogen and 150 p. p. m. of chlorin. My purpose in taking this sample was to compare the nitrifying efficiency of the surface crust where the nitrates had become concentrated with that of soil from the same source taken to greater depths.

*Sample No. 96.*—The next sample came from a peach orchard where the owner complained of the peach leaves turning yellow and the immature fruit dropping. We have never had an opportunity to observe the behavior of bearing peach trees when grown where nitrates are excessive and consequently we did not know just what to expect. So far as our records go, they show that both pears and peaches withstand niter very well. This soil was a nice sandy loam; it exhibited no brown color, and, as a subsequent chemical determination showed, the nitrates were not excessive, although somewhat higher than other soils in that vicinity. We have no reason for thinking that the peach trouble metioned above was caused by the small amount of nitrates present. The sample was collected near one of the affected trees and contained 20 p. p. m. of nitric nitrogen and 170 p. p. m. of chlorin.

*Sample No. 97.*—The next sample came from an apple orchard in a section of the country where no trouble was ever experienced from high nitrates until 1911. Almost every other part had had its trials but this region appeared to have been favored. As I was driving past this orchard one afternoon in October of 1911, I noticed some thirty trees in one corner that were dying unquestionably from too much niter. These were the only trees affected in this way that could be found any place in the neighborhood. The soil is a clay loam and it was rather moist from a recent shower, so it was difficult to determine the presence of the brown color. I visited the place again in July, 1912, and found that the burning had spread over the entire district embracing, I should judge, eight to ten square miles. Practically everything in the way of apple trees was suffering. The owner of the place told me that the burning had all developed since the last irrigation which was begun on Sunday, June 30th, and was continued until the following Wednesday. About three days after he took the water off, he had observed the dark brown stain on the irrigating furrows and in about one week the trees began to burn. That is to say, one week was required for the nitrates, which were carried from the surface to the feeding zone of the apple roots, to produce the physiological effect on the foliage which we have designated as burning.

The soil was hard and dry at the time the sample was taken; there was no brown color visible and judging from the physical condition of the soil, it had received little cultivation and irrigation during the summer and fall of 1912. Nitric nitrogen amounting to 20 p. p. m. and chlorin to 65 p. p. m. were found.

## Foreign Soils

*Sample No. 52.*—Ohio. Received March, 1913; clay loam; moist; corn field; nitric nitrogen 7 p. p. m.; chlorin 8 p. p. m.

*Sample No. 53.*—Georgia. Received March 10, 1913; red gravelly loam; oak and pine forest; wet when sent; nitric nitrogen 5 p. p.m.; chlorin 78 p. p. m.

*Sample No. 54.*—Washington. Received March 9, 1913; dark loam; upland soil from an orchard; typical of the river bench soil common to that locality; moisture good; nitric nitrogen 5 p. p. m.; chlorin 40 p. p. m.

*Sample No. 55.*—Virginia. Received March 10, 1913 heavy clay from an orchard; sample wet due to heavy rains at the time soil was collected; nitric nitrogen 9 p. p. m.; chlorin 74 p. p. m.

*Sample No. 56.*—Oklahoma. Received March 17, 1913; sandy loam; cotton in 1912, dry; nitric nitrogen 11 p. p. m.; chlorin 8 p. p. m.

*Sample No. 57.*—North Carolina. Received March 19, 1913; light sandy loam; sharp sand with little organic matter; water melons 1912; moisture good; nitric nitrogen 7 p. p. m.; chlorin 10 p. p. m.

*Sample No. 58.*—Texas. Received March 18, 1913; dark sandy loam; never received commercial fertilizer or stable manure; cotton 1912; corn 1911; nitric nitrogen 7 p. p. m.; chlorin 98 p. p. m.

*Sample No. 59.*—Georgia. Received March 21, 1913; red clay loam; cotton for last three years with average yield of four hundred pounds per acre; nitric nitrogen 14 p. p. m.; chlorin 106 p. p. m.

*Sample No. 60.*—North Carolina. Received March 22, 1913; light colored clay; planted to corn for several years, gave an average yield of forty to fifty bushels per acre; no manure or fertilizer applied; said to be very good corn land when properly cared for; sample was very dry when received; nitric nitrogen 6 p. p. m.; chlorin 8 p. p. m.

*Sample No. 61.*—North Carolina. Received March 19, 1913; white sandy loam containing a great deal of sharp white sand; very little organic matter; tobacco in 1912; wheat in 1913; wet; nitric nitrogen 3 p. p. m.; chlorin 6 p. p. m.

*Sample No. 62.*—California. Received March 8, 1913; clay loam with some adobe; no white alkali on surface; moist; grapes for past few years; nitric nitrogen 4 p. p. m.; chlorin 26 p. p. m.

*Sample No. 63.*—California. Received March 8, 1913; sandy loam; moist, alfalfa field, no white alkali on surface and no brown color; nitric nitrogen 4 p. p. m.; chlorin 8 p. p. m.

*Sample No.* 64.—California. Received March 8, 1913; sandy loam; moist; in small grain 1912. No white alkali; nitric nitrogen 6 p. p. m.; chlorin 8 p. p. m.

*Sample No. 65.—Arkansas.* Received March 28, 1913; red sandy loam from Arkansas bottom; cotton in 1912, soil very wet when collected, so it was dried before sent; nitric nitrogen 4 p. p. m.; chlorin 62 p. p. m.

*Sample No. 66.*—Oklahoma. Received March 25, 1913; clay loam; sample taken to depth of six inches; alfalfa in 1911, cane in 1912. The person who sent the sample states that it has always been difficult to get trees to grow on this land; nitric nitrogen 40 p. p. m.; chlorin 6 p. p. m.

*Sample No. 67.*—California. Received March 25, 1913; heavy silt loam; white alkali abundant as an incrustation where the sample was taken; no brown color; moist; no irrigation; young mixed orchard; nitric nitrogen 120 p. p. m.; chlorin 700 p. p. m.

*Sample No. 68.*—California. Received March 25th, 1913; light sandy loam, the prevailing soil in this region; no white alkali; sugar-beets in 1911, barley in 1912, and set to plums in 1913; nitric nitrogen 7.4 p. p. m.; chlorin 8 p. p. m.

*Sample No. 69.*—California. Received March 28, 1913; virgin soil from foothills; surface removed to avoid contamination due to wash;

clay; moist; no white alkali; general mountainous vegetation; nitric nitrogen 2 p. p. m.; chlorin 8 p. p. m.

*Sample No. 70.*—California. Received April 2, 1913; "black adobe"; no white alkali; moist; small grain in 1912, nitric nitrogen 5 p. p. m.; chlorin 10 p. p. m.

*Sample No. 71.*—California. Received March 7, 1913; sand and gravel from raw cactus land; moist; no white alkali and no brown color; nitric nitrogen, none; chlorin 6 p. p. m.

*Sample No. 73.*—California. Received April 2, 1913; sandy loam; no white alkali; no brown color; moist; formerly a vineyard; small grain in 1912; nitric nitrogen 7.4 p. p. m.; chlorin 8 p. p. m.

*Sample No. 74.*—Garden City, Kansas. Received April 17, 1913; sandy loam; sugar-beets for past two years, 1911 and 1912; nitric nitrogen 26 p. p. m.; chlorin 2,000 p. p. m.

## DISCUSSION OF RESULTS.

### *Colorado Soils.*

### SERIES I. AMMONIUM SULPHATE

In Table No. 1, will be found the results of our nitrification experiments with Colorado soils and ammonium sulphate. Of the twenty-three soils under study, 17 showed a very marked net gain in nitric nitrogen over the checks; one gave the same increase as the corresponding soil which received no ammonium sulphate and therefore is considered as having given no net gain(1); five contained less than in the beginning. The point of greatest interest in this series is the uniformly large gains which all of the positive soils made. There are no small increases of 10, 20, or 30 parts per million as might be expected, the smallest being 320. Furthermore, there is some justification for setting aside this figure as the lowest since the sample consisted of the surface crust from a brown area and does not represent a four to six inch section of soil as the others do. The nitric nitrogen was high to begin with, 600 p. p. m., and that may have had some retarding influence on the rate of nitrification. If No. 95 is eliminated, then we have the lowest net gain produced by any positive soil as 408 p. p. m. by No. 94, while the average is 672 and the maximum 972.

As a matter of interest in connection with Nos. 94 and 95, the reader's attention is called to the initial nitrate nitrogen in the two samples. It will be remembered that both were taken side by side, but that the former represents a soil-section a short distance from any brown material while the latter is just the brown surface; the first carried 34 p. p. m. and the second 600. The chlorin is considerably lower in the crust than in the section so it is probably the high nitrates that are responsible for the relatively small increase in nitric nitrogen.

(1) By the expression "total gain" is meant the increase in nitric nitrogen over the check at the beginning; by "net gain" is meant the increase over the check at the end.

Considering only those soils which gave positive results, there seems to be practically no difference in the activity of our normal and incipient niter soils as measured by their ability to nitrify ammonium sulphate

Looking next to the samples that show either no gain or a loss of nitric nitrogen, we find that with the exception of No. 78, the raw

**TABLE NO. 1.—Nitrification of Ammonium Sulphate by Colorado Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as $(NH_4)_2SO_4$ Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description. | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | $(NH_4)_2SO_4$ added | Check at begin. | Check at end | $(NH_4)_2SO_4$ added | Total gain | Net gain | |
| 75 Wheat field, clay, normal | .88 | .36 | 1.60 | 7. | 64. | 800. | 793. | 736. | 500. |
| 76 Truck garden, river bottom, loam, normal | 1.20 | .002 | .92 | 54. | 110. | 660. | 606. | 550. | 400. |
| 77 Oat field, clay loam, niter | .32 | .26 | 2.00 | 26. | 76. | 800. | 774. | 724. | 4,500. |
| 78 Raw land, adobe hill | .36 | .60 | 25.00 | 140. | 140. | 108. | —32. | —32. | 700. |
| 79 Apple orchard, red clay loam, niter | .26 | .60 | 9.60 | 5. | 66. | 600. | 595. | 534. | 1,000. |
| 80 Apple orchard, clay loam, niter | .28 | .90 | 68.00 | 13. | 50. | 36. | 23. | —14. | 10,000. |
| 81 Barren field, brown crust, niter | .32 | .22 | 1.60 | 1360. | 1360. | 1240. | —120. | —120. | 32,400. |
| 82 Barren field, clay, niter | 1.60 | .80 | 1.60 | 46. | 120. | 660. | 614. | 540. | 9,800. |
| 83 Apple orchard, heavy clay, niter | .02 | .36 | 2.40 | 6. | 100. | 1040. | 1034. | 940. | 58. |
| 84 Apple orchard, heavy clay, niter | .14 | .52 | 1.00 | Trace | 68. | 1040. | 1040. | 972. | 138. |
| 85 Apple orchard, clay loam, niter | .012 | .10 | 2.00 | 6. | 60. | 600. | 594. | 540. | 1,000. |
| 86 Oat field, sandy loam niter | .0 | .14 | .10 | 130. | 240. | 200. | 70. | —40. | 6,400. |
| 87 Apple orchard, clay loam, niter | .10 | .12 | .60 | 6. | 40. | 840. | 834. | 800. | 202. |
| 88 Apple orchard, clay loam, niter | .40 | .14 | .80 | 70. | 100. | 100. | 30. | 0. | 8,300. |
| 89 Apple orchard, clay loam, niter | .40 | .60 | .14 | 180. | 260. | 800. | 620. | 540. | 1,600. |
| 90 Apple orchard, sandy loam, niter | .32 | .40 | .36 | 13. | 60. | 800. | 867. | 820. | 140. |
| 91 Apple orchard, heavy clay, normal | .32 | .14 | .10 | Trace | 40. | 720. | 720. | 680. | 80. |
| 92 Oat field, sandy loam, niter | 1.40 | .20 | .36 | 320. | 320. | 240. | —80. | —80. | 7,800. |
| 93 Peach orchard, heavy clay, normal | .60 | .60 | 2.40 | 4. | 48. | 880. | 876. | 832. | 120. |
| 94 Apple orchard, clay niter | .14 | 1.20 | .10 | 34. | 92. | 500. | 466. | 408. | 420. |
| 95 Apple orchard, brown surface | .26 | .14 | .60 | 600. | 640. | 960 | 360. | 320. | 150. |
| 96 Peach orchard, sandy loam, normal | .24 | 1.00 | 2.40 | 20. | 60. | 720. | 700. | 660. | 170. |
| 97 Apple orchard, clay niter | .36 | 1.40 | .24 | 20. | 132. | 960. | 940. | 828. | 65. |

adobe hill, all contain very high chlorin; in fact with the exception of No. 82, which gave positive results, the five soils with the highest chlorin are the negative soils. Lipman (1) has shown experimentally that when sodium chlorid is present in soil in amounts equivalent

(1) Lipman, Chas. B., Toxic Effects of "Alkali Salts" in Soils on Soil Bacteria. II Nitrification. Cent. f. Bakt., II. Abt., Bd. 33, p. 305, 1912.

to .2 per cent. of the dry soil, that a very marked toxic effect is produced upon the nitrifying organisms; and that when a concentration of .4 per cent. is reached, no nitrification takes place. This seems to be the most plausible explanation of the failure of our high chlorin soils to produce nitrate. The chlorin in these, when computed as NaCl, gives the following concentrations which fall easily beyond the limits of tolerance as established by Lipman; No. 80, 1.65 per cent.; No. 81, 5.34 per cent.; No. 86, 1.05 per cent; No. 88, 1.36 per cent.; No. 92, 1.30 per cent. While this accounts vary nicely for the lack of nitrifying efficiency on the part of five samples, it makes it very difficult to explain why No. 82 with 9,800 p. p. m. of chlorin or 1.61 per cent. NaCl should respond positively with a net gain of 540 p. p. m. of nitric nitrogen.

On the other hand, Professor Lipman has shown that the presence of .05 per cent and even .1 per cent NaCl has a stimulating effect upon nitrification. Almost all of our positively reacting soils contain moderate amounts of sodium chlorid, varying from .009 per cent. to .165 per cent. and it is not at all improbable that the chlorin acts as an intensifying agent to nitrification.

The lack of nitrifying efficiency shown by No. 78 can hardly be accounted for by the presence of high chlorids, since it carries considerably less than several of the more efficient samples. The high nitrites which are present, 25 p. p. m., seem to indicate a vigorous denitrifying flora stimulated by the sulphate, rather than retarded nitrification. This follows from the fact that the control increased but very little, .24 p. p. m., in nitrous nitrogen and none at all in nitric nitrogen, while with ammonium sulphate added, there was a loss of nitrates and an appreciable increase of nitrites. Are we to infer from this that the $(NH_4)_2SO_4$ has favored the reducing agents? The failure of the control to increase in nitrogen would seem to support the view that the nitrifying organisms were either absent or the conditions were very unfavorable for their development. What has been said here applies equally well to No. 92, except that the high chlorin may account for the failure of the control to increase in nitrates.

The conditions were somewhat different in No. 80. Here we have evidence in the increased nitric nitrogen of the control that the nitrifying organisms were moderately vigorous; however, the addition of the ammonium sulphate has retarded their activity to a very marked degree as indicated by the 68 p. p. m. of nitrite nitrogen and 23 p. p. m. of nitrate nitrogen as compared with .9 p. p. m. and 50 p. p. m. respectively in the control.

Any interpretation that we might give to No. 86 would be little more than mere conjecture, other than to state that something has either interfered with nitrification or that denitrification has been exceedingly rapid in the presence of the ammonium salt. In either case, we should expect to find the nitrates higher than they are. That the nitrifying organisms are present there is no question for the control shows a material gain.

In No. 88, we have nitrification going on in the control but rather feebly. There was no increase in the nitric nitrogen with the additional supply of ammonia nitrogen. Knowing the condition and history of this soil, I am inclined to explain this by a loss of vitality and virulence on the part of the organisms rather than by their inability to attack ammonium sulphate. The water soluble salts in this soil were very high and the nitrifying bacteria were, in all probability, intoxicated, so to speak, by the saline solution.

## Series II. Ammonium Chlorid

The results of the next series are given in Table No. 2. Here the ammonia nitrogen was furnished in the form of ammonium chlorid. A

**TABLE NO. 2.—Nitrification of Ammonium Chlorid by Colorado Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as $NH_4Cl$ Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | $NH_4Cl$ added | Check at begin. | Check at end | $NH_4Cl$ added | Total gain | Net gain | |
| 83 Apple orchard, heavy clay, niter | .02 | .36 | .06 | 6. | 100. | 120. | 114. | 20. | 58. |
| 84 Apple orchard, heavy clay, niter | .14 | .52 | .10 | Trace | 68. | 320. | 320. | 252. | 138. |
| 85 Apple orchard, clay loam, niter | .012 | .10 | .20 | 6. | 60. | 12. | 6. | —48. | 1,000. |
| 86 Oat field, sandy loam, niter | .00 | .14 | .04 | 130. | 240. | 160. | 30. | —80. | 6,400. |
| 87 Apple orchard, clay loam, niter | .10 | .12 | .072 | 6. | 40. | 32. | 26. | —8. | 202. |
| 88 Apple orchard, clay loam, niter | .40 | .14 | .02 | 70. | 100. | 100. | 30. | 0. | 8,300. |
| 89 Apple orchard, sandy loam, niter | .40 | .60 | .08 | 180. | 260. | 200. | 20. | —60. | 1,600. |
| 90 Apple orchard, sandy loam, niter | .32 | .40 | .10 | 13. | 60. | 120. | 107. | 60. | 140. |
| 91 Apple orchard, heavy clay, normal | .32 | .14 | .112 | Trace | 40. | 72. | 72. | 32. | 80. |
| 92 Oat field, sandy loam niter | 1.40 | .20 | .18 | 320. | 320. | 280. | —40. | —40. | 7,800. |
| 93 Peach orchard, heavy clay, normal | .60 | .60 | .112 | 4. | 48. | 120. | 116. | 72. | 120. |
| 94 Apple orchard, clay niter | .14 | 1.20 | .10 | 34. | 92. | 240. | 206. | 148. | 420. |
| 95 Apple orchard, brown surface | .26 | .14 | .06 | 600. | 640. | 680. | 80. | 40. | 150. |
| 96 Peach orchard, sandy loam, normal | .24 | 1.00 | .12 | 20. | 60. | 96. | 76. | 36. | 170. |
| 97 Apple orchard, clay, niter | .36 | 1.40 | .26 | 20. | 132. | 560. | 540. | 428. | 65. |

glance at the net gain column of this table brings out the striking fact that ammonium chlorid does not begin to be as fertile a source of nitric nitrogen as the sulphate. Whether the additional chlorid has exercised an inhabiting action or whether this form of the salt is more resistant to the attacks of the nitrifying organisms is difficult to say. Nine of the fifteen samples gave a positive gain in nitric nitrogen with the chlorid; one showed no increase and five failed to produce as much as the controls. None yielded as much as the respective soils in the sulphate series, and all that fell behind here were also below in the preceding set. All of the negative results point strongly to the inhibition of the nitrifying organisms rather than to denitrification. The net gains in nitric nitrogen varied from 2.13 per cent. to 51.69 per cent. of those secured from ammonium sulphate with the corresponding soils; compared with the returns from ammonium carbonate, the third series, the gains varied from 3.49 per cent. to 37.28 per cent.; with dried blood, the fourth set, they varied from 4.00 per cent. to 57.22 per cent The average net gain in nitrate nitrogen for the positive soils was 120.88 p. p. m., with the maximum of 428.0 p. p. m. and a minimum of 20 p. p. m.

## Series III.. Ammonium Carbonate

Ammonia nitrogen was supplied in the form of ammonium carbonate to the third set of samples. The results of the study appear in

**TABLE NO. 3.—Nitrification of Ammonium Carbonate by Colorado Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as $(NH_4)_2CO_3$ Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | $(NH_4)_2CO_3$ added | Check at begin. | Check at end | $(NH_4)_2CO_3$ added | Total gain | Net gain | |
| 75 Wheat field, clay, normal | .88 | .36 | .152 | 7. | 64. | 720. | 713. | 656. | 500. |
| 76 Truck garden, river bottom loam, normal | 1.20 | .002 | .08 | 54. | 110. | 680. | 626. | 570. | 400. |
| 77 Oat field, clay loam, niter | .32 | .26 | .08 | 26. | 76. | 600. | 574. | 524. | 4,500. |
| 78 Raw land, adobe hill | .36 | .60 | .04 | 140. | 140. | 100. | —40. | —40. | 700. |
| 79 Apple orchard, red clay loam, niter | .26 | .60 | .32 | 5. | 66. | 560. | 555. | 494. | 1,000. |
| 80 Apple orchard, clay loam, niter | .28 | .90 | 48.00 | 13. | 50. | 36. | 23. | —14. | 10.000. |
| 81 Barren field, brown crust, niter | .32 | .22 | .60 | 1360. | 1360. | 1240. | —120. | —120. | 32,400. |
| 82 Barren field, clay niter | 1.60 | .80 | .20 | 46. | 120. | 700. | 654. | 580. | 9,800. |
| 83 Apple orchard, heavy clay, niter | .02 | .36 | .20 | 6. | 100. | 672. | 666. | 572. | 58. |
| 84 Apple orchard, heavy clay, niter | .14 | .52 | .02 | Trace | 68. | 700. | 700. | 632. | 138. |
| 85 Apple orchard, clay loam, niter | .012 | .10 | 3.60 | 6. | 60. | 400. | 394. | 340. | 1,000. |
| 86 Oat field, sandy loam, niter | .0 | .14 | .06 | 130. | 240. | 200. | 70. | —40. | 6,400. |
| 87 Apple orchard, clay loam, niter | .1 | .12 | 5.60 | 6. | 40. | 340. | 334. | 300. | 202. |
| 88 Apple orchard, clay loam, niter | .40 | .14 | .80 | 70. | 100. | 100. | 30. | 0. | 8,300. |
| 89 Apple orchard, sandy loam, niter | .40 | .60 | .12 | 180. | 260. | 600. | 420. | 340. | 1,600. |
| 90 Apple orchard, sandy loam, niter | .32 | .40 | .40 | 13. | 60. | 660. | 647. | 600. | 140. |
| 91 Apple orchard, heavy clay, normal | .32 | .14 | .32 | Trace | 40. | 700. | 700. | 660. | 80. |
| 92 Oat field, sandy loam niter | 1.40 | .20 | .10 | 320. | 320. | 340. | 20. | 20. | 7,800. |
| 93 Peach orchard, heavy clay, normal | .60 | .60 | 1.40 | 4. | 48. | 640. | 634. | 592. | 120. |
| 94 Apple orchard, clay niter | .14 | 1.20 | 9.60 | 34. | 92. | 700. | 666. | 608. | 420. |
| 95 Apple orchard, brown surface | .26 | .14 | .12 | 600. | 640. | 1320. | 720. | 680. | 150 |
| 96 Peach orchard, sandy loam, normal | .24 | 1.00 | 8.00 | 20. | 60. | 120. | 100. | 60. | 170. |
| 97 Apple orchard, clay, niter | .36 | 1.40 | 1.00 | 20. | 132. | 1280. | 1260. | 1148. | 65. |

Table No. 3. They indicate that this compound of ammonium is broken down with ease compared with the ammonium chlorid, but not quite as readily as the sulphate. Eighteen of our soils gave positive gains in nitric nitrogen from the carbonate; one showed no increase and four produced less than the controls. We find the samples which failed to nitrify the carbonate the same four that fell below with the sulphate, and what has been said by way of an attempted explanation of this under the sulphate series should hold equally well here. With the exception of No. 78, all are high in chlorin. A few points of interest in connecting with these negatively reacting soils may be mentioned here: No. 78, the raw adobe hill, failed by 8 p. p. m. to produce as much nitric nitrogen in the presence of the carbonate as of the sulphate; the vigorous denitrification appears to have carried the nitrates beyond the nitrite stage since the nitrous nitrogen is less than in the beginning. We have a rather striking coincidence in the exact agreement of soils 80, 81 and 86 with respect to the nitric nitrogen that they produced in the presence of both ammonium carbonate and ammonium sulphate. No. 92, which failed to give a net gain in nitric nitrogen with $(NH_4)_2SO_4$ yielded an increase of 20 p. p. m. over the control with $(NH_4)_2CO_3$, and this with 7,800 p. p. m. of chlorin present.

The average net gain in nitric nitrogen made by the positively reacting soils was 520.88 p. p. m., the maximum was 1148.0 p. p. m. by soil No. 97, and the minimum 20 p. p. m. by No. 92.

The results of this study indicate that both our normal and incipient niter soils are equally efficient in nitrifying ammonium carbonate.

The presence of large quantities of initial nitrate in the soil without high chlorin such as we find in No. 95 with 600 p. p. m. of nitric nitrogen did not interfere seriously with the nitrificaton process. In this particular instance, a net gain of 680 p. p. m. of nitric nitrogen was secured, although the sample to begin with contained a large excess, it being the brown crust from a niter spot.

### Series IV. Dried Blood

As stated elsewhere, we were curious to learn whether the ammonium compounds that are formed by the ammonification of proteid nitrogen, through the agency of ammonifying bacteria, would respond more or less readily to the nitrifying organisms than would the chemically pure salts. To this end, a fourth series of soils was prepared, to which dried blood was added to furnish the necessary organic nitrogen.

The results of the experiment appear in Table No. 4. In the previous investigation, we determined the ammonifying efficiency of soils from all of these localities except three and found them to be abundantly stocked with ammonifying organisms and capable of converting the nitrogen of the blood into ammonia nitrogen. Having ascertained this fact, we have proceeded on the assumption, in the present work, that ammonium compounds would be available for the nitrifying organisms, and that if there was no increase in nitrate at the end of the experimental period, it was chargeable to the nitrifying flora and not to the ammonifiers.

The addition of the dried blood to the soil appears to have improved the condition for nitrification in several of the samples for twenty of them gave gains in nitric nitrogen above the control; one produced the same and two less. It would be interesting to know whether the increased nitrifying efficiency in these cases has resulted from the additional food material or whether the deleterious action of the high chlorids has been lessened by some combination with the blood.

**TABLE NO. 4.—Nitrification of Dried Blood by Colorado Soils. Nitrogen in Parts Per Million of of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as Dried Blood Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | Dried Blood added | Check at begin. | Check at end | Dried Blood added | Total gain | Net gain | |
| 75 Wheat field, clay, normal | .88 | .36 | .30 | 7. | 64. | 680. | 673. | 616. | 500. |
| 76 Truck garden, river bottom loam, normal | 1.20 | .002 | .26 | 54. | 110. | 680. | 626. | 570. | 400. |
| 77 Oat field, clay loam, niter | .32 | .26 | .88 | 26. | 76. | 600. | 574. | 524. | 4,500. |
| 78 Raw land, adobe hill | .36 | .60 | .64 | 140. | 140. | 140. | 0. | 0. | 700. |
| 79 Apple orchard, red clay loam, niter | .26 | .60 | 1.00 | 5. | 66. | 640. | 635. | 590. | 1,000. |
| 80 Apple orchard, clay loam, niter | .28 | .90 | 88.00 | 13. | 50. | 100. | 87. | 50. | 10,000. |
| 81 Barren field, brown crust, niter | .32 | .22 | .84 | 1360. | 1360. | 740. | —620. | —620. | 32,400. |
| 82 Barren field, clay niter | 1.60 | .80 | 1.70 | 46. | 120. | 500. | 454 | 380. | 9,800. |
| 83 Apple orchard, heavy clay, niter | .02 | .36 | .08 | 6. | 100. | 600. | 594. | 500. | 58. |
| 84 Apple orchard, heavy clay, niter | .14 | .52 | .18 | Trace | 68. | 880. | 880. | 812. | 138. |
| 85 Apple orchard, clay loam, niter | .012 | .10 | .26 | 6. | 60. | 620. | 614. | 560. | 1,000. |
| 86 Oat field, sandy loam, niter | .00 | .14 | .02 | 130. | 240. | 80. | —50. | —160. | 6,400. |
| 87 Apple orchard, clay loam, niter | .10 | .12 | 35.00 | 6. | 40. | 320. | 314. | 280. | 202. |
| 88 Apple orchard, clay loam, niter | .40 | .14 | .60 | 70. | 100. | 240. | 170. | 140. | 8,300. |
| 89 Apple orchard, sandy loam, niter | .40 | .60 | 5.20 | 180. | 260. | 480. | 300. | 220. | 1,600. |
| 90 Apple orchard, sandy loam, niter | .32 | .40 | .60 | 13. | 60. | 600. | 587. | 540. | 140. |
| 91 Apple orchard, heavy clay, normal | .32 | .14 | 8.80 | Trace | 40. | 440. | 440. | 400. | 80. |
| 92 Oat field, sandy loam niter | 1.40 | .20 | .192 | 320. | 320. | 340. | 20. | 20. | 7,800. |
| 93 Peach orchard, heavy clay, normal | .60 | .60 | 40.00 | 4. | 48. | 240. | 236. | 192. | 120. |
| 94 Apple orchard, clay niter | .14 | 1.20 | 4.80 | 34. | 92. | 400. | 366. | 308. | 420. |
| 95 Apple orchard, brown surface | .26 | .14 | .08 | 600. | 640. | 1000. | 400. | 360. | 150. |
| 96 Peach orchard, sandy loam, normal | .24 | 1.00 | .32 | 20. | 60. | 880. | 860. | 820. | 170. |
| 97 Apple orchard, clay, niter | .36 | 1.40 | 1.20 | 20. | 132. | 880. | 860. | 748. | 65. |

No. 78, from the raw adobe hill, presents an interesting case again in this series. It will be remembered that in two preceding studies, Series I and III, this soil showed active denitrification in the presence of the different nitrifiable substances, and that the controls contained the same amount of nitrate at the end of the experimental period as in the beginning. Here, in place of the reduction of its initial nitrates, it has maintained them constant to the end, and while it can show no net gain in nitric nitrogen, it has not lost what it already had, as before.

In soil No. 80, Series I and III, nitrification seems to have been retarded by the presence of the ammonium salts, due probably to combinations of chlorids with the sulphates or carbonates or perhaps to mere concentration of the saline solution. The dried blood in the present series has evidently changed the soil conditions quite materially, for here No. 80 gave a net gain of 50 p. p. m. nitric nitrogen and 88. p. p. m. of nitrous nitrogen over the control, whereas in both preceding studies it had shown a loss in the former but a gain in the latter due presumably to denitrification.

Soil No. 88, which gave no gains in any of the preceding experiments, responded to the dried blood with a net increase of 140 p. p. m. of nitric nitrogen.

Samples Nos. 81 and 86 were unable to utilize the dried blood in the manufacture of nitrates. These same soils, it will be remembered, were deficient in nitrifying efficiency when tested out with the ammonium salts.

No. 81 showed the largest loss in nitric nitrogen, 620 p. p. m., of any soil in any series.

No. 92, which gave no increase with the sulphate and chlorid, showed a gain of 20 p. p. m. here as with the carbonate.

The maximum net gain in nitrogen was made by No. 96 with 820 p. p. m. This figure is rather interesting in view of the fact that the yields of this soil from both ammonium carbonate and ammonium chlorid were among the lowest. The average gain for the positively reacting soils of this series was 431.50 p. p. m., and the minimum 20 p. p. m. by No. 92.

The presence of large quantities of nitrate in the soil to begin with does not appear to interfere seriously with the nitrification of dried blood provided the chlorin is not also high; this is apparent from the results of samples Nos. 81 and 95. Comparing the nitrifying efficiency of our positively reacting normal soils with that of our incipient niter soils, we find that in this series the normal samples have considerably the advantage; the normal gave an average gain of 519.60 p. p. m. of nitric nitrogen against 405.14 p. p. m. for the niter.

## SUMMMARY OF COLORADO SOILS

Seventeen or 73.91 per cent. of the soils under examination were able to convert the nitrogen of ammonium sulphates into nitrate nitrogen; eighteen or 78.26 per cent. accomplished the same with ammonium carbonate and twenty or 86.95 per cent. with dried blood. Of the fifteen that received ammonium chlorid, nine or 60 per cent. gave positive results.

The largest total amount of nitric nitrogen was produced from ammonium sulphate; the next largest from the ammonium corbonate, then the dried blood and least from the ammonium chlorid.

The largest amount of nitric nitrogen produced by any one soil from ammonium sulphate was 972 p. p. m. by No. 84,, a heavy clay niter soil; from ammonium chlorid, it was 428 p. p. m. by No. 97, a clay niter soil; from ammonium carbonate, it was 1148 p. p. m. by No. 97; from dried blood, it was 820 p. p. m. by No. 96, a sandy loam, normal soil.

The average amount of nitric nitrogen produced by a positively reacting soil in each series was as follows: Ammonium sulphate, 672 p. p. m.; ammonium carbonate, 520.88 p. p. m.; dried blood, 431.50 p. p. m.; ammonium chlorid, 120.88 p. p. m.; check 59.30 p. p. m.

The average amount of nitric nitrogen produced by a Colorado soil in the different series, all samples taken into consideration, positive and negative, was as follows: Ammonium sulphate, 484.26 p. p. m.; ammonium carbonate, 398.34 p. p. m.; dried blood, 341.30 p. p. m.; ammonium chlorid, 56.80 p. p. m.; check, 51.30 p. p. m.

The average amount of nitric nitrogen produced by a niter soil in the incipient stage, and a normal soil in each series was as follows: Ammonium sulphate, 710.6 p. p. m. for the nitre, 691.6 p. p. m. for the normal; ammonium chlorid 181.6 p. p. m. for the niter, 46.66 p. p. m. for the normal; ammonium carbonate, 507.6 p. p. m. for the niter and 505.6 p. p. m. for the normal; dried blood, 405.14 for the niter, 519.6 for the normal. The differences in the average gain from the sulphate and the carbonate are so small, 19 p. p .m. for the former and 2 p. p. m. for the latter, that we are reasonably safe in saying that our incipient niter soils and normal soils are equally efficient in nitrifying these substances. In the case of the dried blood, the normal soils have outyielded the others by 114.46 p. p. m. per sample. In the ammonium chlorid series, the number of samples under consideration is too small for the results to carry much weight; however, our figures taken for what they may be worth, indicate that the niter soils are superior to the normal, the former yielding an average of 34.94 p. p. m. of nitrate nitrogen more than the latter.

Considering the positively reacting soils, or those which showed an increase in nitric nitrogen above the controls, we find that 52.94 per cent. of them made their largest gains from the ammonium sulphate; 33.33 per cent. from the ammonium carbonate, 30 per cent from the dried blood and none from the ammonium chlorid; 41.17 per cent. made their second highest gains from ammonium sulphate; 38.88 per cent. from the carbonate; 15 per cent. from the dried blood and none from the ammonium chlorid 11.76 per cent. gave the third largest yields from the ammonium sulphate; 27.77 per cent. from the carbonate; 55 per cent. from the dried blood and 0. per cent. from the chlorid of ammonium.

21.74 per cent. of the soils produced less nitric nitrogen in the presence of ammonium sulphate than the controls, while 4.35 per cent. gave the same; 33.33 per cent. gave less with the ammonium chlorid than the checks, and 6.67 per cent. the same; 17.39 per cent. yielded less from ammonium carbonate than the controls and 4.35 per cent. the same; 8.7 per cent. produced less from dried blood than the controls, and 4.35 per cent. the same.

### *Foreign Soils.*

In order that we might have some first-hand data with which to compare the nitrifying efficiency of our niter soils, we have carried side by side with these, twenty-two soils from localities outside of Colorado. An effort has been made throughout the investigation to eliminate all factors that would tend to lessen the value of the comparative study. With the exception of the collection and shipment of the samples, all have been handled by the same workers so that so far as the personal equation and methods of technique are concerned, the results of both series should be fair to each other and comparable

Ammonium chlorid has been omitted from the list of nitrifiable substances employed in connection with these soils since our experience with the salt and the Colorado samples led us to believe that it possessed little value as a source of nitrogen for measuring nitrifying efficiency.

### SERIES V. AMMONIUM SULPHATE.

In table No. 5 will be found the results of the first set of nitrification experiments with foreign soils in which ammonium sulphate was employed as the nitrifiable substance. The relatively low chlorids in these soils stand out in striking contrast to those with which we have just been dealing, and with the exception of Nos. 67 and 74, the chlorin is so low that it can be considered as a negligible quantity.

Seventeen or 77.27 per cent. of the soils gave positive results with the sulphate and five or 22.73 per cent. negative.

Among the samples which failed to produce as much nitric nitrogen as the controls are two, Nos. 57 and 61, which are of particular interest because of their peculiar physical character; both, it will be remembered, are sandy loams, for the most part clean, sharp, white sand, the latter considerably coarser than the former, and very deficient in organic matter. The writer is well acquainted with both soils and can state that the samples are typical of the regions from which they come. It may be of some interest to note in passing that the Fusarium wilt of water melons has been so serious on the first of these that melon growing has been abandoned almost entirely in recent years; the first observations on the Granville tobacco wilt, caused by *B. solanacearum* and described by Stevens(1) and the writer in 1903, were made on the tract from which No. 61 came. The nitrifying organisms seemed to be present in these samples as shown by the gains in the controls, but the ammonium sulphate inhibited their action almost completely; in fact, in No. 57, it checked it altogether, and a little reduction took place, while in the other sample, there was a gain of 1 p. p. m. nitric nitrogen over the initial content, but still less than the control.

Nos. 58, 59, and 60 all showed the retarding effect of the sulphate on nitrification. That the necessary organisms were present to transform the ammonium nitrogen into nitrate nitrogen is clearly evident for all of the controls gave very appreciable gains.

(1) Stevens, F. L., and Sackett, W. G.; Granville Tobacco Wilt, Bul. 188, N. Carolina Exp. Sta., 1903.

A peculiar condition existed in No. 53 throughout the investigation; the check lost practically all of its nitric nitrogen, but the addition of the ammonium sulphate appeared to have retarded denitrification so that the soil to which this salt was added showed an excess of 3 p. p. m. nitric nitrogen over the control, but at the same time a loss of 2 p. p. m. of its initial nitrate nitrogen. Although it contained more nitric nitrogen than the check at the end of the experiment, it might be grouped more properly with the negatively reacting soils, since the nitric nitrogen which was found was in all probability, a part of the initial content which had not yet been reduced.

**TABLE NO. 5.—Nitrification of Ammonium Sulphate by Foreign Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as $(NH_4)_2SO_4$ Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | $(NH_4)_2SO_4$ added | Check at begin. | Check at end | $(NH_4)_2SO_4$ added | Total gain | Net gain | |
| 52 Corn field, clay loam, Ohio | .002 | .176 | 1.20 | 7. | 60. | 120. | 113. | 60. | 8. |
| 53 Pine forest, gravelly loam, Georgia | Trace | .220 | .44 | 5. | Trace | 3. | —2. | 3. | 78. |
| 54 Apple orchard, loam, Washington | .04 | .340 | .68 | 5. | 90. | 120. | 115. | 30. | 40. |
| 55 Apple orchard, heavy clay, Virginia | Trace | .160 | .80 | 9. | 70. | 240. | 231. | 140. | 74. |
| 56 Cotton field, sandy loam, Oklahoma | .18 | .168 | .80 | 11. | 50. | 70. | 59. | 20. | 8. |
| 57 Water melons, sandy loam, North Carolina | Trace | .168 | .80 | 7. | 46. | 6. | —1. | —40. | 10. |
| 58 Cotton field, sandy loam, Texas | .12 | .160 | .52 | 7. | 50. | 30. | 23. | —20. | 98. |
| 59 Cotton field, clay loam, Georgia | Trace | .152 | .80 | 14. | 60. | 30. | 16. | —30. | 106. |
| 60 Corn field, clay, North Carolina | .16 | .112 | 1.00 | 6. | 70. | 40. | 34. | —30. | 8. |
| 61 Tobacco field, sandy loam, N. Carolina | Trace | .100 | .52 | 3. | 20. | 4. | 1. | —16. | 6. |
| 62 Vineyard, clay loam, California | Trace | Trace | .48 | 4. | 24. | 140. | 136. | 116. | 26. |
| 63 Alfalfa field, sandy loam, California | .04 | .100 | 1.20 | 4. | 46. | 140. | 136. | 94. | 8. |
| 64 Small grain, sandy loam, California | .88 | .320 | 1.20 | 6. | 70. | 200. | 194. | 130. | 8. |
| 65 Cotton field, sandy loam, Arkansas | .60 | .132 | .60 | 4. | 24. | 480. | 476. | 450. | 62. |
| 66 Cane field, clay loam, Oklahoma | .18 | .136 | .80 | 40. | 126. | 180. | 140. | 54. | 6. |
| 67 Mixed orchard, silt loam, California | 1.80 | 1.80 | 24.00 | 120. | 140. | 280. | 160. | 140. | 700. |
| 68 Plum orchard, sandy loam, California | .26 | .140 | 1.40 | 7.4 | 40. | 100. | 92.6 | 60. | 8. |
| 69 Virgin soil, clay, California | Trace | .100 | 1.00 | 2. | 30. | 100. | 98. | 70. | 8. |
| 70 Small grain, black adobe, California | 1.40 | .160 | 1.40 | 5. | 34. | 560. | 555. | 526. | 10. |
| 71 Raw cactus land, sand and gravel. Calif. | Trace | .120 | .64 | 0. | 12. | 13. | 13. | 1. | 6. |
| 73 Vineyard, sandy loam, California | 0.0 | .120 | .80 | 7.4 | 70. | 100. | 92.6 | 30. | 8. |
| 74 Sugar beets, sandy loam, Kansas | 1.2 | .260 | 1.60 | 26.0 | 160. | 800. | 77.4 | 640. | 2,000 |

The raw cactus land from California, No. 71, was very deficient in nitrifying organisms, while the virgin clay soil, No. 69, gave a net gain of 70 p. p. m. nitric nitrogen.

The largest gains in the series were made by the soils from Arkansas, California(1) and Kansas, Nos. 65, 70 and 74, amounting to 450, 526 and 640 p. p. m. respectively. I was somewhat surprised to find No. 65 so active, but disappointed at not getting larger returns from more of the California samples, since I expected them to behave more like the Colorado soils. The large gain in the Kansas sample fulfilled my expectations since it came from just across the state line and is in all respects a Colorado soil.

The nitrites which appear in connection with No. 67, 24 p. p. m., suggest retarded nitrification rather than denitrification. The 700 p. p. m. of chlorin which the soil contained may have had something to do with this, although No. 74 with 2000 p. p. m. exhibits no such quantity of nitrites.

The maximum net gain in nitric nitrogen from ammonium sulfate was made by No. 74, with 640 p. p. m. As mentioned before, this is essentially a Colorado soil, and it is hardly fair to the other samples to give it first place. The next best increase 520 p. p. m. is shown by No. 70, California black adobe. The average gain for all of the positively reacting soils of this series was 150.82 p. p. m. nitric nitrogen, and the minimum, 1 p. p. m. by No. 71.

### Series VI. Ammonium Carbonate

Ammonium carbonate was supplied to the soils of this series as the nitrifiable substance. The detailed results appear in Table 6.

Of the twenty-two samples under study, seventeen or 77.27 per cent. made gains in nitric nitrogen from the carbonate of ammonium, while five or 22.73 per cent. failed to do so. Although the number of samples reacting positively and negatively is the same here as in the preceding set, the same soils have behaved differently. Whereas Nos. 58, 59 and 60 were negative with respect to the sulphate, they are positive in the present series. The most striking difference between the results of the two series is in the increased number of soils that gave large net gains; with ammonium carbonate six responded strongly, as compared with three with the ammonium sulphate. Two of these Nos. 70 and 74, are the same as in Series V, but the other four are all different. Three of them are from California, one from Kansas, one from North Carolina and one from Virginia. The natural inference from such an increased yield of nitric nitrogen is that the ammonium carbonate is more easily nitrified than the sulphate, so far as these particular soils are concerned.

Nos. 57, 61, 62, 63, and 71 all produced less nitrate nitrogen than the controls. In No. 57, there was marked inhibition of nitrification in the presence of the carbonate with a very little reduction. Considerable nitrification took place in the check. Nos. 61, 62 and 71 show that the same conditions existed without the denitrification. With No. 63, the nitrifying activities were not retarded to nearly as great a degree, the check producing only 6 p. p. m. more nitric nitrogen than

(1) No. 70 from California compared very favorably in nitrifying efficiency with the Colorado soils in all of the series.

the carbonate sample. All of these negatively reacting soils contained the necessary nitrifying organisms as manifested by the appreciable gains that the checks made. There seems to be little doubt in the case of the five soils just mentioned that the ammonium carbonate has exercised some toxic action, thus preventing the normal development of the nitrifying flora.

The ammonium carbonate appears to have improved conditions for nitrification very much for Sample No. 69, for it gave a net gain of 450 p. p. m. of nitric nitrogen as compared with 70 p. p. m. in the preceding series.

**TABLE NO. 6.—Nitrification of Ammonium Carbonate by Foreign Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as $(NH_4)_2CO_3$ Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | $(NH_4)_2CO_3$ added | Check at begin. | Check at end | $(NH_4)_2CO_3$ added | Total gain | Net gain | |
| 52 Corn field, clay loam, Ohio | .002 | .176 | Trace | 7.0 | 60. | 200. | 193. | 140. | 8. |
| 53 Pine forest, gravelly loam, Georgia | Trace | .220 | .08 | 5.0 | Trace | 5. | 0. | 5. | 78. |
| 54 Apple orchard, loam, Washington | .04 | .340 | .08 | 5.0 | 90. | 280. | 275. | 190. | 40. |
| 55 Apple orchard, heavy clay, Virginia | Trace | .160 | .02 | 9.0 | 70. | 320. | 311. | 250. | 74. |
| 56 Cotton field, sandy loam, Oklahoma | .18 | .168 | .04 | 11.0 | 50. | 240. | 229. | 190. | 8. |
| 57 Water melons, sandy loam, North Carolina | Trace | .168 | .14 | 7.0 | 46. | 6. | —1. | —40. | 10. |
| 58 Cotton field, sandy loam, Texas | .12 | .160 | Trace | 7.0 | 50. | 240. | 233. | 190. | 98. |
| 59 Cotton field, clay loam, Georgia | Trace | .152 | Trace | 14.0 | 60. | 240. | 226. | 180. | 106. |
| 60 Corn field, clay, North Carolina | .16 | .112 | Trace | 6.0 | 70. | 360. | 354. | 290. | 8. |
| 61 Tobacco field, sandy loam, N. Carolina | Trace | .100 | .12 | 3.0 | 20. | 3. | 0. | —17. | 6. |
| 62 Vineyard, clay loam, California | Trace | Trace | 30.00 | 4.0 | 24. | 4. | 0. | —20. | 26. |
| 63 Alfalfa field, sandy loam, California | .04 | .100 | 26.00 | 4.0 | 46. | 40. | 36. | —6. | 8. |
| 64 Small grain, sandy loam, California | .88 | .320 | .32 | 6.0 | 70. | 160. | 154. | 90. | 8. |
| 65 Cotton field, sandy loam, Arkansas | .60 | .132 | 30.00 | 4.0 | 24. | 120. | 116. | 96. | 62. |
| 66 Cane field, clay loam, Oklahoma | .18 | .136 | .26 | 40.0 | 126. | 240. | 200. | 114. | 6. |
| 67 Mixed orchard, silt loam, California | 1.80 | 1.800 | 74.00 | 120.0 | 140. | 200. | 80. | 60. | 700. |
| 68 Plum orchard, sandy loam, California | .26 | .140 | 74.00 | 7.4 | 40. | 50. | 42.6 | 10. | 8. |
| 69 Virgin soil, clay, California | Trace | .100 | .88 | 2.0 | 30. | 480. | 478. | 450. | 8. |
| 70 Small grain, black adobe, California | 1.40 | .160 | .04 | 5.0 | 34. | 640. | 635. | 606. | 10. |
| 71 Raw cactus land, sand and gravel. Calif. | Trace | .120 | .32 | 0.0 | 12. | 0. | 0. | —12. | 6. |
| 73 Vineyard, sandy loam, California | 0.0 | .120 | .10 | 7.4 | 70. | 320. | 312.6 | 250. | 8. |
| 74 Sugar beets, sandy loam, Kansas | 1.20 | .260 | .12 | 26.0 | 160. | 700. | 674. | 540. | 2,000. |

Nos. 67 and 68 each produced 74 p. p. m. of nitrite nitrogen and Nos. 62, 63, and 65 gave 30, 26 and 30 p. p. m. respectively. In the writer's opinion, these are to be regarded as an indication of interrupted and retarded nitrification rather than of reduction.

The maximum net gain made by any soil in this series was 606 p. p. m. of nitric nitrogen by No. 70, the California black adobe; the average for all positively reacting samples was 214.76 p. p. m. and the minimum 5 p. p. m. by No. 53.

## SERIES VII. DRIED BLOOD

Dried blood was employed as the nitrifiable substance in Series VII. Here also we have an increase in the number of soils yielding comparatively large gains; it will be remembered that the first series gave three such and the next, six, while the present one contains eight. Evidently the nitrogen of the dried blood responded more readily to the

**TABLE NO. 7.—Nitrification of Dried Blood by Foreign Soils. Nitrogen in Parts Per Million of Air-dried Soil as Nitrites and Nitrates from 100 m.g. Nitrogen as Dried Blood. Duration of Experiment: 6 Weeks at 28 Degrees C.**

| Number of Sample and Description | Nitrogen as nitrites in parts per million | | | Nitrogen as nitrates in parts per million | | | | | Chlorin in p. p. m. |
|---|---|---|---|---|---|---|---|---|---|
| | Check at begin. | Check at end | Dried blood added | Check at begin. | Check at end | Dried blood added | Total gain | Net gain | |
| 52 Corn field, clay loam, Ohio | .002 | .176 | .04 | 7.0 | 60. | 480. | 473. | 420. | 8. |
| 53 Pine forest, gravelly loam, Georgia | Trace | .220 | .14 | 5.0 | Trace | 6. | 1. | 6. | 78. |
| 54 Apple orchard, loam, Washington | .04 | .340 | .80 | 5.0 | 90. | 210. | 205. | 120. | 40. |
| 55 Apple orchard, heavy clay, Virginia | Trace | .160 | .056 | 9.0 | 70. | 720. | 711. | 650. | 74. |
| 56 Cotton field, sandy loam, Oklahoma | .18 | .168 | .12 | 11.0 | 50. | 80. | 69. | 30. | 8. |
| 57 Water melons, sandy loam, North Carolina | Trace | .168 | .12 | 7.0 | 46. | Trace | —7. | —46. | 10. |
| 58 Cotton field, sandy loam, Texas | .12 | .160 | .06 | 7.0 | 50. | 200. | 193. | 150. | 98. |
| 59 Cotton field, clay loam, Georgia | Trace | .152 | .12 | 14.0 | 60. | 240. | 226. | 180. | 106. |
| 60 Corn field, clay, North Carolina | .16 | .112 | .072 | 6.0 | 70. | 560. | 554. | 490. | 8. |
| 61 Tobacco field, sandy loam, N. Carolina | Trace | .100 | .18 | 3.0 | 20. | 0. | —3. | —20. | 6. |
| 62 Vineyard, clay loam, California | Trace | Trace | Trace | 4.0 | 24. | 180. | 176. | 156. | 26. |
| 63 Alfalfa field, sandy loam, California | .04 | .100 | 5.00 | 4.0 | 46. | 20. | 16. | —26. | 8. |
| 64 Small grain, sandy loam, California | .88 | .320 | .32 | 6.0 | 70. | 640. | 534. | 570. | 8. |
| 65 Cotton field, sandy loam, Arkansas | .60 | .132 | 30.00 | 4.0 | 24. | 110. | 106. | 86. | 62. |
| 66 Cane field, clay loam, Oklahoma | .18 | .136 | .40 | 40.0 | 126. | 180. | 140. | 54. | 6. |
| 67 Mixed orchard, silt loam, California | 1.80 | 1.800 | 44.00 | 120.0 | 140. | 220. | 100. | 80. | 700. |
| 68 Plum orchard, sandy loam, California | .26 | .140 | 70.00 | 7.4 | 40. | 80. | 72.6 | 40. | 8. |
| 69 Virgin soil, clay, California | Trace | .100 | .60 | 2.0 | 30. | 280. | 278. | 250. | 8. |
| 70 Small grain, black adobe, California | 1.40 | .160 | .20 | 5.0 | 34. | 640. | 635. | 606. | 10. |
| 71 Raw cactus land, sand and gravel. Calif. | Trace | .120 | .32 | 0.0 | 12. | 10. | 10. | —2. | 6. |
| 73 Vineyard, sandy loam, California | 0.00 | .120 | .52 | 7.4 | 70. | 400. | 392.6 | 330. | 8. |
| 74 Sugar beets, sandy loam, Kansas | 1.20 | .260 | .96 | 26.0 | 160. | 760. | 734. | 600. | 2,000. |

nitrifying agents than did the nitrogen of the ammonia salts; whether this was due to its being present in a more available form or whether the additional food material in the blood stimulated microbic activity can only be conjectured.

Of the twenty-two soils under examination, eighteen or 81.82 per cent. gave gains in nitric nitrogen from the dried blood; four or 18.18 per cent. produced less than the controls.

The eight samples which made the largest gains were Nos. 52, 55, 60, 64, 69, 70, 73, and 74; four came from California, one from Kansas, one from North Carolina, one from Virginia, and one from Ohio; five of these are the same that gave the high yields in the preceding series, while Nos. 52 and 64 are new ones to the list.

Soil No. 60 presents a very interesting case in its behavior toward the different forms of ammoniacal and proteid nitrogen. With the sulphate it gave less nitric nitrogen than the control; when associated with the carbonate, a gain of 290 p. p. m. over the check resulted; and from the dried blood, it produced 490 p. p. m., a very nice illustration of the relative availability of the different nitrogenous compounds for the nitrifying flora of a given soil. Essentially the same relations are brought out in No. 55.

Nos. 57, 61, 63 and 71 all produced less nitrate nitrogen than their controls; these behaved similarly in the preceding series. Nos. 57 and 61 show evidence of some reduction. With Nos. 63 and 71, the negative results appear to be due to retarded nitrification rather than denitrification since some gain has been made over the initial nitrogen of the control but not as much as in the control at the end of the experimental period.

Nos. 67 and 68 gave high nitrites here as in the preceding series and what was said there in this connection will apply equally to the present results.

The maximum gain in nitric nitrogen from the dried blood was made by No. 55 with 650 p. p. m.; the average for the positively reacting soils was 267.39 p. p. m. and the minimum gain 6 p. p. m. by No. 53.

## SUMMARY OF FOREIGN SOILS

Seventeen or 77.27 per cent. of the soils under study were able to convert the nitrogen of ammonium sulphate into nitrate nitrogen; the same per cent. accomplished this transformation with ammonium carbonate and eighteen or 81.82 per cent. with dried blood.

The largest total amount of nitric nitrogen was produced from the dried blood; the next largest from the ammonium carbonate, and least from the ammonium sulphate.

The largest amount of nitric nitrogen produced by any one soil from ammonium sulphate was 640 p. p. m. by No. 74, a sandy loam from Kansas; from ammonium carbonate, it was 606 p. p. m. by No. 70, California black adobe; from dried blood, it was 650 p. p. m. by No. 55, a heavy clay from Virginia. It is a significant point that the highest yields from both of the salts were obtained by western soils, while the best return from the dried blood was secured by a southeastern sample. Without exception all of the soils from the southeastern part of the United States made their largest gains from the dried blood; those from Washington, Oklahoma and Texas gave the best results with ammonium carbonate; Arkansas and Kansas (also Colorado) with ammonium sulphate, while the California samples were divided among the three substances. The fact that these soils upon the basis of their ability to produce nitric nitrogen from different nitrifiable materials fall into more or less well defined natural geographical groups, suggests rather strongly the presence of a nitrifying flora in each group, distinct to a greater or less degree from that of another group. Further evidence in support of this view is to be had in the sequence in which the different nitrifiable substances yielded nitric nitrogen in the different groups. All of the southeastern samples, that reacted positively, responded in the following order: Dried blood, ammonium carbonate, ammonium sulphate. The Texas-Oklahoma group gave this sequence: Ammonium carbonate, dried blood, ammonium sulphate. The Colorado samples constitute a third class, in which the prevailing order is ammonium sulphate, ammonium carbonate, dried blood. The number of samples in the first two groups is too small to warrant any positive assertions along this line, but the results are certainly suggestive.

Seven of the nine or 77.77 per cent. of the soils that made the largest gain in nitric nitrogen from dried blood gave second place to ammonium carbonate and third place to ammonium sulphate; seven out of seven or 100 per cent. of those that produced most from ammonium carbonate followed next with the dried blood and then the ammonium sulphate; three of the five or 60 per cent. of those that gave first place to ammonium sulphate, followed with dried blood and then ammonium carbonate.

The average amount of nitric nitrogen produced by a positively reacting soil in each series was as follows: Ammonium sulphate, 152.82 p. p. m.; ammonium carbonate, 214.76 p. p. m.; dried blood, 267.39 p. p. m.; check 47.08 p. p. m.

The average amount of nitric nitrogen produced by a foreign soil in each series, all samples taken into consideration, positive and negative, was as follows:

Ammonium sulphate, 110.36 p. p. m.; ammonium carbonate, 161.63 p. p. m.; dried blood, 214.72 p. p. m.; check 44.93 p. p. m.

Considering the positively reacting soils in each series or those which showed an increase in nitric nitrogen over the checks, we find that 29.41 per cent. made their largest gains from ammonium sulphate, 41.48 per cent. from the ammonium carbonate; 50 per cent. from the dried blood; 29.41 per cent. made their second highest gains from ammonium sulphate; 35.29 per cent. from ammonium carbonate and 44.44 per cent. from the dried blood. 41.18 per cent. produced their third largest yields from the ammonium sulphate; 22.22 per cent. from the ammonium carbonate and 5.56 per cent. from the dried blood. The results point clearly to dried blood as the most fertile source of nitrogen for the formation of nitrates by the majority of the foreign soils; ammonium carbonate comes second and ammonium sulphate last.

22.73 per cent. of the soils produced less nitric nitrogen in the presence of the ammonium sulphate than the controls; 22.73 per cent. gave less with the ammonium carbonate than the checks, and 18.18 per cent. yielded less from the dried blood than the controls.

## COMPARATIVE SUMMARY OF COLORADO AND FOREIGN SOILS.

A comparison of the nitrifying efficiencies of these two groups of soils, taken as integrals, shows at a glance that the Colorado samples are superior to the others in their power of converting ammoniacal and proteid nitrogen into nitric nitrogen.

Considering only those soils that gave a positive reaction for nitrification, we find that the average net gain in nitric nitrogen made by a Colorado soil from ammonium sulphate was 672 p. p. m., while that of a foreign sample amounted to only 150.82 p. p. m.; again, the former

**TABLE NO. 8.—Increase in Nitric Nitrogen in Colorado Soils and Foreign Soils Without the Addition of Any Nitrifiable Substance. Nitrogen in Parts Per Million of Air-dried Soil. Duration of Experiment: 6 Weeks at 28 Degrees C.**

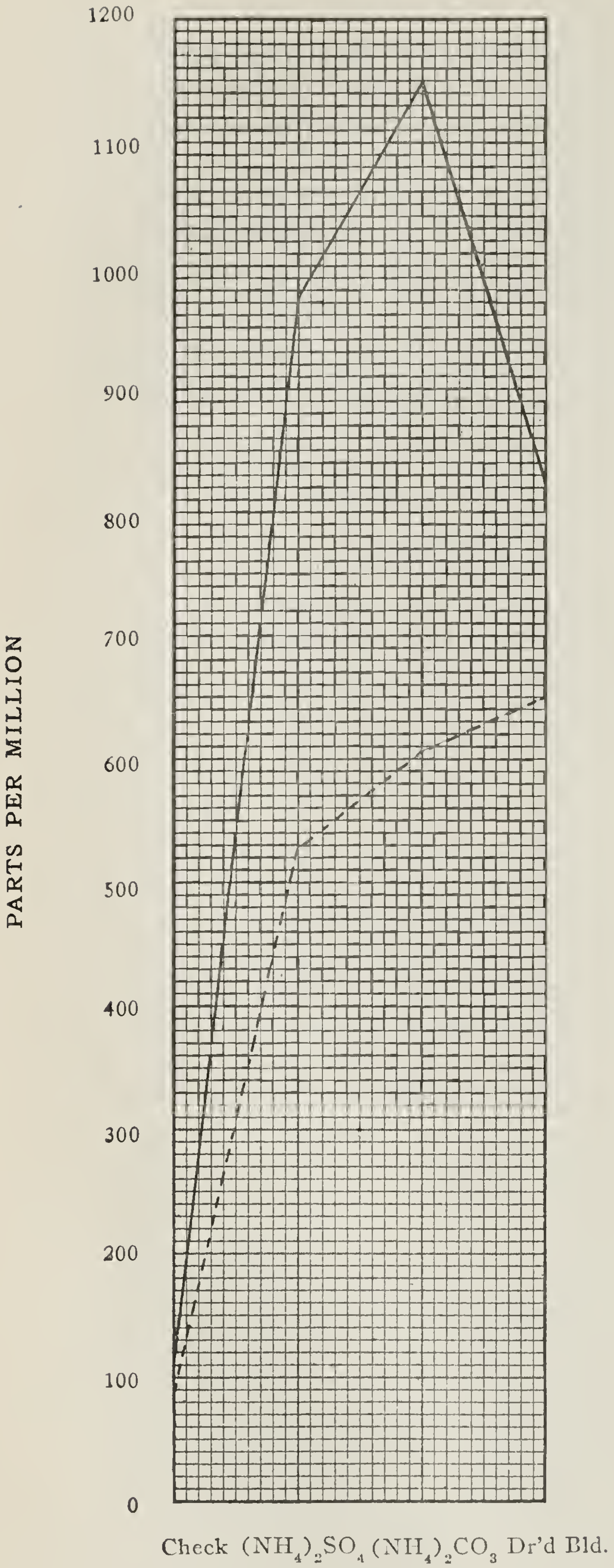
| Colorado Soils | | | | Foreign Soils | | | |
|---|---|---|---|---|---|---|---|
| Sample No. | At beginning | At end | Net gain | Sample No. | At beginning | At end | Net gain |
| 75 | 7. | 64. | 57. | 52 | 7. | 60. | 53. |
| 76 | 54. | 110. | 56. | 53 | 5. | Trace | —5. |
| 77 | 26. | 76. | 50. | 54 | 5. | 90. | 85. |
| 78 | 140. | 140. | 0. | 55 | 9. | 70. | 61. |
| 79 | 5. | 66. | 61. | 56 | 11. | 50. | 39. |
| 80 | 13. | 50. | 37. | 57 | 7. | 46. | 39. |
| 81 | 1360. | 1360. | 0. | 58 | 7. | 50. | 43. |
| 82 | 46. | 120. | 74. | 59 | 14. | 60. | 46. |
| 83 | 6. | 100. | 94. | 60 | 6. | 70. | 64. |
| 84. | Trace | 68. | 68.— | 61 | 3. | 20. | 17. |
| 85 | 6. | 60. | 54. | 62 | 4. | 24. | 20. |
| 86 | 130. | 240. | 110. | 63 | 4. | 46. | 42. |
| 87 | 6. | 40. | 34. | 64 | 6. | 70. | 64. |
| 88 | 70. | 100. | 30. | 65 | 4. | 24. | 20. |
| 89 | 180. | 260. | 80. | 66 | 40. | 126. | 86. |
| 90 | 13. | 60. | 47. | 67 | 120. | 140. | 20. |
| 91 | Trace | 40. | 40.— | 68 | 7.4 | 40. | 32.6 |
| 92 | 320. | 320. | 0. | 69 | 2. | 30. | 28. |
| 93 | 4. | 48. | 44. | 70 | 5. | 34. | 29. |
| 94 | 34. | 92. | 58. | 71 | 0. | 12. | 12. |
| 95 | 600. | 640. | 40. | 73 | 7.4 | 70. | 62.6 |
| 96 | 20. | 60. | 40. | 74 | 26. | 160. | 134. |
| 97 | 20. | 132. | 112. | | | | |

yielded 520.88 p. p. m. from ammonium carbonate and the latter but 214.76 p. p. m.; from dried blood the Colorado soils averaged 431.50 p. p. m. as compared with 267.39 for the other series. This means that the Colorado samples produced an average of 521.18 p. p. m. or 345.56 percent. more nitric nitrogen from ammonium sulphate than the other soils; that they yielded an average of 306.12 p. p. m. or 142.54 per cent. more from the ammonium carbonate, and 164.11 p. p. m. or 61.37 per cent. more from the dried blood. (See Plate II.)

The maximum net gain produced by a Colorado soil from ammonium sulphate amounted to 972 p. p. m., while the highest foreign (1)

(1) Inasmuch as the Kansas soil is in all essentials a Colorado soil, it has not been considered in this comparison.

PLATE I.—MAXIMUM AMOUNTS OF NITRIC NITROGEN PRODUCED FROM THE DIFFERENT NITRIFIABLE SUBSTANCES




——————— Colorado Soils
- — — — — — —Foreign Soils

PLATE II.—AVERAGE AMOUNTS OF NITRIC NITROGEN PRODUCED FROM THE DIFFERENT NITRIFIABLE SUBSTANCES.

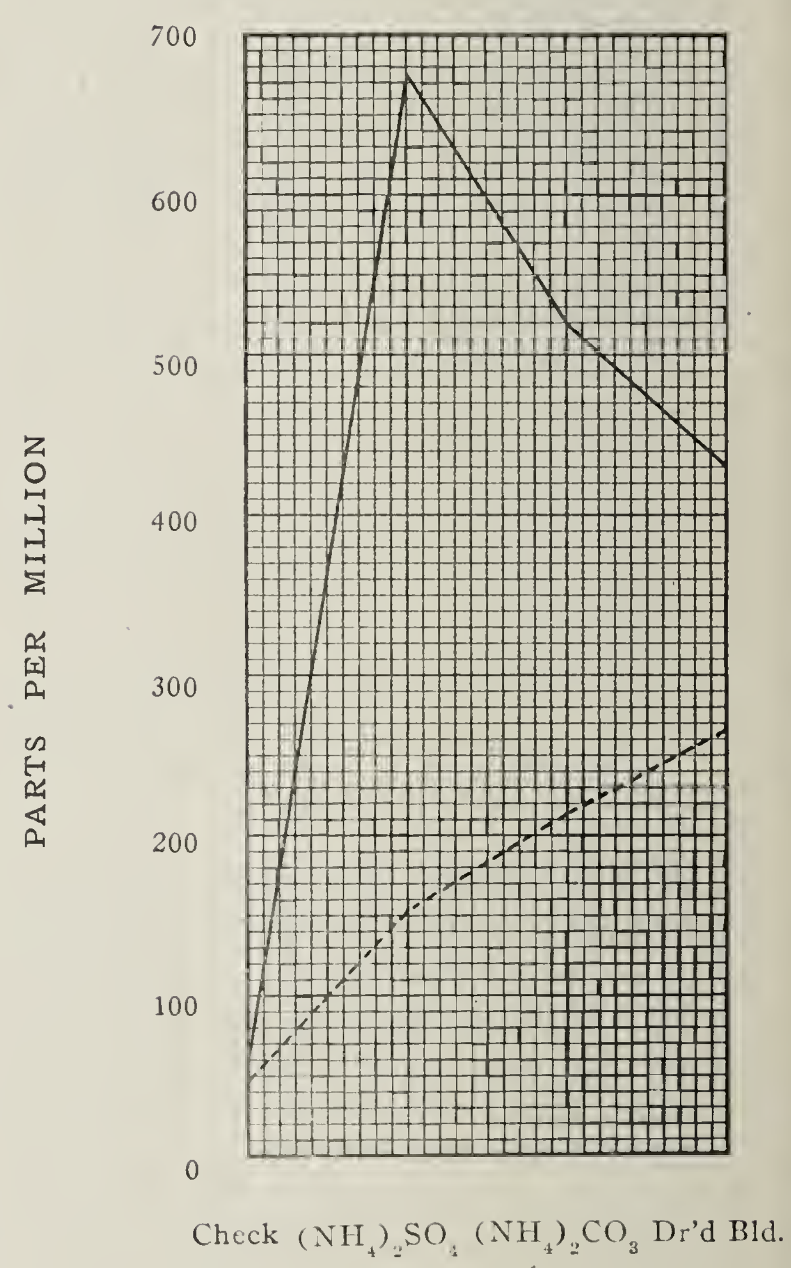
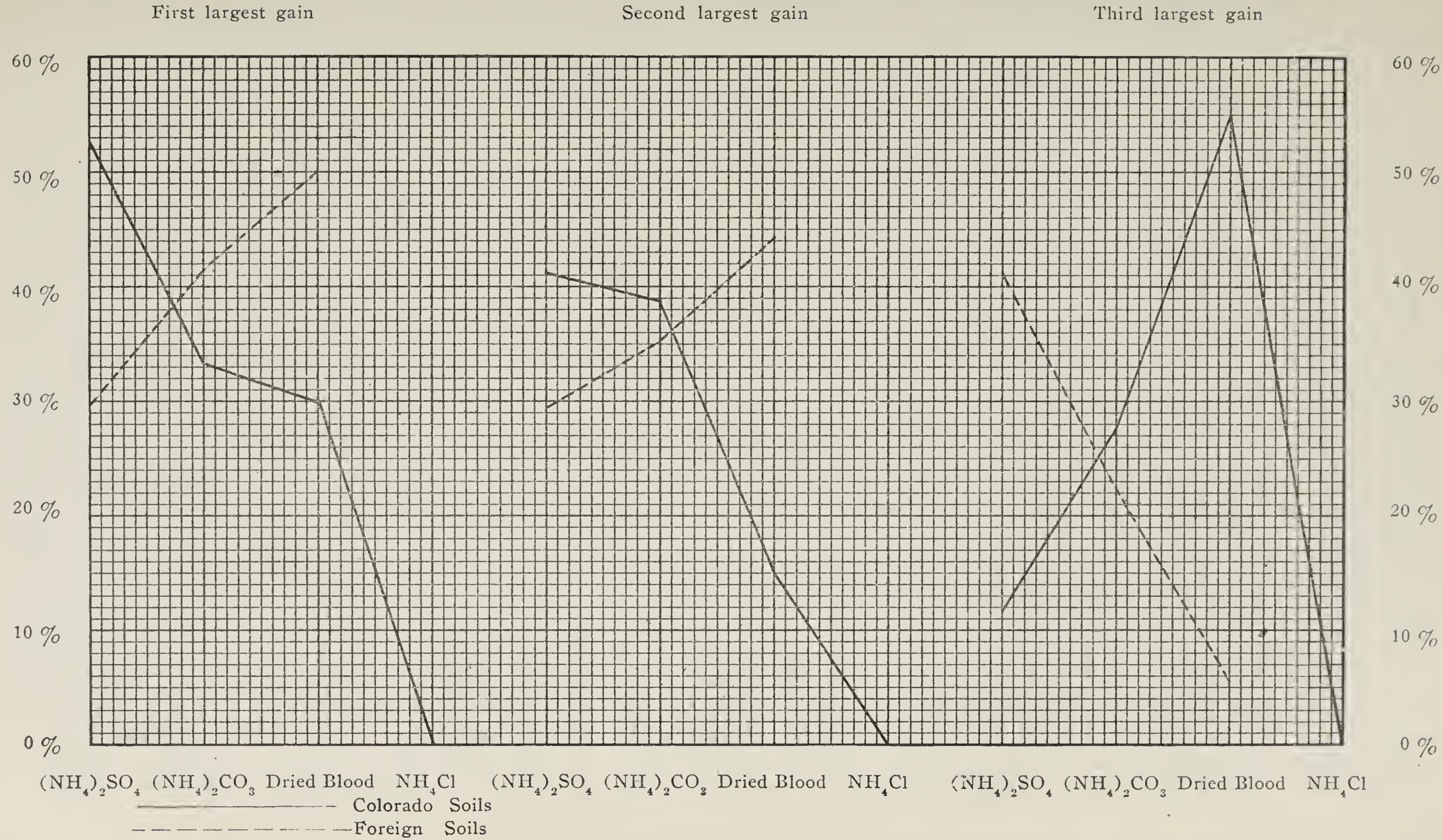


PLATE III. GRAPHIC REPRESENTATION OF THE PERCENTAGE OF POSITIVELY REACTING COLORADO AND FOREIGN SOILS THAT MADE THEIR FIRST, SECOND AND THIRD LARGEST GAINS IN NITRIC NITROGEN FROM THE DIFFERENT NITRIFIABLE SUBSTANCES.



yield was 526 p. p. m.; from ammonium carbonate, the largest net gain by a Colorado sample was 1148 p. p. m., by a foreign soil, 606 p. p. m.; from dried blood the former gave 820 p. p. m., the latter 650 p. p. m. (See Plate I.)

In looking over the net gain columns of the Colorado tables one sees but few positive results under 300 p. p. m. and many above 500 p. p. m. with the exception of the ammonium chlorid series. On the other hand, an inspection of the corresponding columns of the foreign group shows many figures between 20 and 90 p. p. m. and only a few above 250 p. p. m.

A comparison of the average gains in the two sets is given in Tables 9 and 10.

The second conspicuous difference between the two series we find in their inverse ability to nitrify the different materials placed at their disposal. To illustrate—52.94 per cent. of the Colorado samples made their largest net gains in nitric nitrogen from ammonium sulphate as compared with 29.41 per cent. of the others; 33.33 per cent of the soils

**TABLE NO. 9.—Average Net Gain in Nitric Nitrogen by Positively Reacting Colorado and Foreign Soils in Parts Per Million of Air-dried Soil.**

| Nitrifiable substance added: | Nothing | $(NH_4)_2SO_4$ | $(NH_4)_2CO_3$ | Dried Blood |
|---|---|---|---|---|
| Colorado Soils | 59.30 | 672.00 | 520.88 | 431.50 |
| Foreign Soils | 47.08 | 150.82 | 214.76 | 267.39 |
| Excess of Colorado Soils over Foreign Soils | 12.22 | 521.18 | 306.12 | 164.11 |
| Gain per cent. by Colorado Soils | 25.95 | 345.56 | 142.54 | 61.37 |

**TABLE NO. 10.—Average Net Gain in Nitric Nitrogen by Colorado and Foreign Soils in Parts Per Million of Air-dried Soil, all Samples Considered.**

| Nitrifiable substance added: | Nothing | $(NH_4)_2SO_4$ | $(NH_4)_2CO_3$ | Dried blood | $NH_4Cl$ |
|---|---|---|---|---|---|
| Colorado Soils | 51.30 | 484.26 | 398.34 | 341.30 | 56.80 |
| Foreign Soils | 44.93 | 110.36 | 161.63 | 214.72 | |
| Excess of Colorado Soils over Foreing Soils | 6.37 | 373.90 | 236.71 | 126.58 | |
| Gain per cent. by Colorado Soils | 14.17 | 338.80 | 146.45 | 58.95 | |

from Colorado produced their highest yields from ammonium carbonate as against 35.29 per cent of the others; 30 per cent. of those from Colorado made their maximum gains with dried blood as compared with 44 per cent. of those from outside of the state. From this, it is very clear that the majority of the Colorado soils nitrify ammonium sulphate most readily and dried blood least easily, whereas exactly the opposite is true of the foreign samples—ammonium sulphate least easily and dried blood most readily. (See Plate III.)

The superior nitrifying efficiency of the Colorado soils and the inverse relation of their nitrifying power to that of the foreign samples suggest the following:

1. The conditions for nitrification in Colorado soils are superior to those found in the other soils.

2. Colorado soils possess a vigorous nitrifying flora.

3. The nitrifying flora of the Colorado soils is distinct from that found elsewhere; it is either made up of entirely different organisms, or, if the same organisms, they have become so changed by their environment that they behave like different strains.

## CONCLUSIONS

Many cultivated soils of Colorado contain a vigorous nitrifying flora capable of transforming ammoniacal nitrogen into nitrate nitrogen.

Both our normal soils and those in the incipient stage of the niter trouble possess this power in a very marked degree.

Compared with soils from twenty-two other localities outside of the state, the Colorado soils examined are very superior in nitrifying efficiency.

The nitrifying efficiency of Colorado soils bears an inverse relation to that of the foreign soils when referred to ammonium sulphate, ammonium carbonate and dried blood as the nitrifiable substances.

Colorado soils produced their highest average gains in nitric nitrogen from $(NH_4)_2SO_4$; the next largest from $(NH_4)_2CO_3$ and the lowest from dried blood. The foreign soils produced their largest average yields in exactly the reverse order.

The nitrifying flora of the Colorado soils is distinct from that found in the majority of the foreign samples; it is either made up of entirely different organisms, or, if the same organisms, they behave like different strains.

Excessive nitrates do not appear to interefere seriously with nitrification provided the chlorin is low.

Excessive chlorin, with or without excessive nitrates, inhibits nitrification.

Active nitrification takes place in the brown crust from the niter spots provided the chlorin is not excessive.

The sample of raw adobe clay examined was deficient in nitrifying efficiency.

The results of this study together with those of our two previous investigations justify the position that the excessive nitrates present in certain Colorado soils have resulted from the combined action of nitrogen-fixing, ammonifying and nitrifying organisms.

### ACKNOWLEDGMENTS

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# Colorado Agricultural College

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# *Frictional Resistance in Artificial Waterways*

By
V. M. CONE
R. E. TRIMBLE and P. S. JONES

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# *Frictional Resistance in Artificial Waterways*

The use of empirical formulas plays an important part in the design of channels for carrying water. Practically all such formulas contain a factor which represents the resistance to the flow of water offered by the material forming the channel, and consequently there are almost as many different values for this factor as there are kinds of material. The engineer designing an irrigation channel must exercise good judgment in choosing the value of this coefficient or the resulting section will be too large or too small to carry the volume of water desired. If the channel is too large, the construction as well as the maintenance cost will be excessive, while if too small, there may be heavy crop losses because of insufficient water for irrigation.

In order to add to the available information on proper values of the coefficient of roughness in various types of artificial waterways, a series of field experiments was conducted in Colorado during the irrigation seasons of 1912 and 1913. The principal types of channels experimented upon were metallic, reinforced concrete and timber flumes, concrete-lined canals, earth canals, concrete and timber chutes, and inverted siphons of wood stave pipe, located on irrigation systems in the Cache la Poudre, Arkansas, Grande, Gunnison, Uncompahgre and San Luis Valleys.

PURPOSE OF INVESTIGATION. 1. To determine the coefficient of roughness in empirical formulas for several types of open channels; and also to determine whether such coefficient changes with variations of discharge of the channel.

2. To determine the loss of head in water flowing through siphons, and to compare Kutter's formula with the ordinary friction formula as adapted to pressure pipes.

3. To make current meter measurements throughout cross-sections of several channels to permit the vertical velocity curves to be plotted, and, from a standpoint of accuracy, to compare the integration and single point methods with the multiple point method.

EQUIPMENT AND METHODS USED. The same current meter was used in all the experiments, being a light type of the Price rod meter. This instrument was rated at Berkeley, California, just prior to beginning the experiments, and upon their completion was rated by the Bureau of Standards, Washington, D. C. The former ratings were used for the season of 1912 and the latter for 1913. A high grade wye level, target leveling rod reading to thousandths of a foot, standard steel tape, and graduated hard wood stick with tapered edge, were used.

In choosing the waterways upon which to conduct the experiments, particular care was exercised in selecting those typical of the class or group being investigated. Those possessing the slightest changes in the value of the hydraulic elements throughout the length of the section were best adapted for the purpose of experiment. Sufficient length was selected to accurately obtain the slope of the water surface. Other conditions being uniform, the length required varied inversely as the fall of the water surface. The distance required to develop the true fall was not so long, however, as to introduce a broken profile of the water surface gradient. Wherever possible, sections were selected on tangents, to avoid effect of curvature.

As repeated experiments were made upon some of the conduits as a check, or to determine any change in the value of the coefficient with the variation in discharge, permanent bench marks were established at convenient points along the section, from which future elevations of the water surface could be determined, or the wetted areas could again be cross-sectioned.

In all of these tests particular care was exercised in obtaining the correct discharge by current meter measurement, but at the same time the fact was not overlooked that measurement of the cross-sectional elements at the several stations was of equal importance in obtaining the coefficient of friction for any given waterway. In most cases the discharge was likely to fluctuate slightly while the test was being made, hence the importance of a simultaneous determination of the slope, cross-sectional elements and discharge, or where this was impossible, as but two men were in the field, slope and cross-sectional measurements were taken immediately after the current meter measurement near the head of the section, proceeding from the upper to the lower end. Hence, under such conditions it seemed inadvisable to spend time in making more than two determinations of the discharge, especially on a large channel where much time was consumed in doing so. The integration method was preferred for measurements in shallow streams. Independent meter measurements checked with an error seldom greater than 1.5 percent, and usually close to 0.5 percent.

check measurements being made by two methods. In some cases the discharge measurements were not made within the experimental section, but at some convenient support near the upper or lower end of the section. In every case, however, the flow was measured at a point near enough to make the seepage loss a negligible quantity.

In some places there was no foot bridge across the channel and wading had to be resorted to, which introduced a slight error in the discharge measurements, but it will be shown later that where the coefficient of roughness alone is desired, a small error in the determination of the discharge has an inappreciable effect upon the value of the coefficient. In all current meter measurements, cross-sections were chosen in which the filaments of flow apparently approached and receded from the section in parallel lines.

Values for the coefficient of roughness in the general formula of Ganguillet and Kutter, were secured from the field data by graphic methods for slopes up to .0621 feet per foot, and by computation for greater slopes.

## METALLIC FLUMES

All of the metallic flumes upon which tests were made are of the semi-circular type, and may be divided into the following three classes, according to the characteristics of their interior surfaces:

GROUP 1. Flumes whose connections at the joints are countersunk to the plane of the sheet metal, and which present a smooth, unobstructed water face.

GROUP 2. Flumes whose joint connections protrude into the waterway beyond the plane of the sheet metal.

GROUP 3. Flumes constructed of corrugated metal and whose corrugations at right angles to the line of flow offer the only frictional resistance.

In most of these flumes tie beams extended across the waterway, upon which bench marks were established at the upper and lower ends of the sections, and at intermediate points where necessary. Because of the fluctuations of the water surface, the vertical distance from these benches to the water was measured directly with the rod, readings being taken at the highest and lowest levels. In this way it was possibly by averaging the two readings to minimize the error in obtaining the slope of the water surface.

The weight of the water caused distortion of the original semi-circular cross-sections, and consequently it was necessary to make two sets of measurements to obtain the wetted cross-sectional area and wetted perimeter. The mean maximum depth of water in the center of the channel was measured with a graduated hard-wood stick, having a beveled edge. By use of plumb bob and tape the mean length of wetted chord was determined, and having

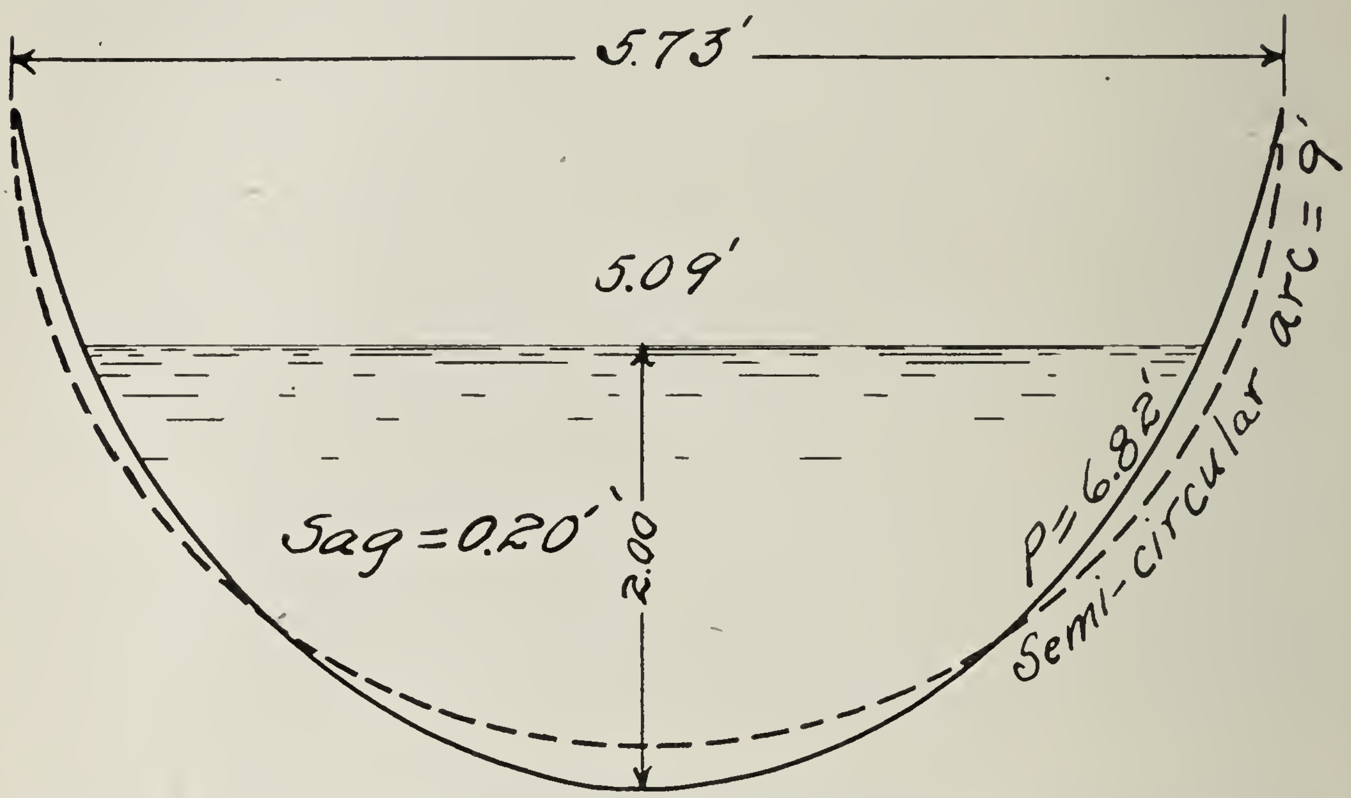


Fig. 1. Cross-section of Metallic Flume, Uncompahgre Project, Montrose.

measured the semi-circular arc of the flume, the wetted perimeter was determined by measuring the dry arcs directly with the tape.

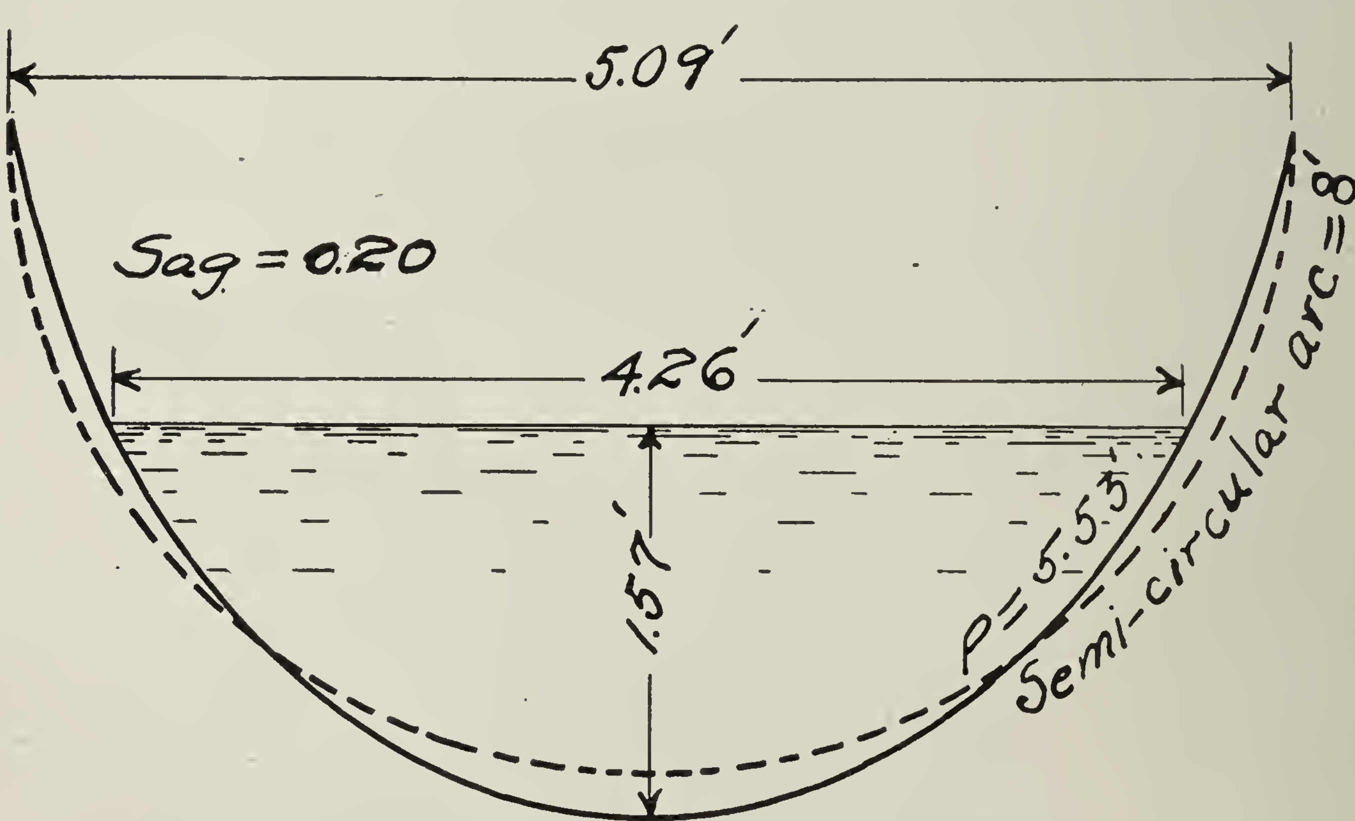


Fig. 2. Cross-section of Metallic Flume, Uncompahgre Project, Montrose.

These elements, viz., diameter, semi-circular arc, dry arc, wetted perimeter, wetted chord and maximum depth of water, when fitted together diagramatically, determined the form of curve assumed by the sheet metal under the weight of the water. Wetted areas were obtained from the diagram by use of the planimeter.

Figures 1 and 2 show cross-sections of flumes on the King Lateral Extension on the Uncompahgre Project, near Montrose. The dashed lines represent the semi-circular shape of the flume when empty, and the parabolic form of curve assumed by the sheet metal under the weight of the water is represented by the solid lines. The bottoms of these flumes were depressed 0.2 feet when about one-third full of water.

Figure 3 shows a cross-section of a flume on the Garland Canal, Blanca. A depression of 0.11 ft. on the bottom takes place when this flume is one-eighth full. Sufficient measurements could not be made to determine the distorting effects of other heads because of the difficulty of having the quantity of water varied. However, these serve to illustrate the fact that allowance should

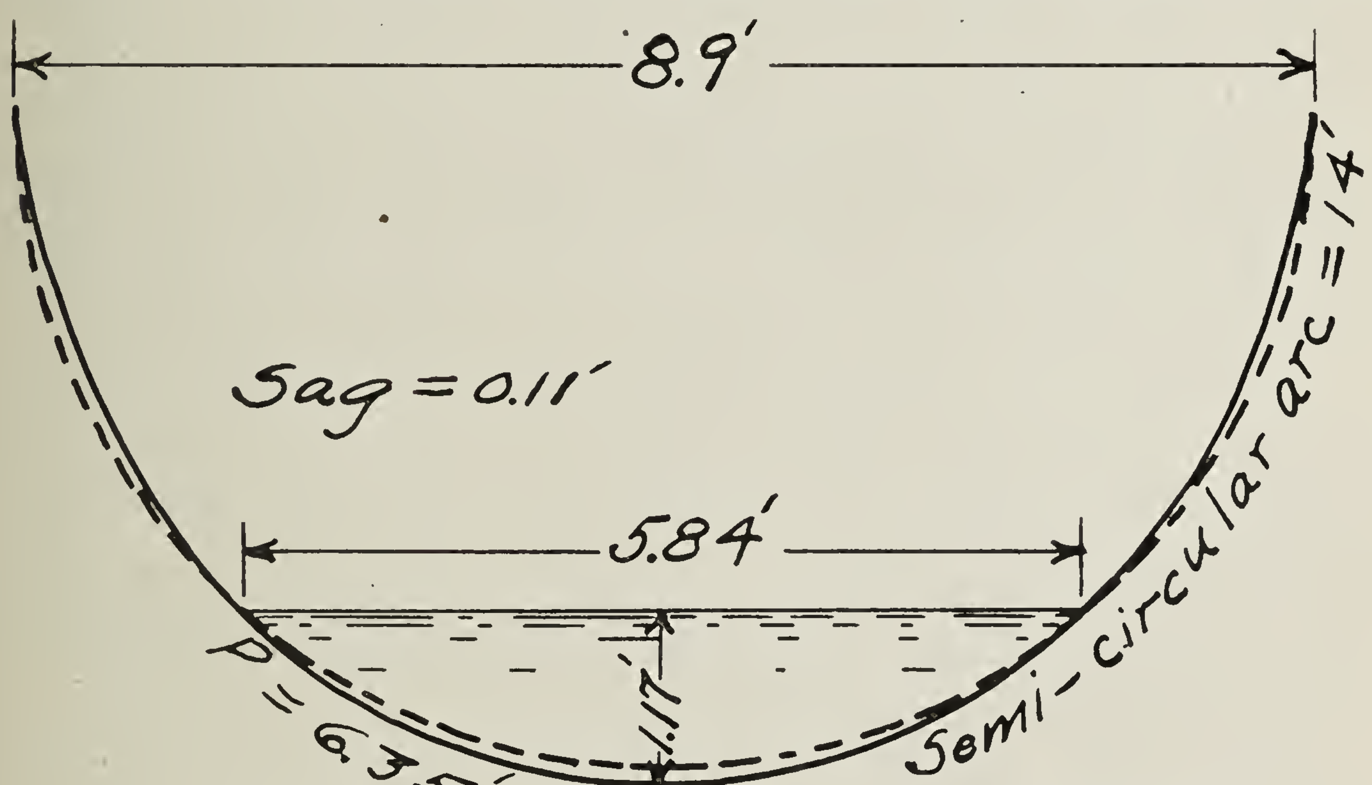


Fig. 3. Cross-section of Metallic Flume, Garland Canal, Blanca.

be made for this sag if the proper grade and elevation of the flume in relation to the channels of approach and recession be maintained when water is passing through. The change in the amount of cross-sectional area due to this distortion, is inappreciable and would not affect the carrying capacity of the flume.

The corrugated flumes experimented upon showed no change under weight of water from the semi-circular form.

GROUP NO. 1. SHORT FLUMES WITH WASTE-WAYS. On the Willcox canal, of the Grand Valley Irrigation District, near Grand Valley, are a number of rather short flumes which span the arroyos leading from the mesas and serve as wasteways in case of breaks in the banks of the canal. The wasteway consists of a 10x3 feet hole, cut lengthwise in the bottom of the flume near the middle of its length, and opening into a wooden box encasing the bottom of the outside of the flume. Wasteway gates are built into one side of this box. The flumes experimented upon are from 70 to 90 feet in length and with semi-circular arcs of 168 inches. Duplicate experiments were made upon each flume as a check upon the value of the coefficient. Table 1 shows the results of these experiments.

TABLE 1—HYDRAULIC ELEMENTS IN FLUMES WITH WASTEWAYS.

| Length of Section Tested | Discharge sec-ft. | Area of Wetted Section sq. ft. | Mean Velocity ft. per sec. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|
| 79.6 | 15.72 | 5.83 | 2.70 | 7.02 | 0.83 | 0.00216 | 63.6 | 0.0211 |
| 79.6 | 27.68 | 9.50 | 2.91 | 8.32 | 1.14 | 0.00168 | 66.4 | 0.0219 |
| 69.6 | 14.05 | 9.12 | 1.54 | 8.23 | 1.11 | 0.00043 | 70.6 | 0.0202 |
| 69.6 | 22.22 | 12.93 | 1.72 | 9.53 | 1.36 | 0.00043 | 71.2 | 0.0210 |

The results of these experiments indicate that the effect of the wasteway in the flume of short length, is to reduce its carrying capacity by increasing the coefficient of friction. For flumes of this class, less than 100 feet long and having wasteways similar to the above type, a mean value for (n) of 0.021 is indicated.

FLUMES ON TANGENTS WITH NO IRREGULARITIES. About 3,000 feet of flume had been constructed in the winter of 1912-13 upon the Garland canal of the Trinchera Irrigation District, near Blanca. The length of semi-circular arc was 168 inches. Because of the excellency of the construction, uniform grade and perfect alignment it was especially well adapted to purposes of experiment. (Plate I.)

Tests were made upon the tangents between curves in April, 1913.

Experiments were also made upon a flume of the Minnesota canal near Paonia, in October, 1913. The grade of this flume was not uniform throughout its entire length, so that only two sections were tested, but these had uniform grade and sufficient fall to allow of an accurate determination of the slope. No transverse bracing whatever existed in this flume, and during the three seasons it had been in operation sag had taken place in cross-section and caused a displacement of the uprights and drawing together at the top. For this reason the mean wetted area was obtained by taking cross-sectional depths, which were plotted, and the wetted perimeter was measured with a pair of dividers.

Table 2 gives the results of these tests:

TABLE 2

HYDRAULIC ELEMENTS IN FLUMES HAVING NO IRREGULARITIES.

| Name of Canal | Length of Section Tested ft. | Discharge sec-ft. | Area of Wetted Section sq-ft. | Mean Velocity sec. ft. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|---|
| Garland ......... | 450 | 19.59 | 3.62 | 5.41 | 5.95 | 0.608 | 0.0028 | 131.1 | .0109 |
| Garland ......... | 650 | 19.59 | 3.66 | 5.34 | 6.00 | 0.610 | 0.0023 | 142.3 | .0101 |
| Garland ......... | 325 | 19.59 | 4.45 | 4.40 | 6.44 | 0.691 | 0.0022 | 112.5 | .0126 |
| Minnesota ....... | 70 | 7.04 | 1.17 | 6.01 | 3.12 | 0.374 | 0.0069 | 118.1 | .0111 |
| Minnesota ....... | 200 | 7.04 | 1.17 | 6.01 | 3.13 | 0.374 | 0.0052 | 136.2 | .0099 |

The value of (n) indicated in this class of flumes is 0.011.

GROUP NO. 2. FLUMES ON TANGENTS WITH NO IRREGULARITIES. All of the flumes of this class upon which experiments were conducted, are located upon the King Lateral Extension of the Uncompahgre Project, United States Reclamation Service, near Montrose. The flumes are of excellent construction, there being no irregularities in alignment or grade. The grade of each being quite heavy, no difficulty was experienced in getting the true slope of the water surface. Several cross-sectional areas and water surface elevations were taken throughout the length of each. The experimental results are given in Table 3, upon flumes with semi-circular arcs of 108 inches, 120 inches and 96 inches respectively.

TABLE 3—HYDRAULIC ELEMENTS IN FLUMES OF GROUP NO. 2.

| Length Section Tested feet | Discharge sec-ft. | Area of Wetted Section sq. ft. | Mean Velocity ft. per sec. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|
| 300.5 | 39.19 | 7.32 | 5.35 | 6.82 | 1.072 | 0.00386 | 83.1 | .0179 |
| 189 | 33.30 | 5.77 | 5.77 | 6.30 | 0.916 | 0.00537 | 82.3 | .0177 |
| 635 | 23.72 | 4.65 | 5.10 | 5.53 | 0.841 | 0.00411 | 86.6 | .0166 |

A mean value of 0.0174 is indicated for this class of flumes.

GROUP NO. 3. CORRUGATED FLUMES. Experiments were conducted upon the corrugated flumes on the Stewart, and Fire Mountain canals near Paonia, in October, 1913.

A metal flume having a semi-circular arc length of 132 inches, and a length of 1,745 feet, carried the water of the Stewart canal around a steep hillside and contained numerous curves and tangents, a portion of which is shown in Plate II. Because of the rather poor alignment of tangents, nothing definite could be done

Plate I. Metallic Flume, Garland Canal, Blanca.

Plate II. Corrugated Flume, Stewart Canal, Paonia.

in the way of finding the true effect of curvature in retarding the flow. It was with the idea of obtaining the value of the coefficient for this particular flume that the tests were made. Elevations of the water surface and the cross-sectional elements, were determined at intervals throughout the entire length. Figure 4 shows the alignment of this channel. Individual sections upon which determinations of (n) were made, are indicated by the alternate solid and dashed lines. The values of the coefficient for each section are written opposite. Two independent experiments were made upon this flume on different days. The results are as shown on the diagram, Fig. 4, and in Table 4, which gives mean values for the entire length of the flume.

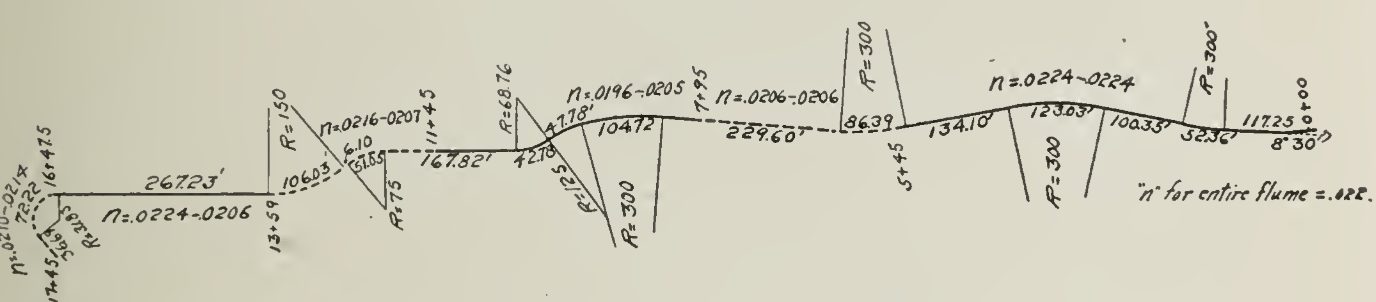


Fig. 4. Corrugated Metallic Flume, Stewart Canal, Paonia.

Figure 5 shows the alignment and results of tests on the flume of the Fire Mountain canal over Hubbard Creek. The mean

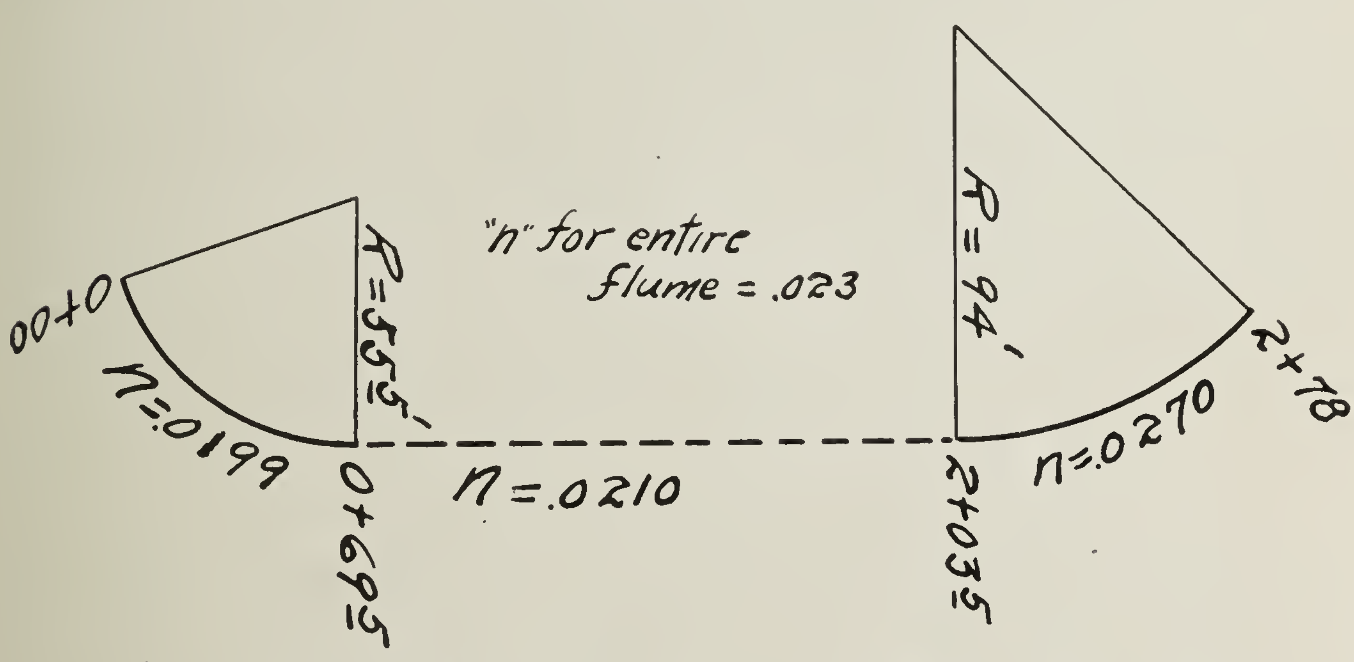


Fig. 5. Corrugated Metallic Flume, Fire Mountain Canal, Paonia.

hydraulic elements for this flume, taken as a whole, are shown in Table 4. Its semi-circular arc is 144 inches.

Because of the short length and slight fall so much weight cannot be attached to the experiment on the Fire Mountain flume as to the ones on the Stewart flume.

In determining the carrying capacity of corrugated flumes these data indicate a safe value of (n) to be 0.0225.

TABLE 4—HYDRAULIC ELEMENTS OF CORRUGATED FLUMES.

| Name of Canal | Discharge sec-ft. | Area of Wetted Section sq-ft. | Mean Velocity ft. per sec. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coeficient (n) |
|---|---|---|---|---|---|---|---|---|
| Stewart ........... | 14.7 | 7.67 | 1.918 | 7.35 | 1.043 | 0.000892 | 62.8 | 0.0222 |
| Stewart ........... | 14.5 | 7.65 | 1.897 | 7.37 | 1.038 | 0.000879 | 62.8 | 0.0222 |
| Fire Mountain ..... | 16.88 | 8.84 | 1.910 | 7.96 | 1.110 | 0.000871 | 61.4 | 0.0230 |

## TIMBER FLUMES

BENCH FLUMES ON ORCHARD MESA POWER CANAL. About a mile above Plateau Creek on Grande River, is located the headworks of the Orchard Mesa Power Canal. Owing to the close proximity of the river to the bluffs it was necessary to use an aggregate length of several miles of rectangular wooden flumes, interspersed with earth canal, to convey the water around the hillside to the power house below the Orchard Mesa at Palisade (Plate III). This flume was built in the winter of 1909-1910.

The flume is irregular in alignment, being made up in sections varying in length from less than 100 feet to over 600 feet, connected by sharp angles. The waterway averages twelve feet in width, with a depth of six feet, and is laid on a grade of about 4.5 feet per mile. The sides and bottom are of planed lumber with tongue and groove joints. In nearly every section has been placed two-inch by four-inch posts vertically along the sides at intervals of about 100 feet, the purpose of these being to check the flow at low heads that the sides of the flume might be kept from drying out and leaking badly when larger heads were turned in.

A line of levels was run along each division of the flume, and benches established at points on the sides at the upper and lower ends of the sections to be experimented upon. The elevation at each side along the bottom was also obtained. It was found that the flume had settled in many places as much as 0.3 feet below grade. During a time when the water was out of the canal accurate measurements were made of the widths at the top and bottom, at the upper and lower ends of each section, and although the flume was apparently designed for a width of 12 feet, this dimension did not prevail exactly throughout.

It was necessary in choosing the proper place for the ends of the section to consider the effect of the angle upon the flow of the water entering and leaving the section. Usually the condition was that of eddies and whirls and the banking of the water on the outside. Hence usually as much as 30 feet above or below the turn was allowed for the water to regain its flow in an undisturbed condition.

Several experiments were made at heads varying from 60 to 230 second feet. The unevenness of the water surface necessitated the taking of two readings from the bench marks to the water at its lowest and highest stages, and the mean of these was used in the computations for the slope. Table 5 shows the results of 75 experiments on 22 sections of this canal.

Of the 22 sections experimented upon, 17 show a higher value of (n) for the highest than for the lowest discharges. Of these 17. 14 have a greater slope of water surface for the highest than for the lowest heads. Only eleven, however, indicate a gradual increase of the value of (n) with that of the hydraulic radius. At the bottom of Table 5 is given the mean values of the elements obtained for each discharge. As will be noted there is no apparent change in the value of (n) with that of the hydraulic radius. However, to make the change apparent, of the ten mean values obtained, arranged in order of corresponding discharge from least to greatest, an average of 1-4, 4-7 and 7-10 indicate (n) to be .0117, .0121, and .0124, respectively. This set of experiments indicates the possibility of a variation in the value of (n) with the change in hydraulic radius for a rectangular flume of this type at least, and that this value increases with the discharge. These data are not positive proof of such variation, but they are presented here merely as a suggestion. Even if this change in the value of (n) does occur, it is probably not of great practical concern.

An average value for the coefficient of roughness of this flume is 0.0122.

There follows a brief description of other timber flumes investigated, and Table 6 gives the hydraulic elements as determined. The results are of value merely in illustrating the condition of some flumes after a period of use. Many of these may not originally have been built upon the proper grade to have the same carrying capacity as the channel leading to or away from them, or if formerly well designed and constructed, subsequent conditions may have caused sagging or irregular alignment.

REDLANDS MESA FLUME, GRAND JUNCTION. The flume is in excellent condition as regards the character of the material of which it is constructed, the lining being tongue and

TABLE 5

HYDRAULIC ELEMENTS FOR THE ORCHARD MESA POWER FLUME.

| Length of Section Tested | Discharge sec-ft. | Area of Wetted Section sq-ft. | Velocity ft. per sec. | Wetted Perimeter | Hydraulic Radius | Slope ft. per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|
| 132 | 136.1 | 29.41 | 4.63 | 16.88 | 1.742 | .000687 | 133.9 | .0123 |
| 132 | 169.5 | 33.33 | 5.09 | 17.53 | 1.901 | .000695 | 139.9 | .0120 |
| 132 | 209.3 | 37.90 | 5.52 | 18.32 | 2.068 | .000680 | 146.2 | .0117 |
| 132 | 219.4 | 40.05 | 5.47 | 18.70 | 2.140 | .000838 | 129.3 | .0131 |
| 200 | 136.1 | 27.59 | 4.94 | 16.59 | 1.663 | .001003 | 120.7 | .0127 |
| 200 | 169.5 | 29.72 | 5.70 | 16.91 | 1.757 | .000883 | 144.7 | .0115 |
| 200 | 209.3 | 35.55 | 5.89 | 18.41 | 1.930 | .001242 | 120.1 | .0137 |
| 200 | 219.4 | 37.53 | 5.86 | 18.24 | 2.058 | .001342 | 111.4 | .0151 |
| 300 | 136.1 | 27.47 | 4.96 | 16.53 | 1.661 | .000832 | 133.1 | .0124 |
| 300 | 169.5 | 31.90 | 5.32 | 17.30 | 1.843 | .001046 | 121.0 | .0138 |
| 300 | 209.3 | 36.08 | 5.80 | 18.00 | 2.004 | .000693 | 155.7 | .0110 |
| 300 | 219.4 | 38.24 | 5.74 | 18.36 | 2.083 | .000626 | 156.6 | .0109 |
| 200 | 136.1 | 25.70 | 5.30 | 16.18 | 1.588 | .000980 | 134.4 | .0121 |
| 200 | 209.3 | 34.10 | 6.14 | 17.65 | 1.932 | .001016 | 138.7 | .0121 |
| 200 | 219.4 | 35.59 | 6.17 | 17.89 | 1.988 | .001266 | 122.8 | .0139 |
| 360 | 136.1 | 26.92 | 5.06 | 16.49 | 1.631 | .000747 | 145.0 | .0114 |
| 360 | 169.5 | 30.57 | 5.55 | 17.09 | 1.789 | .000761 | 150.3 | .0111 |
| 360 | 209.3 | 34.47 | 6.07 | 17.84 | 1.932 | .000720 | 162.9 | .0104 |
| 360 | 219.4 | 36.09 | 6.08 | 18.01 | 2.004 | .000636 | 170.3 | .0100 |
| 196 | 136.1 | 27.09 | 5.03 | 16.50 | 1.642 | .000617 | 158.0 | .0105 |
| 196 | 169.5 | 31.28 | 5.42 | 17.20 | 1.820 | .000633 | 159.5 | .0105 |
| 196 | 209.3 | 35.30 | 5.93 | 17.87 | 1.974 | .000954 | 136.7 | .0123 |
| 196 | 219.4 | 36.79 | 5.96 | 18.12 | 2.030 | .000903 | 139.3 | .0122 |
| 144 | 136.1 | 28.73 | 4.74 | 16.79 | 1.711 | .000554 | 153.9 | .0108 |
| 144 | 169.5 | 32.38 | 5.24 | 17.40 | 1.860 | .000665 | 148.8 | .0113 |
| 144 | 209.3 | 35.44 | 5.91 | 17.90 | 1.981 | .001157 | 123.3 | .0136 |
| 144 | 219.4 | 36.46 | 6.02 | 18.07 | 2.019 | .000949 | 137.6 | .0122 |
| 208 | 136.1 | 25.32 | 5.38 | 16.22 | 1.560 | .000853 | 147.4 | .0111 |
| 208 | 169.5 | 28.63 | 5.92 | 16.77 | 1.708 | .000945 | 147.7 | .0112 |
| 208 | 209.3 | 31.56 | 6.64 | 17.28 | 1.825 | .000974 | 157.3 | .0108 |
| 208 | 219.4 | 33.12 | 6.62 | 17.53 | 1.891 | .001151 | 142.1 | .0119 |
| 220 | 136.1 | 24.91 | 5.46 | 16.54 | 1.506 | .000728 | 163.7 | .0100 |
| 220 | 169.5 | 29.12 | 5.82 | 16.87 | 1.725 | .000842 | 152.8 | .0109 |
| 220 | 209.3 | 33.40 | 6.27 | 17.58 | 1.899 | .000847 | 156.7 | .0109 |
| 220 | 219.4 | 34.78 | 6.31 | 17.82 | 1.952 | .000801 | 159.5 | .0107 |
| 244 | 136.1 | 27.30 | 4.99 | 16.64 | 1.640 | .001025 | 120.2 | .0137 |
| 244 | 169.5 | 29.97 | 5.66 | 17.02 | 1.758 | .001041 | 132.1 | .0127 |
| 244 | 209.3 | 34.92 | 6.00 | 17.84 | 1.958 | .000984 | 136.7 | .0123 |
| 216 | 169.5 | 31.08 | 5.45 | 16.59 | 1.875 | .001102 | 119.8 | .0139 |
| 216 | 209.3 | 36.84 | 5.68 | 18.16 | 2.030 | .001052 | 123.1 | .0138 |
| 216 | 219.4 | 37.02 | 5.93 | 18.19 | 2.019 | .001191 | 129.7 | .0140 |

TABLE 5—Continued.

| Length of Section Tested | Discharge sec-ft. | Area of Section sq-ft. | Velocity feet per sec. | Wetted Perimeter | Hydraulic Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|
| 116 | 136.1 | 26.85 | 5.06 | 16.56 | 1.622 | .001101 | 119.6 | .0137 |
| 116 | 169.5 | 30.42 | 5.57 | 17.09 | 1.780 | .001325 | 114.8 | .0140 |
| 116 | 209.3 | 36.46 | 5.74 | 18.09 | 2.015 | .001222 | 115.6 | .0145 |
| 116 | 219.4 | 35.98 | 6.10 | 18.02 | 1.995 | .001394 | 115.8 | .0145 |
| 172 | 169.5 | 29.70 | 5.71 | 16.28 | 1.824 | .000877 | 142.7 | .0118 |
| 172 | 209.3 | 35.49 | 5.90 | 17.93 | 1.980 | .001005 | 132.2 | .0129 |
| 172 | 219.4 | 34.58 | 6.34 | 17.78 | 1.943 | .001180 | 132.3 | .0128 |
| 208 | 136.1 | 24.72 | 5.52 | 16.22 | 1.521 | .001466 | 116.9 | .0139 |
| 208 | 169.5 | 29.58 | 5.74 | 16.95 | 1.742 | .001192 | 126.1 | .0131 |
| 208 | 219.4 | 33.64 | 6.52 | 17.64 | 1.908 | .001754 | 112.8 | .0149 |
| 324 | 63.3 | 18.84 | 3.36 | 15.14 | 1.244 | .000500 | 134.5 | .0117 |
| 324 | 139.5 | 30.36 | 4.60 | 17.06 | 1.780 | .000673 | 132.7 | .0125 |
| 324 | 214.9 | 39.06 | 5.51 | 18.51 | 2.110 | .000846 | 130.7 | .0130 |
| 324 | 228.8 | 40.50 | 5.65 | 18.75 | 2.160 | .000794 | 136.3 | .0126 |
| 136 | 63.3 | 15.30 | 4.14 | 14.55 | 1.051 | .001051 | 124.6 | .0121 |
| 136 | 139.5 | 26.58 | 5.25 | 16.43 | 1.617 | .000934 | 135.0 | .0122 |
| 136 | 228.8 | 38.34 | 5.97 | 18.39 | 2.085 | .001007 | 130.3 | .0130 |
| 147 | 139.5 | 26.28 | 5.31 | 16.38 | 1.605 | .000557 | 177.7 | .0093 |
| 147 | 214.9 | 36.12 | 5.96 | 18.02 | 2.004 | .000543 | 180.6 | .0095 |
| 147 | 228.8 | 38.16 | 6.00 | 18.36 | 2.079 | .000645 | 163.7 | .0106 |
| 581 | 63.3 | 15.73 | 4.02 | 14.63 | 1.074 | .000725 | 144.1 | .0108 |
| 581 | 139.5 | 26.28 | 5.31 | 16.36 | 1.606 | .000675 | 161.5 | .0102 |
| 581 | 214.9 | 38.04 | 5.65 | 18.34 | 2.075 | .000959 | 126.8 | .0133 |
| 581 | 228.8 | 39.52 | 5.79 | 18.59 | 2.126 | .001045 | 122.8 | .0139 |
| 308 | 63.3 | 17.23 | 3.67 | 15.86 | 1.087 | .000564 | 141.6 | .0109 |
| 308 | 139.5 | 28.20 | 4.95 | 16.70 | 1.688 | .000726 | 141.5 | .0118 |
| 308 | 214.9 | 38.94 | 5.52 | 18.49 | 2.105 | .000768 | 137.3 | .0122 |
| 308 | 228.8 | 40.74 | 5.64 | 18.79 | 2.170 | .000801 | 135.1 | .0127 |
| 404 | 177.8 | 33.54 | 5.30 | 17.57 | 1.909 | .000577 | 159.8 | .0106 |
| 404 | 213.1 | 41.21 | 5.17 | 18.86 | 2.188 | .000421 | 170.4 | .0101 |
| 305 | 177.8 | 33.88 | 5.26 | 17.64 | 1.919 | .000879 | 128.1 | .0130 |
| 305 | 213.1 | 42.86 | 4.98 | 19.13 | 2.239 | .000696 | 126.2 | .0137 |
| 420 | 177.8 | 36.12 | 4.92 | 18.03 | 2.003 | .000555 | 147.6 | .0115 |
| 420 | 213.1 | 45.44 | 4.68 | 19.58 | 2.320 | .000548 | 131.4 | .0131 |
| 1 | 63.3 | 16.77 | 3.80 | 15.05 | 1.114 | .000710 | 136.2 | .0114 |
| 2 | 136.1 | 26.83 | 5.09 | 16.51 | 1.624 | .000883 | 137.2 | .0120 |
| 3 | 139.5 | 27.54 | 5.08 | 16.59 | 1.659 | .000713 | 149.7 | .0112 |
| 4 | 169.5 | 30.59 | 5.56 | 17.00 | 1.798 | .000924 | 138.5 | .0121 |
| 5 | 177.8 | 34.51 | 5.16 | 17.75 | 1.944 | .000670 | 145.2 | .0117 |
| 6 | 209.3 | 35.21 | 5.96 | 17.91 | 1.964 | .000965 | 138.9 | .0123 |
| 7 | 213.1 | 43.17 | 4.94 | 19.19 | 2.249 | .000555 | 142.7 | .0123 |
| 8 | 214.9 | 38.04 | 5.66 | 18.34 | 2.074 | .000779 | 143.8 | .0120 |
| 9 | 219.4 | 36.14 | 6.08 | 18.03 | 2.002 | .001079 | 134.7 | .0126 |
| 10 | 228.8 | 39.45 | 5.81 | 18.57 | 2.124 | .000858 | 137.6 | .0126 |

groove, mill-planed lumber. The grade, however, was insufficient to prevent considerable deposition of silt on the bottom, the sediment being as much as 0.5 feet deep in places. The cross-section is 5.62 feet by 2.8 feet, and the length tested is 296 feet.

FLUME NO. 42, WILLCOX CANAL, GRAND VALLEY This flume is approximately twenty years old, and in 1912 had been repaired and lined with a patent roofing material, shown in Plate IV. This consists of flexible cement, reinforecd in the center with imported burlap, backed with highly compressed saturated felt and surfaced with flake mica. The lining is well joined and presents a very smooth surface. The alignment and grade of the flume are very poor and sediment is deposited in several places due to sagging. The width of waterway is 3.5 feet.

FLUME OVER CHICOSA CREEK, OXFORD CANAL, FOWLER. This structure is twenty-three years old and is still in excellent condition of grade and alignment. The channel is 4.35 feet by 9.7 feet. The sides are formed of 2x12-inch boards, with one-fourth by three inch crack battens on the inside of the flume, as shown in Plate V. The flooring is composed of 2x12-inch boards laid at right angles to the line of the flume, but these are so regular as to apparently form a very smooth surface. However, the data indicates a high frictional resistance. With the flooring of this type there is a tendency for silt to be deposited in the cracks, thus preventing leakage, an advantage in this respect over that of flooring placed longitudinally.

EAST CANAL CHUTE, UNCOMPAHGRE PROJECT. This flume is of practically the same age and cross-section, and has the same type of lining as that of the High Mesa Chute. The fall is eleven feet per 100 feet. It also has a low value of (n).

**TABLE 6—HYDRAULIC ELEMENTS IN TIMBER FLUMES AND CHUTES.**

| Name of Flume | Length of Section Tested ft. | Discharge sec-ft. | Area of Wetted Section sq-ft. | Velocity ft. per sec. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|---|
| No 42 | 360 | 6.33 | 3.74 | 1.69 | 5.46 | 0.685 | .000610 | 83.4 | .0162 |
| Chicosa Creek | 1712 | 16.01 | 10.41 | 1.54 | 11.23 | 0.928 | .000274 | 96.4 | .0150 |
| High Mesa Chute | 175.6 | 8.45 | 0.48 | 17.61 | 2.48 | 0.194 | .1331 | 109.4 | .0104 |
| East Canal Chute | 169.5 | 4.17 | 0.36 | 11.60 | 2.29 | 0.157 | .1133 | 86.9 | .0118 |

See also Table 5, Orchard Mesa Power Canal Flume, pages 14 and 15.

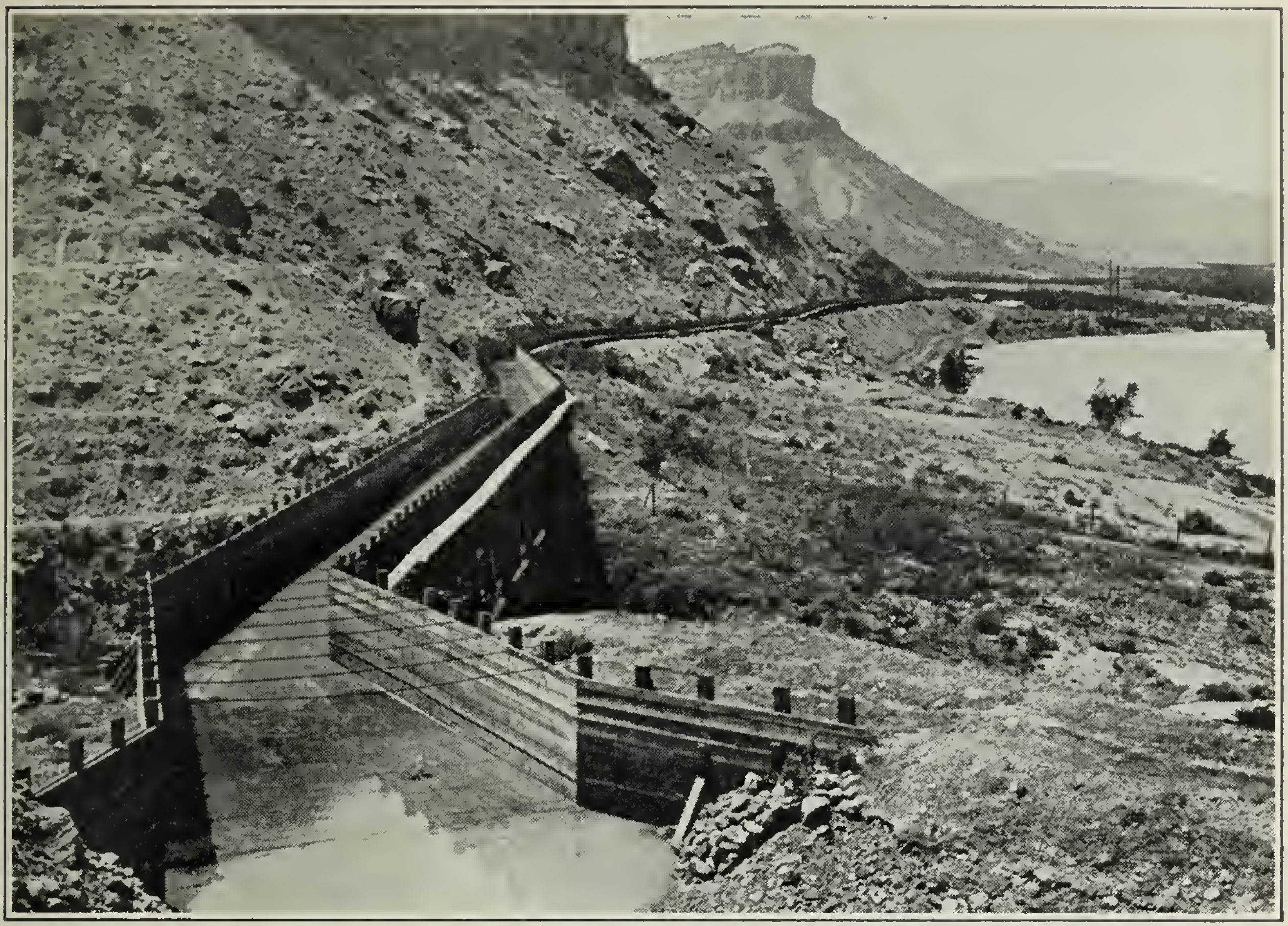

Plate III. Timber Flume, Orchard Mesa Power Canal, Palisade.

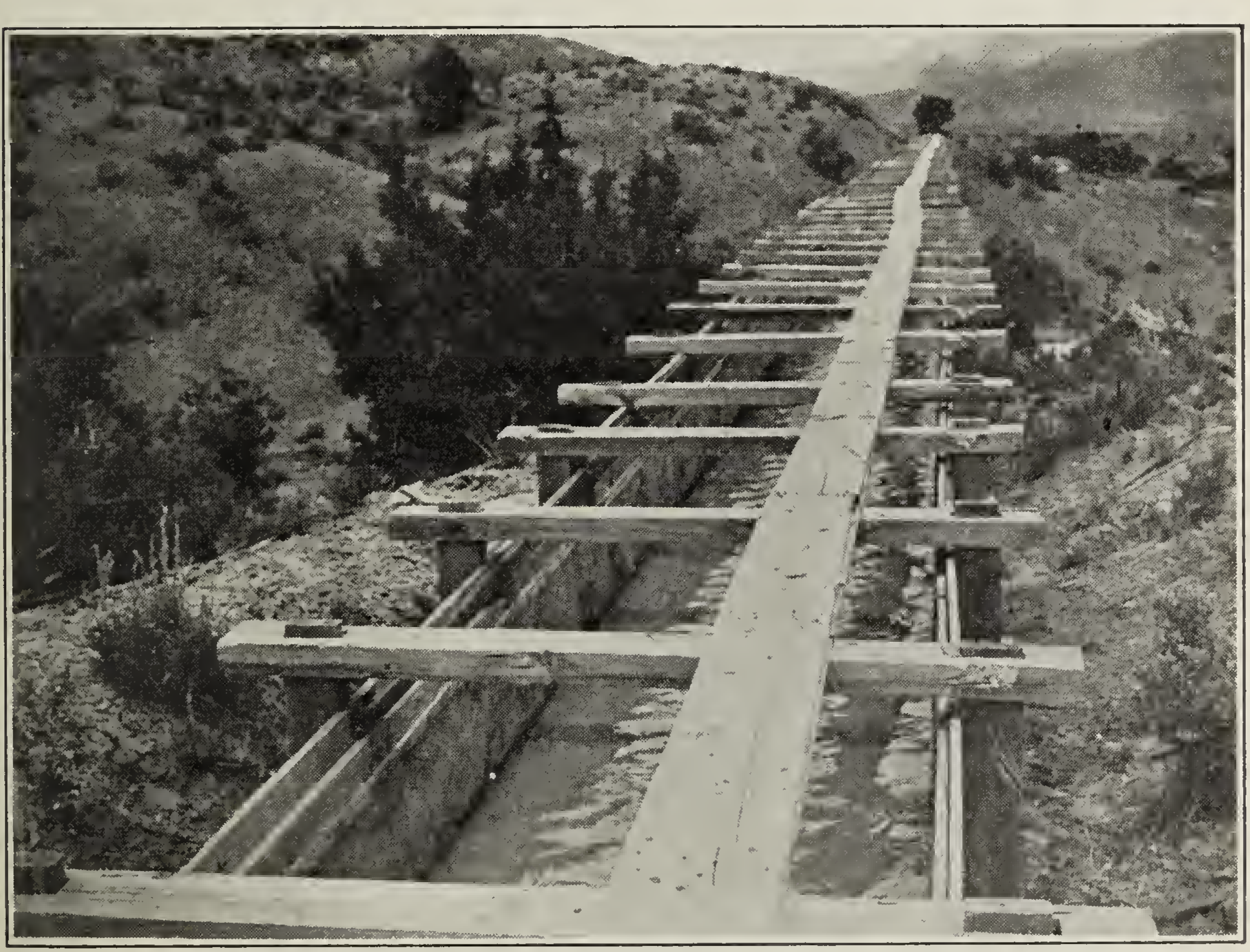

Plate IV. Timber Flume, Lined With Patent Roofing, Willcox Canal, Grand Valley.

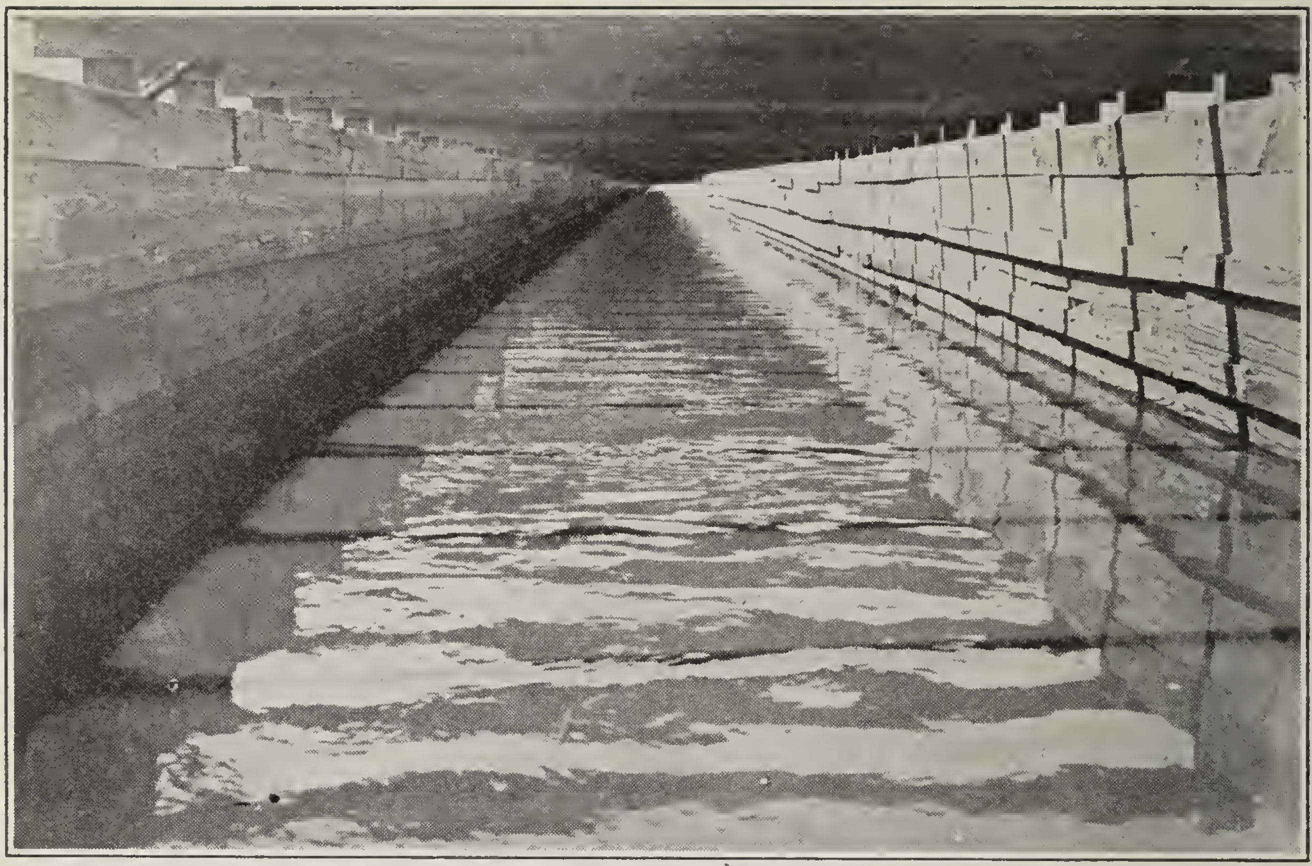

Plate V. Timber Flume Across Chicosa Creek, Fowler.

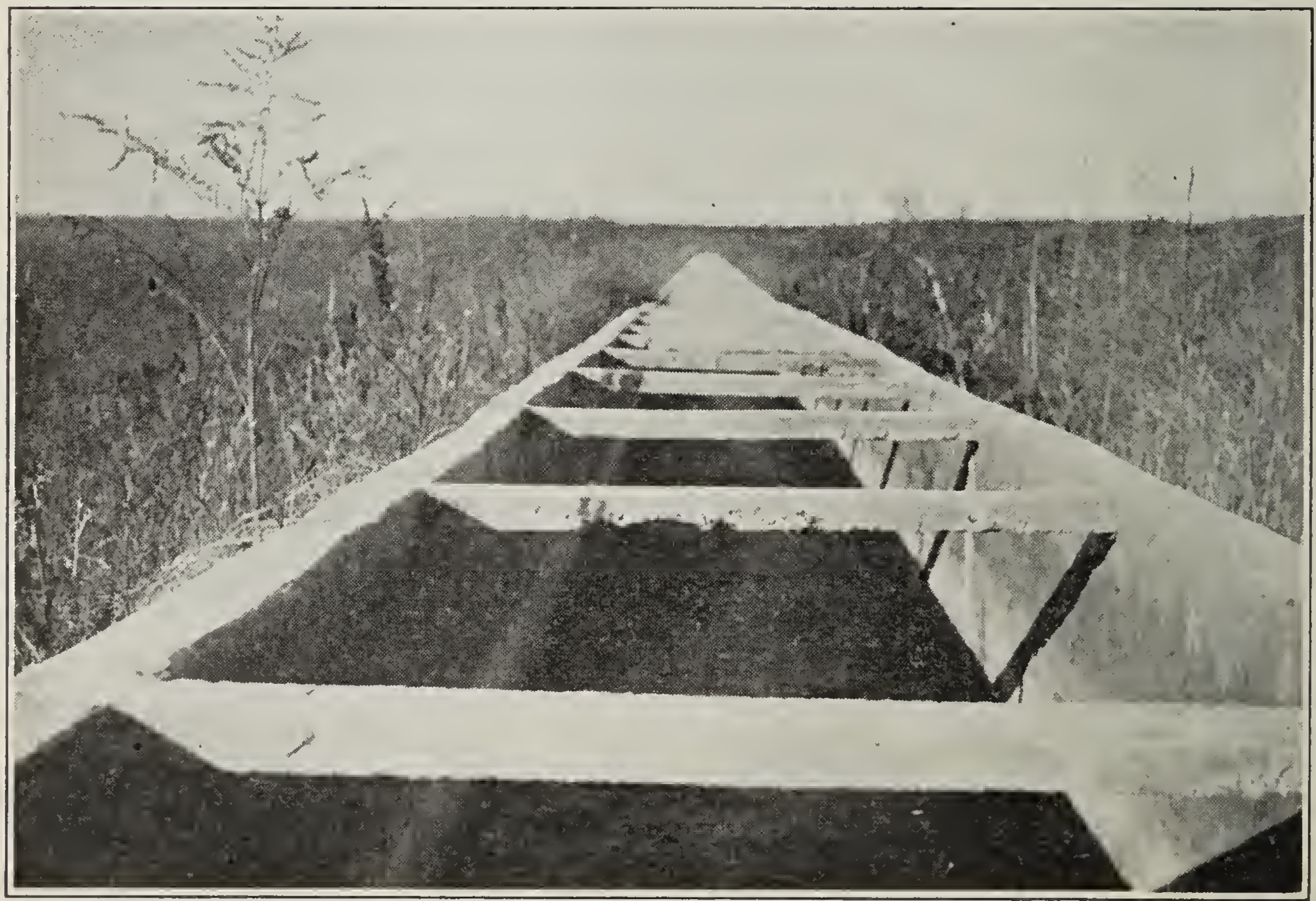

Plate VI. Concrete Flume, Long Pond, Fort Collins.

HIGH MESA CHUTE, UNCOMPAHGRE PROJECT. This chute was built in the spring of 1913 and the experiment was made upon it in June. The waterway is composed of 2x12-inch boards on each side, joined by 2x12-inch boards at the floor, giving ten inches by two feet as the dimensions of the cross-section. The lumber is mill-planed. It has a fall of about thirteen feet per 100 feet. As will be noted the coefficient (n) is rather low for this type of lining.

## CHUTES

Since from a construction standpoint practically all chutes may be classified as flumes or lined channels, the data has been placed under those headings. Experiments were made upon two timber and three concrete-lined chutes, included in Tables 6 and 7.

## CONCRETE-LINED CHANNELS

LONG POND REINFORCED CONCRETE CHUTE, FORT COLLINS. Long Pond Reservoir is situated on a ridge to the north of the Cache la Poudre River, near Fort Collins, and is used for the storage of water to be supplied to the Larimer & Weld canal during the latter part of the irrigation season. The slope from the reservoir to the Larimer & Weld canal is such as to prohibit the use of an earth section to convey the water, hence a reinforced concrete chute, resting on piers from one foot to five feet high, was provided. (Plate VI.) This was constructed in the fall of 1910. The chute is rectangular in cross-section, being 4.4 feet wide by 2.7 feet deep, and having a grade of three percent. The velocity of the water varies from 12 to 20 feet per second, depending upon the discharge. The channel has a smooth cement lining and is in very good condition. The structure is over 1,000 feet in length, but owing to curves and change of grade at inlet and outlet, only a 600-foot section was experimented upon. During a period when the channel was not in use, levels were run over this section and benches established upon the sides 100 feet apart, cross-sectional elevations of the bottom being taken opposite these points.

During August and September, 1912, five experiments were made upon the flow of water in this flume, at different heads, for the purpose of determining any variation of (n) with the change in hydraulic radius. The current meter measurements were made near the inlet in a section of light grade where the water had not yet attained a high velocity. Readings were taken to the water surface from all benches, the mean of the highest and lowest pulsations being used in computing the slopes and other hydraulic elements.

Table 7 gives the results of these experiments. To make any variation in the value of (n) apparent, the experiments are arranged according to discharge from least to greatest. An average of 1-3, 2-4, 3-5 indicate mean values of (n) to be .0122, .0117 and .0121, respectively, from which a comparison can be made. These limited data do not throw any light upon the variation in the value of (n) with the discharge. The mean coefficient of roughness for this chute is .012.

REINFORCED CONCRETE FLUME OVER DRY CREEK, HANDY CANAL, LOVELAND. This flume has a maximum elevation above the creek bed of about 30 feet, and is supported upon concrete columns. The total length is approximately 650 feet, and it is built in two sections of different grades, the upper being about 130 feet long with a fall of 5 feet, and the lower 520 feet long with a fall of 8 feet. The cross-section is rectangular, being 7.9 feet wide by 3 feet deep. The channel is lined with cement mortar, trowel finished, and is in very good condition, giving a velocity in the lower section of about 13 feet per second. Because of the short length of the upper section it was discarded and the lower one chosen for the purpose of experiment, 514.5 feet of which was tested. This flume was built in the spring of 1906.

SOUTH CANAL, U. S. RECLAMATION SERVICE, UNCOMPAHGRE PROJECT. Although much of this canal is concrete-lined, great difficulty was experienced in selecting suitable sections for the purpose of experiment, owing to the short distance between curves, and the roughness of the water surface, which rendered an accurate determination of the slope quite difficult. Two short sections of heavy grade, and one long one of light grade, were finally chosen as being typical of this type of canal, and as presenting the most favorable conditions for determining the hydraulic elements. The canal is designed for a carrying capacity of 1,300 second feet, but the 60 to 100 sec. ft. conveyed at the time of the tests is believed to be sufficient to permit of a reasonably accurate determination of the frictional resistance for this type of concrete lining. The surface of the channel has been left in the condition given it by the forms, the boards on the face of which having been placed longitudinally in the direction of the channel. The concrete lining was placed during 1906 and 1907.

Two chutes were experimented upon. The one at Mile Post No. 2 has a bottom width of 10.1 feet, side slopes 1 to 4, and a grade of seven percent. At Mile Post No. 9 the chute has a bottom width of 13 feet, side slopes 1 to 2 and a grade of seven percent. The length of section tested on the former was 201 feet and on the latter 142 feet. There was also a section 730 feet in length between stations 489+45 and 496+75, which was tested. This has a bottom width of 13 feet, side slopes 1 to 2, and a grade of .15 percent. In Table 7 the sections are designated as (a), (b), and (c) respectively.

Fortunately, near the upper and lower ends of the chutes, beams had been placed over the channel as a means of reinforcing the sides against earth pressure, and from these, cross-sectional and slope measurements were taken. (Plate VII.) For the other section the rodman used a fireman's ladder placed against the side slope and held from above, as a means of getting the elevation of the bottom of the channel and the water surface. On chutes of heavy grade, depths in a section were measured perpendicularly to the bottom, rather than in a vertical direction.

The results of these tests show an average value of (n) to be .0161 for this kind of lining, which, as would naturally be expected, is somewhat higher than that of the cement, or mortar-faced lining.

TABLE 7

HYDRAULIC ELEMENTS OF CONCRETE-LINED CHANNELS AND CHUTES.

| Name of Channel | Length of Section Tested ft. | Discharge sec-ft. | Area of Wetted Section sq-ft. | Velocity sec-ft. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|---|
| Long Pond Chute ......... | 600 | 35.79 | 2.78 | 12.87 | 5.68 | .489 | .02978 | 106.6 | .0125 |
| Long Pond Chute ......... | 600 | 78.32 | 4.29 | 18.26 | 6.36 | .674 | .02968 | 128.9 | .0113 |
| Long Pond Chute ......... | 600 | 100.38 | 5.61 | 17.89 | 6.96 | .806 | .02943 | 116.1 | .0128 |
| Long Pond Chute ......... | 600 | 104.47 | 5.17 | 20.21 | 6.76 | .765 | .02990 | 133.5 | .0111 |
| Long Pond Chute ......... | 600 | 122.94 | 6.24 | 19.70 | 7.24 | .862 | .02971 | 122.9 | .0123 |
| Dry Creek Flume ......... | 514.5 | 154.00 | 9.76 | 15.78 | 10.35 | .942 | .01459 | 134.5 | .0115 |
| South Canal (a)........... | 201 | 89.80 | 5.78 | 15.52 | 11.28 | .514 | .07180 | 80.8 | .0158 |
| South Canal (b)........... | 142 | 59.68 | 5.28 | 11.32 | 13.92 | .379 | .07230 | 68.4 | .0171 |
| South Canal (c)........... | 730 | 111.30 | 23.66 | 4.71 | 16.82 | 1.406 | .00151 | 102.1 | .0155 |

## EARTH CHANNELS

These investigations were made chiefly upon some of the larger canals of the Arkansas, San Luis and Grand Valleys. The main object in view was to ascertain the amount of frictional re-

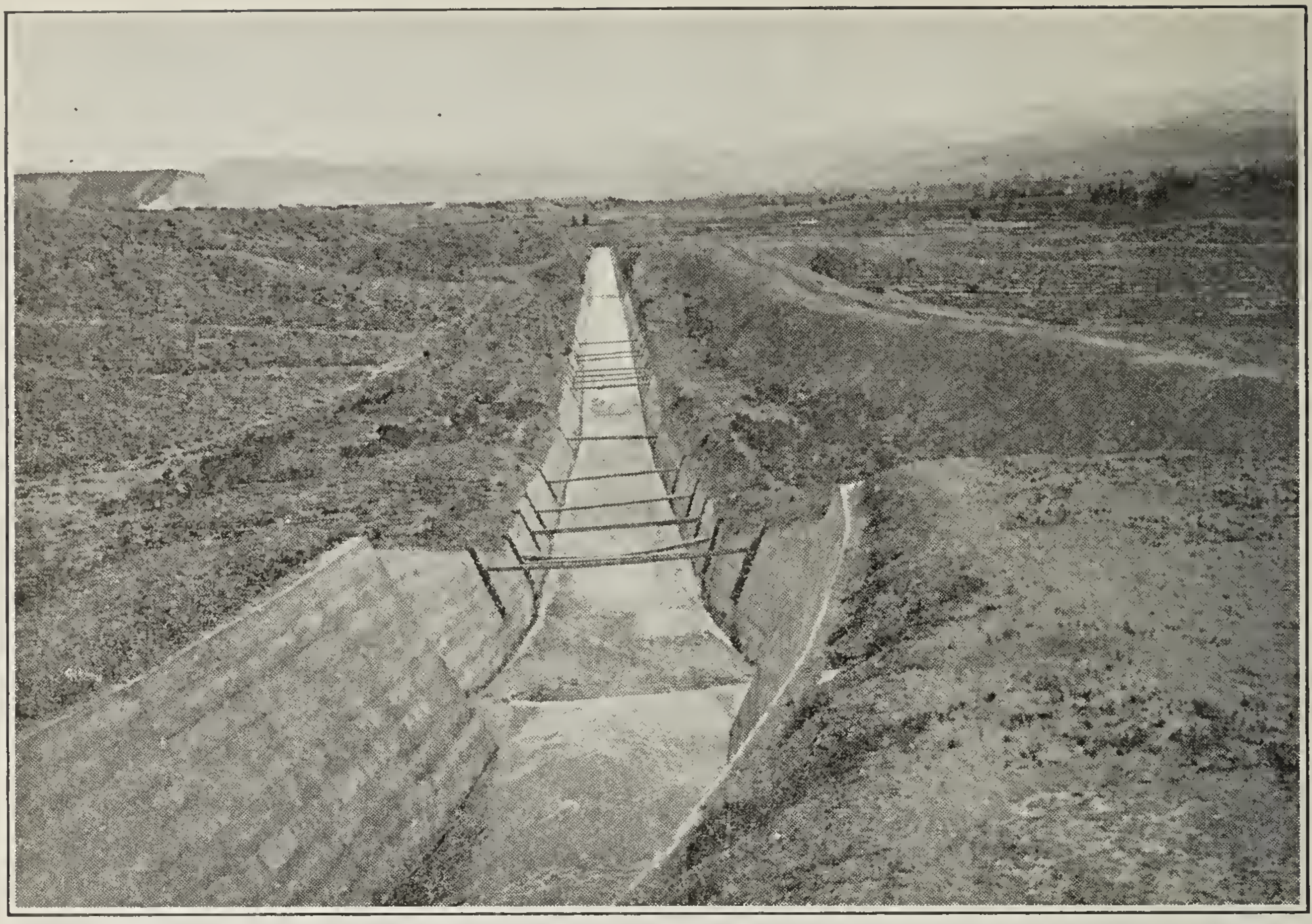

Plate VII. Concrete Chute, Uncompahgre Project, Montrose.

Plate VIII. Lateral No. 1, Rio Grande Canal System, Del Norte.

sistance offered by various kinds of material (gravel, rock, soil, or vegetation) covering the sides and bottom of the channel.

Sections on tangents were selected for experiment, and these were made as long as possible, that an accurate determination of the true slope of the water surface might be made. At the same time due care was exercised in choosing sections in which values of the hydraulic elements were to all appearances fairly constant throughout the channel tested. In short sections of 600 feet or less, cross-sectional measurements of water surface elevations were determined at the ends and middle of the section, while for longer sections these measurements were taken regularly from 300 to 800 feet apart, depending upon the uniformity of the section. In securing the elevations of the water surface two stakes were driven into the channel, so that their heads were below the water surface. Into the top of one stake was driven a nail whose head was flush with the water surface at the lowest pulsation, and similarly a nail was driven into the other stake to mark the highest level of pulsation. Opposite each point at which measurements were to be made, permanent bench marks were established and the elevations of the cross-sectional profile from bank to bank were tied into these. To eliminate the error due to a slight fluctuation in the discharge during the test, the position of the water surface at the various sections was marked simultaneously with the taking of the current meter measurements, or immediately thereafter. In the latter instance elevations of the water surface were marked beginning at the upper end, rather than by proceeding from the lower to the upper end. Cross-sectional elevations were taken of the bed of the canal at intervals from 0.5 feet to 4 feet, depending upon the regularity of the profile. The profiles were subsequently plotted and from these the wetted perimeters were measurd with a pair of dividers. Wetted areas were computed from the depths rather than by measurement with the planimeter. The mathematical mean of these values was used in the computations.

The accompanying diagrams, Figs. 6 to 17 inclusive, illustrate typical cross-sections assumed by the canals after years of use. Along with some of these profiles are shown dimensions and form of the canal as originally constructed, but unfortunately with most of them there is no record concerning the shape and dimensions of the original cross-section. The cross-sections shown were obtained by plotting on a large scale the several cross-sections taken in the field, and from these a new perimeter was adopted to represent an average.

Table 8 giving the results of the experiments on earth canals, was computed from the mean of all the wetted areas and perimeters in each of the sections.

CANALS OF THE RIO GRANDE SYSTEM, DEL NORTE. The main canal of this project diverts water from the Rio Grande river where it enters the San Luis Valley, west of Del Norte. About a mile and a half below the diversion dam is the first bifurcation which is at the head of Lateral No. 1. About two miles east of this point Lateral No. 1-c takes out of Lateral No. 1.

The slope of the land of the San Luis Valley is exceptionally uniform for miles, consequently the canals are built on tangents for great distances. Under these conditions an excellent opportunity was presented for making hydraulic experiments of this nature. The material composing the bed of the canals varies from fine gravel to smooth, rounded, water-worn rocks six inches or more in thickness. Near the foot-hills, in the main canal, the waterway is very rough, being formed by the larger sized stones, while out farther in the valley, as in Lateral No. 1-c, the rocks are smaller and fewer in number, and there is more gravel, which offers less resistance to the flow of the water.

The section selected on the main canal was just above the first bifurcation and had a length of 2,000 feet with a fall of six feet.

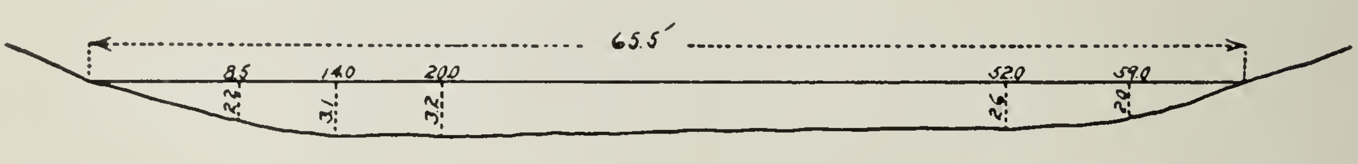


Fig. 6. Main Canal, Rio Grande System, Del Norte.

(Fig. 6.) Benches were established at the outer edge of the bank every 500 feet opposite the places at which measurements were to be made in determining the hydraulic elements. On July 20, 1912, elevations of the water surface were taken opposite these points, but owing to the large head of water and the swiftness of the current in the channel, wading was impossible at the time. Just below the bifurcation are two concrete rating stations with swing bridges, one in connection with the Main canal and the other in Lateral No. 1, from which the current meter measurements were made. The sum of the two discharges, 707 second feet, was taken as the discharge of the Main canal in the 2,000-foot length.

The upper end of the experimental section on Lateral No. 1 was about a mile below the first bifurcation. This was an even mile in length and presented ideal conditions for experimental work. (Plate VIII.) The fall was about 19.5 feet to the mile. The cross-section is shown in Figure 7. A line of benches was established 600 feet apart, and on July 20 elevations of the water surface were taken opposite these places. The water was too swift, however, to wade, so that the discharge was measured at the rat-

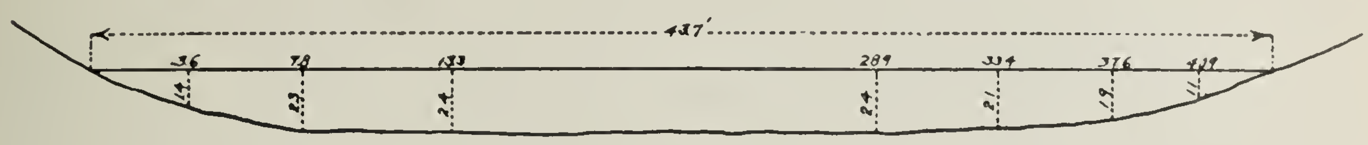

Fig. 7. Lateral No. 1, Rio Grande System, Del Norte.

ing station at the head of the canal, two percent being arbitrarily deducted for seepage loss in transit, leaving the discharge 380 second feet.

Lateral No. 1-c conveys the water down a steeper slope than do the other two canals, causing drops to be constructed about every 1,300 feet, and thereby limiting the length of test section on this canal to 1,238 feet. The cross-section is shown in Figure 8. As on the other canals, the water was too swift for taking the cross-sectional elements in July, but benches were established about 400 ft. apart and water surface elevations taken opposite these, while the gaging was done just below the drop at the head of the section where the current was not too swift to prevent wading.

On October 5 and 6, 1912, other experiments were conducted upon these canals, which at the time carried only low heads, these being 85 second feet, 33 second feet and 23 second feet respectively. On Lateral No. 1 measurements of the discharge were made at both the lower and upper ends of the mile section, to determine the loss or gain, if any, by seepage. The results were as follows:

| Station | Time | Sec. Ft. |
|---|---|---|
| 0+00 | 1:30 P. M. | 33.306 |
| 52+80 | 3:00 P. M. | 33.345 |

For a small head the change is inappreciable, but with a large discharge it is believed that a deduction of two percent as used for the measurement in July, is sufficient to cover all loss by seep-

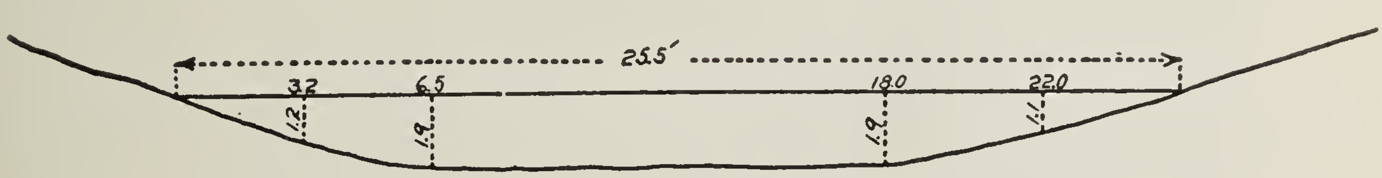

Fig. 8. Lateral No. 1-c, Rio Grande System, Del Norte.

age to the river in the two miles of section from the gaging station to the lower end of the section tested. At this time, also, cross-sectional elevations were taken opposite the bench marks, the channel being in such stable condition that it was believed that no appreciable change of cross-section had taken place from July to October.

On April 24, 1913, two more experiments were made upon the Main canal and Lateral No. 1, there being no water in Lateral No. 1-c. The discharges were 73 and 26 second feet, respectively.

The results of these tests are shown in Table 8. These canals show a higher coefficient of roughness for low heads than for high, differing in this respect from the timber flumes on the Orchard Mesa Power Canal. In other words, these rough channels gave a value for (n) which varies inversely as the hydraulic radius, which would indicate that the roughness in earth canals has a greater influence in retarding the flow of small heads of water than the same degree of frictional resistance exerts on high heads. In designing large canals in this class of materials, therefore, the lowest values of (n) given in the table should be used, while for smaller channels use should be made of the greatest values of (n).

BESSEMER CANAL, PUEBLO. This canal has been in operation about twenty-three years. From the few records available as regards the original cross-sections, the bottom width was five and one-half feet, side slopes one and one-half to one, and maximum depth of water eight feet. As the canal was operated at high stages of water, a decided tendency was developed to deposit sediment on the slope near the water surface, and to scour out at the bottom of the slope. In the sandy-loam, mesa soil, or in the extremely sandy soil of the river bottom near the headgate, the tendency has been to widen to a shallow channel with almost vertical sides. This tendency is less marked in the adobe or clayey soils. The diagrams of the cross-sections, Figures 9, 10, 11 and 12, illustrate this. In cleaning the channels on mesa lands a section was adopted which seemed to be naturally formed by the water. This was gradually widened to 8 feet on the bottom, the sides adjusting themselves in a general way to a slope of from 1 to 1, to 1¼ to 1, which section has seemed to maintain itself. The diagrams show a comparison of the original section, with the section worked to in cleaning the canal, and the section which the water seems inclined to establish. It has a high hydraulic radius and approaches an egg shape.

Four sections of this canal were experimented upon with the idea of noting the change in the value of the coefficient with the variation of the kind of material composing the bed. In each of these sections the channel is in excellent condition, perfectly straight and of uniform cross-section and grade. Elevations of the water surface and cross-sectional area measurements were made at intervals throughout their lengths. The water surface pulsated .01 feet.

Section (a), Fig. 9, borders on Stone Street, Pueblo, and is 1,495 feet in length. Its bed is of smooth, waterworn adobe, from which project very fine rootlets from the cottonwood trees planted in rows on either side of the canal.

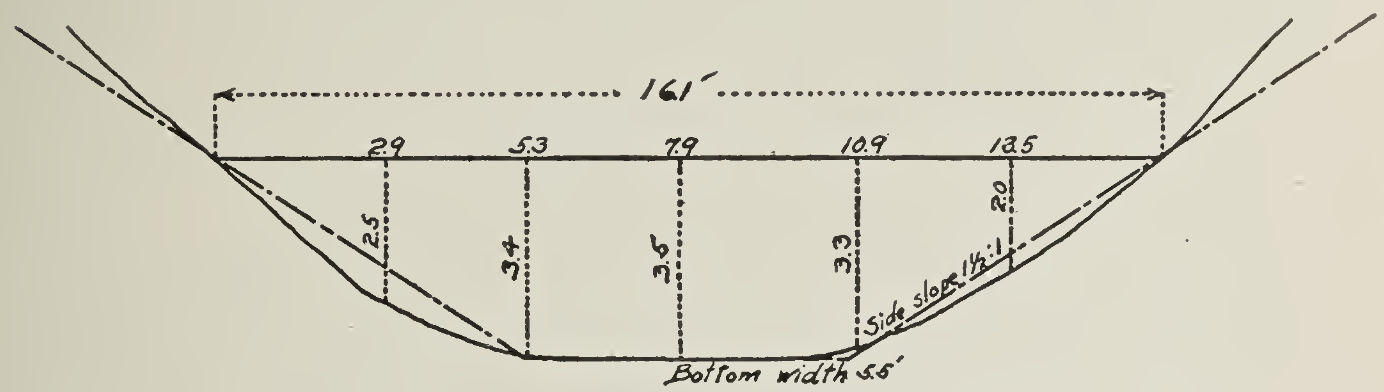


Fig. 9. Section (a), Bessemer Canal, Pueblo.

Section (b), Fig. 10, also bordering on Stone Street, Pueblo, has a lining of smooth, waterworn adobe, but the absence of rootlets accounts for the low value of (n) in comparison with section (a). Its length is 1,600 feet.

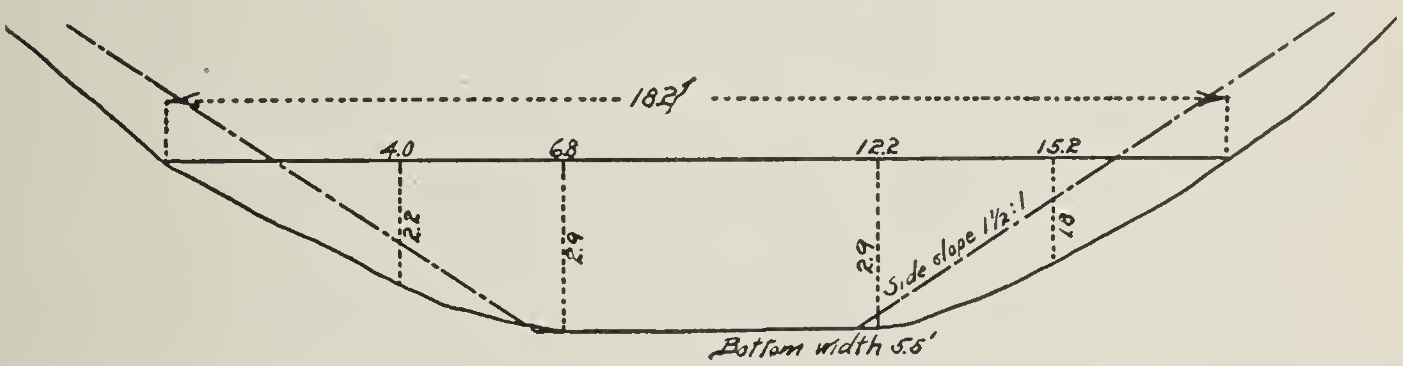


Fig. 10. Section (b), Bessemer Canal, Pueblo.

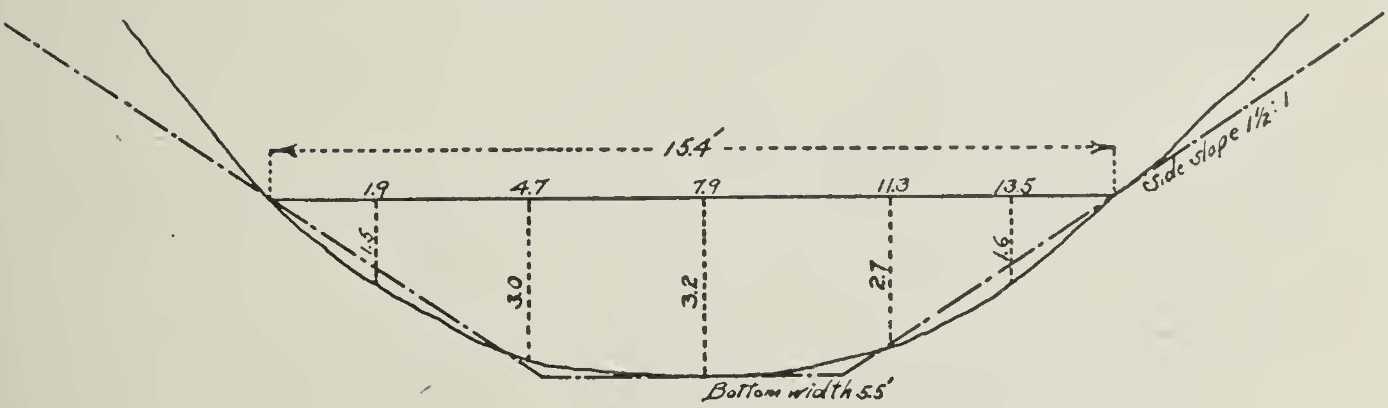


Fig. 11. Section (c), Bessemer Canal, Pueblo.

Section (c), Fig. 11, and (d), Fig. 12, located on the north side of Adams Street, Pueblo, have beds composed of fine silt merging into clays, with a liberal sprinkling of loose stones from 1 inch to 3 inches in thickness. The sections are 1,194 feet, and 2,002 feet in length, respectively.

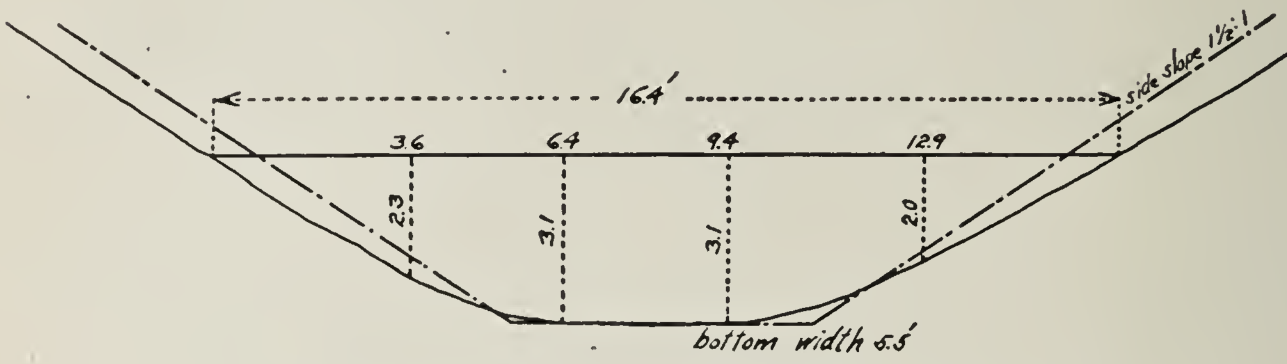


Fig. 12. Section (d), Bessemer Canal, Pueblo.

ROCKY FORD CANAL, ROCKY FORD. Two sections were tested, and in both, cross-section measurements and water surface elevations were taken at both ends and at intermediate points.

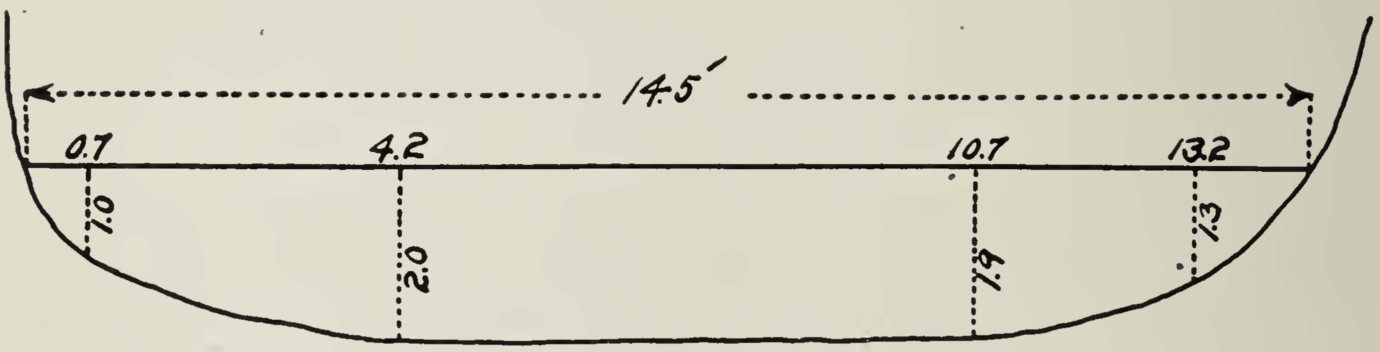


Fig. 13. Section (a), Rocky Ford Canal, Rocky Ford.

Section (a), Fig. 13, along Sycamore Street, Rocky Ford, is 1,000 feet in length, and has a bed of fine, loose sand. The sides are of clay with fine grass roots projecting. Some grass overhangs the bank into the water. This portion of the canal is somewhat crooked and the banks irregular.

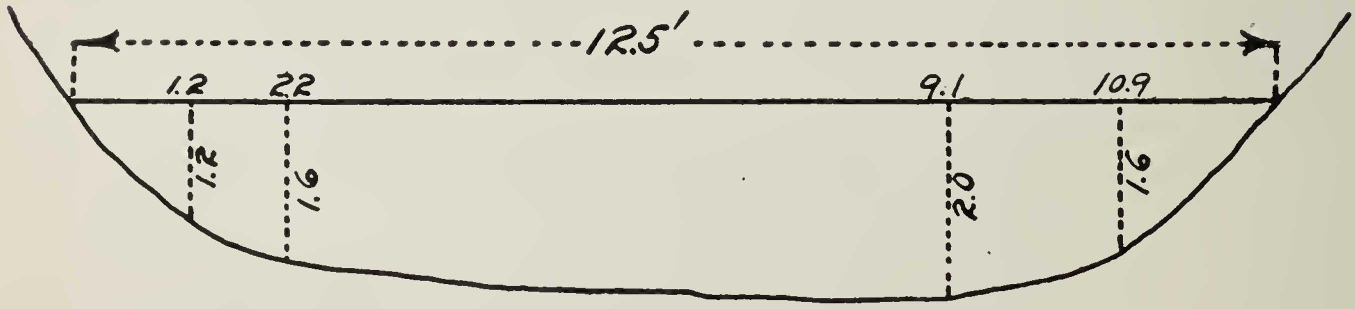


Fig. 14. Section (b), Rocky Ford Canal, Rocky Ford.

Section (b), Fig. 14, 1,350 feet in length and located one-half mile east of Rocky Ford, has a straight alignment. The bed is of fine sand, with sides of clay. Some grass overhangs into the water. The pulsation of the water surface was .01 feet.

The friction coefficients of these two sections are almost identical.

FORT LYONS CANAL, LA JUNTA. This canal, Fig. 15, one of the largest in Colorado, was built to carry 2,000 second feet of water, and is over 113 miles in length. The experiment was made in August, at a season when the canal was carrying little

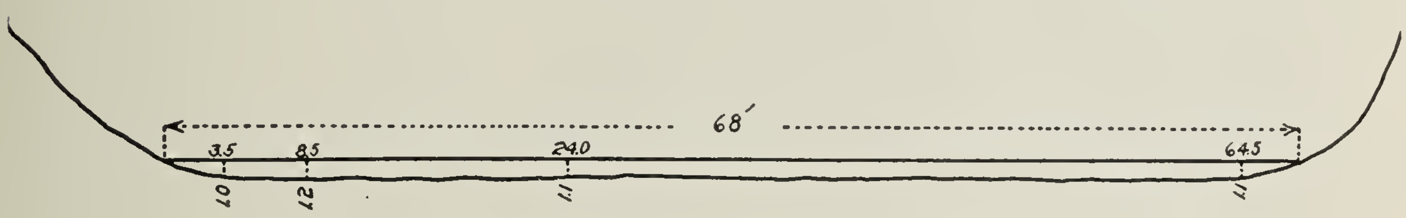


Fig. 15. Fort Lyons Canal, La Junta.

more than its first priority. The 137.26 second feet conveyed completely covered the bed of the canal for a width of from 65 to 70 feet, and from a depth of from 1 to 1.5 feet, making the conditions for such a test very favorable. The 2,600-feet section investigated, is located about five miles east of La Junta. It is constructed on a tangent, except for possibly 100 feet at the ends which are slightly curved. The canal bottom is composed of very fine silt merging into fine sand, and this in places is quite boggy. It is exceptionally smooth and regular and free from any impediments to check the flow of the water. This accounts for a lower coefficient than ordinarily assigned to earth channels. The pulsation of the water surface was inappreciable.

JARBEAU POWER CANAL, RIFLE. An experiment was made upon this waterway just a few days after it had been put in operation for the first time and before much change in the cross-

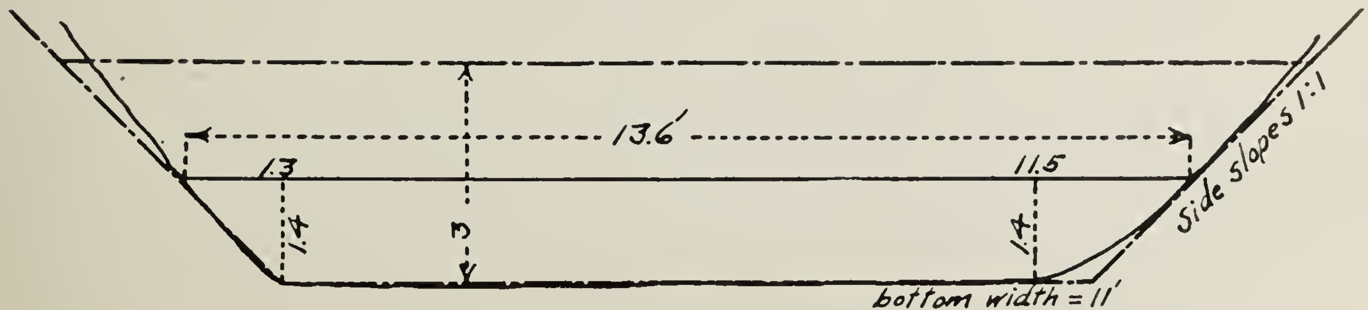


Fig. 16. Jarbeau Power Canal, Rifle.

section had taken place, as shown in Fig. 16. In the 900-foot section investigated, the upper 300 feet had a bed composed of clayey loam with a few scattering, smooth, waterworn stones projecting. The bed of the other part of the section was of clayey loam upon which aquatic moss was beginning to grow. This canal also had an exceptionally low frictional resistance. The section was designed as follows: Bottom width, 11 feet; water depth, 3 feet; side slopes, 1 to 1. The hydraulic elements used were:

| | |
|---|---|
| Wetted area | 42.0 sq. ft. |
| Wetted perimeter | 19.5 ft. |
| Hydraulic radius | 2.15 |
| Slope | .0005 |
| Velocity | 2.2 ft. per second |
| Discharge | 93.7 sec. ft. |
| (n) | 0.025 |

MESA LATERAL, GRAND VALLEY CANAL, GRAND JUNCTION. The sections investigated were 550 and 600 feet in length and at the time of experiment were carrying close to their full capacity. The bottom was smoothly lined with a fine sediment, while the sides were composed of a rather uneven surface of clay loam. Short grass grew on the bank which was submerged 0.5 feet when the canal was full, as in this experiment.

WILLCOX CANAL, RIFLE. The portion of this canal experimented upon was a 400-foot stretch just below the concrete siphon under Rifle Creek. The bed consists of fine silt, sand and pebbles, with a thin scattering of rounded, waterworn stones about 6 inches in diameter. This canal was first put into operation in

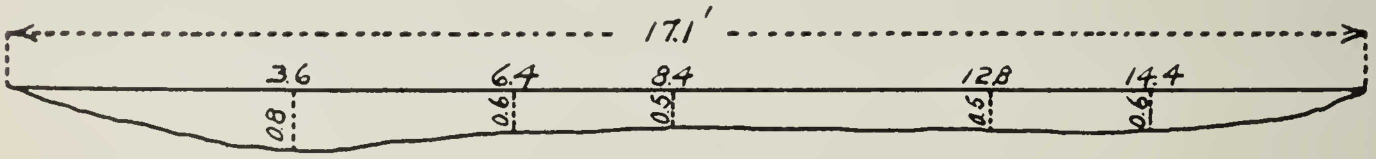


Fig. 17. Willcox Canal, Rifle.

the spring of 1912, and its cross-section is shown in Fig. 17. The head carried at the time of the test in September, 1913, was less than one-twentieth of the designed capacity of the channel.

Table 8 gives the results of all the experiments on earth channels.

TABLE 8—HYDRAULIC ELEMENTS OF EARTH CHANNELS.

| Name of Channel | Length of Section Tested ft. | Discharge sec. ft. | Area of Wetted Section sq-ft. | Velocity ft. per sec. | Wetted Perimeter lin. ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) |
|---|---|---|---|---|---|---|---|---|---|
| Rio Grande System— | | | | | | | | | |
| Main Canal | 2000 | 707.00 | 146.05 | 4.84 | 65.7 | 2.225 | .00307 | 58.4 | .0284 |
| Main Canal | 2000 | 85.13 | 45.81 | 1.86 | 54.3 | 0.844 | .00299 | 37.0 | .0342 |
| Main Canal | 2000 | 75.07 | 39.06 | 1.92 | 52.1 | 0.749 | .00300 | 40.4 | .0309 |
| Lateral No. 1 | 5280 | 380.00 | 81.62 | 4.66 | 43.7 | 1.868 | .00366 | 56.3 | .0284 |
| Lateral No. 1 | 5280 | 33.34 | 22.71 | 1.47 | 34.5 | 0.659 | .00368 | 29.8 | .0386 |
| Lateral No 1 | 5280 | 27.16 | 19.52 | 1.39 | 32.8 | 0.596 | .00362 | 29.9 | .0221 |
| Lateral No. 1c | 1238 | 143.60 | 37.22 | 3.86 | 26.2 | 1.422 | .00220 | 68.8 | .0221 |
| Lateral No. 1c | 1238 | 22.60 | 12.70 | 1.78 | 19.6 | 0.648 | .00204 | 48.9 | .0249 |
| Bessemer Canal a | 1495 | 57.98 | 37.15 | 1.56 | 18.15 | 2.045 | .00036 | 57.5 | .0281 |
| Bessemer Canal b | 1600 | 57.98 | 37.27 | 1.55 | 19.87 | 1.877 | .00024 | 72.9 | .0219 |
| Bessemer Canal c | 1194 | 42.35 | 36.65 | 1.16 | 17.78 | 2.063 | .00026 | 50.0 | .0321 |
| Bessemer Canal d | 2002 | 42.35 | 33.56 | 1.26 | 18.55 | 1.808 | .00028 | 55.9 | .0280 |
| Rocky Ford Canal a | 1000 | 41.20 | 24.44 | 1.68 | 16.08 | 1.521 | .00058 | 56.5 | .0266 |
| Rocky Ford Canal b | 1350 | 34.33 | 19.79 | 1.73 | 13.98 | 1.415 | .00069 | 55.3 | .0269 |
| Fort Lyons Canal | 2600 | 140.55 | 75.60 | 1.86 | 66.80 | 1.132 | .00038 | 89.5 | .0165 |
| Jarbeau Power | 900 | 32.27 | 16.43 | 1.96 | 14.75 | 1.114 | .00049 | 83.8 | .0176 |
| Mesa Lateral a | 550 | 42.16 | 27.91 | 1.51 | 16.52 | 1.689 | .00022 | 78.3 | .0200 |
| Mesa Lateral b | 600 | 40.32 | 27.40 | 1.47 | 16.46 | 1.663 | .00026 | 70.6 | .0220 |
| Willcox Canal | 400 | 15.29 | 8.78 | 1.74 | 26.30 | 0.334 | .00334 | 52.1 | .0205 |

## GENERAL SUMMARY OF (n).

### Semi-Circular Metallic Flumes.

| | (n) |
|---|---|
| Smooth, unobstructed water face; with wasteways, and of length less than 100 feet | 0.021 |
| Smooth, unobstructed water face | 0.011 |
| Joint connections protruding into the waterway beyond the plane of the sheet metal | 0.0174 |
| Corrugations at right angles to the line of flow | 0.0225 |

### Timber Flumes.

| | |
|---|---|
| Lined with patent roofing material | 0.016 |
| Planed lumber, battens on the sides; flooring placed transversely | 0.015 |
| Planed lumber; battens on the sides; flooring placed longitudinally | 0.012 |
| Planed lumber; no battens; perfect alignment | 0.011 |

### Concrete-lined Channels.

| | |
|---|---|
| Smooth concrete or mortar-finished surface | 0.012 |
| With surface left unplastered in condition given it by the forms | 0.016 |

**Earth Channels.**

| | |
|---|---|
| Bed exceptionally smooth and of fine silt; very uniform in cross-section; perfectly straight alignment | 0.017 |
| Bed of hard, water-worn adobe | 0.022 |
| Bed of coarse gravel and small, loose stones | 0.024 |
| Banks of smooth clay; bottom of fine sand; grass over-hanging banks into water | 0.027 |
| Bed of hard, water-worn adobe; many fine roots projecting | 0.028 |
| Bed of fine silt, merging into clay; liberally sprinkled with large, loose stones | 0.030 |
| Bed of little gravel but composed mainly of smooth, rounded stones, 6 inches or more in thickness | 0.032 |

## SIPHONS

During the summer of 1913 a number of experiments were made to determine the coefficient of friction in wood stave pressure pipe under actual field conditions. By far the greatest difficulty encountered in the making of these tests was the determination of the elevation of the mean water level at each end of the siphon, specially at the inlet where there was an eddying motion and boiling effect of the water. This was satisfactorily overcome, however, by siphoning water from the wood stave pipe, over the in-take wall and into a bucket which rested on a firm foundation.

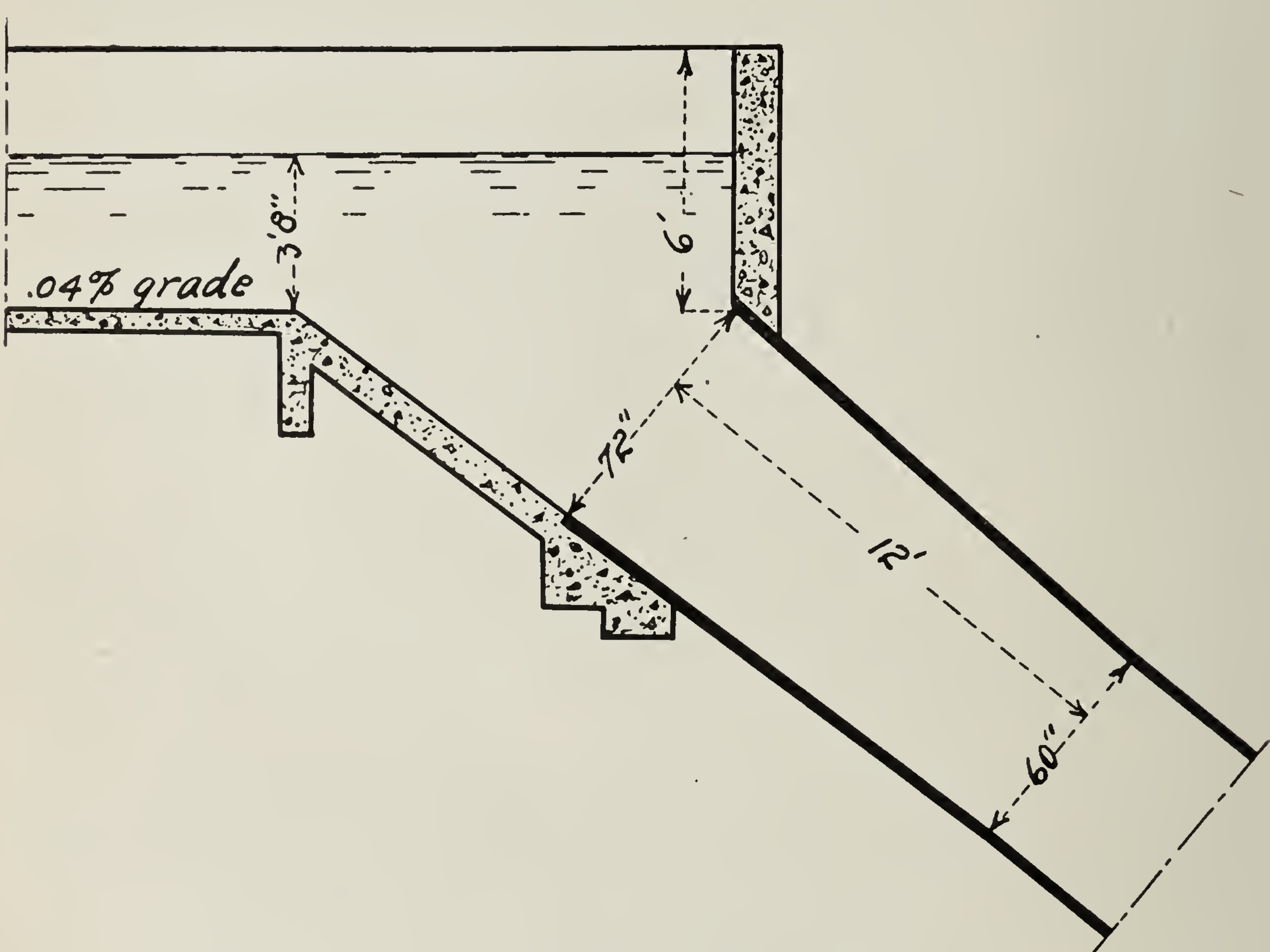


Fig. 18. Siphon Inlet, Arkansas Valley Conduit, Pueblo.

A weight placed on the end of the half-inch siphon hose kept it well below the water surface. The elevation was then taken from the water in the bucket.

The discharge was measured with the current meter in the open channel leading to or away from the siphon. Data relative to profile, alignment, length and diameter of pipe was obtained from the engineering offices in connection with the projects.

ARKANSAS VALLEY CONDUIT, PUEBLO. This channel, which supplies the water to the Minnequa steel plant of the Colorado Fuel & Iron Company, at Pueblo, heads on the Arkansas River about thirty miles above Pueblo, and closely follows the

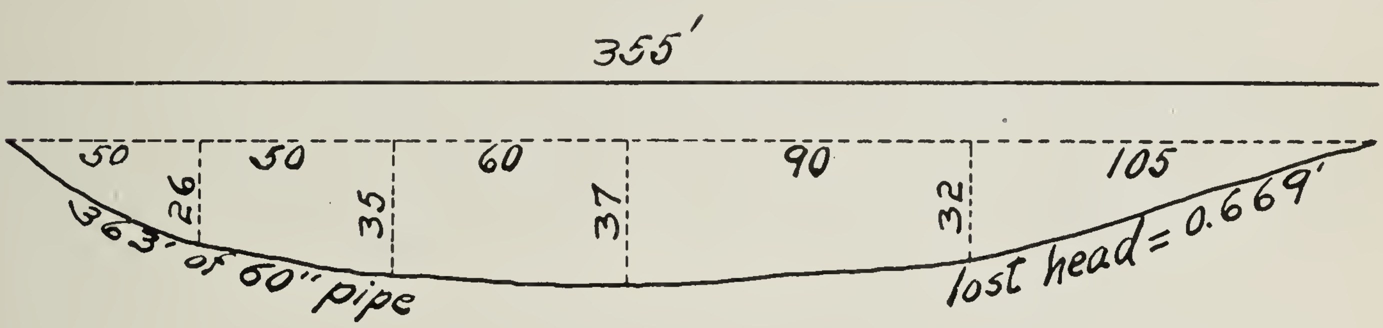


Fig. 19. Siphon No. 13, Arkansas Valley Conduit, Pueblo.

bluffs until it reaches the open mesa a few miles below Pueblo. To prevent seepage losses in the shaley material characteristic of that region, a considerable portion of the canal was concrete-lined. Numerous arroyos cross the right-of-way and at these places inverted siphons were constructed, varying from a few hundred feet

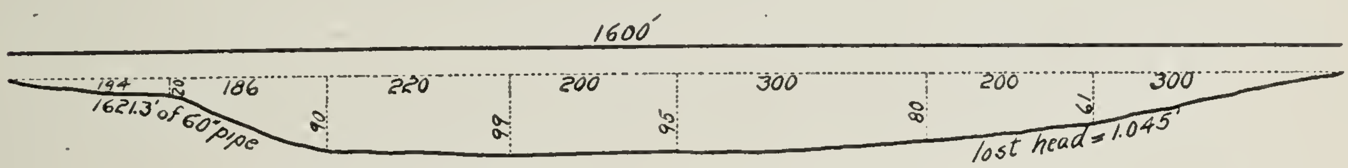


Fig. 20. Siphon No. 14, Arkansas Valley Conduit, Pueblo.

to over 2,700 feet in length, and with diameters from 48 inches to 60 inches. Plans and elevations of several of these siphons are shown in Figs. 19 to 27, inclusive. These are of wood stave pipe, but after only three or four years of service dry rot began and all of the twenty-five siphons were encased in reinforced concrete.

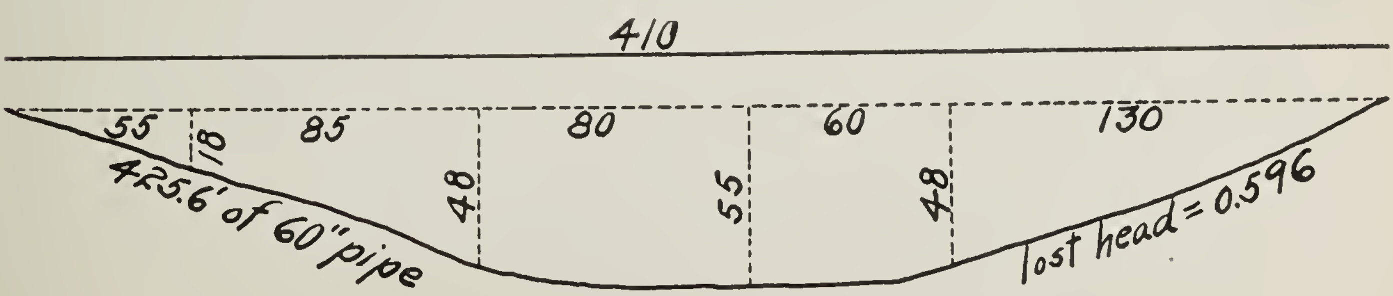


Fig. 21. Siphon No. 12, Arkansas Valley Conduit, Pueblo.

The interior, or water-surface of the pipe, is in good condition. The inlet and outlet structures are substantially constructed of reinforced concrete, to which the pipe is rigidly joined, as shown in Fig. 18. For the purpose of minimizing, or entirely overcoming, loss of head due to contraction at inlet, the end of the pipe is flared at the rate of one inch to the lineal foot until the diameter at the

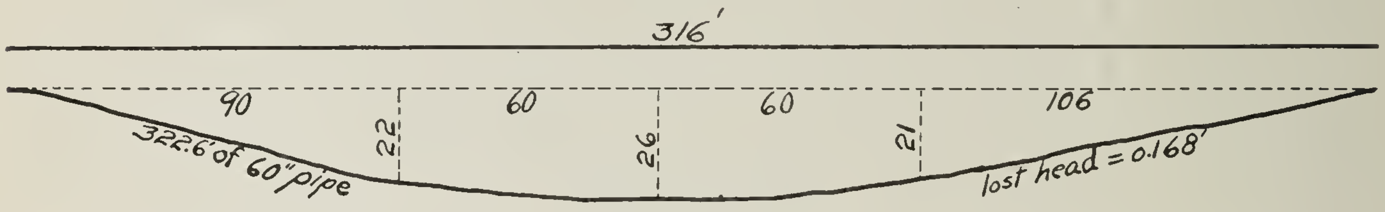


Fig. 22. Siphon No. 6, Arkansas Valley Conduit, Pueblo.

entrance is increased by one foot over the diameter of the main pipe. Wasteways are provided in the channels just above the intakes, from which are discharged surplus flood waters collected from the hillsides in times of heavy rain. There are no grating

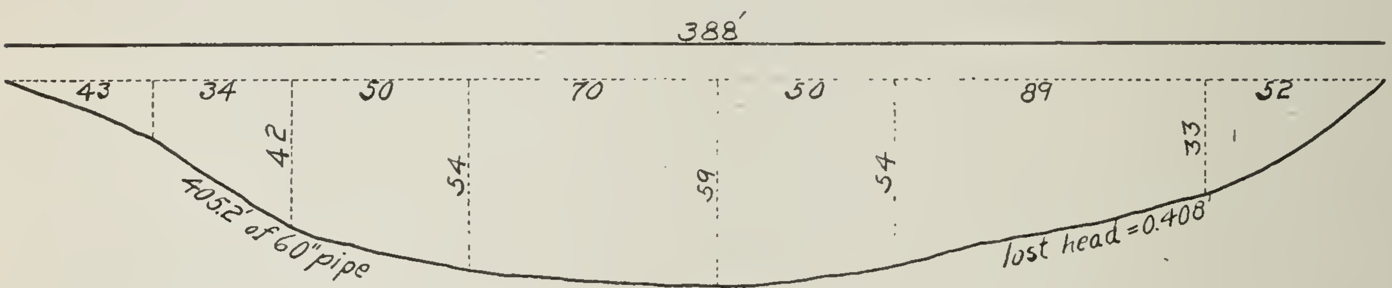


Fig. 23. Siphon No. 8, Arkansas Valley Conduit, Pueblo.

screens at either end of the siphon, for the reason that little debris of a floating nature is carried by the canal, and in freezing weather ice would form over the screen so as to completely block the flow; neither are there any blowoffs at the lowest points along the pipe

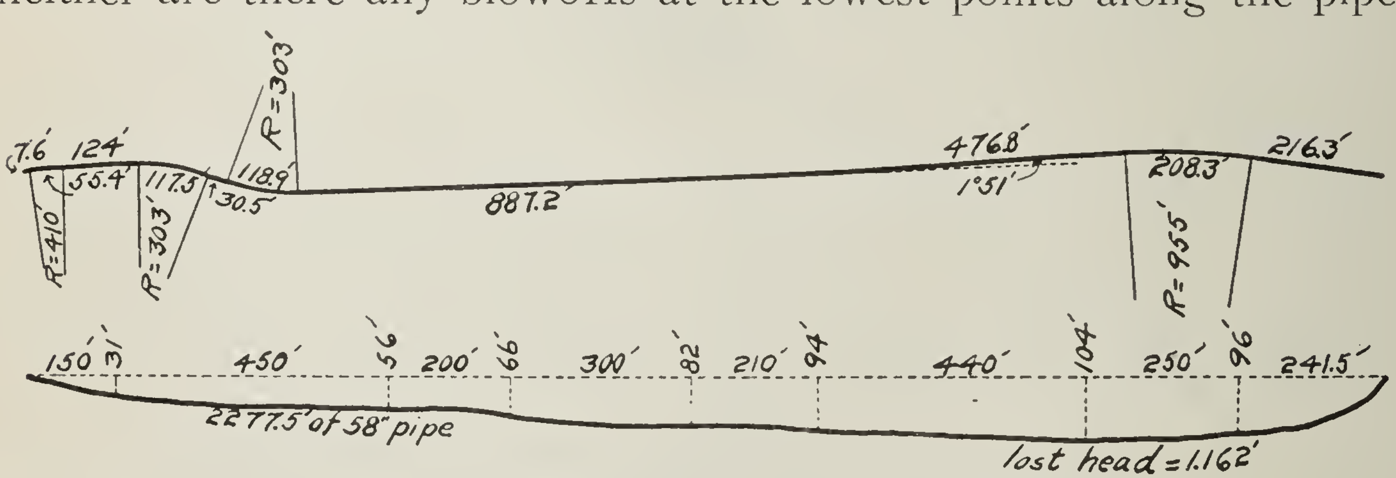


Fig. 24. Siphon Nos. 18 and 19, Arkansas Valley Conduit, Pueblo.

line, it evidently being believed that the velocities of from 2.5 to 3.5 feet per second on the conduit would effectually prevent the deposition of sediment. No information exists as to what extent, if any, gravel or particles of shale obstruct the pipe at the bottom

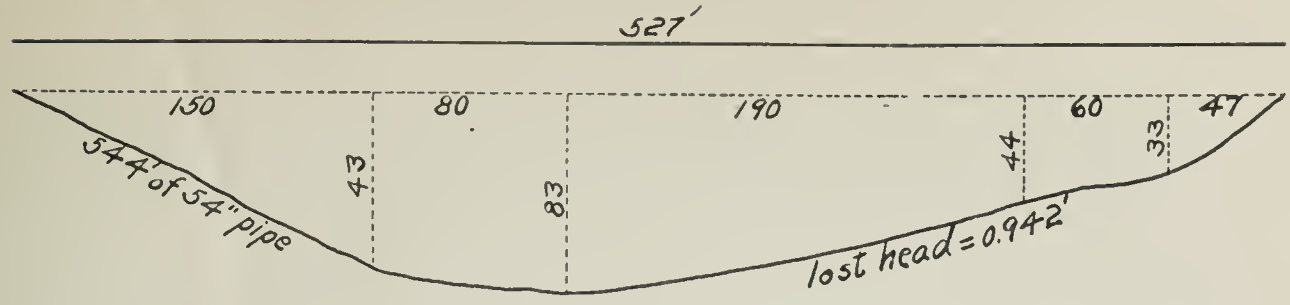


Fig. 25. Siphon No. 17, Arkansas Valley Conduit, Pueblo.

of the depressions, but the high values of (n) obtained for some of the siphons indicate the presence of debris or other unfavorable condition within those pipes.

Experiments were conducted upon this series of siphons on August 10 and 11, 1913. The structures had been in use since the

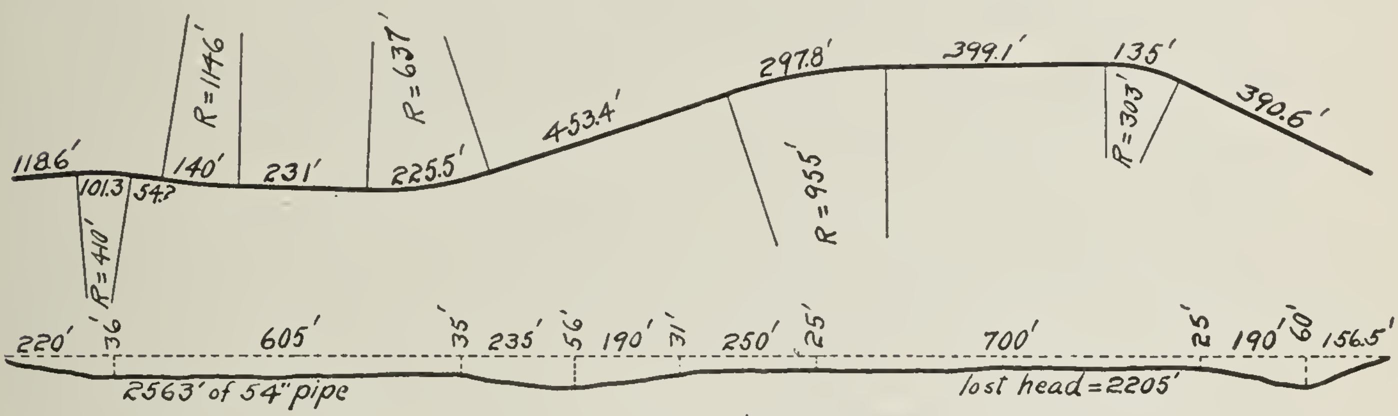


Fig. 26. Siphon No. 7, (lower), Arkansas Valley Conduit, Pueblo.

spring of 1907. There are over twenty-five siphons on this canal, but with the method used in determining the loss of head, tests could not be made upon those having very turbulent condition at the inlet, due to the drop into the penstock or having high walls over which the water could not be siphoned with the hose. Furthermore, the flow into the conduit was practically constant which prevented the determination of the effect of velocity upon the friction factors. Elevations of the water surface were referred to the company's bench marks established upon the concrete inlet and outlet structures.

Regarding the effect of ice in retarding the flow of the water in siphon No. 23, which is 50 inches in diameter, 2,797.6 feet in length, and under a maximum pressure head of 147 feet, Mr. R. M. Hosea, Chief Engineer of the Colorado Fuel & Iron Company, says: "The intake end of siphon No. 23 troubles us in winter time particularly by the formation of anchor ice inside the pipe, which appears to take place on the ascending leg of the pipe to such an extent as to check the discharge with a plug of ice particles. When the plug is forced through in advance of the water, on one or two occasions we have had it fill the ditch section so that the water ran over the sides of the ditch on top of the ice. What takes place inside the pipe is only surmised, but we believe that the ice floats in the upper half of the pipe until it accumulates sufficiently to form

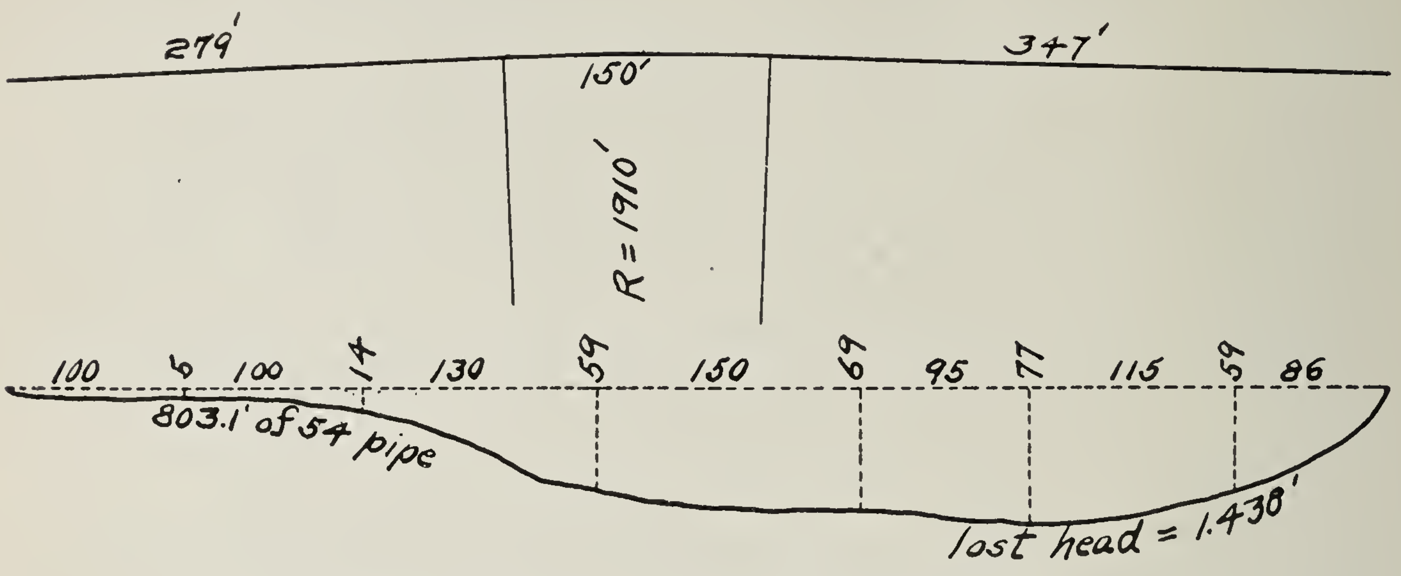


Fig. 27. Siphon No. 9, Arkansas Valley Conduit, Pueblo.

a plug, and this plug is forced out after the water backs up in the approach to the pipe and increases the pressure sufficiently to break the plug."

Table 9 shows the factors of flow in these siphons under conditions found in them during August, 1913.

REDLANDS MESA SIPHONS, GRAND JUNCTION. These are of 48-inch bore throughout, buried beneath about two feet of earth, except at the lowest points where a few feet are exposed. (Figs. 28 and 29.) As there are no blowoffs, it is believed that the velocity of 1.6 feet per second, which was found in the test made June 15, 1913, was hardly sufficient to prevent some

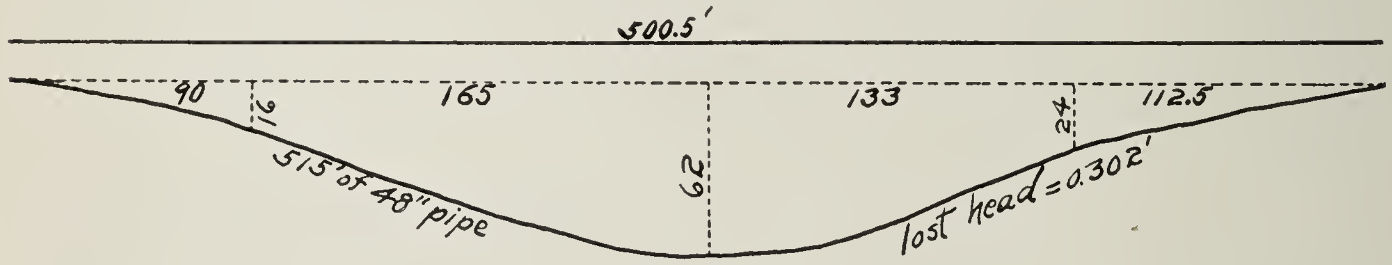


Fig. 28. Siphon (a), Redlands Mesa Canal, Grand Junction.

deposition of the red sandy sediment characteristic in that region of the water diverted from the Gunnison River. No doubt, however, when the canal is carrying its full capacity, sufficient velocity is developed to remove this deposit of silt, though coarser material may still remain. One instance is reported of a dead cow having been carried through the siphon which would indicate sufficient

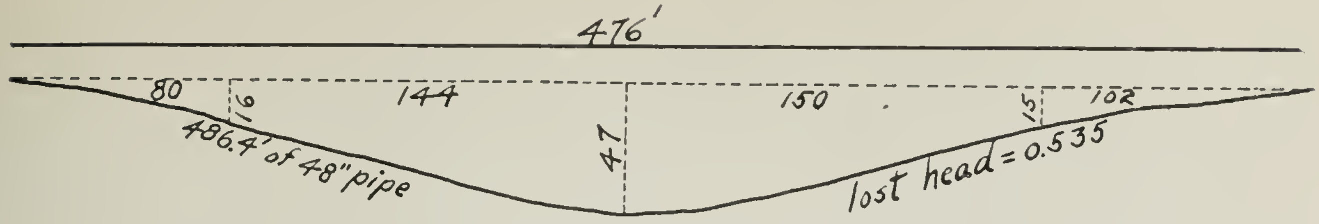


Fig. 29. Siphon (b), Redlands Mesa Canal, Grand Junction.

force of current to remove large obstructions of a floating nature.

Neither end of the pipes were flared, and at the time of these tests while the outlet ends were entirely submerged the water at the intake ends was only about three feet deep. The cross-section of the pipe was completely filled at about four feet from the entrance. A deposit of silt about 0.5 feet thick covered the bottom of the pipe at the outlet. The water at inlet and outlet was very quiet.

SIPHON UNDER PURGATOIRE RIVER, LAS ANIMAS. The Jones Extension of the Las Animas Consolidated Canal conveys water across the Purgatoire River by means of a 36-inch wood stave pipe. The pipe is buried about ten feet beneath the shifting sands of the river bed, and has a maximum pressure head, at its lowest point, of about 20 feet. No provision is made for draining the siphon at its lowest point. This conduit was tested for less of head on August 8, 1913. It was newly constructed, having been in operation only a portion of that season. Conditions were especially favorable for this experiment as the water entered and left the channel very quietly, and it is thought the 2.16 feet velocity obtained therein, together with the short period it had been in use, is reasonable evidence that no debris or silty deposits existed in the bore.

GENERAL RESULTS. Table 9 gives the data relative to the dimensions of pipe and maximum pressure heads, together with the hydraulic elements arranged in the order of corresponding mean velocities in the bore. In columns 9, 10 and 11 are given values of the coefficients commonly used in estimating the carrying capacity of pipe lines. Column 8 enables a comparison to be made of the loss of heads in the siphons on a basis of a 1,000-foot length of pipe. The other columns are self-explanatory.

The wide range in the amount of lost head per 1,000 feet of pipe, and the values of the coefficients hardly justify a close comparison.

As was previously stated, the high values of (n) obtained for some of the siphons indicates a deposit of debris at the low point of the siphon, or other condition which retards the flow of water. There were no means for inspecting the interior of the pipe, but as there are no known reasons for doubting the accuracy of the experimental data, it is probable that the pipes in question were not clean, and these data indicate their interior condition. It is not to be understood that values for (n) of 0.027, or even 0.019, are recommended for wood stave siphons properly constructed and in good condition of alignment and interior. The siphons which were expected to be in good condition did show low values of (n), but the entire data indicate the condition that may be obtained in siphons after a few years of operation where no provision is made for cleaning them.

TABLE 9—HYDRAULIC ELEMENTS OF WOOD STAVE SIPHONS.

| Name of Siphon | Diameter (in.) | Length of Pipe (ft.) | Maximum Pressure head | Discharge sec-ft. | Mean Velocity ft. per sec. | Total loss of Head | Loss of Head per 1000 ft. | (c)* | (n)** | (F)*** |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Redlands Mesa (b) ......... | 48 | 486 | 51 | 20.34 | 1.62 | 0.497 | 1.021 | 49.4 | .0271 | .1005 |
| Redlands Mesa (a) ......... | 48 | 515 | 66 | 20.44 | 1.63 | 0.202 | .392 | 82.2 | .0172 | .0380 |
| Jones Extension ............ | 36 | 815 | | 15.25 | 2.16 | 0.515 | .632 | 98.6 | .0140 | .0262 |
| Arkansas Val. Conduit No. 13. | 60 | 363 | 37 | 49.70 | 2.53 | 0.669 | 1.843 | 52.8 | .0275 | .0925 |
| Arkansas Val. Conduit No. 14. | 60 | 1621 | 99 | 49.70 | 2.53 | 1.045 | 0.644 | 89.7 | .0169 | .0324 |
| Arkansas Val. Conduit No. 12. | 60 | 426 | 55 | 50.73 | 2.58 | 0.596 | 1.400 | 61.8 | .0238 | .0675 |
| Arkansas Val. Conduit No. 6.. | 60 | 323 | 26 | 53.99 | 2.75 | 0.368 | 1.141 | 72.7 | .0204 | .0486 |
| Arkansas Val. Conduit No. 8.. | 60 | 405 | 59 | 53.99 | 2.75 | 0.408 | 1.007 | 77.6 | .0193 | .0429 |
| Arkansas Val. Cons. 18 & 19. | 58 | 2278 | 104 | 52.68 | 2.88 | 1.162 | 0.510 | 116.0 | .0134 | .0192 |
| Arkansas Val. Conduit No. 17. | 54 | 544 | 83 | 52.68 | 3.31 | 0.942 | 1.732 | 75.0 | .0195 | .0458 |
| Arkansas Val. Conduit No. 7.. | 54 | 2563 | 60 | 53.99 | 3.39 | 2.205 | 0.861 | 109.1 | .0139 | .0220 |
| Arkansas Val. Conduit No. 9.. | 54 | 803 | 77 | 53.99 | 3.39 | 1.438 | 1.790 | 75.6 | .0193 | .0449 |

*Value of (c) in Chezy Formula $V = c\sqrt{rs}$.

**Value of (n) in Kutter's Formula.

***Value of (f) in formula for lost head due to friction and curvature.

$$h = f \frac{L}{d} \frac{V}{2g}$$

# THE EFFECT UPON "n" OF VARIATION IN HYDRAULIC FACTORS

Many times in determining the carrying capacity to be assigned to a channel under construction, doubt arises as to the proper coefficient of roughness to use, or as to what safety factor to apply for any possible future variation in the value of the coefficient.

Table 10 illustrates the manner in which the discharge fluctuates with a variation in (n). Four typical classes of lining were selected to show this, viz., metal, concrete, timber and earth. The middle row of each group is from data actually observed in the field, while the others are computed from values of (n) changed by five units in the fourth decimal place, the hydraulic radius and slope, of course remaining constant in all cases. From the percentage values which refer to each group, it will be observed that the discharges vary in the inverse ratio as the coefficient of roughness, the hydraulic radius and slope remaining constant.

In this connection there may also be noted the accuracy of current meter measurement required to produce an erroneous value of (n). For a low value of (n) a 4 percent error in current meter measurement changes the coefficient .0122 to .0117, for instance. Or, with high value of (n) a 2 percent error in meter measurement changes .0285 to an erroneous value of .0280. Hence it is believed an error of 1.5 percent, or less, in current meter measurement was allowable in obtaining the correct discharge of the various channels under test.

TABLE 10—EFFECT UPON "n" OF VARIATION IN HYDRAULIC FACTORS.

| Name of Channel | Comparative Percentages of Q | Discharge sec-ft. | Area of Wetted Section sq-ft. | Velocity ft. per sec. | Wetted Perimeter lin-ft. | Hydraulic Mean Radius | Slope feet per foot | Coefficient (c) | Coefficient (n) | Comparative Percentage of (n) |
|---|---|---|---|---|---|---|---|---|---|---|
| King Lateral | 103 | 34.45 | 5.77 | 5.97 | 6.30 | 0.916 | .00537 | 85.05 | .0170 | 103 |
| Metallic | 100 | 33.30 | 5.77 | 5.77 | 6.30 | 0.916 | .00537 | 83.21 | .0175 | 100 |
| Flume | 97 | 32.26 | 5.77 | 5.59 | 6.30 | 0.916 | .00537 | 79.65 | .0180 | 97 |
| Long Pond | 104.5 | 128.92 | 6.24 | 20.66 | 7.24 | 0.862 | .02971 | 128.80 | .0117 | 104.5 |
| Concrete | 100 | 122.94 | 6.24 | 19.70 | 7.24 | 0.862 | .02971 | 122.82 | .0122 | 100 |
| Chute | 95.5 | 117.48 | 6.24 | 18.83 | 7.24 | 0.862 | .02971 | 117.36 | .0127 | 95.5 |
| Orchard Mesa | 104 | 228.76 | 36.79 | 6.22 | 18.12 | 2.030 | .000903 | 145.28 | .0117 | 104 |
| Timber | 100 | 219.40 | 36.79 | 5.96 | 18.12 | 2.030 | .000903 | 139.32 | .0122 | 100 |
| Flume | 96 | 210.88 | 36.79 | 5.73 | 18.12 | 2.030 | .000903 | 133.92 | .0127 | 96 |
| Rio Grande | 102 | 720.61 | 146.05 | 4.93 | 65.70 | 2.222 | .00307 | 59.59 | .0280 | 102 |
| Main Canal | 100 | 707.00 | 146.05 | 4.84 | 65.70 | 2.222 | .00307 | 58.45 | .0285 | 100 |
| Earth | 98 | 694.61 | 146.05 | 4.76 | 65.70 | 2.222 | .00307 | 57.44 | .0290 | 98 |

## RELATION OF CURRENT METER METHODS TO FRICTIONAL RESISTANCE IN WATERWAYS

If there was no frictional resistance within a carrying channel, the filaments of flow would be parallel and of uniform velocity. In other words, if the sides and bottom offered no resistance to flowing water, the velocity would be the same throughout all parts of the cross-section. A chip floating on the surface would indicate the true velocity, which, multiplied by the cross-sectional area of the channel would give the exact flow. One current meter measurement at any point in the water would be sufficient, and stream rating would be a very simple operation.

However, the lines of flow are not parallel in either the horizontal or vertical plane, nor are their characteristics exactly the same in any two channels, because of the variation in cross-sections, and the wide range in the frictional resistance offered by the many materials of which waterways are constructed. Such irregularities have brought the current meter into universal use for measuring the velocity of water in open channels where it is impractical to install a permanent device, such as a weir.

Of the four principal methods of stream gaging with a current meter—multiple point, vertical integration, six-tenths, and the two- and eight-tenths methods—many hydrographers acquire the habit of using one method for practically all conditions. Some even assert that the method they use meets all types of channels and all conditions of flow with a uniformly nice accuracy. For the purpose of throwing some light on this subject, experiments were made on several types of channels. These were gaged in such a manner as to permit their vertical velocity curves to be plotted, as in Figs. 30 to 33 inclusive, and also to give a comparison of the several methods.

In measurements made to determine velocities in cross-section and to compare the integration and multiple point methods of measurement, the meter was held at points of 0.2, 0.3, 0.4, 0.6 and 0.8 of the depth in each vertical plane, and in a few instances at every 0.2 foot depth. These vertical velocity curves were taken at points approximately 1/10 the width of the channel for canals having greater widths than 10 feet. For narrow channels points were chosen about 0.5 feet apart. The meter was held at each point about 40 seconds. In taking the integration measurements a complete number of trips was made from top to bottom of the channel rather than endeavoring to operate the meter during a fixed number of seconds. The meter was moved slowly and at a uniform rate in the vertical plane. Gage readings of the level of the water in the channel were taken before and after making the current meter measurements, in order to note any change.

To obtain the maximum surface velocity of some sections, bits of sticks were thrown into the swiftest current and allowed to travel the length of the section. They did not all cover the distance in the same length of time, but the time interval of the fastest float was recorded.

The methods used in the experiments for comparing current meter methods, agree essentially with those outlined by Mr. F. C. Scobey, Irrigation Investigations, U. S. Department of Agriculture.

VERTICAL VELOCITY CURVES. Of the several channels in which experiments were made, four have been chosen for the purpose of illustrating the distribution of velocities in the cross-

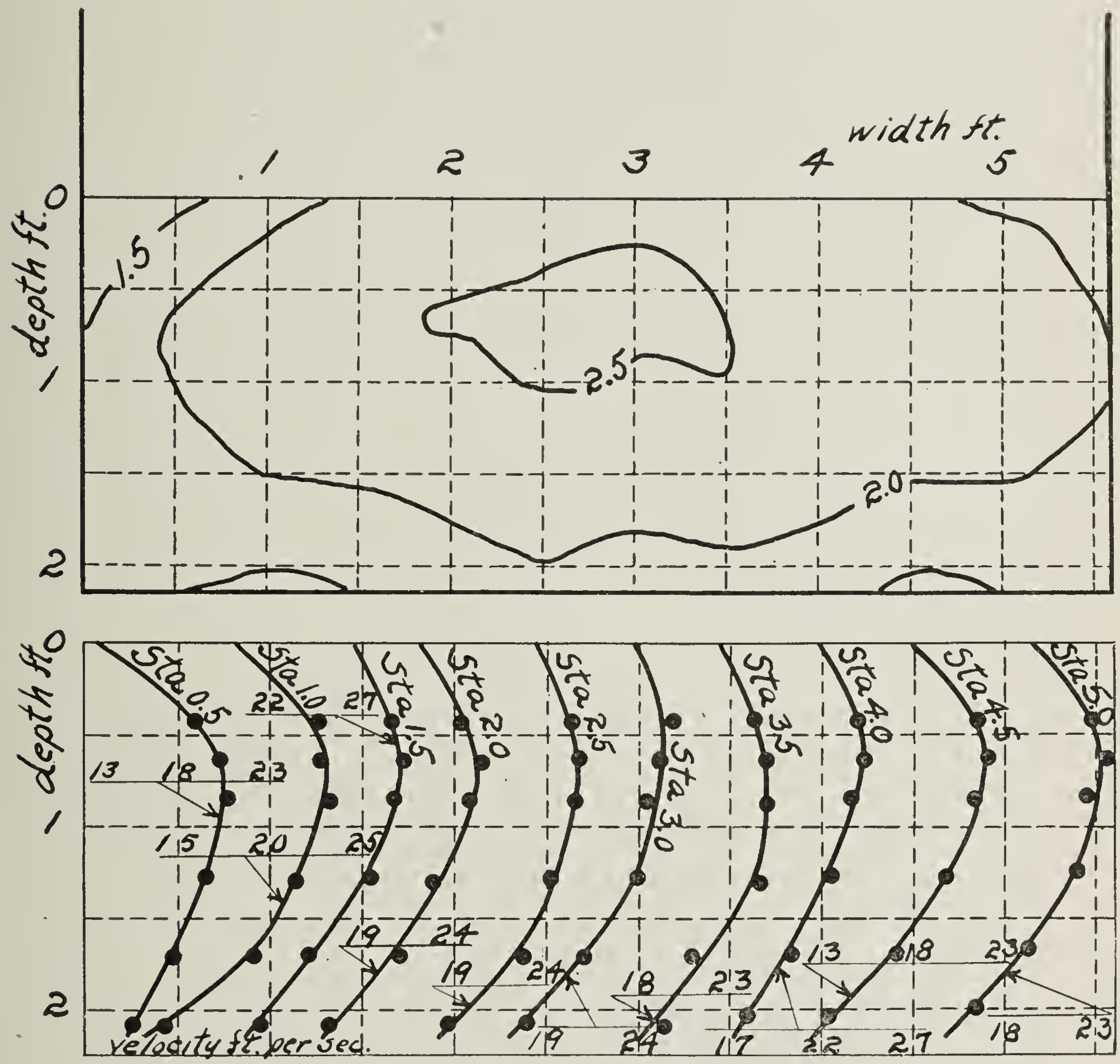


Fig. 30. Timber Flume, Pueblo Waterworks, Pueblo.

section. These are graphically represented in Figs. 30, 31, 32, and 33. The upper diagram in each figure shows the cross-section of the waterway, with lines of equal velocity, while the lower diagram shows the vertical velocities for each station in the section.

Figure 30 represents the condition of flow in a timber flume on

TABLE 11

CURRENT METER MEASUREMENTS IN TIMBER FLUME. PUEBLO WATER WORKS, PUEBLO.

| Station | Depth Ft. | Discharge Sec. Ft. | | | | Relative Percentages | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 |
| 0.5 | 2.15 | 2.93 | 3.11 | 2.95 | 3.14 | 100.0 | 106.1 | 100.8 | 107.1 |
| 1.0 | 2.15 | 2.16 | 2.20 | 2.25 | 2.30 | 100.0 | 101.9 | 104.1 | 106.4 |
| 1.5 | 2.15 | 2.27 | 2.27 | 2.30 | 2.43 | 100.0 | 100.0 | 101.2 | 107.1 |
| 2.0 | 2.16 | 2.39 | 2.41 | 2.47 | 2.46 | 100.0 | 100.9 | 103.2 | 102.9 |
| 2.5 | 2.16 | 2.51 | 2.51 | 2.60 | 2.64 | 100.0 | 100.0 | 103.6 | 101.1 |
| 3.0 | 2.16 | 2.41 | 2.53 | 2.47 | 2.58 | 100.0 | 105.0 | 102.5 | 107.1 |
| 3.5 | 2.16 | 2.36 | 2.34 | 2.42 | 2.53 | 100.0 | 99.2 | 102.5 | 107.1 |
| 4.0 | 2.11 | 2.28 | 2.26 | 2.35 | 2.38 | 100.0 | 99.1 | 103.0 | 104.3 |
| 4.5 | 2.11 | 2.17 | 2.18 | 2.26 | 2.31 | 100.0 | 100.4 | 104.1 | 106.5 |
| 5.0 | 2.11 | 3.78 | 3.87 | 3.89 | 4.07 | 100.0 | 102.3 | 102.9 | 107.8 |
| Totals ... | | 25.26 | 25.68 | 25.96 | 26.84 | 100.0 | 101.7 | 102.8 | 106.3 |

the Pueblo Municipal Waterworks System. The cross-section was taken near the middle of a tangent about 1,000 feet in length, giving a uniform distribution of the velocities which varied from 25 feet per second midway between the sides and at about 0.3 of the depth below the surface, to 1.5 feet per second at points along the bottom and sides.

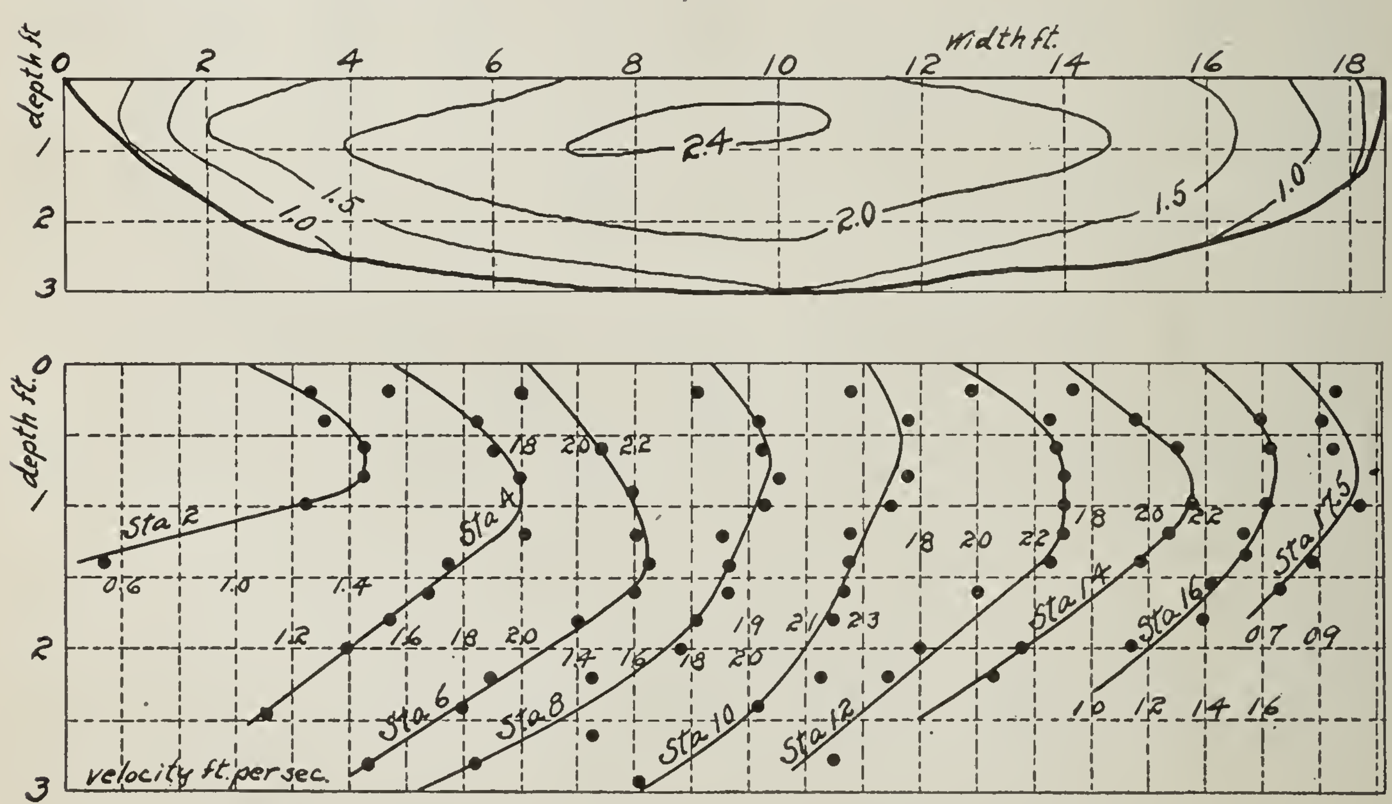


Fig. 31. Earth Section, Larimer County Canal No. 2, Fort Collins.

TABLE 12

CURRENT METER MEASUREMENTS IN LARIMER COUNTY CANAL NO. 2, FORT COLLINS.

| Station | Depth Ft. | Discharge Sec. Ft. | | | | Relative Percentages | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 |
| 2 | 1.70 | 3.84 | 4.39 | 3.40 | 4.28 | 100.0 | 114.2 | 88.6 | 111.5 |
| 4 | 2.50 | 8.05 | 7.85 | 8.15 | 8.70 | 100.0 | 97.6 | 101.1 | 108.0 |
| 6 | 2.81 | 10.68 | 10.62 | 10.40 | 11.69 | 100.0 | 99.7 | 97.6 | 109.3 |
| 8 | 2.97 | 12.65 | 12.12 | 13.54 | 13.19 | 100.0 | 95.9 | 107.1 | 104.1 |
| 10 | 3.01 | 12.82 | 12.58 | 13.06 | 13.18 | 100.0 | 97.9 | 101.7 | 102.6 |
| 12 | 2.85 | 11.23 | 11.06 | 9.92 | 11.51 | 100.0 | 98.4 | 88.2 | 102.4 |
| 14 | 2.65 | 9.59 | 9.70 | 9.43 | 9.80 | 100.0 | 101.1 | 98.3 | 102.1 |
| 16 | 2.32 | 6.44 | 6.71 | 6.71 | 7.18 | 100.0 | 104.3 | 104.2 | 111.6 |
| 18 | 1.76 | 3.21 | 3.64 | 3.14 | 3.46 | 100.0 | 113.2 | 97.9 | 107.9 |
| Totals ... | | 78.51 | 78.67 | 77.75 | 82.99 | 100.0 | 100.2 | 99.0 | 105.7 |

Figure 31 shows an unusually symmetrical condition of flow, as found in an earth section of the Larimer County Canal No. 2, near Fort Collins. This constitutes an ideal cross-section for current meter work, so far as uniformity in variation of velocities is concerned. The velocity at the bottom of the deep portion of the section is almost 1.0 feet per second greater than that near the banks where the water is shallow.

Figure 32 also represents an earth section. This gaging was taken in the Hottel Mill Canal, Fort Collins, at a point on a long easy curve, which accounts for the area of maximum velocity being somewhat off center. The swiftest current is thrown toward the other bank. This same effect is shown in the cross-sectional diagram of the timber flume on the Redlands Power Canal, Grand Junction, Fig. 33. The gaging was made about 30 feet below where the canal joined the flume at a very slight angle, and hence the greater velocity on one side. However, this inequality of velocity distribution was not in the least apparent to the eye.

The effect of frictional resistance to the flow is represented by the drag at the lower part of the vertical velocity curves. As will be observed, the curves for the timber flumes are flatter than those for the earth sections, and approach more nearly a vertical position, which indicates the variation in roughness of the bed. In general it may be said that the amount of distortion of the vertical curves from a vertical line varies directly as the roughness of the bed.

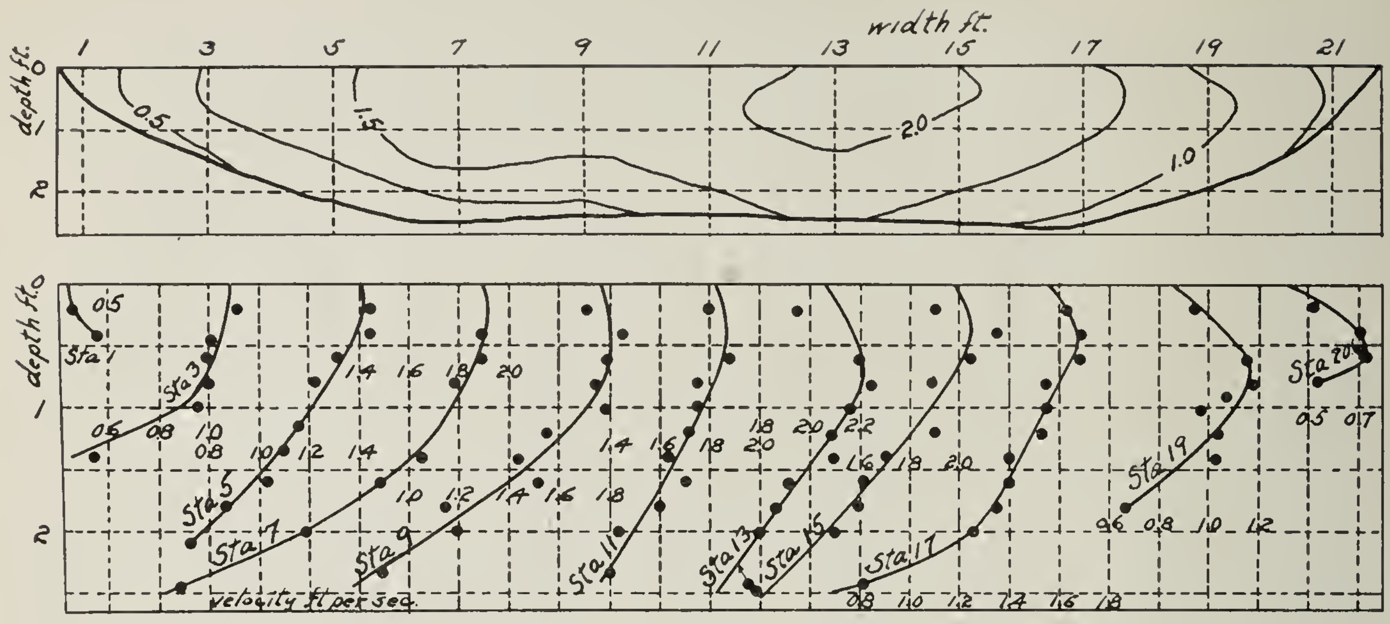


Fig. 32. Earth Section, Hottel Mill Canal, Fort Collins.

**TABLE 13**

**CURRENT METER MEASUREMENTS IN HOTTEL MILL CANAL, FORT COLLINS.**

| Station | Depth Ft. | Discharge Sec. Ft. | | | | Relative Percentages | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 |
| 1 | 0.51 | 0.37 | 0.49 | 0.35 | 0.38 | 100.0 | 132.3 | 94.7 | 102.8 |
| 3 | 1.45 | 3.05 | 2.99 | 2.96 | 3.29 | 100.0 | 98.1 | 97.1 | 107.9 |
| 5 | 2.26 | 4.94 | 4.94 | 5.59 | 4.85 | 100.0 | 100.0 | 113.1 | 98.2 |
| 7 | 2.44 | 7.38 | 7.38 | 7.73 | 7.82 | 100.0 | 100.0 | 104.7 | 106.0 |
| 9 | 2.42 | 7.42 | 7.61 | 7.57 | 7.28 | 100.0 | 102.7 | 102.1 | 98.2 |
| 11 | 2.43 | 8.21 | 8.36 | 8.36 | 8.02 | 100.0 | 101.8 | 101.9 | 97.7 |
| 13 | 2.48 | 9.84 | 9.99 | 9.99 | 10.04 | 100.0 | 101.3 | 101.4 | 102.1 |
| 15 | 2.56 | 8.60 | 8.55 | 9.11 | 8.50 | 100.0 | 99.4 | 105.9 | 98.9 |
| 17 | 2.50 | 6.97 | 6.52 | 7.26 | 6.92 | 100.0 | 93.6 | 104.2 | 99.3 |
| 19 | 1.92 | 3.75 | 4.02 | 3.60 | 4.06 | 100.0 | 107.2 | 96.0 | 108.2 |
| 20.6 | 1.08 | 0.77 | .84 | .61 | 0.87 | 100.0 | 109.1 | 79.3 | 113.0 |
| Totals ... | | 61.30 | 61.71 | 63.13 | 62.02 | 100.0 | 100.7 | 103.0 | 101.2 |

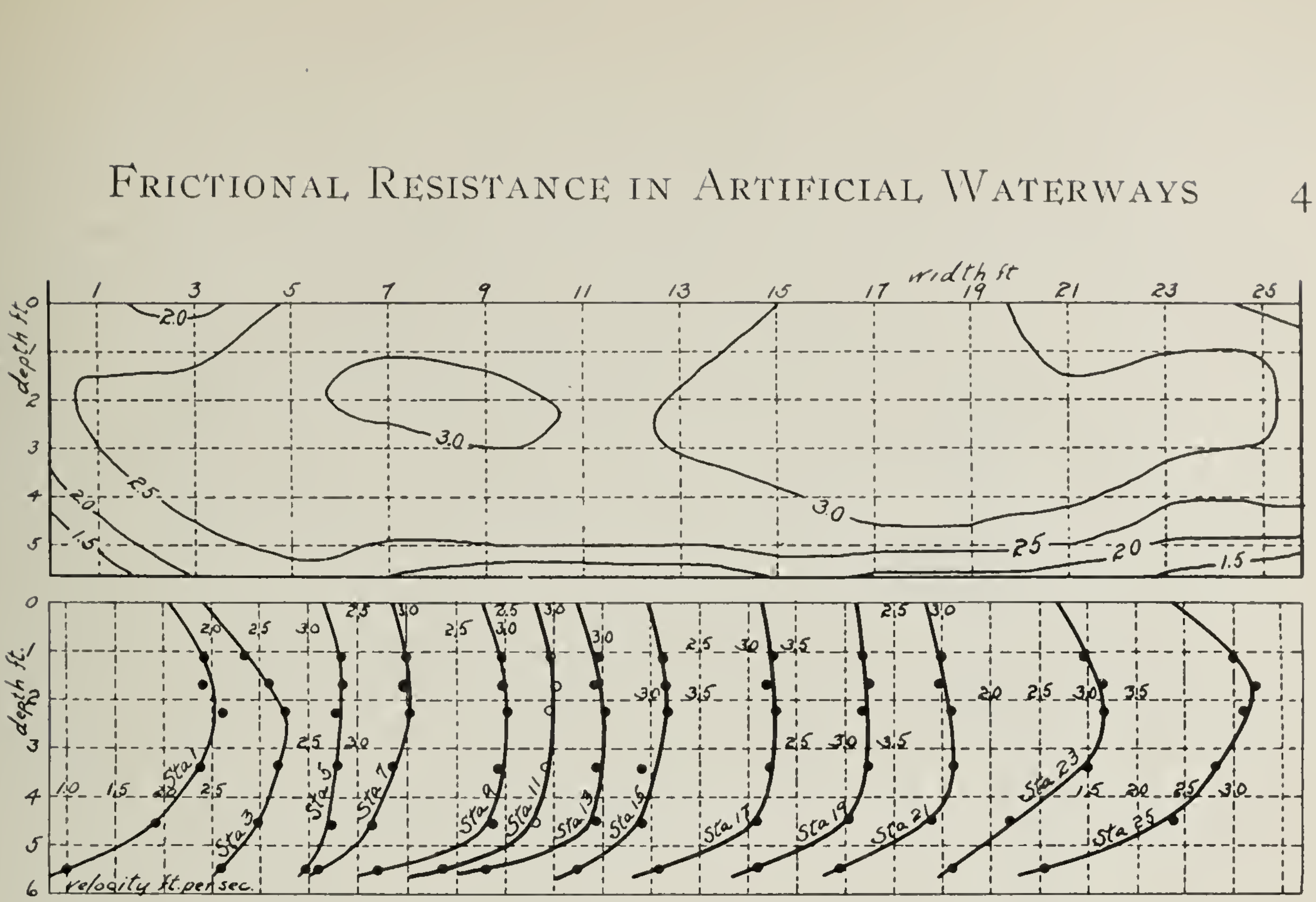


Fig. 33. Timber Flume, Redlands Power Canal, Grand Junction.

**TABLE 14**

**CURRENT METER MEASUREMENTS IN TIMBER FLUME, REDLANDS POWER CANAL, GRAND JUNCTION.**

| Station | Depth Ft. | Discharge Sec. Ft. | | | | Relative Percentages | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 |
| 1 | 5.68 | 24.08 | 23.74 | 24.76 | 27.26 | 100.0 | 98.6 | 102.6 | 113.5 |
| 3 | 5.68 | 27.38 | 27.49 | 27.38 | 30.67 | 100.0 | 100.5 | 100.0 | 112.1 |
| 5 | 5.68 | 30.22 | 31.24 | 31.58 | 31.58 | 100.0 | 103.3 | 104.2 | 104.1 |
| 7 | 5.68 | 30.79 | 31.58 | 32.15 | 32.38 | 100.0 | 102.5 | 104.3 | 105.1 |
| 9 | 5.68 | 30.90 | 30.67 | 33.40 | 33.40 | 100.0 | 99.4 | 108.1 | 108.1 |
| 11 | 5.68 | 30.90 | 30.56 | 32.83 | 33.06 | 100.0 | 98.9 | 106.2 | 107.1 |
| 13 | 5.68 | 30.67 | 31.13 | 32.72 | 33.28 | 100.0 | 101.5 | 106.7 | 108.5 |
| 15 | 5.68 | 32.60 | 31.81 | 34.31 | 32.94 | 100.0 | 97.6 | 105.1 | 101.0 |
| 17 | 5.68 | 33.85 | 32.94 | 35.90 | 36.47 | 100.0 | 97.3 | 106.0 | 107.8 |
| 19 | 5.68 | 33.40 | 34.76 | 35.33 | 36.69 | 100.0 | 103.9 | 105.8 | 109.9 |
| 21 | 5.68 | 31.47 | 32.04 | 33.40 | 35.33 | 100.0 | 101.8 | 106.2 | 112.1 |
| 23 | 5.68 | 29.54 | 29.20 | 29.51 | 33.97 | 100.0 | 98.9 | 100.0 | 115.0 |
| 25 | 5.68 | 30.44 | 32.94 | 30.67 | 31.92 | 100.0 | 108.1 | 100.1 | 104.7 |
| Totals ... | | 396.24 | 400.10 | 413.94 | 429.05 | 100.0 | 100.97 | 104.47 | 108.28 |

## COMPARISON OF CURRENT METER METHODS

In the following discussion it will be assumed that the multiple point method of determining the flow in open channels is the most accurate, because it calls for the greatest number of velocity determination in each vertical section. It must be admitted, however, that it is not always the most practical. In Tables 11, 12, 13

TABLE 15

COMPARATIVE RESULTS OF CURRENT METER MEASUREMENTS.

| Channel | Mean Depth of Water ft. | Mean Velocity Ft. per sec. | Discharge Sec. ft. | | | | Relative Percentages | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 | Mult. Pt. | Integration | 0.2 & 0.8 | 0.6 |
| Redlands Power Flume................ | 5.7 | 2.8 | 396.24 | 400.10 | 413.94 | 429.05 | 100.0 | 100.97 | 104.47 | 108.28 |
| Pueblo Water Works Flume........... | 2.2 | 2.1 | 25.26 | 25.68 | 25.96 | 26.84 | 100.0 | 101.7 | 102.8 | 106.3 |
| Delta Mill Flume...................... | 2.5 | 3.4 | 47.74 | 48.04 | 48.57 | 49.52 | 100.0 | 100.7 | 101.9 | 103.9 |
| Church Canal Rating Flume........... | 1.6 | 2.8 | 53.43 | 53.31 | 53.52 | 57.60 | 100.0 | 99.8 | 100.2 | 107.9 |
| Agricultural Canal Rating Flume..... | 1.0 | 2.4 | 31.29 | 32.87 | 32.12 | 34.48 | 100.0 | 105.1 | 102.6 | 110.1 |
| Farmers' High Line Rating Flume..... | 1.6 | 4.3 | 172.45 | 170.48 | 169.13 | 169.65 | 100.0 | 98.9 | 98.2 | 98.3 |
| Delta Mill Canal...................... | 2.2 | 1.4 | 44.45 | 45.98 | 45.54 | 48.60 | 100.0 | 103.3 | 102.4 | 109.3 |
| Hottel Mill Canal..................... | 2.0 | 1.3 | 61.30 | 61.71 | 63.13 | 62.02 | 100.0 | 100.7 | 103.0 | 101.2 |
| Hottel Mill Canal..................... | 2.0 | 1.3 | 53.89 | 55.84 | 55.72 | 57.94 | 100.0 | 103.7 | 103.5 | 107.5 |
| Larimer Co. Canal No. 2.............. | 2.5 | 1.7 | 78.51 | 78.67 | 77.75 | 82.99 | 100.0 | 100.2 | 99.0 | 105.7 |
| Totals.......................................... | | | 964.56 | 972.68 | 985.38 | 1018.69 | 100.0 | 100.8 | 102.2 | 105.6 |

and 14, derived from the data from which Figs. 30, 31, 32 and 33 were constructed, the discharges indicated by the several methods are compared on a percentage basis, taking the multiple point deteamination as 100 per cent. This procedure is also applied in Table 15, which summarizes the determinations of flow in ten flumes, rating flumes and canals, including the four previously stated. The channels are all comparatively shallow, ranging from 1.0 to 5.7 feet in mean depth of water, with mean velocities of from 1.3 to 4.3 feet per second. It will be observed from the relative percentages of the aggregate discharge, given at the bottom of Table 15, that the multiple point method gives the least value and that the vertical integration, the 0.2 and 0.8 depth, and the 0.6 depth methods give higher values by percentages of 0.8, 2.2, and 5.6 respectively. These data, and general observations, apparently warrant the following statements:

1. The multiple point method, whereby the velocity is obtained by holding the meter successively at points relatively close together in a vertical plane, gives the closest determination of the actual mean velocity. Where accuracy is more essential than time, and where the condition of flow will not change during the time required to make the rating, the multiple point method should be used. The greater the number of points taken, the more accurate will be the determination.

2. The vertical integration method, in which the mean veloctiy at each station in the cross-section is determined by moving the meter slowly upward and downward, is particularly applicable where reasonable accuracy is desired in a comparatively short time. The water should not be too deep nor too swift to permit of the meter being moved with a uniform, slow motion in a vertical line. It is very essential that a sufficient number of complete trips be made from top to bottom, and as previously stated, that the motion be slow and unvarying. Under suitable conditions this method gives results next in accuracy to the multiple point, but the accuracy depends largely upon the skill of the operator. Some hydrographers allow a little longer time when near the top and the bottom, but since these points are the most unreliable in the section, such practice is questionable, for it has a tendency to give them too much weight in the average result.

3. The 0.2 and 0.8 method, which consists in taking separate velocity measurements at two-tenths and at eight-tenths of the depth of water at each station, and using their average as the mean velocity for the vertical section, is third in point of accuracy. This method is more rapid than either of the previous ones, but

should not be used in very narrow or very shallow channels.

4. The 0.6 method assumes the average velocity from top to bottom to be represented by the velocity at six-tenths of the depth from the surface. Actual experience has shown that this is not true in all cases, for the coefficient to be applied to velocities at this depth ranges in deep channels from 0.94 to 1.04, and in shallow channels from 0.97 to 1.04*. In some cases the mean velocity does occur at exactly 0.6 of the depth, but the error may be at least as great as six percent.

With either the 0.2 and 0.8, or the 0.6 method, approximate results will probably be obtained, the degree of accuracy varying with the cross-sectional factor and the roughness of the material. However, for large streams, and a swift current, they are to be preferred to the multiple point or vertical integration methods.

Obviously many sections of canals are unsuited to current meter work and quite unreliable results would be obtained by whatever method used. Very often when the water is not clear, what appears to the eye to be a good place for taking a rating has some hidden obstruction which exerts an influence on the lower portion of the section. This would be detected by the multiple point method, somewhat compensated for in the vertical integration method, but might cause serious error by the 0.2 and 0.8, or 0.6 method.

Due regard should always be paid to securing a favorable section for rating. It should be free from debris, moss and other aquatic growth, and the channel should be straight, or fairly so, both above and below for a distance varying with the quantity of water and general conditions. For accuracy of measurement it is essential that the water flow in as nearly straight lines as possible. Just as it is necessary to choose a suitable section for rating a channel, so is it necessary to suit the method to the conditions which obtain therein. In an ideal section each of the four methods will give reasonably accurate results, but a perfect section is rarely encountered. The value of a current meter measurement often depends as much upon the hydrographer's judgment in choosing the method and place of rating, as upon his kill in manipulating the instrument. The novice should use the more simple methods.

Acknowledgment.—To the managers and engineers of the canal systems upon which these experiments were conducted, acknowledgments are here made for the assistance rendered in permitting access to original records, and otherwise facilitating the work.

*"River Discharge," Hoyt & Grover, p. 50.

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Bulletin 195 May, 1914

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

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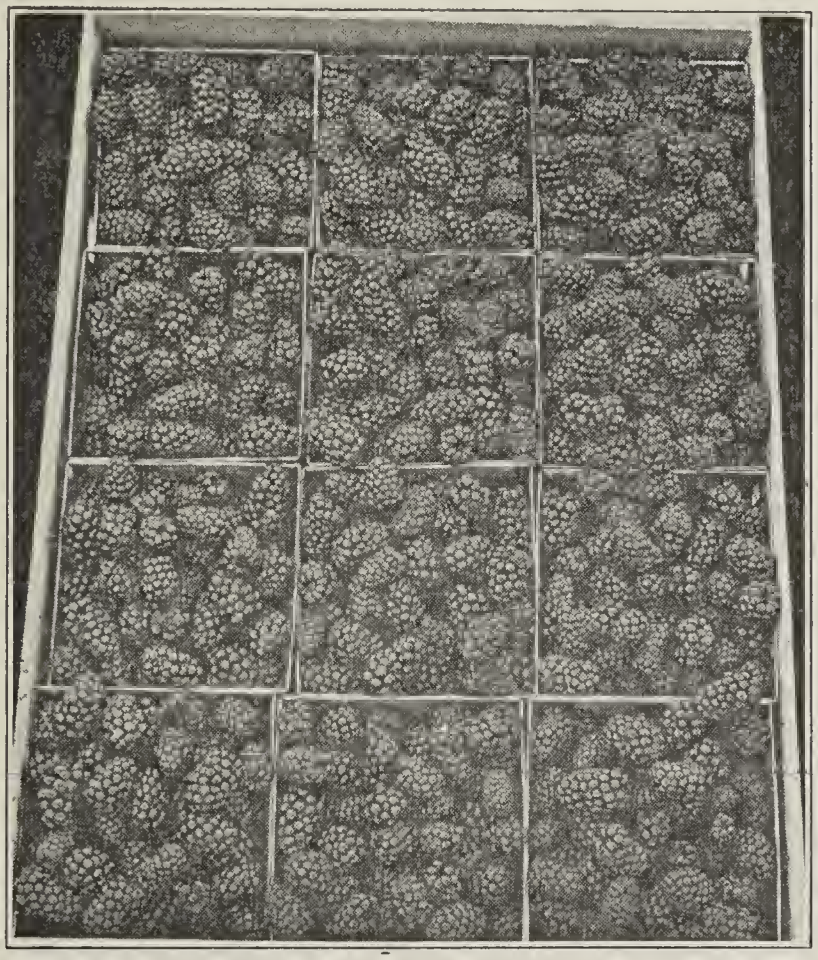
# Small Fruits for Colorado



By E. P. SANDSTEN

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1914

# The Agricultural Experiment Station
FORT COLLINS, COLORADO

# Small Fruits for Colorado

By E. P. SANDSTEN

Small fruit growing is rapidly becoming an important industry in many sections of Colorado. The numerous mining towns and camps in the State afford an excellent market for the fruit, and since most of these towns are not surrounded by arable land, there is practically no local competition. An excellent market in many of the large cities in the Mississippi and Missouri Valleys is awaiting the Colorado growers, as these centers consume large quantities of berries, and since the Colorado berries ripen much later than the home-grown and southern fruits, there is little or no competition. With a large and growing market for these fruits, the Colorado growers should take advantage of their opportunity and supply this demand with first-class fruit, packed and handled in the most approved manner.

*Soil Requirements.*—All the small fruits, such as strawberries, red raspberries, black raspberries, currants, and gooseberries, require a well drained, loamy soil. While heavy clay or adobe soil will grow these fruits, the best results are obtained on soils that are more open or porous. The subsoil must be open to permit perfect drainage; otherwise the plantations will be short-lived. The land should have sufficient slope to insure perfect surface drainage.

*Preparation of the Soil.*—New land should not be planted to small fruits. At least two years should be allowed to subdue the land, meanwhile growing such crops as require deep cultivation and irrigation. Land on which alfalfa has been growing for a few years is generally in fine condition for a small fruit plantation, especially if the last crop or cutting is plowed under instead of harvested for hay.

The land should be plowed to the depth of 8 to 10 inches in the fall and cross-plowed to the same depth in the spring, after which it should be thoroughly pulverized and brought into a fine silt. Poor preparation of the land is often the sole cause of failure.

## Red Raspberry.

*Planting.*—The planting should be done in the spring as soon as the soil is in workable condition. Strong yearling plants are better than older plants and will make more satisfactory growth. The plants should be set in rows six feet apart and four feet apart in the rows. This distance gives ample room for thorough cultivation and irrigation. If planted closer, the roots will not have sufficient feeding room and the plants will crowd one another. Thorough cultivation is just as important as irrigation; in fact, more so, as the number of irrigations ordinarily given can be reduced by one-half if frequent and thorough cultivation is practiced. Ordinarily the plants are obtained from some nursery. Plants taken from a nearby plantation of known varieties and free from disease, give excellent results. Only young plants or suckers should be planted.

Few fruits are produced the second year, and the aim should be to grow strong, vigorous plants rather than early fruit production. After the plantation comes into bearing, each plant or hill should not be allowed to grow more than twelve new canes each year. These should be reduced to eight or ten in the spring. The extra canes are to replace those that happen to break in covering and uncovering. All others should be removed as soon as they appear. By keeping these young canes or suckers down, the strength is thrown into the main canes, thus promoting stronger growth and greater fruiting capacity.

As soon as the picking season is over, all the canes that bore fruit should be cut out and burned. Cut as closely to the ground as possible; otherwise the crown of the plant becomes elevated and thus increases the difficulty of covering in the fall of the year; also the root system tends to become shallow and concentrated in the ridge along the row. Keep the land around the bushes and the row as level as possible.

*Pruning.*—Extensive experiments have been made as to the value of pruning the red raspberry to encourage lateral branching and thus the production of more fruiting wood. Almost without exception, these experiments have been negative; in other words, no beneficial effect from the pruning has been obtained. In the case of healthy cane growth, it may be advisable to cut back the canes in the spring after uncovering. If pruning is done in midsummer, the secondary branches formed will be more or less destroyed in covering and uncovering and nothing is gained. The purple-cane varieties are generally cut back either in the fall or the spring. This cutting back is almost necessary, since the canes often grow to the length of ten or twelve feet. From one to four feet is cut off, depending upon the length of the canes.

While training or supports are not necessary in growing the red raspberries, for the purple-caned varieties and the black-cap, a trellis is advisable, as it keeps the canes from bending to the ground and also prevents the canes from growing out of line, thus interfering with the cultivation. The best trellis is made by setting posts one rod apart in the row, then stringing two smooth wires one on each side of the post, then training the canes between these wires. If large posts are not available, a crosspiece of 2 by 4 is nailed on the post and the two wires strung from these. This will give a greater distance between the wires and consequently more room for the canes. If the crosspieces are bolted on the post the wire can easily be taken down in the fall when it is time to cover the canes.

*Cultivation.*—Commercial raspberry growing is not profitable unless the best care is taken of the plantation. Cultivation should start as soon as the bushes are uncovered in the spring and continue until the middle of August or first of September. One cultivation a week is not too much. The first two or three cultivations in the spring should be rather deep to thoroughly loosen and aerate the soil. Subsequent cultivations may be shallow. Many growers stop cultivating during the picking season. This is wrong, as the plant at this time needs plant food more than at any other time and if the plants have been set far enough apart and trellis used, shallow cultivation can be continued without damage to the plants and fruit. As soon as the crop is harvested, the old canes should be cut out and burned. About the last of August or first of September cultivation should cease so as to permit the wood to harden up and mature before cold weather sets in.

*Winter Protection.*—With few exceptions, winter protection is necessary to insure a crop in Colorado. In some cases the mere laying down or bending over the canes to protect them against the cold and drying winds is all that is necessary, though the safest and most efficient way is to bury the canes. that is, cover them with soil to the depth of three or four inches. The covering should be done as late as possible, but before the ground is frozen. Select days during which there is no freezing temperature; otherwise the canes are apt to break when bent to the ground for covering. With some varieties having strong and brittle canes it is often necessary to remove a spadeful of soil from the side of the cane towards which the canes are bent and in extreme cases the soil is removed on both sides. Generally, only enough earth is used to completely cover the canes and success is dependent not upon the thickness of the covering but upon the completeness of the cover. Strawy manure will serve the same purpose as earth, if obtainable in sufficient quantity to make a complete covering.

The canes should be uncovered as late as possible in the spring to avoid early spring frosts, yet the covering should not be permitted to remain too long, as it is apt to injure the young growth. Ordinarily when the buds have well started the covering should be removed. Care should be taken in uncovering so as not to break or otherwise injure the canes and the soil should be leveled off completely; otherwise in a few years the bushes will stand on a ridge and the feeding area of the plants is greatly decreased. The number of canes left for fruiting depends greatly upon the variety and the fertility of the soil. Generally, from eight to ten canes are left in each hill. If too many are left, inferior size berries result, with correspondingly smaller profit.

*Fertilizers.*—If manure is used as a covering for winter protection, the finer portion should be left to be cultivated in, and in most cases this amount is sufficient as annual top dressing.

*Varieties.*—Practically all the standard varieties can be grown in Colorado, below the altitude of 7,000 feet in northern Colorado and higher elevations in the southern and western portions. At greater elevations greater care and precaution must be taken to protect the plants against late spring frost and early frost in the autumn. This is especially true for the northern half of the State. The best developed small fruit section in Colorado is around Loveland and Fort Collins. This section is admirably adapted to this industry and with the development of a well organized marketing system, it bids fair to become an important producing center. The standard variety for this section is the *Marlboro,* a large, firm, pale red berry possessing excellent shipping qualities. It is a vigorous grower, hardy and quite resistant to disease. *Cuthbert* is also extensively grown. *Cuthbert* is a large dark red variety of high quality and when not over-ripe possesses good shipping qualities. It is also a strong grower and for home consumption it is superior to the Marlboro. For special and particular markets the Cuthbert is the berry par excellence. *Turner* and *Loudon* are good hardy varieties, but inferior to the above mentioned varieties in size, vigor and productiveness. Loudon is perhaps the hardiest of the red raspberries and should be tested out in sections where the Marlboro and the Cuthberts are not sufficiently hardy.

## THE PURPLE-CANE RASPBERRIES.

*Varieties—Schaffer's Colossal.*—An old variety extensively planted in the Mississippi Valley. It is a very strong grower, often producing canes ten to twelve feet in length. This variety is now superceded in many localities by *Chicago,* where it has proven more productive and superior in quality. Both are standard purple-cane varieties for Colorado. In habit of growth they are very similar, both producing heavy crops of large purple berries.

The purple-cane varieties are best adapted for local markets, as the fruit does not possess as good shipping qualities when fully ripe as the red varieties. The price obtained for the fruits of the purple-caned varieties is generally higher.

## Black Raspberries, or Black Caps.

Black caps are not extensively grown in Colorado, though the price obtained for the fruit is generally higher than for the red or purple-caned varieties. The black caps require more care in cultivation and irrigation, as under careless cultural methods the fruit has a tendency to become small and dry. They are better adapted to a moister climate, though with good care and with favorable soil conditions they can be grown successfully where the red varieties are grown:

*Varieties.*—The following varieties have been grown at Fort Collins and are commended for the Eastern Slope:

*Kansas.*—One of the earliest varieties, fruit of good size and fine quality. An excellent dessert berry and when not picked too ripe stands shipment well. It is also a hardy and vigorous grower.

*Gregg.*—A medium late berry, ripens from a week to ten days later than Kansas. Like Kansas in size and quality, but not quite so juicy. Will stand shipment better than Kansas. It is also a productive and strong growing variety.

*Conrath.*—An early ripening variety, fruit large and coal black. An excellent variety for local market, but rather soft for long-distance shipment. The quality is of the best and the fruiting season long. Recommended for home use and for local market.

## Blackberries.

The climate of Colorado, except in small isolated areas, is not adapted to blackberry culture. The blackberry, being a native of the shady, damp woods, would naturally not be expected to thrive on our dry, hot plains and valleys and the few attempts to grow this bramble have proven failures. In moist, narrow mountain valleys or on mountain slopes and on sub-irrigated land which carry little or no alkali, blackberries may be grown successfully.

The land intended for blackberries should previously to planting have been cultivated a couple years, at least. The land should be plowed in the fall to the depth of eight to ten inches and in the spring put in thorough tilth before planting.

*Planting.*—The plants should be set in rows eight feet apart and the plants five or six feet apart in the row. Yearling plants should be used. Thorough cultivation should be practiced throughout the growing season. The blackberry requires a large amount of water during the fruiting season and if it is not supplied, the fruit will be small, hard, and worthless. The blackberry is more tender than the red raspberry and the black cap, and requires winter covering or protection. This is done as in the case of the red raspberry, by bending over the canes and covering with four or five inches of soil.

*Pruning.*—The blackberry requires constant and careful pruning. The first year after planting, the canes are permitted to grow undisturbed. The pruning begins with the second season. The growing canes should be cut off when two and a half to three feet high. This will start them to branch. Later in the season it may be necessary to pinch off the tips to prevent the canes growing too long. Only a small crop is obtained the second year. In the fall of the second year or as soon as the fruiting season is over, the old canes or the canes that bore fruit, should be cut out and burned, as they will die naturally after fruiting. From ten to twelve canes should be covered. This number provides for extra canes should any be broken during the process of covering and uncovering. Ordinarily four to six canes are all that each plant can support and the rest should be cut out; otherwise they will weaken the productiveness of the plants.

Winter protection is necessary in almost every locality in the State. While some years protection may not be necessary so far as the canes or wood growth is concerned, it has been found from experiment that the canes are considerably weakened if unprotected and that as a consequence the quality as well as the quantity of the fruit is considerably curtailed. The bushes are laid down and covered in the same manner as the red raspberry, only more care must be taken as the canes are more brittle and are apt to break if extra care is not taken in bending the canes.

In order to get abundance of soil as well as room for the canes they should be bent over so as to form an angle of 45 degrees with the rows. If the canes are bent in line with the row and covered, there is a tendency for the rows to become elevated or ridged. This encourages the roots to grow in the ridges and close to the surface, causing short-lived plants and making it more difficult to get water to the bushes.

## DEWBERRIES.

The station frequently receives inquiries about the cultivation of the dewberry and a brief account of its culture will be given.

Dewberries are native to the moist woods and moist climate and do not do well on the open plains. In the high mountain valleys and with moist subsoil, the culture of the dewberry may prove a success. Western slope has a number of mountain valleys where the dewberry should prove a success and where at the present time a few commercially successful plantations are found. Yet we would not advise anyone to go into the business on a commercial scale without preliminary testing of varieties and their adaptability to local conditions. The land for dewberries is prepared in the same manner as for red raspberries. The plants should be set in hills five by five or six by six. One and two-year-old plants should be set. Plants should either be obtained from a known field or from

*A profitable dewberry field on the western slope.*

reputable plant dealer or nursery. The dewberry has been under cultivation for a relatively short time, and it may be said that reliable varieties have not as yet been developed. Further, the fruiting capacity of the existing varieties varies greatly within the individual variety, making the plantation an uncertainty unless the prospective grower has an opportunity to get his supply of plants from bearing hills. On these accounts, the growing of dewberries on a commercial scale is beset by many difficulties and failures. The cultivation of the dewberry does not differ from that of the blackberries or red raspberries. Clean and thorough cultivation is essential to success.

*Pruning.*—In the eastern states no pruning is done except the removal of the old fruiting canes after the harvest. In the west and on fertile soil the plants are apt to produce too many canes at the expense of fruit production, and pruning should be practiced. From ten to fourteen canes should be permitted to grow and fruit. All others should be cut out. The tips on the canes are not cut back.

Winter protection is necessary the same as for the raspberries. A liberal application of well rotted barnyard manure is very beneficial to the plantation.

Dewberries are not trained but permitted to spread on the ground. All attempts at training either on trellis or on stakes have proven failures.

*Varieties.*—Only relatively few varieties are offered for sale and most of these are of uncertain value. *Lucretia* and *Bartel* are the two most reliable varieties and the former one is more extensively planted.

## LOGANBERRY.

The Loganberry should be classed as a dewberry, as it resembles the dewberry closer than any other of the brambles. It is a cross between the red raspberry and the western dewberry, *Bubus vitifolius*. It is grown quite extensively on the Pacific Coast and in the inland valley east of the coastal range of mountains. Where the soil and climatic conditions are favorable, it is prolific and a profitable crop. Its value for Colorado has not been sufficiently tested to warrant us to recommend planting on a commercial scale. Two or three commercial plantations are found on the western slope which appear to be a success. It is probable that with careful selection of soil and site this may become an important industry. The fruit is on the average as large as the blackberry or larger. In shape, the fruit is decidedly oblong, individual fruits being often over two inches in length. The color is shining black and very attractive. In flavor, it approaches the red raspberry, but the quality is generally considered inferior. Like the dewberry and black raspberry they are propagated by tipping.

*Planting and Cultivation.*—The cultural requirements are the same as for blackberries. The young plants are not robust and require careful cultivation and attention. The plants set in rows five by five or four by six feet are trained on trellis as raspberries.

From four to eight canes should be permitted to grow to each hill. All others should be cut out. The loganberry is not sufficiently hardy to stand our winters without protection and should be covered and treated like the raspberry. The pruning is the same as for black raspberry.

## STRAWBERRIES.

*Soil.*—Strawberries can be grown on almost any kind of soil, but thrive best on a rich sandy loam. Abundant moisture and good surface drainage are essential. Where irrigation is necessary, ground with a gentle slope is preferable, as the water will flow down the furrows without running over and flooding the rows. Land which, for two or three years, has been planted to crops requiring clean cultivation is best, as new land generally gives poor results.

*Preparation.*—Late in the fall, a heavy dressing of manure (the amount depending upon the condition of the soil) should be applied to the ground selected for planting and plowed under. The depth of plowing is important. Ten inches is none too deep; cross-plow again in the spring so as to obtain a perfect plant bed. A thoroughly prepared field is very important for the production of vigorous plants and first quality fruit. Poor preparation of the land cannot be remedied completely through cultivation after the plants are set.

*Planting.*—Rows are then laid off about four feet apart and the young plants are set twelve to eighteen inches apart in the row. In planting, care should be observed to use only young and vigorous plants. Such plants have long, light-yellowish roots, while the roots of old plants are black and should be rejected. About one-third of the length of the roots should be clipped off; and the planter must not allow the roots to be exposed to the sun. A brief exposure will sometimes make their subsequent growth very uncertain. In setting the plants, the roots are arranged fan-shaped and the earth carefully pressed around them, leaving the crown a very little lower than the surrounding earth, being careful not to cover it. If the ground is dry at time of planting, water should be used in the holes in which the plants are set. All blossoms that appear during the first season should be pinched off.

*Cultivation.*—Light surface cultivation should follow the planting. This should be given as often as is necessary to conserve moisture and keep down weeds. In July, runners will start, and these should be trained along the rows so as not to interfere with cultivation. Four to six runners are as many as should be allowed to put out from one plant. Each runner should be allowed to set two, or at most three, plants, all others being cut off. In humid climates, these runners will take root and start new plants which will bear the following year, but in Colorado it is usually necessary to cover the runners at intervals with a small amount of earth. When winter comes on, the plants are mulched with straw to a depth of about six inches. The cleanest straw obtainable should be used in order to avoid weeds the following spring. This mulch protects the plants during the winter and spring, and may retard the blooming period a few days. In the spring, the straw is either removed from the field or worked around the crowns to form a bed

*A promising field of strawberries—first season.*

for the berries, keeping them out of the dirt, and helping to keep down weeds and retain moisture. The remainder is removed to allow irrigation and cultivation.

After the first crop of berries is harvested, the vines should be mowed down and the old plants hoed out, leaving only the younger ones. A top dressing of fine well rotted stable manure may be applied to advantage, and cultivation should be continued throughout the summer. The plants are mulched again in the early winter. After the second crop has been harvested the following spring, the field is plowed up and planted to some other crop. While it is possible to grow three or more crops from the same bed, the yield decreases rapidly and it is more profitable to start a new bed. Some growers prefer a raised bed about two feet wide, leaving two feet for cultivation, claiming that the bed so made is easier to irrigate. Personally, we prefer planting on the level, as ridged beds dry out more quickly and the water has to run for a longer time. Where extra fancy fruit is demanded, hill culture is employed. The land is prepared in the same manner as for rows. The plants are set in hills three by three feet. Some growers set only one plant to the hill, others three, or four. In the latter case no runners are permitted to grow, at least not more than to provide for three or four new plants for the following year to replace the old ones. By this system extra large berries are obtained, though relatively few in number. The cost of cultivating and weeding is greatly reduced under hill culture system, as the field can be cultivated both ways, though it takes considerable time to cut off runners. The hill system is not recommended for the general grower or for the average market. The yield in quart per acre from hill culture is considerably less and the market is too limited for extra fancy fruit to warrant the average grower to employ the hill system of culture.

*Varieties.*—In selecting varieties, the grower ought to choose those that are best adapted to his particular conditions of climate, soil and market. There is hardly a single variety that is adapted to all localities and the grower must discover for himself what varieties will do best in his particular section. Some of the best varieties of strawberries have imperfect or pistillate flowers and must be pollinated by other varieties in order to bear fruit. In such cases the two varieties must be planted near each other, say three rows of the variety with imperfect flowers and one row of the variety with perfect flowers, alternately.

It is very difficult to give a list of varieties which will prove satisfactory in all parts of the state, because productiveness and quality are greatly affected by local conditions. It is always desirable that the prospective grower inform himself on varieties by visiting plantations in the neighborhood and by personal observation and talk with the successful growers he will avoid costly mistakes. The following varieties, however, have proven valuable both at the Experiment Station and in other parts of the State, and are recommended:

| | |
|---|---|
| Bederwood | (Perfect flowers). |
| *Captain Jack | " " |

*Adapted to heavy land.

| | |
|---|---|
| Ivanhoe | (Perfect Flowers). |
| Marshall | " " |
| Parker Earle | " " |
| Splendid | " " |
| Thompson | " " |
| Wm. Belt | " " |
| Haverland | (Pistillate flowers). |
| Warfield | " " |

Bederwood and Thompson bloom at the same time as Warfield and Haverland, respectively, and are recommended for planting with the latter varieties.

## CURRANTS.

*Soil and Requirements.*—Currants can be grown on almost all kinds of soils, though they prefer a deep, rich, moist loam. As in the case of raspberries, the land should be well prepared by deep and thorough plowing and subsequent pulverization of the soil. While fruit may be obtained from planting on dry land, the size and quantity of fruit produced is small and would not pay as a commercial proposition. For family use, however, enough can be grown with moderate expense and trouble. For dry land planting, fall plowing to the depth of ten or twelve inches is necessary. Planting should be done as early as possible in the spring, then thorough cultivation practiced until hot weather comes, or about the middle of June. Then the plantation should be carefully mulched with strawy manure or twelve to eighteen inches of short straw, which should be held in place by poles or other material to prevent blowing away and to compact the mulch to prevent evaporation from the soil below. Deep fall plowing should be practiced regularly so as to be able to store up all the rainfall during winter and spring. The bushes should also be planted farther apart to permit plowing and deep cultivation.

*Planting.*—One-year-old plants from cuttings should be used. The planting should be done as early in the spring as possible. Set in rows five feet apart and the bushes five feet apart in the rows. Cut back the plant to two or three buds to encourage branching. When severe pruning is practiced and when the bushes are grown to a single stem, four by four is sufficiently far apart, but where the bushes consist of a large number of canes, five by five is the proper distance.

*Cultivation and Irrigation.*—Cultivation should be frequent and thorough and the plants should at no time suffer from lack of water. Frequent irrigation should not be practiced, as it tends to produce a shallow root system and encourages excessive wood growth. When irrigating, give a thorough soaking, saturating the subsoil to the depth of at least two feet. Then by frequent surface cultivation to prevent surface evaporation, the soil will be in moist condition and slowly supply the roots with the needed moisture. During the later period of ripening the fruit, more water is needed and the plants should be well supplied. Always cultivate in the irrigation ditches as soon as the land is dry enough to work. Never let the land become baked or crusted, as it injures the roots by raising the temperature of the soil and prevents a thorough aeration of the soil.

*Pruning and Training.*—Generally in commercial plantations no pruning is practiced. A required number of canes or shoots are permitted to grow and branch. When grown to a single stem or to a standard, we have a miniature tree with definite trunk and crown. To accomplish this, the lower buds are rubbed off and the shoot cut off to the height at which we wish to start the crown or head. Six to ten inches is the usual height of the trunk and the head is formed in the same manner as in apples or pears. The currants when grown in bush form require considerable pruning to produce the highest quality of fruit. On strong soil from one-third to one-half of the young canes or shoots should be removed each year, also about one-fourth of the old fruiting shoots. In pruning the currant, the age of the cane is a secondary consideration up to the age of five or six years. Vigor and productiveness should be the criterion in the removal of old canes, as well as the young ones. When the bushes reach the age of five or six years, fewer new canes are produced and only enough of these should be left as are needed to replace old ones cut out. If too many canes are permitted to grow, the fruit will be small and inferior. A strong, healthy annual growth is essential to the production of fine fruit.

*Fertilization.*—The best fertilizer for currants is stable manure. This should be applied in the fall of the year and scattered around the base of the bushes. This will give the crowns a protection for the winter besides adding fertility to the soil. In the spring of the year the manure should be removed from around the crowns and then scattered between the rows. Care should be taken to remove all the manure and to leave the ground level; otherwise the accumulation will raise the bush above the general level of the land and the root system will develop on top of the ridges. With good care a currant plantation should last eight or more years.

## GOOSEBERRIES.

Gooseberries are only grown to a limited extent in Colorado. Few commercial plantings exist, though almost every kitchen garden has a few bushes. The gooseberry requires a deep, moist soil, well drained and abundantly supplied with vegetable matter. This bush fruit cannot be grown successfully without irrigation in Colorado and only the hardiest varieties should be planted. The soil for gooseberries should be prepared in like manner as for currants. Two-year-old plants should be used. They should be set in squares five by five and cultivated both ways.

*Varieties.*—Only the American varieties can be grown in Colorado. Some of the hybrids may do well in favorable localities. Where the hybrids can be grown they should be planted closer together, four by four feet being a good distance. They are less vigorous than the native varieties and, while the berries are much larger, the yield per bush is much less. Two-year-old plants are best for planting. Plant as early as possible in the spring. Always trim off the broken or torn roots but leave the top untouched. Thorough cultivation is absolutely necessary to success. Gooseberries stand drought poorly, so care should be taken to keep the soil moist, but not wet. Many experienced growers prefer to plant the gooseberries in the orchard to give the bushes partial shade and this practice is to be commended if the grower is willing to give thorough cultivation to both the fruit trees and the gooseberry bushes. On the open plain without at least partial protection by windbreaks or shade trees, gooseberry growing will not be a success and commercial planting should not be attempted. The following varieties are recommended for Colorado:

*Downing.*—One of the hardiest and best known varieties of the American type. It is hardy, vigorous, and productive. The fruit is of fine quality, but is apt to be small, especially under poor cultural methods. For culinary purposes it is superior to the large English berries.

*Oregon Champion.*—This variety is a favorite in the Arkansas Valley. It resembles Houghton and seems to be a selection from that variety.

*Houghton.*—A well known iron-clad variety widely planted in the north Mississippi Valley. Fruit smaller than Downing but a vigorous and productive grower.

*Smith.*—A probable hybrid between Houghton and an English or European variety. It is a hardy and productive variety. Fruit larger than Houghton and Downing and stands high in favor with many growers.

*Red Jacket.*—Another hybrid between Houghton and Red Warrington (European). One of the best varieties for fancy fruit. Fruit larger than any of the pure American varieties, of good quality. When fully ripe does not stand shipping well.

In some favorable sections of the state the English varieties may be grown successfully. The following varieties are recommended:

*Crown Bob.*—A dwarf variety producing large fruit of excellent quality.

*Industry.*—This is perhaps the most popular of the English varieties. It is vigorous and productive. Fruit large and of high quality.

*Wellington Glory.*—An excellent variety that has succeeded well in America.

*Pruning.*—The American varieties are vigorous growers and tend to produce a large number of branches or canes. This tendency should be checked to some extent; otherwise the fruit produced is apt to be small. The pruning may be done either in the spring or fall. Some of the old wood should be removed each year and a corresponding number of new branches be substituted. The balance of the new shoots should be cut out. About six or eight branches are all that should be allowed to fruit. The Hybrid and English varieties require practically no pruning. The English varieties may be pruned into tree form the same as the currants, as they are stocky and upright growers, while the American varieties have slender branches and often assume a weeping form. No training is necessary. The plants are left to grow in their natural way.

The following varieties are recommended: Houghton, Downing, Smith's Improved, semi-hardy for very favorable locations.

*Winter Protection.*—While the American varieties are considered hardy, it is advisable to give slight protection. This consists in scattering a liberal quantity of stable manure around the crown and in among the branches of the bushes. This should be carefully and completely raked out in the spring and scattered between the rows and later worked into the soil. In dry weather a heavy mulch of green alfalfa or other green material should be placed between the plants to keep the ground cool and moist. Coarse litter of any kind may be used so long as it does not contain weed seed.

## INSECTS INJURIOUS TO SMALL FRUITS.

While there are a number of insects that infest the small fruits, hardly any of them are sufficiently injurious to cause any serious concern to the growers. The currant worm is sometimes present and does considerable damage. This insect can be kept in control by the use of White Hellebore when applied at the rate of one ounce to three gallons of water. In buying Hellebore from the drug store insist that it be fresh, for it loses its strength with age and has little effect as an insecticide.

## FUNGOUS DISEASES.

There are a number of diseases common to small fruits occurring in Colorado and some years cause considerable damage. While as yet we have had no serious and extensive outbreaks, their presence calls for preventive measures.

*Anthracnose* is more or less common to the red and black raspberries and is readily distinguished by greyish colored spots on the canes. When these discolorations or spots become numerous the canes are apt to die.

This disease is easily controlled by systematic cutting out of the affected canes and burning them. All the old canes should also be cut out as soon as the fruiting season is over, and burned. The young canes should be sprayed with Bordeaux Mixture, full strength, starting early in the spring before the leaves come out and before the disease appears. It is a preventative and not a cure and should be applied as a safeguard against the appearance of the disease. Later applications should be given after the young canes have started to grow, using Bordeaux Mixture half strength. (Avoid diseased plants in setting out a plantation.)

*Root Gall.*—A disease quite common on the raspberries in many sections of the state. Nothing can be done in the way of treatment. As the name indicates, the disease appears on the roots, forming tumors or galls which greatly interfere with the distribution of food materials and when these galls are present in large quantities the canes become sickly, stunted, and shriveled. In setting out a new plantation, great care should be taken to eliminate all plants that show indications of root gall. Even doubtful plants should be thrown out.

*Orange Rust.*—This disease infests the gooseberries and currants. It is readily recognized by the orange colored spots usually on the under side of the leaves. When this disease has gained a foothold nothing can be done to eradicate it, as the fungus lives within the tissue of the leaf.

Preventative measures can be taken by applying Bordeaux Mixture half strength to the plants with the first appearance of the spots or, better still, before the spots appear. In badly infested cases the infested portion of the plant should be burned and the remaining portions thoroughly sprayed with Bordeaux as indicated above.

*Raspberry Cane Blight.*—This fungous disease is widely distributed through the eastern and middle states, doing considerable damage to raspberry plantations. It is also found in Colorado, though up to the present little damage has been done.

The disease generally starts near the ground on the fruiting canes in small patches which gradually enlarge and often completely girdle the cane, causing death. Generally the patches move upward on the canes without girdling. The diseased spots are usually lighter in color than the natural color of the cane, but the dead tissue below is dark brown. At later stages these spots become darker in color with a smoke-like appearance due to presence of spores. Diseased canes are brittle and easily broken, due to the dead and dry areas.

*Remedies.*—The surest way to control this disease is to cut out and burn all infested canes as soon as the disease is discovered. The old fruiting canes should also be cut out and burned as soon as the harvest is past. Remove and burn all litter and dead branches or wood among the bushes. Give a thorough application of Bordeaux Mixture, full strength, early in the spring before the leaves come out and one or more applications during the summer, using Bordeaux half strength.

*Sphaerella, Cane Blight.*—This disease of the raspberry has been quite destructive in northeastern Colorado, and Professor Sackett, of the Experiment Station, has made a thorough study of it during the past three or four seasons. The results of Professor Sackett's work will be presented in a bulletin soon to be published.

The presence of the disease is indicated by bluish brown patches on the lower portions of the canes, the wood underneath turning dark brown and dying. The fruiting canes generally suffer most and often the fruiting buds on the lower half or three-quarters of the stems are killed, thus greatly reducing the yield. Spraying with Bordeaux Mixture, full strength, early in the spring before growth starts and two or three weeks later, using Bordeaux Mixture, half strength, is recommended. Precautions should be taken in planting by setting only healthy plants. Diseased canes should be cut out and burned as soon as discovered.

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Bulletin 196 June, 1914

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

# SOME SOIL CHANGES PRODUCED BY MICRO-ORGANISMS

(POPULAR)

*By* WALTER G. SACKETT

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| HON. WILLIAM HARRISON | Clifton, | 1917 |
| HON. CHAS. PEARSON | Durango, | 1919 |
| HON. R. W. CORWIN | Pueblo, | 1919 |
| MRS. J. B. BELFORD | Denver, | 1921 |
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# SOME SOIL CHANGES PRODUCED BY MICRO-ORGANISMS

By Walter G. Sackett

The prosperous farmer has learned through the school of experience that if he follows certain practices he can keep his land in a productive condition. This practical knowledge is of inestimable value, but it does not go far enough. In order to be able to proceed intelligently and to meet problems out of the ordinary routine, when they arise, he should know more about the fundamental principles which underlie his profession. While there are many factors concerned in the conservation of plant food in the soil, the part which micro-organisms play is among the most important, and in the pages which follow, it is the purpose of the writer to present as clearly as possible a story of the activities of soil bacteria, yeasts, and molds.

Before passing to a consideration of the work which bacteria perform in the soil, it may be well to learn something of the nature of these micro-organisms themselves.

## THE NATURE OF BACTERIA.

In the year 1675, Anton van Leeuwenhoek, a skilled lens maker of Delft, Holland, observed for the first time what we know today as bacteria. He devoted much of his time to examining through the microscope such material as was especially suited to testing his lenses, and on the occasion mentioned, he chanced to be looking at some tartar scraped from the teeth and mixed with a little water. To his great surprise and wonder, Leeuwenhoek saw what he believed to be, "many tiny animals which moved about in a most amusing fashion." He described the different shapes and supplemented his observations with drawings which resemble closely the present day forms. He was mistaken, however, in interpreting what he found as animal life, for the careful study of recent years has shown that bacteria or germs belong to the plant kingdom. To be sure, they are different from the plants with which most of us are familiar, but their food habits, the chemical composition of some of them, their simple shapes and their relation to such recognized plant forms as the molds and yeasts place them unquestionably with the lower forms of vegetable life.

Much of our knowledge of these organisms remained locked up in the mysteries of speculation and conjecture for nearly two hundred years, until finally in 1882, Dr. Robert Koch, a German bacteriologist, discovered a means of growing bacteria outside of their natural environment. While great progress has been made in the science of bacteriology since that time, and numerous new and highly specialized methods of cultivating germs have been devised, yet it is interesting to note, in passing, that many of these depend upon the fundamental principles demonstrated by Koch, and without his splendid achievements, they might never have been possible.

The public has been extremely unfortunate in the way in which it has acquired a great deal of its knowledge of bacteria. Much of this information has come to us through the medium of patent medicine advertisements, quack medical advice, and testimonials for worthless water filters. What one of my readers, while consulting the family almanac to find the time of the next new moon, has not paused for a moment to look at some hideous picture, purporting to be the exact likeness of the germs of some terrible disease, which can be cured absolutely by taking two bottles of So and So's Bitters? Our conception of bacteria as gained from this sort of rubbish is as far from the truth as the east is from the west. Everything from an innocent cray fish to a writhing sea serpent with yawning jaws, gnashing teeth and a lashing tail is herded into these illustrations to send a thrill of horror over the victim who reads his fate.

Bacteria are very simple in shape, and can be divided on this basis into three general classes. An easy way to remember the three different groups is to think of them as resembling in outline lead pencils, marbles and cork screws, although, of course, so small as to be seen only by the aid of a powerful magnifying glass. (See Plate I.) The bacteriologist knows the lead pencil or rod type as a *bacillus,* the marble or spherical one as a *coccus,* and the cork screw, curved or comma form as a *spirillum*. The bacillus group has the largest membership of the three, and includes such germs as produce typhoid fever, diphtheria, tuberculosis, anthrax, lock jaw, pear blight, alfalfa blight, potato wilt, black rot of cabbage, bitter milk, sauer kraut, vinegar, etc.; next in numbers come the cocci (pronounced coxi), represented by the germs of pneumonia, sore throat, erysipelas, boils and pus; the spirilla constitute the smallest division, in which we find the germs of Asiatic cholera, syphilis and relapsing fever. These are only a few of the hundreds that are known, but they will serve to illustrate the classification.

Next, let us see something about the size of these tiny plants.

It will be impossible in an article of this kind to tell how they are measured, although the process is comparatively simple. The reader will have to take the writer's word for it that it can be done and with a remarkable degree of accuracy. Some of the cocci or spherical forms are so small that it has been estimated that one billion could easily be contained in a drop of water having a volume of about one fortieth of a teaspoonful. With many of the rods or bacilli, we should need fifteen to twenty thousand individuals placed end to end to make one inch. The largest bacteria, as a rule, are found among the spirilla. These vary in length from one twelve thousandth to one six hundred twenty-fifth of an inch and from one fifty thousandth to one seven thousandth of an inch in diameter, while the bacilli average around one fifteen thousandth of an inch long by one thirty thousandth of an inch in diameter.

Although extremely small, bacteria make up for this deficienc by their tremendous numbers, through which agency they are capable of accomplishing wonderful results, both as friends and foes, in a remarkably short time. Multiplication takes place, by a process called fission, once about every twenty minutes to a half hour and proceeds by a geometrical progression. Thus, if we have a single living germ at the present moment, it will increase in size, and at the end of twenty minutes, will divide in the middle by the formation of a cross partition (fission), and each half will become a complete organism in itself. We thus have two germs; these two again divide by the same process so that after twenty minutes more, there are four and then eight, sixteen, thirty-two, sixty-four, etc. If there were no forces to check this growth, it would be difficult, indeed, to predict just what would become of the rest of us here upon the earth; but, fortunately, multiplication is controlled by the excretions of the germs themselves. It has been estimated that if division took place once every twenty minutes, and that it proceeded at this rate uninterrupted for twenty-four hours, the descendants of one germ would number 1,806,655,286,826,042,269,-696, or, in round numbers, 1,800,000 trillions. Considering that each organism was one fifteen thousandth of an inch long, the above number, if placed end to end, would make a string nearly two trillion miles long; it would reach to the sun and back again 10,000 times, would go around the earth's equator 70,000,000 times, and it would take a ray of light 100,000 years to pass from one end of it to the other.

The parent cell and all of its descendants constitute a bacterial colony, and when the microorganism is grown on a suitable food stuff so that all of the offspring is retained in one place, the colony first appears to the naked eye as a tiny speck which grows to the size of a pin head or larger depending upon the species and the environmental conditions. (See Plates II and III.)

Any growth of bacteria, yeasts or molds is spoken of as a *culture;* if this is made up of several different kinds of organisms, it is referred to as a *mixed culture* (Plate III, 2.), but if it is composed of only one species, then it is termed a *pure culture* (Plate III, 1). Thus, we have pure culture starters for butter, cheese and vinegar.

Although we do not ordinarily think of plants as being able to move about, some bacteria, notably the rods and spirals, possess this power in a very marked degree. They are provided with very fine, hair-like appendages, known as flagella, which extend outward from the body of the cell like the legs of a "grand-daddy-long-legs." Sometimes they come out from all sides of the germ and again only from the ends. These are kept moving rapidly all of the time with a lashing motion, much as a fish moves its fins, and by this means the bacteria are able to swim from place to place through the body fluids, decaying matter, milk, water, etc.

Many bacteria and molds, as well as some yeasts, develop bodies which are known as spores. These are much more resistant to extremes of heat, drought, famine and chemicals than the ordinary or vegetative forms and serve to tide the organism over unfavorable periods which would have meant almost certain death and annihilation of the species. Whereas many bacilli in the vegetative stage are killed by ten minutes exposure to the temperature of 140 degrees Fahrenheit, some spores can withstand the temperature of boiling water for upward of sixteen hours. Many soil organisms possess spore stages, but, fortunately for man and beast, the number of disease producing bacteria which have this property is small.

### *Source of Plant Foods.*

Between 97 and 98 per cent. of the weight of a growing plant is made from the carbon dioxide gas of the air and the water in the soil. The supply of these two substances is unlimited. The remaining 2 to 3 per cent., which constitutes the ash, is obtained largely from the soil, and the elements which compose this portion occur in limited quantities only. Year after year these mineral substances are appropriated by plants, and this constant drain for countless centuries would have exhausted the supply most certainly, were it not being replenished from some source. That this loss is restored is evidenced by the fact that our native plants continue to grow for generation after generation on the same virgin soil without any apparent loss of vigor, the soil remaining as fertile as ever. Clearly, the problem for the scientific farmer is to ascertain the factors which have kept up the fertility of the virgin soil and apply them intelligently to cultivated land. By this means alone, can we hope to maintain undiminished the productiveness of our agricultural lands.

*Number and Distribution of Bacteria in the Soil.*

The prevailing idea of a soil is that it is a mixture of finely ground rock particles and organic matter capable of supporting plant life. Now, there was a time when this definition would fulfill the requirements, but, in the light of our present knowledge, it is altogether inadequate. It ignores absolutely the presence of millions upon millions of microscopic plants and animals whose presence is indispensable to the continued fertility of the soil. Let us remember, then, in passing, that a soil is not a dead mass of inert material, but rather that it is a teaming complex of living beings.

Of the three groups of plants which constitute the microbial flora of a soil, bacteria are considerably more abundant than either molds (fungi) or yeasts. Just as with the larger plants, with which we are more familiar, there are certain factors that affect the number of bacteria in a soil. Among the most important of these, may be mentioned moisture, air, organic matter, mineral foods, acidity, or alkalinity, toxic bodies and temperature. As a rule sandy soils contain the fewest microorganisms, relatively speaking, because of the deficiency of organic matter and the poor water holding power. However, if such soils are plowed deeply and a liberal amount of green material is thoroughly incorporated, the germ content may be increased considerably. An ordinary sandy soil will often contain less than 100,000 bacteria per gram (one twenty-eighth of an ounce), but after some attention has been given to its cultivation, the count may increase to several millions per gram.

In the rich loam soils, the numbers range from 1,000,000 to several millions and even into the billions, due to the high organic content which favors bacterial growth.

In the heavy, compact clay soils, such as our typical adobe, the germ count is considerably less, owing both to the poor aeration and absence of organic matter.

Under artificial conditions, such as are offered in a greenhouse, where the moisture, temperature, and food supply are especially favorable, it is not uncommon to find numbers ranging around 100,000,000 per gram. The same is true of soil from sewage farms and of soil which has been partially sterilized either by disinfectants or heat in order to destroy certain animal forms that have been shown to feed upon bacteria. On the whole, it may be said that microorganisms are most abundant in the soils which are in the highest state of cultivation, and as a rule those soil conditions which are favorable to the growth of the higher plants are also well suited to the development of bacteria.

### *Distribution of Bacteria at Different Depths.*

From what has been said already concerning the factors which favor the growth of soil bacteria, it would be natural to suppose that the organisms would be most abundant in the surface layers that receive manure and more thorough aeration through cultivation.. This is exactly the case. Bacteria are most numerous in the first seven to eight inches of an arable soil; the germicidal action of the sunshine and the drying at the very surface reduce the numbers there somewhat. Below sixteen inches, the count falls off very rapidly, until at three feet, in the rainfall sections, it is said the soil is nearly sterile. The texture of the soil, however, makes considerable difference in the lower limit, since with a more open, loose structure, organisms are very apt to find their way to the lower levels. In irrigated regions, we know that bacteria frequently occur at depths greater than three feet, for it is not uncommon to find tubercles on alfalfa roots, produced by bacteria, eleven to twelve feet below the surface. Other bacteria have been found as deep as eight or ten feet in open soils where the drainage is good and where alfalfa roots have penetrated the earth to considerable depths. They have undoubtedly been carried down from the surface with the irrigating water and have followed the paths of alfalfa roots to the lower regions. In the more compact soils, we find the lower limit of microbial activity much nearer the surface since the conditions for aeration are poorer, and the filtering action of the finely divided soil tends to prevent a very extensive penetration even under a head of irrigating water.

## THE DECOMPOSITION OF ORGANIC MATTER.

### *The Availability and Source of Plant Food.*

The superior quality of well rotted manure, which has not been allowed to become worthless by leaching, as compared with the fresh product, is so well known to all experienced farmers that any comment on this point would be presumptuous. Again, when a heavy stand of alfalfa, red clover, or vetch is plowed under in a green condition in the spring, the benefit from this is not apparent for three or four weeks. In other words, the plant food contained in the fresh stable manure or the green crop is locked up in some unavailable form which is of no use to growing plants until decomposition has set in. So far as the chemical elements present are concerned, they are essentially the same in both old and new manure, but the combinations are quite different after decay begins. Plants and animals, as well as the excrement from the latter, are made up of very complex compounds. Experience has taught us that it would be folly to attempt to grow a crop of oats on a barn floor by supplying the seed with fresh fish, alfalfa hay, or cottonseed meal; but sow the oats in the ground, and let any of the above substances be incorporated with the soil, and in a reasonable length of time the effect of the fertilizer will be apparent. It would be equally absurd to think of raising a child, or a colt, or a calf, on a simple plant ration of nitrate of soda, superphosphate of lime and sulphate of potash with a little lime, magnesium, iron and sulphur for seasoning. Plants must have their food in a very simple form, while animals require theirs in a much more complex condition. Herein lies the explanation of the availability of plant food in thoroughly decomposed manures.

Were it not for microorganisms, there could be no such thing as decomposition, and every dead plant and animal would remain forever unchanged upon the earth. Not only would this globe soon become a rather unsightly dwelling place, but the energy locked up in these inert bodies would be an extravagant waste. Nature has provided wisely for this exigency, and has stocked the air, soil, and water with myriads of microscopic scavengers. (Plate III, 3, 4, 5, 6.) Although these are tiny plants, they can obtain their food from the dead bodies of plants and animals. In their ability to break these down and simplify them so that they can be of use to other plants, they rival our chemists with all of their splendid laboratory equipment.

## THE TRANSFORMATION OF CARBON.

The chemical element, carbon, occurs in its purest form as the diamond and as graphite. We know it in a less pure state as coal, charcoal, coke and lamp black. When it is combined with hydrogen, it forms such compounds as illuminating gas, acetylene, and marsh gas. In the plant world it is found associated with oxygen and hydrogen in the form of sugar, starches, cellulose, woody tissue, fats, and waxes, and when nitrogen and sulphur are added to these three elements, the resulting compound contains the essentials of protein. In fact, carbon enters into the composition of practically all plant and animal tissues. From this, it is clear that the demand for carbon must be very great, and in order to satisfy the demand, either the supply must be unlimited or the carbon is used over and over again. We shall find that the latter is the case. As pointed out elsewhere, plants obtain this element from the carbon dioxide of the air, of which about three parts in ten thousand are carbon dioxide. Animals secure their carbon from their foodstuffs. most of which come either directly or indirectly from plants. In the last analysis, it is plain to be seen that all of the carbon dioxide comes from the air. The supply of this gas is maintained practically constant in Nature through the oxidation of carbon and its compounds. Immense quantities of carbon dioxide are returned to the atmosphere during the burning of coal, wood, and gas. The carbon in these substances unites with oxygen to form carbon dioxide, the hydrogen combines with more oxygen to form water, and the mineral residue constitutes the ash. Many organic substances are eaten by animals, and, after serving their purpose, the carbon which enters into their composition is exhaled as carbon dioxide.

Another very important agency in setting free carbon dioxide is the work of micro-organisms. It was believed for a long time that the splitting up of complex substances during decay, accompanied by the liberation of different gases, was a purely chemical process, but it is very doubtful, in the light of our present-day knowledge, if this could take place without the intervention of bacteria, yeasts, and molds.

Sugars are among the first substances to be attacked by yeasts and molds in their search for food, and, as a rule, they are broken up into carbon dioxide and alcohol. This fermentation is perfectly familiar to anyone who has ever observed sweet cider changing into hard cider, or who has tasted jam or canned fruit which has "worked." The characteristic flavor in the latter case is due to the alcohol, and the frothing in the former is caused by the escaping carbon dioxide. The gas liberated in this way joins the supply in the air and once more it is ready to be taken up again by the leaves of some green plant and made into starch and sugar. The alcohol, likewise, passes into the air, under ordinary conditions, and ultimately is oxidized into carbon dioxide and water. Some bacteria, also, can accomplish the destruction of sugars. This may lead to the production of a number of alcohols, carbon dioxide, hydrogen, methane or marsh gas, and several different organic acids, among which may be mentioned butyric, lactic, acetic, formic, and propionic. The first three of these are met with frequently around the farm, and when the place of their occurrence is mentioned, they will be recalled readily. Butyric acid gives the peculiar, rancid odor to butter and limberger cheese, and the bitter flavor to milk; lactic acid is the common acid of sour milk; the characteristic and pleasant acidity of cider vinegar is due to acetic acid. When such acids are set free in the soil, they act upon the mineral constituents and bring into solution certain compounds which are essential to plant growth. The acids are not apt to become very abundant in a well-drained and aerated soil, especially in Colorado, where there is so much calcium carbonate present with which they can combine. Furthermore, it has been shown that bacteria and molds can utilize the salts of certain organic acids such as acetates, propionates, butyrates, citrates, malates, succinates, tartrates, valerates and formates as a source of energy, and ultimately reduce them to carbonates, carbon dioxide and water. It is indeed a rare occurrence to find arable land in this state which is acid, although a few such have been noted by Dr. Headden. When this does happen, it is due largely to the presence of the so-called "humic acids" and acid humates, complex organic compounds about which we have but little definite knowledge. A liberal application of lime or ground limestone to soils in this condition usually alleviates the trouble in time. Blair states that the average acid soil of Florida requires 1,500 pounds of lime per acre to neutralize the acid to a depth of nine inches, yet it is not uncommon to find peat and muck lands where the acidity is many times this amount.

The alcohols produced are of considerable commercial importance as well as of scientific interest. They include ethyl or grain, propyl, butyl and iso-butyl alcohol.

The changes produced in starches are very similar to those met with in the sugars. However, before any carbon dioxide, alcohol, etc., can be set free, it is necessary to convert the starch into sugar. This is accomplished by a secretion from the microbial cells, called an enzyme, and the specific enzyme or ferment in this case is diastase. After this change is brought about, the fermentation and the products found are in all respects identical with those formed during the breaking down of sugars.

Cellulose, which constitutes a large per cent of the weight of woody tissue, and of which the cell walls of young plants are composed almost entirely, is very useful in maintaining the proper physical condition of a soil. Straw, cotton fiber and flax fiber are common examples of this material. It is this compound in the spruces, aspens, and cottonwoods that makes them valuable for paper-making. When incorporated with the soil in the form of strawy manure or green crops, it decomposes slowly under the action of micro-organisms, keeps the land loose and open, and increases the water-holding capacity to a remarkable degree. Cellulose is a compound of carbon, hydrogen and oxygen, and is closely related to the sugars and starches in point of chemical composition. Certain bacteria of the soil, notably a group designated as *Amylobacter,* are known to feed upon it, and gradually to resolve it into carbon dioxide, hydrogen, methane and fatty acids. Here, again, the carbon dioxide is returned to the air. Some molds as well as bacteria can produce similar changes. However, the chemical reaction of the soil determines largely whether the decomposition will be brought about by bacteria or molds, since the former are active only in an alkaline environment, while the latter thrive best under acid conditions.

Anyone who has ever strolled or ridden through our mountain forests must have been impressed with the immensity of the timber waste. And yet is this waste? When we stop to think of the tremendous amount of energy and plant food which is being liberated through the decay and destruction of these fallen logs, the problem assumes quite a different light. The fertility of the mountain soils which wash into the gulches is too well known by every ranchman to need further comment. The fallen trees appear to remain unchanged for years, but with the passing of time, they become spongy and punky through some agency not clear at first, and slowly but surely the hard, woody trunk is converted into a soft, brittle mass which eventually crumbles into a brown powder. This soon becomes incorporated with the soil and furnishes food for other plants. The decomposition which takes place here is, for the most part, a destruction of cellulose compounds, and is carried on not only by micro-organisms but also by some of the large, fleshy fungi, familiar to us as toadstools. In fact, fungi, or molds, are largely responsible for the destruction of the woody tissue. The larger forms initiate the attack on the surface, and send their thread-like "rootlets," known as hyphae, beneath the bark and into the tissue. By means of enzymes and other chemical substances with which they are supplied, the wood is softened, and the way is paved for other fungi, and wood-eating insects. After the decay is well advanced, bacteria probably join hands with the other agents and hasten the final transformation. Thus, through the decay of timber, there are restored to the atmosphere carbon dioxide and water through the oxidation of carbonaceous material; and to the soil, carbonic acid, organic acids, organic matter and mineral substances.

As yet, nothing has been said about the destruction of fats, gums and waxes. Whether fats or waxes, bacteria, yeasts and molds, through the immediate action of enzymes, convert these fatty substances into glycerine and fatty acids, both of which may be oxidized finally into carbon dioxide and water.

Thus it is, that the carbonaceous materials contained in plant and animal tissues undergo decomposition at the hands of soil micro-organisms. The carbon of the complex compounds is transformed into carbon dioxide, which either passes into the air to replenish the atmospheric supply, or unites with water to form carbonic acid and ultimately soil carbonates.

## TRANSFORMATION OF NITROGEN.

We come next to a consideration of soil nitrogen which, from the standpoint of conservation of plant food, is unquestionably the most important of all the elements. It is not that the supply of nitrogen is so limited, for approximately 79 per cent of the air consists of this gas, but rather, that it does not exist in any quantity in a form that plants can utilize. To be of value to vegetation, it must be present in the soil, either in the form of nitrates, or possibly as ammonium salts, but the stock of both of these is far from abundant.

The world's supply of commercial nitrate is derived almost exclusively from two sources—guano and Chile saltpeter; some nitrate of potash comes from the plains of the Ganges River in India. All of these are becoming exhausted rapidly, and already guano has ceased to be of any importance. While it is difficult to obtain any precise estimate of the amount of available saltpeter in the beds of Chile and Peru, South America, it is quite certain that if the present rate of consumption continues,—2,597,754 tons for the year 1910—it cannot last for any great length of time, some placing the limit at less than forty-five years. At $50 or $60 per ton, an application of two hundred to three hundred pounds of nitrate of soda per acre soon runs into money, and the commercial article, while rich in nitrate, is at the same time so expensive that the cost makes it almost prohibitive for the average farmer.

Dr. Headden informs me that our ordinary Colorado soils contain from .0037 to .0121 per cent (150-450 pounds per acre foot) of nitrates expressed as nitrate of soda, an amount far too small to permit of any wasteful methods in farming. From this is is quite clear that unless more attention is given by our agriculturists to maintaining the soil-nitrogen by the application of manure or commercial fertilizer, it will be but a few years, relatively speaking, until our fields will be unproductive and worthless.

During their growth, green plants use nitrates to build up complex nitrogenous compounds which we call proteids, and the animals which feed upon them, convert these proteids into still different forms. Such substances as bone glue or glutin, mucus, gelatine, egg albumin, legumin and the fibrin of the blood are produced in this manner. A portion of the proteid appropriated by animals is retained throughout life, but a second part is consumed by the body to furnish heat and energy. However, while this is going on, the proteid is being broken to pieces. Much of the carbon is oxidized and exhaled as carbon dioxide, while the waste nitrogen is carried off by the kidneys as urea in the urine. In this way, the complex nitrogen molecule is considerably simplified, but not to such a degree that the resulting compounds are of any immediate benefit to plants. It has been estimated that the human race alone excretes 38,000 tons of urea daily, to which must be added the much greater amount voided by animals. In the light of this fact, does it not behoove all thrifty farmers to provide some means for conserving the liquid manure around the stables. Who knows how long such thoughtless waste is to go unpunished?

When these same plants and animals die, and they are returned to the soil, quantities of nitrogen remain locked up in the complex proteid compounds of their bodies. Neither they nor the urea, just mentioned, are of any use whatsoever to future plant generations unless their nitrogen can be converted into nitrates. Thanks to the presence of soil micro-organisms, a means has been provided by which the complex nitrogenous compounds in decaying organic matter can be converted into nitrates, and if the agriculturist will see to it that his land receives a reasonable amount of organic nitrogen from year to year, either as stable manure or green crops, and if he, himself, is equally diligent in the cultivation and irrigation of his soil, there need be no alarm over a nitrogen famine.

### *Ammonification.*

In the transformation of the nitrogen of proteid bodies and their cleavage products we recognize three well defined stages. The first of these deals with the production of ammonia by bacteria from the complex organic matter; in the second, the ammonia nitrogen is converted into nitrous acid and nitrites, and in the third, the nitrites are changed into nitric acid and nitrates. The term "Ammonification" is applied to the first process while the combined action of the last two is spoken of as "Nitrification." For the present, we shall confine our attention to ammonification.

Like the higher plants and animals, bacteria must have their food in a liquid condition before it can be assimilated. In order to facilitate the solution of the complex proteids from which the ammonifying bacteria derive their nourishment, certain digestive enzymes, similar to pepsin and trypsin in animals, are secreted by the tiny cells. As a result, the protein compounds are broken down first into albumoses and then peptones, the latter being soluble and consequently in a form which bacteria can use for food. From these peptones, amino acids are formed which themselves serve as food and ultimately give rise to ammonia and carbon dioxide. The enzyme which is responsible for this digestion is known as a proteolytic or peptonizing ferment since it is capable of changing proteids into peptones.

Bacteria which grow best in the absence of air (oxygen), known as anaerobes, are believed to play an important part in the early stages of putrefactive decomposition, and it is to their activities that we must charge most of the malodorous gas formation which accompanies decay.

Now, while the bacteria are busily engaged in decomposing nitrogenous material whereby their existence is maintained, a large number of substances of little or no value to them are split off from the complex nitrogen molecule. These are known as cleavage or by-products. Again, during the growth and metabolism of the micro-organisms themselves, various waste products are excreted from their cells. The disagreeable and peculiarly characteristic odors evolved during putrefaction and decay are often directly traceable to one or more of these secondary compounds. Thus we always associate the odor of rotten eggs with hydrogen sulphide, and the pineapple odor of old, rancid milk with butyric ether. The list of known substances which owe their origin to a fermentation of this nature is a long one, and in all probability is far from complete.

The decomposition of urea is of particular interest, since it is one of the most fertile sources of ammonia. This transformation is brought about by the enzyme *urease,* which converts urea into ammonium carbonate, by simply adding a molecule of water, simple hydrolysis. Anyone who has been around a stable or a pile of fresh manure could not fail to have detected the strong odor of ammonia liberated from this substance. And right here is where a tremendous nitrogen loss occurs. Had the urine, from which the ammonia was formed, been absorbed by dry peat, saw dust or a similar medium, a large part of the ammonia with its 82 per cent of nitrogen might have been saved instead of passing off into space. If absorbents are impractical, then the stables should be so constructed that the urine from the animals housed therein will drain into a pit or cistern prepared for this purpose. It should not be allowed to accumulate for any length of time, but should be sprayed or sprinkled upon the soil at once since there is considerable loss from standing. Since ammonium carbonate is a volatile substance, when manure is allowed to dry there is very great danger of the carbonate disintegrating and the ammonia escaping. For this reason, it is a poor policy, especially under our arid conditions, to spread manure on a field any length of time before it is to be plowed under. For the same reason, a manure pit is preferable to the ordinary compost heap. This should be located so that ditch water can be turned in from time to time and the proper moisture conditions maintained.

Throughout our study of the decay of nitrogenous material, we are chiefly concerned with the destiny of the nitrogen. This we have found is either set free as ammonia by the ammonifying bacteria during the process of ammonification or converted into ammonium carbonate by the uro-bacteria. If liberated as ammonia, it will either escape into the air or unite with carbonic acid, which is usually present during this fermentation, to make ammonium carbonate. In this form it is less apt to get away, if properly handled, and as such it will await the further changes to be initiated by the nitrifying organisms.

Soil bacteria, as a general thing, have greater endurance, and can withstand more severe treatment than other plants with which we are more familiar. Their growth and development in the soil are governed largely by conditions which are in man's control. They require about the same amount of moisture as other crops; a temperature of 82°—86° F. suits them; a well drained, aerated, thoroughly cultivated soil, abundantly supplied with organic matter favors their growth. They will not succeed well in acid land. and if such a condition exists, it should be corrected by liming.

Another factor which cannot be lost sight of is the beneficial as well as detrimental influence which our alkali salts may exert upon the micro-organisms. Lipman† of California, in his recent studies upon the effect of alkali salts upon ammonification has shown that ordinary salt, sodium chloride, and sodium sulphate

†Lipman, Chas. B., Toxic Effects of "Alkali Salts" in Soils on Soil Bacteria. I. Ammonification; Cent. f. Bakt. Abt. II., Bd. 32, No. 1-2, p. 58, 1911.

are toxic for ammonifying bacteria when added in small quantities to an alkali free soil. Sodium carbonate, on the contrary, exercises a stimulating effect when present in amounts equivalent to .1 per cent of the dry weight of the soil.

The ability to produce ammonia from organic matter is a function common to many soil bacteria. Marchal has reported seventeen different species which belong to this class. Among the more active ammonifiers may be mentioned *Bacillus mycoides, Bacillus proteus vulgaris, Bacillus mesentericus vulgatus, Bacillus subtilis, Bacillus janthinus, Bacillus coli communis, Bacillus megaterium, Bacillus fluorescens liquefaciens, Bacillus fluorescens putidus,* and *Sarcina lutea.*

A study of over thirty different Colorado Soils, representing the prevailing types to be found in the state, has shown them to possess exceptional ammonifying efficiency as compared with soils from other regions. The results obtained from six Colorado samples are given in the table which follows:

*Table No. 1. Ammonification in Colorado Soils.*

| Source and Character. | Per cent. of nitrogen converted into ammonia in 7 days from 100 m. g. organic nitrogen as: | | | |
|---|---|---|---|---|
| | Cottonseed Meal. | Dried Blood. | Alfalfa Meal. | Flaxseed Meal. |
| Orchard; heavy adobe clay; niter | 42.31 | 47.04 | 12.78 | 8.09 |
| Orchard; clay loam; niter | 51.98 | 47.98 | 15.30 | 1.12 |
| Orchard; sandy loam; niter | 47.10 | 52.64 | 13.69 | .21 |
| Orchard; sandy loam; normal | 25.92 | 18.03 | 12.06 | 6.30 |
| Beet field; gravelly clay; normal | 28.02 | 39.79 | 2.83 | 5.26 |
| Truck patch; silt loam; normal | 21.09 | 25.08 | .73 | 3.11 |

The results of this work indicate that both cottonseed meal and dried blood yield ammonia nitrogen readily under the action of our soil bacteria, and therefore they would be desirable materials to employ as commercial nitrogen fertilizers; the nitrogen of alfalfa meal appears to be about one-third as available as that of blood and cottonseed meal; while the nitrogen of flaxseed meal, relatively speaking, is almost unavailable.

A detailed account of our ammonification investigations has been published as Bulletin 184 of this Station.

*Nitrification.*

The change of ammonia and ammonia compounds in the soil into nitrates was looked upon for a long time as a purely chemical process. The transformation was explained as due to electrical discharges in the atmosphere, to natural combustion, or to the oxidation of organic matter in combination with calcium, magnesium, iron and manganese compounds. The reason for believing this was that nitrates are almost universally present in cultivated land combined with calcium or magnesium. In 1862, Pasteur expressed the belief that the formation of nitrates in the soil and in decaying organic matter might be due to biological activities. Muller, a few years later while studying the nitrites and nitrates in sewage and drinking water, came to look upon their presence as the work of micro-organisms. The exact nature of nitrification was not fully understood, however, until 1877 when Schlosing and Muntz demonstrated clearly that it was brought about by biological agents. Their classic experiments showed that when a dilute solution of ammonia is passed through a long tube filled with soil, nitrates appear in the resulting liquid in place of the ammonia contained in the original solution; in other words, contact with the soil had changed the ammonia to nitrate. Furthermore, if the soil in the tube is first sterilized by heat or chloroform or other germicides, and the ammonia solution is passed through subsequently, no change takes place. But if the sterilized soil is reactivated by inoculating it with a small quantity of fresh soil, its nitrifying power is again restored. It was quite clear from this that a close relation must exist between the life in the soil and the nitrifying process. Accordingly, bacteriologists set to work at once to discover, if possible, the specific micro-organisms which were responsible for the transformation. Years were spent in diligent search, but only negative results rewarded their labor. At last, in 1890, Winogradsky succeeded in isolating certain bacteria which were capable of producing nitrates from ammonia solutions. His investigations showed, further, that nitrification or the oxidation of ammonia into nitrates takes place in two separate steps, and that two distinct classes of bacteria are involved in these changes. The first stage is the oxidation of ammonia into nitrous acid and nitrites; the second, the oxidation of the nitrites into nitric acid and nitrates. Winogradsky designated the organisms which are responsible for the first step as nitrous or nitrite bacteria and called the two species *Nitrosomonas* and *Nitrosococcus*. The former represents varieties obtained from soil in Europe, Asia and Africa, while the latter, those isolated from American and Australian samples. To the organism accomplishing the second step, known as the nitric or nitrate bacteria, he gave the name *Nitrobacter*.

In addition to these forms, Kaserer claims to have isolated an organism, *Bacillus nitrator*, which is capable of oxidizing ammonia directly to nitrate. Corroborative evidence upon this discovery has not been received as yet, and should it be confirmed, even then, the number of known nitrifying organisms is very small.

Nitrification, then, may be defined as the process by which ammonia compounds are changed to nitrites and nitrates by the action of nitrifying bacteria.

Inasmuch as nitrates in reasonable amounts are very desirable assets to all soils, it may be worth while to ascertain under what conditions nitrification proceeds most rapidly. In the first place, it is obvious that the soil must be supplied with adequate organic matter from which the ammonifying bacteria can produce ammonia. Since nitrification is an oxidizing process, the soil must be well aerated by thorough cultivation and proper drainage. One of the reasons that surface soil is more fertile than sub-soil is because the looser texture of the upper layers permits the easy penetration of atmospheric oxygen, a requirement for active nitrification. Conn states that, "about 65 per cent. of the total nitrification occurs in the upper twelve inches of soil, 30 per cent. more in the layers from twelve to thirty inches lower, and little or none below this." Sufficient moisture must be furnished for the growth of the bacteria, about the same as for ordinary crops. Nitrification takes place through a wide range of temperatures; feeble at 40° F.; marked at 55° F.; and best at 85° F. From this it will be observed that nitrification in the soil is going on most vigorously from July to October, a time of the year when the nitrates formed are of immense value to growing crops. The toxic substances excreted by the roots of higher plants are believed to be injurious to the nitrifying organisms, and therefore the urgent need of crop rotations. Acid soils prohibit nitrification, and if such conditions exist, they should be corrected by liming. There should be an ample supply of lime, magnesia and other basic materials to insure the prompt neutralization of the nitrous and nitric acid as well as any organic acids that may be formed. Excessive amounts of certain alkali salts may prove objectionable.

Among the numerous theories which have been advanced to account for the saltpeter beds of Chile and Peru, is the belief that the areas now occupied by these deposits were at one time arms of the ocean, and with the gradual rising of the western coast, these bodies of water became inland seas, which could be replenished only at high tide. Quantities of sea-weed are supposed to have grown in these shallow basins, and after decomposing, their nitrogen was changed by nitrifying bacteria into nitrates. The high temperature, the lack of rainfall and the absence of an outlet all assisted in the concentration of the nitrate in these areas until the material which accumulated reached into the millions of tons.

Thus, through the agency of microorganisms by the processes of ammonification and nitrification, the unavailable nitrogen of decomposing organic matter is changed into nitrates and restored to the soil in a form which is indispensable to all plant life.

Nitrification* in Colorado soils is a topic to which we have given considerable attention during the past year because of its relation to the niter trouble which is discussed on page — of this paper. The results of the investigation indicate that this process goes on much more actively in our soils than in many soils from other parts of the United States. Work which is in progress at the present time may shed some light upon this point, but just now we cannot say whether it is due to peculiar soil conditions which are especially suited to the development of the nitrifying organisms, or possibly, to the presence of new species of bacteria which are exceptionally alert biochemically. This difference in nitrifying efficiency is illustrated very well in Table 2 which gives the net gain in nitrates made by Colorado and foreign soils when supplied with ammonia nitrogen in the form of ammonium sulphat and ammonium carbonate.

*Table No. 2. Nitrification of Ammonium Sulphate and Ammonium Carbonate by Colorado and Foreign Soils.*

| Source and character of soil. | Net gain in nitrates per million parts of air-dried soil from 100 m. g. ammonia nitrogen as: | |
|---|---|---|
| | Ammonium sulphate. | Ammonium carbonate. |
| Colorado; wheat field; clay; normal | 3258 | 2899 |
| Colorado; peach orchard; heavy clay; normal | 3681 | 2620 |
| Colorado; apple orchard; heavy clay; niter | 4302 | 2798 |

*The detailed account of this investigation has been published as Bulletin 193, Colo. Exp. Sta., "The Nitrifying Efficiency of Certain Colorado Soils," January, 1914.

| | | |
|---|---|---|
| Colorado; apple orchard; clay loam; niter | 3541 | 1328 |
| Colorado; apple orchard; sandy loam; niter | 3629 | 2656 |
| Colorado; apple orchard; clay; niter | 3665 | 5081 |
| Georgia; pine forest; gravelly loam | 13 | 22 |
| Oklahoma; cotton field; sandy loam | 89 | 841 |
| Washington; apple orchard; loam | 133 | 841 |
| Ohio; corn field; clay loam | 266 | 620 |
| California; vineyard; clay loam | 513 | loss |
| Virginia; apple orchard; heavy clay | 620 | 1107 |
| Kansas; sugar beet field; sandy loam | 2833 | 3098 |

Duration of the experiment was six weeks at 28 degrees C.

*Denitrification.*

*Denitrification* may be defined as the partial or complete reduction of nitrates. It is the reverse of *nitrification,* and from an economic standpoint, is to be regarded as undesirable, since there is an actual loss of valuable nitrate. Whereas in nitrification, oxygen is added to ammonia and nitrites to form nitrites and nitrates respectively, in denitrification, the oxygen is taken away from the nitrates and they are reduced to nitrites, ammonia, and even to a point where free nitrogen is liberated, and oxides of nitrogen are formed. In a strictly scientific sense, denitrification applies only to the complete reduction of nitrates to gaseous nitrogen. The list of micro-organisms that can produce this phenomenon is a long one, and includes both bacteria and molds.

In soil and manure, most of these develop readily in the presence of air (aerobic), however, in the role of denitrifiers, they appear to be favored by the partial exclusion of air. A fine grained, close, compact soil, in other words a heavy soil, to which excessive quantities of fresh, strawy manure (50 to 60 tons per acre) have been added, presents the optimum conditions for bacterial denitrification. The free circulation of air is interfered with seriously in a soil of this character, and the growth of the denitrifying organisms is favored by the large amount of readily decomposable organic matter. Under such conditions, there may be a loss of nitrogen both from the soil and from the manure, since the bacteria, in all probability, will draw upon the nitrate for the necessary oxygen with which to liberate energy from the organic compounds. In this manure, the nitrates which we have been striving to restore to the land, and maintain there, may be changed from valuable plant food into an inert gas. On the whole, the danger from denitrification under field conditions has been greatly over-estimated, and the farmer who applies from ten to twenty tons of well rotted manure per acre and who keeps his land well cultivated, need feel little concern from losses on this account. It is true, however, in truck gardens and greenhouses, where the ground is pretty well saturated, and where an abundance of organic material is used, a temporary loss of nitrates is sometimes experienced.

Those who have held that soil may suffer a loss of nitrates following the application of fresh manurs, if such is the fact, have explained the phenomenon by saying that vast numbers of denitrifying bacteria, which do the damage, are introduced with the manure. While the bacterial content of the soil is unquestionably increased by this addition, the reduction is probably due to an entirely different cause. The large amount of organic matter in the manure appears to be immediately responsible for the trouble by furnishing abundant food for the denitrifying organisms already in the soil. A mere increase in numbers would have little to do with stimulating activity, and furthermore, ordinary soils usually contain enough of these organisms to accomplish the reduction if adequate organic matter is supplied.

The manure heap presents an additional field for the study of nitrate reduction. There are so many factors that can influence microbial activities here that conflicting statements have arisen regarding the different changes supposed to take place. According to the best authorities, there may be some loss from denitrification in the surface portion where the air circulates more freely and where nitrates may have been formed by nitrification. Deeper down in the pile, it is a question whether there is any reduction since, except in very old manure, there are probably no nitrates present owing to the unfavorable conditions for nitrification and nitrate formation. On the other hand, in old, well rotted manure, where one might expect to find nitrates, there is not enough fresh organic matter to stimulate the denitrifying bacteria.

### *The Fixation of Atmospheric Nitrogen.*

Separate and distinct from *Nitrification,* which has been described above, is the process of *Nitrogen Fixation.* The former deals entirely with the transformation of nitrogen already present in the soil, while the latter is concerned solely with the nitrogen of the atmosphere. Nitrification explains how the ammonia nitrogen which is obtained from protein decomposition is converted into nitrites and nitrates. Nitrogen fixation accounts for the addition and accumulation of nitrogen in the soil from the atmosphere.

The increase in fertility accruing to land fallowed for a number of years is common knowledge to every experienced farmer. The available potash and phosphoric acid may have increased some, but the greatest difference observed is in the amount of nitrogen present. At the end of the fallow period, we should expect to find, and do find, more nitrate nitrogen due to nitrification, but far more important than this is the appreciable addition to the total nitrogen. Now the air with its 79 per cent. of nitrogen could easily supply this amount provided some means were at hand for transferring it from the atmosphere in a gaseous form to the soil in a combined form.

Many chemical theories were formulated and expounded during the third quarter of the nineteenth century to explain this phenomenon, but all failed when put to practical tests. For a long time it had been observed that plants of the legume family, represented by alfalfa, clover, peas, and beans, made good yields irrespective of the nitrogen in the soil. Not only was this true, but the soil itself was benefited by the legume, as was indicated by the crop that followed. This led to an analysis of the soil which showed very clearly that it actually contained more nitrogen after it had grown a crop of peas than before. In other words, the increase in nitrogen was, in some way, related to the life processes of the leguminous plant. Finally, the mystery was solved, and it was proven conclusively that the responsible agents were specific soil bacteria which both independently and when associated with legumes held the key to the great storehouse of atmospheric nitrogen, and that through their activities alone, this supply of nitrogen could become available for the higher plants.

We recognize two distinct types of activity and two different groups of bacteria in the fixation of atmospheric nitrogen. In the one, the micro-organism performs the work by itself; in the other, the combined action of germ cell and legume is required. The former is spoken of as *non-symbiotic* and the latter as *symbiotic fixation.*

### *Non-Symbiotic Fixation.*

In the early experiments which were conducted by Berthelot in 1885, to determine the cause of the increase of nitrogen in fallow ground, two lots of soil were obtained from the same source. One portion was sterilized by heat to destroy all life, and the other was kept in its normal condition. Both samples were exposed side by side to the same conditions and both were treated as nearly alike as possible. After a given length of time had elapsed, the total nitrogen was determined in each, and it was found that the heated portion had remained practically unchanged, while the other showed a decided gain. This proved beyond a doubt that the nitrogen increase in the fallow ground was in some way intimately associated with the life of the soil microorganisms. Winogradsky, in 1892, succeeded in isolating an organism, *Clostridium pastori.num,* which was capable of forming nitrogen compounds, under anaerobic conditions, in the culture medium which contained no nitrogen. A very valuable addition to our knowledge of the subject was made when Beijerinck, in 1901, reported his discovery of a group of large, aerobic bacteria capable of building up protein compounds from atmospheric nitrogen. To this group, he gave the name *Azotobacter.* Two species were described by him, *Azotobacter chroococcum* and *Azotobacter agilis,* and since then five or six others have been added to the list. Both the anaerobic and the aerobic forms are widely distributed in cultivated soils. In addition to these, a slight fixation has been secured with several of the ordinary soil bacteria but not enough to be of any economic importance.

In this connection may be mentioned the commercial preparation "Alinit," a pure culture of *Bacillus ellenbachensis,* which was exploited a number of years ago in Germany as a panacea for worn out land. It was to be used for inoculating soil and by virtue of the nitrogen fixing bacteria which it contained, wonderful gains in nitrogen were to be expected. Like many such phenomenal discoveries, it failed to accomplish the extravagant claims made for it, and it was soon forgotten save for its record in the annals of science.

Several attempts have been made to inoculate soil with pure cultures of Azotobacter but with little success. As with Alinit, the failure to secure satisfactory results have been due in a large measure to unfavorable soil conditions, namely, acid soils, insufficient moisture, lack of basic carbonates, and mineral salts.

While the mechanism of nitrogen fixation within the bacterial cell is not clearly understood, it is believed that the Azotobacter cell utilizes the nitrogen of the atmosphere to build up protein compounds. These in turn undergo decomposition, and through the action of the ammonifying and nitrifying organisms, they are converted into nitrates.

It is believed that during the process of fixation, Azotobacter derives the energy for this function from the organic material present, and the results of certain experiments have shown that the amount of nitrogen taken up bears a definite relation to the quantity of carbonaceous material consumed. From this it follows that an abundant supply of organic matter in the soil is one of the requirements for active nitrogen fixation.

A careful study of some thirty Colorado soils was made by the writer over three years ago, for the purpose of learning whether there was any relation between the high nitrate content of these soils and soil bacteria. The samples collected represented orchard land, raw land, beet, alfalfa, and grain fields, and truck gardens. It was suspected that possibly Azotobacter, favored particularly by the alkaline reaction of the soil, was fixing immense amounts of nitrogen as protein, which was subsequently converted into nitrates by ammonification and nitrification. This question is of tremendous economic importance since the amount of niter in some localities is approaching 100 tons per acre foot, and all kinds of vegetation are dying as a result of the accumulation. In describing the serious condition brought about by this trouble, I can do no better than to restate what I have said on this subject in a former bulletin.

"Somewhat over a year ago, Dr. Headden called my attention to the extremely large quantities of nitrates present in certain Colorado soils, stating at the time that these nitrates were frequently associated with a brown discoloration of the soil, and that this color was often confined to well defined areas varying in size from three feet in diameter to an acre or more; furthermore, that these so called "brown spots" were not fixed, inert quantities related to some recognized geological formation, but that they were alive, and in the process of making as evidenced not only by the rapid progress with which the then existing spots were spreading, but also by the almost continual appearance of new spots both in old and new localities.

Dr. Headden has been studying our alkali soils and drainage waters for the past sixteen years, and he tells me that complaints of "brown spots on which nothing will grow" have been common, but more so during the past five years; reports have been received from the cantaloupe growers that their melons are deteriorating in quality without any assignable cause; truck gardens, alfalfa, oat, barley and sugar beet fields have been developing barren patches where a uniform stand was always obtained in former years; in some parts of the state, the sugar content of the sugar beets as well as the purity and tonnage have fallen off until it is a ponderous question with the farmers and sugar factories whether the growing of sugar beets in those localities is any longer a profitable industry; but equally serious, if not even more so than any of these, is the destruction which is being wrought in some of the apple orchards of Colorado.

Newly set trees, trees that have just come into bearing, and trees that are fifteen to twenty-five years old, in fact, trees of all ages, seem to suffer alike. It is not an isolated tree here and there that has died, but thousands, representing many acres of orchards in widely separated districts, have perished during the past two seasons.

When one is brought face to face with facts of such tremendous economic importance as these, he can scarcely fail to be impressed with the deplorable condition of affairs, and is forced to the position that something out of the ordinary is taking place, and that it is not without a cause.

With reference to the occurrence and distribution of the nitre areas, Dr. Headden gives the following in Bulletin 155 of this station:

'This trouble was not confined to any one section, but was common to several sections of the state. While it, in all probability, depends upon soil conditions, these conditions are met with in so many places that it is necessary to consider the condition rather than the soil itself. It sometimes occurred in light and sandy loams, and sometimes in clayey soils. It is sometimes in comparatively low lying lands, again in the low lying portions of higher lands, and again on the hillsides. The road side, a ditch bank, and the cultivated fields represent the range of places in which this thing may reveal itself. There is one thing common in all of its occurrences, namely, a brown color in the surface soil. This color is less marked in the sandy soils than in the so-called adobe soils. Perhaps this is due to the presence of the deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films.'

'We find the nitrates present in soils, where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet, there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali, but that the nitre in such cases appears on higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs.'

In driving through those districts which are suffering with this trouble, the most striking feature to one not conversant with the symptoms is the brownish, black and, to all appearances, wet condition of the soil. This can be seen along both sides of the travelled road, and often extends to the irrigating ditch, or fence on either side, and into the adjoining fields. I think of nothing which describes the color better than the appearance of soil where crude oil has been spilled, as is done frequently in orchards where oil pots have been used in heating, or, if you please, where the roads have been sprinkled with oil. Considerable disappointment is experienced, however, when this blackened surface soil is examined for it is often found to be a dry crust, rather than a wet one, one-fourth to one-half inch in thickness, underlaid with one or two inches of material of a very mealy character, beneath which the soil looks like any other soil. Sometimes the surface is so moist as to be slippery, due, probably, to the presence of quantities of deliquescent salts. As one walks over a field in this condition and breaks through the hard crust, the sensation experienced has been likened to walking on corn meal or ashes.

Concerning the condition of the soil met with under the mealy layer, I can not go into details since Dr. Headden has treated this phase of the question very fully and completely in his publications, suffice it to say that free water is seldom found nearer to the surface than five feet, and in most cases the soil is in what would be considered a nice moist condition; again in the heavier lands, we may expect and do find them rather sticky near the surface and of a gumbo character as the water plane is approached.

The brown color often appears on the banks of the irrigating ditches, eight to ten inches above the level of the water, and along the upper edge of the irrigation furrows. Extending lengthwise of these, it manifests itself a few days after irrigation as broad bands of pigment which might easily be mistaken for manure stains, so far as color is concerned, especially if the field or orchard had been fertilized recently. It is not uncommon to find large tracts of land where the nitrates have become so abundant as to be deleterious to the crops, yet where no discoloration is apparent on the surface. It is difficult to say in such instances whether no color is being produced or whether it is developing so gradually and uniformly that it can not be detected readily.

The economic outlook of this problem is, indeed, a serious one. Bushels of wheat have been planted on heavy nitre soils, and if it germinated at all, only a very small percentage ever came through the ground. Oats and barley have suffered the same fate. Corn has germinated in some fields, and made a sickly, yellow growth of six inches to a foot and then died. Sugar beets, if they grew at all, have gone to tops, while the roots have taken on all sorts of abnormal, irregular shapes, typical "tub-beets," to say nothing of the inferior quality of the beet from the sugar standpoint. Dr. Headden has collected a great deal of data on this point which will be presented by him in due time. The money loss to the farmers in seed alone has amounted to thousands of dollars. But the orchardist has been unquestionably the heaviest loser, for not only has he been deprived of the crop for the current season, but he has also lost the trees upon which he is dependent for future crops, at least we have yet to see a single tree which has shown any indication of recovery. Added to this and worse than all, perhaps, is the utter worthless and hopeless condition of his soil for agricultural purposes. The apple, cherry, apricot and plum, all appear to suffer about equally, while the pear and peach, thus far, have exhibited marked resistance, the peach having been observed to suffer least of all.

The symptoms of excessive nitre in the soil as manifested in apple trees are so characteristic that it may be well to describe them briefly in passing. The first indication is the firing or burning of the leaves along the margins, beginning at the apex, extending rapidly along the edge, inward toward the midrib and downward toward the base until the entire leaf has turned brown. There is no occasion for anyone who is familiar with the yellowing of foliage due to lack of proper drainage to confuse this with the nitre burning, for the appearance of the leaves in the two cases is entirely distinct. Whole trees have been known to undergo this transformation in less than three weeks time. In fact, Dr. Headden reports having killed a four-year-old tree in an experimental orchard in four days by applying twenty pounds of nitrate of soda around the roots and then irrigating at once to bring the nitre into solution. In reference to the behavior of this tree, he says, "The effects were in all respects similar to those produced in other orchards" under natural conditions. If the burning of the leaves occurs early in the season, the trees will often exert a feeble effort to put forth a second crop of leaves. These are usually small, whitish leaves and inclined to be rather pubescent. Such trees, laden with one-third to one-half grown apples, seldom mature any fruit, and in all probability will be dead by spring. If the attack comes late in August or September, the chances are that the fruit will mature, but it will be undersized and of poor quality; no new leaves will be expected to appear and the old ones will cling to the twigs late into the fall. The following spring, it is very likely that an attempt will be made at leafing out, but as stated above the leaves will be small, yellowish-white and few in number, and by the middle of the season the tree will be dead.

Before proceeding further, I wish to make it perfectly clear that what I have said is not to be interpreted as applying to all of our arable land or to more than a very small percentage. While the matter is eminently serious, it by no means justifies the position that our agricultural interests as a whole are in jeopardy."

A full account of this investigation has been published already (1), the results of which show that *Azotobacter chroococcum* is present in most of the soils examined and that the characteristic dark brown color referred to above is due, in a large part, to the pigment produced by *Azotobacter chroococcum.*

In view of the results which we have obtained in our studies of non-symbiotic nitrogen fixation in Colorado soils, together with those cited in connection with ammonification and nitrification, we feel reasonably safe in asserting that the excessive nitrates which we find are the result of bacterial action.

In order that the reader can have a more definite idea of the amount of nitrates which have been found in some of these once arable soils, I am giving below in Table No. 3, a few figures on this point which have been furnished to me by Dr. Headden.

By way of comparison, I may say that an average amount of nitrate, expressed as nitrate of soda, for our cultivated fields is from .0037 to .0121 per cent., 150 to 450 pounds per acre-foot.

*Table No. 3. Nitrates in certain nitre soils.*

| Source | Material examined | Percent water soluble | Percent nitrates in water soluble | Percent nitrates in air dried soil |
|---|---|---|---|---|
| Black spot in barley field.. | Surface soil two inches | 13.4 | 41.859 | 5.628 |
| Young orchard | Surface soil | 22.466 | 29.114 | 6.54 |
| Young orchard | Surface soil two inches | 8.23 | 8.173 | .673 |
| Alfalfa field | Top soil five inches | 7.78 | 33.06 | 2.571 |
| Oat field | Surface soil two inches | 5.42 | 50.221 | 2.722 |
| Orchard | Top soil 12 inches | 6.51 | 43.57 | 2.837 |
| Corn and rye... | Surface soil | 4.67 | 7.352 | .342 |
| Old orchard | Surface soil | 6.65 | 5.746 | .382 |

These figures may mean more when I say that one of the above samples, which carried 2.873 per cent. of nitrates in the

(1) Bacteriological Studies of the Fixation of Nitrogen in Certain Colorado Soils, Bulletin 179, Colorado Experiment Station, 1911.

surface foot, contained nitrates corresponding to 113,480 pounds, or 56.74 tons per acre foot; in another sample, taken to a depth of five inches, the area involved being about eight acres, sodic nitrate corresponding to 344,000 pounds or 172 tons was found in the surface five inches; in the top four inches of another eight acre tract, the equivalent of 189,971 pounds or 95 tons was found.

With such quantities of niter in the soil as these figures indicate, it seems hardly necessary to look elsewhere for an explanation of the death of our trees and crops.

Our laboratory studies and field observations have led us to believe that a number of factors are concerned in bringing about this sad condition of certain Colorado soils. There seems to be little doubt that in many cases the trouble has been aggravated by the too liberal use of irrigating water. To over-irrigate seems to be a common fault with many of our agriculturists. Azotobacter thrives best when the soil contains from 15 to 18 per cent. of moisture, practically the same as that required by growing crops. It does not succeed well where the ground is too wet or badly seeped; however, a constant supply of moisture favors its development. Continued, clean cultivation stimulates the activity of the organisms both by aerating the soil, and by raising the soil temperature through the free access of the sun's rays. The neutral or alkaline reaction of Colorado soils, due to the large amounts of carbonate, is unquestionably the limiting factor which makes our soils superior to those of the East and Middle West in promoting the growth of Azotobacter.

The one objection that has been raised to the Azotobacter theory, as an explanation of the excessive nitrogen, is the small amount of organic matter in our soils from which to derive the energy necessary for such a large amount of fixation. In a measure, this is true, if we understand the term *organic matter* in the ordinarily accepted sense; our soils are not rich in this constituent. It has been demonstrated that some of the simpler green plants that grow in the soil and in water, known as algae, can furnish Azotobacter with this energy. Following this clue, we have undertaken a systematic study of the algae which occur in the niter soils, and I am glad to be able to state at this time that our search has been richly rewarded. Professor Robbins, who has had charge of this phase of the investigation*, has found some twenty-four different species of blue-green algae, occurring in

*Bul. 184, Part II, Colo. Exp. Station, "Algae in Some Colorado Soils," June, 1912.

relatively large numbers, in these areas. If it is true that algae and organic matter are equally valuable as sources of energy, then there should be no question about energy for Colorado Azotobacter. However, in regard to algae and organic matter being the sole sources of energy for these organisms, we are open to conviction.

### *Symbiotic Fixation of Atmospheric Nitrogen.*

The liberal use of leguminous crops such as red clover and alfalfa in the role of green manures has come to be recognized today as one of the most important steps toward placing our agriculture upon a modern, scientific basis. There is not a practical farmer but who acknowledges the inestimable value of plowing under a heavy alfalfa sod for potato land. If he is a successful man, he does not, or at least he should not, follow wheat with wheat, but seeds his field to alfalfa or some other leguminous plant which he has found by experience will make up in some mysterious way for the deficiency in soil fertility caused by the preceding crop. This is the principle upon which the rotation of crops is based.

If the Leguminosae possess such restorative properties, there must be some peculiarity in their nature and habits to account for this remarkable power. From the earliest days of agriculture, it has been recognized that this family of plants has a decidedly beneficial effect upon the soil. Almost nineteen hundred years ago, it was observed and noted by such men as Pliny the Elder that, "The bean ranks first among the legumes. It fertilizes the ground in which it has been growing as well as any manure. The lupine enriches the soil of the field or vineyard as well as the very best manure. The vetch, too, enriches the soil and requires no attention in its culture." Varro, in De Re Rustica, 1, 23, writes, "Legumes should be sown in light soils; indeed they are planted not so much for their own crop as for the following crop, since when they are cut and kept upon the ground they make the soil better. Thus the lupine is wont to serve as a manure where the soil is rather thin and poor." The early writings on agriculture are full of just such references to the importance and necessity of including some leguminous crop in the regular rotation. Naturally, the explanations for this conservation of fertility were many and various, but the one which received most favor was the belief that the root system of these plants was much more extensive than that of grains and root crops, and in consequence brought up plant food from greater depths, which was not only available for the legume, but also served for subsequent crops. Thaer in 1809 ventured the statement, without any experimental evidence, that the cultivation of leguminous plants might improve the soil by taking up nutrient material from the air and depositing it in the soil by means of the roots and stubble. In the light of our present knowledge, this was, indeed, a remarkable conjecture. Some years later John showed that there was not only an increase in humus following a leguminous crop but also a definite increase in the nitrogen content. This discovery led to numerous attempts to explain the source of the added nitrogen. The most common theory advanced for this phenomenon was the absorption of nitrogen gas by the plants through the leaves, but the classic experiments of Boussingault, in 1854, together with those of Gilbert, Lawes and Pugh showed the fallacy of any such idea. Nothing which approached an explanation of the question was reached until 1886 when Helriegel and Willfarth demonstrated that the source of nitrogen for this class of plants was unquestionably the air, and that when such plants were grown in nitrogen free soil, the growth always took place after the formation of nodules or swellings on the roots, and therefore there must be some definite relation between nitrogen fixation and root nodules. The results obtained by these two men were later substantiated by the investigations of others and a solution of the long unsolved problem was promised.

This discovery cleared up quite a big part of the mystery connected with the question, and investigators at once turned their attention to finding a possible cause for the formation of these galls or nodules. Insect bites, worm bites and pathogenic fungi were resurrected to explain these hypertrophyed roots. Some considered them fungus growths similar to sclerotia; others looked upon them as modified lenticels, undeveloped buds and spongy roots. As early as 1860, Woronin described these structures in detail and said he believed they were caused by vibrio-like organisms which he had discovered within the nodule, but he carried his work no farther. Later observers also found these so-called bacteroids but paid little attention to their significance. Accounts of their work indicate that they were seeking larger game.

In 1879, Frank showed that these root tubercles were absent on plants grown in sterilized soil, and that they were not mere reserve storehouses for protein substances, but stood in direct causal relation to the fixation of atmospheric nitrogen. Although Woronin almost thirty years before had discovered that these enlargements were filled with micro-organisms, their true bacterial nature was not definitely established until 1888 when Beijerinck isolated and grew them upon an artificial culture medium composed of a decoction of pea leaves, gelatin, asparagin and saccharose. To the causal organism he gave the name *Bacillus radicicola.*

Following close upon the discovery of the relation of nodule bacteria to nitrogen fixation in the Leguminosae came the idea of utilizing these bacteria commercially. Experiments had shown that where soils were deficient in these germs, they could be made much more productive if inoculated with a soil known to contain an abundance of the coveted organisms. Accordingly, there have appeared on the market in recent years pure cultures of these bacteria under the trade names of "Nitragin," "Nitro-Culture," etc. It was intended primarily to use this material on the seed, but it could be employed to inoculate the soil if desired. Columns of print have been used to exploit these preparations which are offered for sale at the modest price of $2.50 for material sufficient for one acre.

The first cultures that were distributed in this country were put up in a dry condition on small tufts of absorbent cotton. From these, the purchaser prepared his own liquid culture with which to inoculate the seed by adding the dried material to a certain nutrient solution, the ingredients of which accompanied the cotton. This method failed for two reasons: first, the bacteria could not withstand the drying on the cotton; and second, the farmer possessed neither the facilities nor the technical skill necessary to grow the liquid cultures and keep them pure. The outcome was cultures of doubtful purity and virulence, with a glaring lack of uniformity and agreement in the results obtained by using them. This difficulty has been overcome in a large measure by the preparation and sale of concentrated liquid cultures and cultures put up on a solid medium, so that all the purchaser is required to do now is to shake up or mix the cultures with a stipulated amount of clean water, and use this at once to inoculate the seed. Kellerman, of the U. S. Department of Agriculture, reports successful inoculations in 76 per cent. of his field tests with the liquid culture, and Edwards, of the Guelph, Ontario Experiment Station, has secured positive benefits in 65 per cent. of his trials with the solid form.

As the question stands at present in the United States, practical experiments have shown that the use of pure cultures is attended with much uncertainty. Where the soil is well adapted to a leguminous crop, pure culture inoculations have succeeded very well, but where the soil conditions are adverse, the simplest, surest and most economical method of inoculation is by means of soil collected from a locality where the desired bacteria are abundant as indicated by the nodules on the roots of plants. One to two hundred pounds of such soil per acre scattered over the field will almost always produce a satisfactory inoculation, other things being favorable.

Although the nodule forming bacteria are cross-inoculable to a certain extent on different legumes, a higher per cent of successful inoculations has been obtained when the culture employed has been isolated from the same species as the legume to be inoculated. For this reason, when ordering either cultures or soil, the specific legume for which the material is desired should be stated. For example, an alfalfa culture should be purchased for alfalfa, and not a bean or a cow pea culture; the same applies to soils.

In using soil for inoculating land, the danger of introducing obnoxious weeds and plant diseases must not be overlooked. In this connection may be mentioned the recent discovery that the organism of crown-gall, *Pseudomonas tumefaciens,* is widely distributed in cultivated soils, and that its attacks are not confined to fruit trees only, but that they extend to the sugar beet, salsify, tomatoes, and many other plants, including the legumes.

The chemical reaction of the soil has been shown to be a limiting factor to successful inoculation, neutral and alkaline soils being preferred. Another investigator has observed that seeds in swelling, previous to germination, secrete a substance which tends to prevent the formation of nodules. The character of the soil, the subsoil, and the drainage are additional factors which must be taken into consideration.

## CHANGES IN MINERAL SUBSTANCES.

In addition to the carbon and nitrogen which enter into the composition of plant tissues, there are several other elements equally indispensable to their growth. Phosphorus, potassium, sulfur, calcium, magnesium, iron and silicon, all share in the make-up of green plants. Inasmuch as these elements occur in all soils, more abundantly in some than in others, we have given ourselves little concern over the time when they shall cease to be plentiful. Already, the potash, phosphoric acid, and lime (calcium) have become practically exhausted in some soils, and they are being supplied in the form of commercial fertilizers as superphosphate of lime, sulphate of potash and limestone respectively. In some soils, it is not so much a question of the supply being depleted as it is a matter of converting the material at hand into forms which plants can use. It is this phase of the question which will be taken up in the next few pages.

*Phosphorus.*

Soil phosphates as they occur in Nature, are but slightly soluble in water, and during the growing season, when the demand is heavy, they often fail to go into solution rapidly enough to satisfy the needs of plants. In soils where the phosphoric acid is low, the deficiency is usually made up by applying some form of commercial fertilizer known to contain a considerable quantity of phosphorus. For this purpose, either superphosphate of lime, ground bone, phosphate rock, or Thomas slag may be used. With the exception of the superphosphate, the phosphorus in the other materials is in an insoluble form, and therefore of no immediate value to plants. As has been noted before, during the decomposition of organic matter, a number of organic acids are formed by soil micro-organisms. It will be remembered, also, that quantities of carbon dioxide are liberated during sugar and starch fermentation, and that this unites with water to form carbonic acid. Now, while all of these acids are weak, relatively speaking, they nevertheless play a very prominent part in bringing the insoluble phosphates into solution.

Some time ago the writer conducted a series of experiments to determine the value of these acids as solvents for the phosphate of ground bone and phosphate rock. The results of this work* indicated that when bonemeal was added to milk, and the milk was allowed to sour, 25.31 per cent. of the phosphate was made soluble by the lactic acid which developed in the milk. Again, when ground bone was added to beer wort which was undergoing both alcoholic and acetic fermentation, 53.55 per cent of the phosphate became soluble in 15 days. Employing dilute lactic acid, 0.1 per cent., 3.13 per cent. of the bone phosphate was rendered soluble in five days; while the same strength of acetic acid gave 4.12 per cent. These figures will suffice to show that the dilute organic acids, though weak, are nevertheless potent factors in bringing insoluble compounds into solution. Other experiments conducted at the same time lead us to believe that acids are not the sole solvents, for, under favorable conditions, certain soil bacteria, independent of acid formation, are capable of converting small quantities of insoluble phosphates into a soluble form. In one case, 1.19 per cent. of the insoluble phosphate

* The Solvent Action of Soil Bacteria upon the Insoluble Phosphate of Raw Bone Meal and Natural Raw Rock Phosphate. Sackett, Patten and Brown. Special Bulletin No. 43, Michigan Experiment Station. 1908.

of bone was made available; in another, .46 per cent of the phosphate of phosphate rock was changed into a soluble form. In neither case was any acid present. Similar phenomena have been reported by Stoklasa, and Koch and Kroeber. Although our data on this line of investigation is very meager, there is reason for believing that the conversion is brought about through enzyme action.

The marked deficiency of phosphoric acid in acid soils is further evidence that soil acids are directly concerned in liberating phosphoric acid from its mineral compounds. At the same time that soil micro-organisms are breaking down organic substances and liberating acids to dissolve the phosphate, they, themselves, are appropriating small quantities of phosphoric acid for their own use. Like the higher plants, we find phosphates present in their tiny cells in very appreciable quantities. The ash of bacteria and fungi frequently contains more than 50 per cent. of phosphate.

Plants obtain their phosphorus from the soil as soluble phosphate, and animals, in turn, feed upon these plants. Both contain phosphates in their tissues, but in forms too complex to be of service to future generations of plants until they are simplified. This is accomplished in time by bacterial decomposition, and the complex phosphates are again returned to the soil. Thus, the phosphorus cycle in Nature is completed.

*Potassium.*

The principal source of potassium in our soils is the potash feldspar which occurs in quantity in the country rock. Through countless ages, these great masses of granite have been crumbling and disintegrating, due to the action of heat and cold, freezing and thawing, wind and rain, until today the finely divided particles constitute a large part of the soil. Orthoclase, the potash bearing feldspar, is a silicate of potash and alumina. However, under the agencies of decomposition, its identity is lost in the formation of potash zeolites, hydrated silicates of alumina and potash. It is in this form that the potash is found in the soil. Such a compound is far too complex to be of any immediate benefit to plant life unless some easy means of getting it into solution can be found. Here, as with phosphorus, the organic acids and carbon dioxide produced during the decomposition of organic material by soil bacteria attack the potash zeolites and set free the potassium, as potassium carbonate, which is readily soluble in water. The nitric acid formed during nitrification and the sulphuric acid resulting from the oxidation of hydrogen sulphide together with various organic acids may also combine with potassium to form potassium nitrate, potassium sulphate and a number of organic salts of potassium. Once more we see that the micro-organisms of the soil are the responsible agents in restoring potassium to the soil in a form which plants can use.

### *Sulphur.*

In our arid soils, sulphur abounds in calcium sulphate as gypsum, and in sodium sulphate and magnesium sulphate, two of our common white alkalies.

When protein compounds undergo decomposition in the absence of oxygen, quantities of hydrogen sulphide are evolved. This gives rise to the disagreeable odors so characteristic of putrefaction. The oxidation of the hydrogen sulphide, liberated in this manner, furnishes energy to a group of organisms known as the "sulphur bacteria." As a result of this oxidation, free sulphur is produced which may often be seen within the bodies of the bacteria as minute red granules. The sulphur may be further oxidized to sulphur dioxide which later may be changed to sulphuric acid in the presence of oxygen and water. Such a thing as a free sulphuric acid in our soil, however, would be a rare occurrence, for it would combine immediately with a lime or magnesium base to form calcium or magnesium sulphate. Plants obtain the sulphur for their proteids from some of the soluble sulfates and animals feed upon these plants. When plants and animals die, the sulphur present in their tissues is restored to the soil through the combined action of decomposing and sulphur bacteria.

### *Iron.*

Among the larger bacteria, we find certain groups which are characterized by a deposit of iron rust or iron oxide in the sheath surrounding the cells. Attention has been called to these, particularly because of the trouble which they have caused in municipal water supplies by plugging the pipes with their growth. These organisms are said to possess the power of precipitating iron oxide out of a dilute solution of iron salts; and through the exercise of this function, great masses of a slimy, gelatinous, rusty growth are produced in the water mains which give no end of annoyance to those who have charge of the distribution of such water.

In considering the relation of bacteria to the iron compounds, the deposits of bog iron in swamps and wet places are of considerable interest since it was believed at one time that they owed their origin to the reduction of iron sulphate by bacteria. Later authorities, however, claim that the precipitation of the iron oxide is a mechanical rather than a chemical process, but whether chemical or mechanical, it is a significant fact that bacteria are intimately associated with the phenomenon.

Soil bacteria, like other plants, need a little iron for their growth. Lipman and Koch have noted that this is particularly true for the nitrogen fixing organisms.

*Calcium (Lime) and Magnesium.*

So far as furnishing favorable conditions for the growth and activity of micro-organisms, the arable soils of Colorado offer all that could be desired. The one thing, above all others, which makes them especially well adapted to the development of soil bacteria is their neutral or alkaline reaction. This is made possible by the presence of quantities of calcium and magnesium compounds. Frequent reference has been made already to the damage which may result to an otherwise fertile soil by allowing it to become acid. When this condition exists practically all bacteriological processes cease. The principal function of the calcium and magnesium carbonates is to neutralize the various acids formed during protein-decomposition; to combine with the nitric acid resulting from nitrification by which calcium and magnesium nitrates are formed; and to unite with the sulphuric acid set free by the so-called "sulphur bacteria" to form calcium and magnesium sulphates. Thus, the soil acids, which if allowed to accumulate might prove detrimental, are neutralized, and all injury to the soil flora from this cause is prevented.

Although our soils at present are rich in calcium carbonate and sulphate, there is nevertheless a large annual loss due to the appreciable amounts which are carried away in the drain waters. We have seen that carbon dioxide is generated in quantity during the fermentation of sugars, starches, etc. When this gas is dissolved in water it constitutes carbonic acid, which has a marked solvent action upon carbonate of calcium. Through this agency, immense caves have been formed in the limestone regions of the United States, and tons of rock are transported annually to the ocean in solution as the acid carbonate of lime. A small portion of this is utilized by the various shellfish in the construction of their shells; the remainder goes to form the limestone deposits of future generations.

## PLATE I

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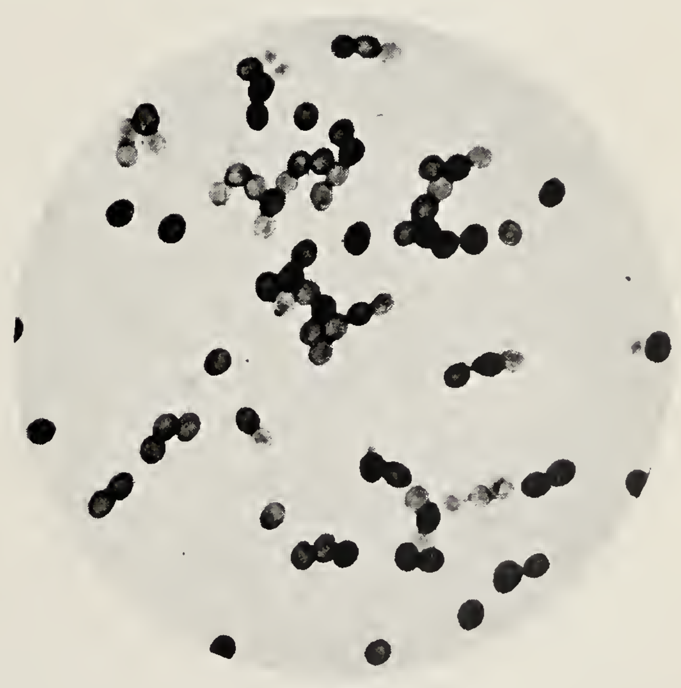

6.

## PLATE II

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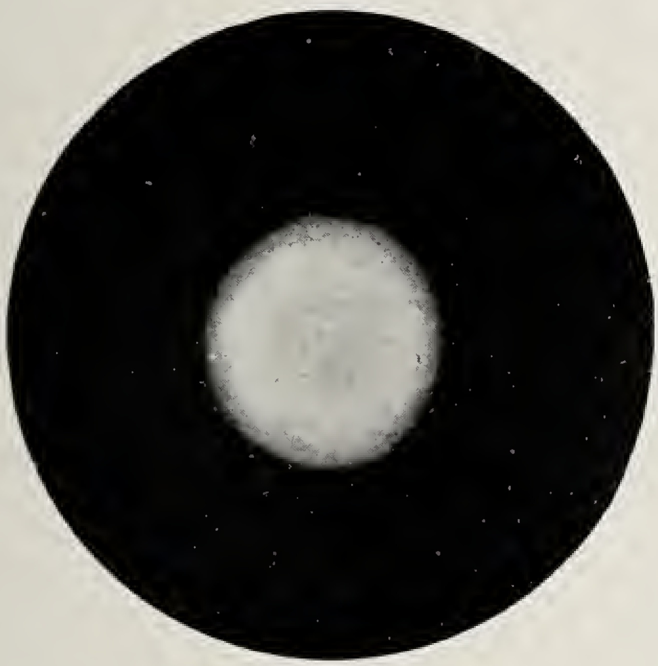

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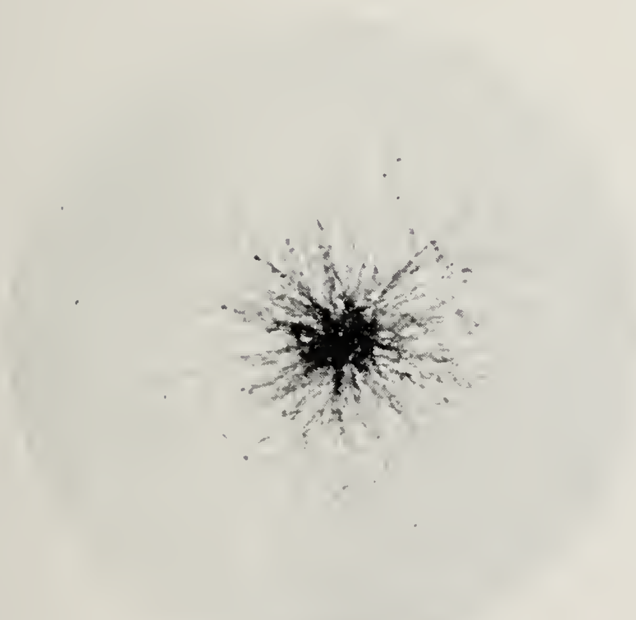

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# PLATE III

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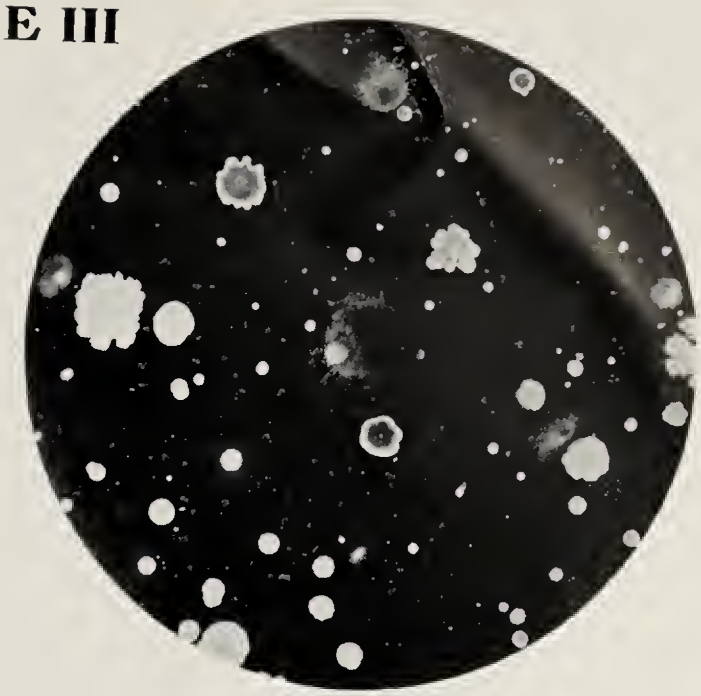

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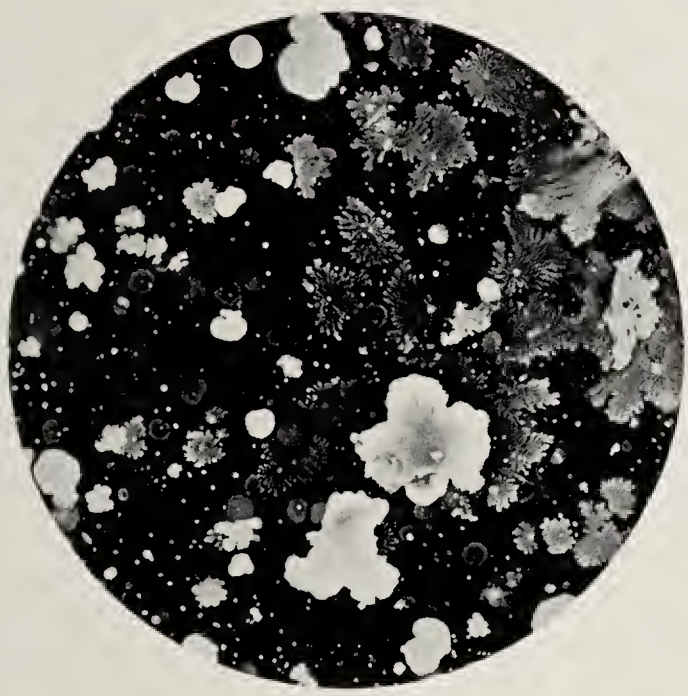

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4.

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## EXPLANATION OF PLATES.

### *Plate I.*

Fig. 1. Staphylococcus pyogenes aureus, a pus-forming coccus; magnified 1000 times.
Fig. 2. Azotobacter chroococcum, a non-symbiotic nitrogen fixing coccus; magnified 1000 times.
Fig. 3. Bacterium mycoides, a denitrifying bacterium (rod type) found in soil; magnified 1000 times.
Fig. 4. Spirillum rubrum, a harmless spirillum found in water; magnified 1000 times.
Fig. 5. Saccharomyces cerevisiae, the yeast cells from compressed yeast; magnified 1000 times.
Fig. 6. Spores of Penicillium glaucum, the common blue mold on canned fruit; magnified 1000 times.

### *Plate II.*

Fig. 1. Colony of Bacterium mycoides.
Fig. 2. Colony of Bacterium tuberculosis (human).
Fig. 3. Colony of Pseudomonas medicaginis, the cause of the stem blight of alfalfa.
Fig. 4. Colony of Bacterium diphtheriae (human).
Fig. 5. Colony of Sphaerella rubina, a fungus or mold causing the spur blight of red raspberries.
Fig. 6. Colony of Azotobacter chroococcum.

### *Plate III.*

Fig. 1. A *pure culture* of Bacillus amylovorus, the germ of pear blight. Note the similarity of the colonies in a pure culture.
Fig. 2. A *mixed culture.* Note the unlike character of the colonies in a mixed culture.
Fig. 3. Colonies of bacteria from soil.
Fig. 4. Colonies of bacteria from water.
Fig. 5. Colonies of bacteria and molds from dust.
Fig. 6. Colonies of bacteria from air.

b

Bulletin 197 May, 1914

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

# HOG CHOLERA CONTROL

By GEO. H. GLOVER

# NECROTIC STOMATITIS

By I. E. NEWSOM

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station

FORT COLLINS, COLORADO

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# Hog Cholera Control

By GEO. H. GLOVER

## INTRODUCTION.

Hog cholera is the greatest menace to the hog raising industry. Were it not for cholera, hog raising in practically all sections of Colorado, would be one of the most profitable branches of the livestock business. It is conservatively estimated that more than 90 per cent of the deaths of hogs from disease are caused from hog cholera.

Until recently the idea prevailed that hogs in Colorado, because of altitude and climatic conditions, were immune to cholera and this delusion has no doubt been responsible for much spreading of the disease in the state. The loss from hog cholera throughout the nation exceeded one hundred million dollars in 1913, and in Colorado over half a million, mostly in the San Luis valley, with several outbreaks in the Arkansas valley and the northern portion of the state, east of the mountains.

We are convinced, after our experience with hog cholera in the San Luis valley, that the disease can be controlled, but to accomplish this throughout the state there must be active and efficient supervision, combined with hearty co-operation on the part of hog raisers, importers and dealers.

This bulletin is prepared primarily to furnish information to the farmer as to what will be expected of him in a united effort to control hog cholera in the state.

The principles of farm sanitation and a practical application of the same are not generally well understood, neither is the importance of this subject fully appreciated by the farmer. If the farmer had made as intelligent use of the principles of sanitation on the farm as has been made in the control of diseases in man, the extensive dissemination of hog cholera, tuberculosis, contagious abortion, glanders and other infections would never have happened.

## CAUSE OF HOG CHOLERA.

There is only one thing that will cause hog cholera and that is the specific germ of the disease. Worms will not cause hog cholera, neither will poor feed, impure drinking water, change of feed, crowding them together in transportation, or filthy conditions generally, but all these things may be looked upon as accessory causes, inasmuch as they weaken the constitution and natural resistance to the disease.

Hog cholera made its first appearance in the United States in the year 1833 and investigations have been conducted almost constantly since that time to determine the cause. Salmon and Smith, in 1885, isolated and described an organism which they called *Bacillus cholerae suis* and declared it to be the causative factor. In 1903 de Schweinitz and Dorset demonstrated conclusively that the infecting agent existed in the body fluids and would pass through the finest porcelain filters. Dorset, Bolton and McBryde later demonstrated that the *Bacillus cholerae suis* was not the specific germ of hog cholera, but that it was caused from an ultra microscopic organism that was non-filterable.

Recently Walter E. King, of the Research Laboratories of Parke, Davis & Co., has reported the finding, and seemingly has demonstrated, a protozoan which is uniformly present in the blood of hogs affected with cholera. This organism has been named *Spirochaeta suis* and while the author assumes the probable relationship of this organism to hog cholera, as the causative factor, yet at this writing he admits that its significance in this connection is not definitely determined.

## SUSCEPTIBILITY.

The period of incubation is the time between exposure to the disease and the appearance of the symptoms and it varies widely in different diseases. In hog cholera it varies from four days to two weeks, depending upon the age of the hogs, their thrift, natural resistance to the disease and the virulence of the infection.

In most outbreaks of cholera there are a few individuals that have a high degree of resistance and do not contract the disease, and a few may have it and recover. All breeds of hogs, including the mule-foot, are about equally susceptible and there is no appreciable difference between the breeds as to the number that will ultimately recover.

## SYMPTOMS.

There are at this time no other serious diseases among hogs in Colorado, and any disease making its appearance among hogs should be looked upon with suspicion. The symptoms manifested are not uniform throughout, but the first indication is usually a refusal to come to the trough for food and to lie buried deep in the litter. There is fever, and the animal sways from side to side as he walks. There is usually constipation at first, followed by diarrhoea with yellowish or dark colored feces. The skin on the belly and back of the ears sometimes shows a purplish red discoloration, but this symptom is not to be depended upon and is more liable to be found in the acute cases. The respirations are rapid, the heart beat is quickened, the eyes may be inflamed, and the general appearance of the animal is one of extreme dejection. Many outbreaks of hog cholera are mixed infections and this greatly complicates the symptoms. There may be a cough and there may not, depending upon whether the respiratory tract and lungs are involved.

## POST MORTEM APPEARANCES.

The lungs may reveal extensive inflammation, or there may be collapsed areas, quite small or extensive. Usually the lungs are covered with minute blood spots, pin-point in size, or the spots may be purplish in color and much more extensive.

In the same outbreak one hog may show extreme involvement of the lungs, while in another case the lungs may appear nearly normal, save for the minute pin-point hemorrhages which are most always present. The heart may have blood spots on it from hemorrhages, but as a rule has very few lesions.

The stomach usually shows congestion of the mucous lining in the lower portion and occasionally ulcers will be found in the mucous coat.

The kidneys may appear quite normal, but more often will be found congested and occasionally will present a characteristic "turkey-egg" appearance from minute hemorrahagic spots which are better revealed by removing the kidney capsule.

The spleen or "melt" presents various lesions. Frequently it is congested, enlarged and softened. In chronic cases it may be small and hardened from connective tissue hyperplasia.

The bladder may be found quite normal, or there may be extreme congestion and the inner lining will be thickened, "lumpy" and have dark purple spots. The intestines are quite sure to be involved and show much congestion. Near the ileo-cecal valve, where the small intestine opens into the large one, there is almost sure to be found erosions and characteristic button-shaped ulcers which stand out prominently from the surrounding mucous membrane.

Examination of the lymphatic glands is of prime importance in suspected cases of hog choelra. These glands in hog cholera are congested and enlarged. The color is changed from a light gray to red or almost black. Some of these glands may be found along the intestines on the outside, (mesenteric) beneath the skin, high up on the inside of the thighs, (inguinal), near the lungs, (bronchial and mediastinal), and in the neck near the angle of the jaw.

## TREATMENT.

Although many "cures" for hog cholera have been advertised, none of them have stood the test and farmers should be on their guard against proprietary remedies which are guaranteed to not only prevent hog cholera, but cure it as well, and will do neither.

## HOG CHOLERA IN THE SAN LUIS VALLEY.

The plan of control adopted in the San Luis Valley, Colorado, succeeded and is to be recommended. In this instance, the chief consideration was given to quarantine and disinfection. Anti-hog cholera serum was used freely, but virulent blood was not used for simultaneous vaccination. In the twelve months prior to February, 1913, fully 60 per cent of hogs in the San Luis Valley died of cholera and the loss was estimated at $400,000. One year later we find, as the result of organization, efficient veterinary supervision and hearty co-operation, that there are but two farms in the valley where cholera exists. These farms are now under close quarantine and the disease is practically eradicated.

### REPORT OF WORK DONE BY THE MONTE VISTA HOG GROWERS' ASSOCIATION FROM FEB. 10, 1913, TO FEB. 1, 1914.

| | |
|---|---|
| Number of visits | 823 |
| Average visits per day | 2.34 |
| Number of visits for other purposes than treating hogs | 313 |
| Places on which dead hogs or other dead animals were found | 58 |
| Number of hogs vaccinated | 2,940 |
| Number of these hogs in infected or exposed herds | 2,410 |
| Number of hogs that died after vaccination | 367 |
| Per cent of hogs that lived | 87½ |

More than one-half the loss occurred in three herds. In these the disease had existed for two weeks or more, the hogs were in a weakened condition, lousey, constipated, and received almost no care, both before and after being vaccinated.

In October we had difficulty in getting serum owing to the extensive outbreaks of hog cholera throughout the middle west states, and to this trouble was due our greatest losses. Even then, if the sick hogs had been isolated, the loss would have been greatly reduced, but the owners were too busy to give the hogs proper attention and suffered accordingly. The chief value in the use of the serum is early administration. It has been proven beyond a doubt that once the disease has gained headway, treatment is of no value.

The prime factor in the control of hog cholera is sanitation and care of the hog. Keep the hogs in a healthy condition by the use of properly balanced feed. Avoid sudden changes of feed—they oft-times cause bowel disorders. See that the water supply is pure and wholesome. Filthy, stagnant water, and water from ditches is a probable source of disease. Clean water is a necessity for the health of the hog. And this is usually the least expensive ingredient in the make-up of the hog and at the same time the most important, it should be supplied in abundant quantities.

Provide a wallow or shallow vat for the hog and he will dip himself and keep free from lice and other germs. Have a good dry shed, free from draughts, for his sleeping quarters. A straw stack is absolutely unfit for hogs to sleep in. They burrow into the stack, become heated, and upon coming out are in prime condition to contract pneumonia. Clean this shed out weekly and sprinkle lime freely about.

Keep your neighbors, their hogs and their dogs away from your hogs and pens, and keep yourself away from his. Remember that hog cholera is a germ disease caused by a germ, and in no other way, and if you keep your premises free from germs your hogs will never have cholera.

The time to clean up is before the disease gets into the herd and a few hours a week spent at this will mean dollars and cents to you later. If you take proper care of a herd of two hundred hogs you will have most of your time involved.

Give your hogs good care and attention and you will be justly rewarded, for the hog is the best profit-maker on the farm.

This association, formed one year ago, for the purpose of eradicating hog cholera in this part of the San Luis Valley, has been most successful in its purpose. Any farmer or business man should feel proud to be a member of an organization whose work has been so effective. Our success is being watched throughout the entire middle west and the methods adopted and employed by this association in combating the dreadful disease, are meeting hearty approval of the best informed experts engaged in a like fight against hog cholera, and is frequently being mentioned in various agricultural journals throughout the country.

In forming your own conclusions, first compare the loss in this vicinity during 1913 with that during the year 1912, and please remember the summary is made up from results obtained in herds which were treated by our veterinarian only, and we must not lose sight of the saving of neighboring herds by reason of the disease being stopped soon after breaking out and not allowed to spread.

The association has worked diligently with the sole purpose in mind of adopting and using the most effective and expedient method known to experienced and scientific men today, to eradicate hog cholera in this territory. With the most favorable climatic conditions in our favor, if we will stand together and work with a friendly and mutual purpose, we will, by co-operation and eternal vigilance, have regained our position as one of the best and most profitable hog producing districts in the United States.

## FINANCIAL STATEMENT.

Covering Period from February 10, 1913, to January 31, 1914.

Receipts.

| | |
|---|---|
| Membership | $1,600.00 |
| Donations | 804.50 |
| Fees from Non-members for Services of Veterinarian | 70.25 |
| | $2,474.75 |

Disbursements.

| | |
|---|---|
| Salary of Veterinarian to January 10 | $1,980.00 |
| Salary of Secretary to January 10 | 165.00 |

| | |
|---|---|
| Expense of incorporating, including purchase of stock certificates, seal, etc., also attorney's fees.................. | 56.70 |
| Printing, stationery, postage and incidental expense.......... | 70.35 |
| Cash in bank .............................................. | 202.70 |
| | $2,474.75 |

CHARLES EDMAN, Secretary.
P. C. GUYSELMAN, Veterinarian.

This bulletin is prepared and sent to the farmers of Colorado in the hope that they will profit by the experience of San Luis Valley and control hog cholera before it has become widely disseminated over the state and its control becomes apparently a hopeless task.

## HOW THE DISEASE IS SPREAD.

Regardless of breed or condition of hogs, they cannot contract hog cholera unless the virus of this one disease is carried to them, any more than you can have a crop of wheat without sowing the seed. Self-interest actuates the average farmer to save his own hogs regardless of his neighbor. From the standpoint of the sanitarian who is seeking to eradicate hog cholera the most important thing is to prevent the carrying of the virus from infected premises.

The following are a few suggestions as to ways the disease is spread:

1. By leaving dead hogs in the fields and ditches or by the roadside. Buzzards, magpies, pigeons, stray dogs and other animals that carry the infection should be looked after. There is a state law which requires that dead animals shall be burned or buried immediately. Burning is preferable, but where there is not sufficient fuel to burn them, such as in the plains district, they should be covered with lime and buried six feet deep.

2. By persons carrying the infection on their feet. It should be remembered that the pig pens are impregnated with the infecting material from the discharges of diseased hogs and the owners of healthy hogs should not go, nor allow the hired help to go, on premises where there are sick hogs.

3. By hogs having access to ditches and creeks where there are diseased hogs upstream. In this case it will be better to remove them at once and supply them with water from a well.

4. By shipping in stock hogs; trailing them along the public roads and failing to observe the state law, which requires that hogs moved from one part of the state to another, or from one farm to another, shall be held eighteen days in quarantine before being mixed with other hogs. This law will work some inconvenience to farmers who have been in the habit of exchanging stock hogs, but

this is a dangerous practice and other arrangements can be made.

5. By shipping hogs to market as soon as they show evidence of cholera. This necessitates either driving them along the public roads to the railroad yards or transporting them in wagons. While en route, both before loading on the cars and after, excreta is scattered along the highways, spreading infection to adjacent farms. All railroad yards and cars used for shipping hogs are looked upon as infected and hogs shipped either by freight or express, save for immediate slaughter, should be treated with anti-hog cholera serum before shipping, or, in case of a short journey, immediately upon arrival at their destination.

6. By feed that has become contaminated. Corn and other foodstuffs are sometimes hauled in a wagon that was previously used for transporting hogs to market. Garbage from hotels and restaurants fed to hogs without being thoroughly cooked is a source of danger because of uncooked pork rinds from diseased carcasses and entrails from chickens kept on cholera infested farms. Hogs kept around slaughter houses and fed offal from cholera infected hogs contract the disease.

7. By many ways too numerous to mention it is possible for hog cholera infection to be spread to healthy hogs, but it should be remembered that in the great majority of cases infection can be easily traced to conditions that might have been avoided, and is to be charged to ignorance, carelessness or indifference.

Hog cholera should be looked upon the same as smallpox, diphtheria and scarlet fever, as an infection, and to be controlled in the main by application of the same general principles of sanitation, with quarantine and disinfection as the prime factors.

## SUGGESTIONS FOR HOG CHOLERA CONTROL.

1. By hog growers associations or other organizations wherein voluntary co-operation is encouraged, and compulsory co-operation can be secured through the offices of close veterinary supervision. Since the state does not provide ample veterinary supervision, farmers' organizations already existing, or new ones, should take active and immediate measures to control hog cholera. The County Agriculturalist may appropriately assume leadership in this work. The organization should be numerically strong enough to represent a majority of the best farmers in a district and financially strong enough to employ a veterinarian for at least part of his time.

Since the law does not provide for the appointment of deputy state veterinarians, it will be well to make the veterinarian employed a deputy sheriff and instruct him to proceed as follows:

a. Visit every farm in his district and leave appropriate written instructions.

b. If hog cholera is found on the farm, specific directions should be given to confine the hogs, move the apparently well ones to clean pens, and at once administer the serum-alone treatment. The remaining hogs should be destroyed and their carcasses burned, or buried deep after covering each carcass with a bushel of lime.

c. Orders should be given to clean the infected pens, burn the litter, remove two inches of the surface soil, whitewash the fences and hog houses, disinfect the feed troughs, and everything that may have become contaminated. A reliable and cheap disinfectant is pure crystals of *carbolic acid,* melted by heat and mixed with water in the proportion of six ounces carbolic acid to one gallon of water. For sprinkling on the floors, manure, bedding and hard ground where the surface soil cannot be removed, *chlorinated lime* (one pound of chloride of lime dissolved in three gallons of water) will be satisfactory. *Corrosive sublimate* (bichloride of mercury) in the proportion of 1 to 1,000 is prepared by dissolving one ounce of corrosive sublimate in eight gallons of water. This drug is very poisonous and must be handled with care. *Formalin* is very useful, especially in closed buildings and is made in five per cent solution by mixing one pint of 40% formalin with a gallon of water.

d. Magpies, pigeons, buzzards, stray dogs or other animals that make the rounds from farm to farm, should be looked after in a way that seems most appropriate.

e. Quarantine signs should be placed conspicuously on hog pens and front gate: *Quarantine—Hog Cholera—Keep Away From Hogs.*

f. The work of the veterinarian in charge should be to not only enforce necessary regulations, but he should seek the co-operation of the farmer by explaining to him *why* it is necessary to guard against every possible means of spreading the infection in the neighborhood. The central thought with the veterinarian in charge should not be to save the hogs for this one man, but to confine the disease on this one farm, and the farmer, if he is a good citizen, will concur, for he will realize that it is "Better to be one of a successful community than the successful one in a community of failures."

g. When the veterinarian visits a farm and finds the hogs healthy, he should investigate the food and water supply and every possible means of infection and advise the farmer accordingly. He should insist on hog pens being cleaned as often as once a week and lime scattered freely in the pens. Many a farmer by eternal vigilance has kept his hogs healthy while his careless neighbor has suffered a total loss of his swine herd.

g. The man with the healthy herd should be instructed to notify the veterinarian at once upon the appearance of disease, and the veterinarian should be ready with a supply of serum to treat them at once by the serum-alone method.

h. There being very little hog cholera in the state, and the object being to eradicate it, the virulent blood for use by the simultaneous method is considered neither necessary nor advisable.

2. Aside from farmers' organizations there seems at present no way to control this or other pestilences among animals. The next legislature should provide deputies for the State Veterinarian with sufficient funds to systematically control this disease before it has become so widely disseminated over the state as to ruin our hog raising industry.

❈ ❈ ❈

# Necrotic Stomatitis

*(Diphtheria in Calves. Sore Mouth Disease in Pigs. Lip and Leg Ulceration in Sheep.)*

By I. E. NEWSOM

## *Introduction.*

These diseases have caused such widespread loss in Colorado during the past ten years, and so many requests for information concerning them have come to the Station, that it was deemed advisable to collect such information as was available and condense it in a short pamphlet, so that the farmers and stockmen might become better acquainted with the symptoms and methods of handling the outbreaks. This is not written as a report of work done at the Colorado Experiment Station, but is intended merely as a collection of facts from a variety of sources in order that they may be presented in concise form for ready reference by the stockman himself.

## *Cause.*

These three diseases, while being caused by the same organism, nevertheless show such differences in symptoms and methods of control, that it is desirable to treat them under separate headings. The cause is always a specific thread-like bacterium (*Bacillus Necrophorous*), that gains entrance through the abraded skin or mucous membrane. This organism seems to be present in practically all


*Calf Diphtheria, Lower Jaw; a, two large ulcers.* *See page* 13.

Colorado soil, where animals are kept, and may at any time produce serious disease in our young animals. It differs from many other disease producing bacteria, in that it does not multiply when exposed to the air, thus it must get in below the surface of the skin or mucous membrane before it can produce serious trouble.

While a wound is necessary for the entrance of the organism, it must not be concluded that this wound need be one that is readily seen. When we consider that the germ could enter an abrasion that was not over one-twenty-five thousandth of an inch in diameter, it can be readily appreciated that wounds are liable to be present in the mouth at any time that are of sufficient size to allow the disease to get a foothold. Especially is this true when animals are placed on rough food, such as coarse alfalfa, or hay containing Russian or Canadian thistles.

## CALF DIPHTHERIA.

### *History and Distribution.*

It is not known exactly how long this disease has infected Colorado calves, but in 1902 and 1903 it was brought so forcibly to the attention of Dr. A. B. McCapes, who was then state veterinarian, that he furnished material for an investigation of the disease, to the United States Bureau of Animal Industry at Washington. The results of the investigation made at that time are recorded in B. A. I. Bulletin No. 67, to which the reader is referred for an exhaustive discussion of the matter.

In 1907 Dr. Chas. G. Lamb, State Veterinarian, after having visited several outbreaks, considered it of sufficient importance that he prepared a special bulletin on the subject, which was published by the State Stock Inspection Board.

Dr. B. F. Kaupp, formerly pathologist to the Experiment Station, studied several outbreaks between 1908 and 1912. From veterinary practitioners all over the state come letters mentioning the disease, and judging from the letters received from stockmen during the last few years, the disease continues to exact its toll from the cattle industry.

Although some communities have suffered more than others, it seems probable that there have been cases in practically every county in the state. The disease seems to have been unusually prevalent in the region between Colorado Springs and Denver, known as the Divide. It has also been frequently reported from North Park.

Young animals are nearly always the sufferers, although it has in a few instances been reported in older cattle. It would seem from this that older cattle acquire a certain resistance, as it seems probable that they are under the same exposure and are as liable to have abrasions in the mouth, particularly since they suffer from "lumpy jaw," the organism of which gains entrance in the same manner.

Teething may account for a part of the unusual prevalence in young animals, as during the time the teeth are breaking through the gums there is an excellent chance for disease-producing organisms to enter.

Most cases are reported in the winter time, when the calves are not at pasture. This seems to be explained by the fact that the coarse hay is more apt to wound the mucous membranes than is the grass at pasture. Further, it is quite probable that the organisms are more numerous in the corrals and around the barns than on the ranges and in the pastures.

*Symptoms.*

The symptoms are of special interest to the stockman since it is by these that he will recognize the disease and an early recognition is of the utmost importance. The ailing calf is first noticed to be dull and may refuse to take food. Often if food is taken it is only partially masticated and is not swallowed, but collects in the mouth in large masses, so that what appear to be large swellings of the cheeks are in reality caused by accumulation of food in the mouth. There will be drooling from the mouth and on opening, a particularly offensive odor will be noticed. In fact, this odor when once recognized is quite characteristic. A close examination will reveal ulcers varying in size from a pinhead to two or three inches in diameter. The ulcer is covered with a thick yellow cheesy mass, which adheres rather firmly to the underlying tissues. This mass will vary in thickness according to the length of time the disease has run. These ulcers are frequently found on the sides of the tongue and alongside of the molar teeth, but may be situated far back in the throat, thus rendering it impossible for the calf to swallow.

The animal at this time will be found to have a high fever, the temperature varying from 104 to 107 F. There may or may not be diarrhoea present. Extreme weakness prevails, the calf sometimes dying within a few days after symptoms are noticed. In some instances, particularly if the disease continues for as much as two or three weeks, the lungs, liver and intestinal tract may show the necrotic patches. Without treatment very few cases recover, but most of those affected die in from three days to five weeks.

*Spread.*

The disease spreads rapidly throughout a herd, but does not spread readily from one farm to another. The probable reason for its rapid spread in a herd, is that all being subjected to the same conditions are equally liable to abrasions in the mouth at about the same time, so that if the organism produces disease in one animal, it will in a considerable percentage of those on the same feed. It seems probable that suckling calves often get the infection from the teats of the mother, that have been contaminated with manure. The organism has been proven to exist in the manure of many animals.

The question of the transmissibility to other animals and to man naturally arises, and in this connection it has been definitely proven that the disease can be transmitted, artificially to pigs and lambs, as well as rabbits and guinea pigs. Since this organism is responsible for a large number of conditions in the different animals, it seems only fair to suppose that it readily passes from one to another. The history of outbreaks that have occurred in the state hardly bear out this contention as, while not unknown, it is rather rare to find the disease affecting more than one species of animal at one time and on the same place. When the disease affects calves it is usually only the calves that are affected. When the hogs are affected the calves do not often show signs of disease, and so we might go throughout the list.

The disease should not be confused with the diphtheria of man, as it is not caused by the same organism and has no relation to it. It seems, however, that men do occasionally contract the disease, although no cases of death have been reported. A few cases of severe sore throat have been attributed to contact with both diseased calves and pigs. Care should, therefore, be used in disinfecting the hands after treatment of infected animals.

*Treatment.*

The matter of treatment, while requiring some trouble, is relatively simple when we consider the fatality of the disease. Fortunately in calves the ulcers do not usually extend beyond the mouth and they are, therefore, quite accessible. The two essentials to remember are that the germ does not thrive when exposed to air and that treatment must be provided before the disease is too far advanced.

Good results have been obtained by forcing open the mouth, scraping off the cheesy layer with a blunt instrument and swabing the denuded surface with any good antiseptic. Special attention must be given to scraping away the cheesy membrane, as this exposes the organisms to the air, in which they soon die. This scraping can be done with the handle, or even the point of a tablespoon. A swab can be readily made by wrapping the end of a small stick with a piece of absorbent cotton. The antiseptic to be used rests somewhat with the individual. Excellent results have been obtained with a 5 per cent solution of carbolic acid (a tablespoon and a half of acid to a pint of water), although some report even better results with stronger solutions. Direct application of the antiseptic to the ulcer is preferable to a general irrigation of the mouth, as a stronger antiseptic can be used and the germicide is brought into direct contact with the organisms.

Care should be used that the animal does not swallow any considerable percentage of the solution. Creolin in the same strength, potassium permanganate 2 per cent and Lugols solution of iodine *straight*, are very useful. This treatment should be employed daily until the animal shows considerable improvement. Reports from this treatment have been very satisfactory, many saying that after the treatment was started they did not lose an animal.

Prevention consists in isolating all animals infected, and complete disinfection of the barns and corrals with a 5 per cent solution of crude carbolic acid, six ounces to the gallon. This can be best administered with a spray pump. The solution should contain enough lime so that it will be quite apparent when all surfaces have been covered with the spray. Some corrals seem to be so badly infected that the disease breaks out regularly every year. In such places, thorough disinfection is almost a necessity. It is doubtful if much can be done by withholding certain kinds of food because most any kind of hay is likely to produce abrasions in the mouth. It would certainly be wise, however, to feed the best hay to the calves, giving that which is coarser and contains thistles to the older animals.

## SORE MOUTH IN PIGS.

### *History.*

Sore Mouth or Necrobacillosis of pigs first received general attention in Colorado in the years 1904 and 1905. For the next two or three years it reached rather appalling proportions, particularly in the San Luis Valley, where it became such a menace to hog raising that it practically stiffled the industry. During those years it became so prevalent in the young pigs about Denver that it was causing more trouble than cholera. This meant much when it is remembered that cholera was a constant resident in the pens at that time. Also it was responsible for the death of many hogs throughout the Arkansas Valley, in Northern Colorado and along the Platte as far east as the state line.

Unquestionably there was a generous admixture of cholera in some of these outbreaks, and it has always been an open question in the minds of those who made the investigations as to just how much of the loss to attribute to cholera and how much could properly be charged to the bacillus necrophorous. Many outbreaks showed typical necrotic ulcers in the mouth and throughout the alimentary canal with many skin and sheath lesions, while others gave the lesions which are recognized as typical for cholera. Even this would not have complicated matters so much had there not been outbreaks in which all gradations from the lesions of pure necrotic stomatitis to the typical lesions of hog cholera were present in the same herd and at the same time. This problem of the relation existing between these two diseases, the Veterinary Division of the Experiment Station has set itself to work out. In the meantime we can only say that there are two very serious and menacing diseases of hogs in our state, that one of them is necrotic stomatitis and the other is cholera, either of which is to be found uncontaminated by the other, but that in a considerable number of cases the bacillus necrophorous acting as a secondary invader in hogs already ill with cholera, becomes so virulent and produces such extensive lesions as to almost obscure the original disease.

Since 1909 the disease has not attained its former virulence, but during this time there has been more cholera than ever. It is to be remembered, however, that if the proper conditions arise this may at any time again become a very serious disease.

*Symptoms.*

From our experience in Colorado we must describe the symptoms of this disease somewhat differently from the orthodox view. While it most commonly attacks the young pigs, particularly sucklings, it has by no means confined itself to these animals, spreading rapidly through the herd and killing many old hogs. The young pigs are usually attacked first and with them the fatality was much greater, but the old animals died in great numbers.

The ulcers frequently started in the mouth, but the bacteria seemed especially virulent so that extension was rapid. There was invasion of bone and loosening of teeth and even channels from the mouth to the nasal cavity or even to the exterior were not rare. In little pigs the toxemia was so great that death often resulted with no other lesions than those in the mouth, but in the older animals large cheesy ulcers, yellow, or yellowish brown in color, were to be found in the stomach and throughout the large intestines. These ulcers in the stomach were not uncommonly the size of the palm of a man's hand. The cecum was frequently found to be lined with a solid membrane of this cheesy material, there being no differentiation between the margins of individual ulcers. Many of these animals showed deep cheesy ulcers on the skin, especially of the legs, and many of the males exhibited like masses of necrotic material within the sheath. These acute cases were always associated with a high fever.

In the older hogs the disease sometimes took a chronic form. Frequently the ulceration of the jaw bones resulted in deformities of the face with sometimes such a twisting of one or both jaws that eating was difficult. A few of these hogs would live for months, only to be finally destroyed by the owner because they were stunted, emaciated and valueless.

Many show symptoms which are not easily differentiated from cholera. They become dull, refuse food, have high fever, show diarrhoea and die rapidly. The difference is hardly to be appreciated by stockmen and even experts are sometimes confused. In a general way, however, hemorrhagic lymph glands, redness of skin and red spots on the kidneys will point to cholera, while large areas of necrosis, particularly if in the mouth, will point to necrotic stomatitis.

### *Treatment.*

Treatment is most difficult because the ulcers are not confined to the mouth, but extend throughout the digestive tract. Probably there is no known medicinal remedy, the administration of which is of much value. The removal of well hogs to new quarters with thorough disinfection of the premises as described in the previous disease, is always to be tried. Young pigs should have their heads dippped into a 5 per cent solution of creolin once daily. The sows are to be driven through a shallow vat of the same solution in order that their teats may be disinfected. The hogs should be kept under strict quarantine and after the outbreak is over, a thorough clean-up of the pens is necessary. All litter should be burned as well as all dead hogs, the pens should be white-washed and disinfected.

## LIP AND LEG ULCERATION IN SHEEP.

### *History.*

This disease first assumed formidable proportions in Wyoming in 1908 and 1909 and while it has never been a serious disease among Colorado sheep, yet it has in the past and is still causing our sister state on the north a considerable amount of trouble. For a time all movement of sheep from our feed lots was restricted on account of this disease, but these restrictions have now been removed. While Wyoming has suffered most, we have not entirely escaped.

Ever since the feeding of sheep, on a large scale, was started in Northern Colorado, feeders have been cognizant of a scaly, scabby condition of the lips which comes on within a week after the animals are placed on feed and usually passes off a week or two later without causing any special harm. The following experiment has been reported:

Sheep were divided into two lots, one of which was placed on third cutting alfalfa and beet pulp, and the other on first cutting alfalfa which had very hard and coarse stems. The first lot remained free from this trouble, while the second showed the usual scabby condition of the lips. This would seem to prove that the abrasions are made by the rough food. However, it is very difficult, if not impossible in most of these cases to demonstrate the presence of bacillus necrophorous. In a few instances, these conditions have not healed readily, but have taken on the cheesy appearance and characteristic odor of bacillus necrophorous. Some deaths have resulted from this progressive ulceration.

In Wyoming and in a few instances in our own state, the disease becomes more virulent. The ulcers in addition to forming on

*Lip Ulceration, Sheep.*

the lips the to be found on the legs just above the hoof and in males a common seat of ulceration is in the sheath, while in females the vulva frequently becomes swollen and ulcerated. These ulcers show no tendency to heal and frequently end in death.

*Treatment.*

Treatment consists in the local application of antiseptics to the ulcers. Each animal of an infected flock must be caught, the ulcers exposed, the cheesy mass raked off to expose the raw surface, and the surface liberally swabbed with some good antiseptic.

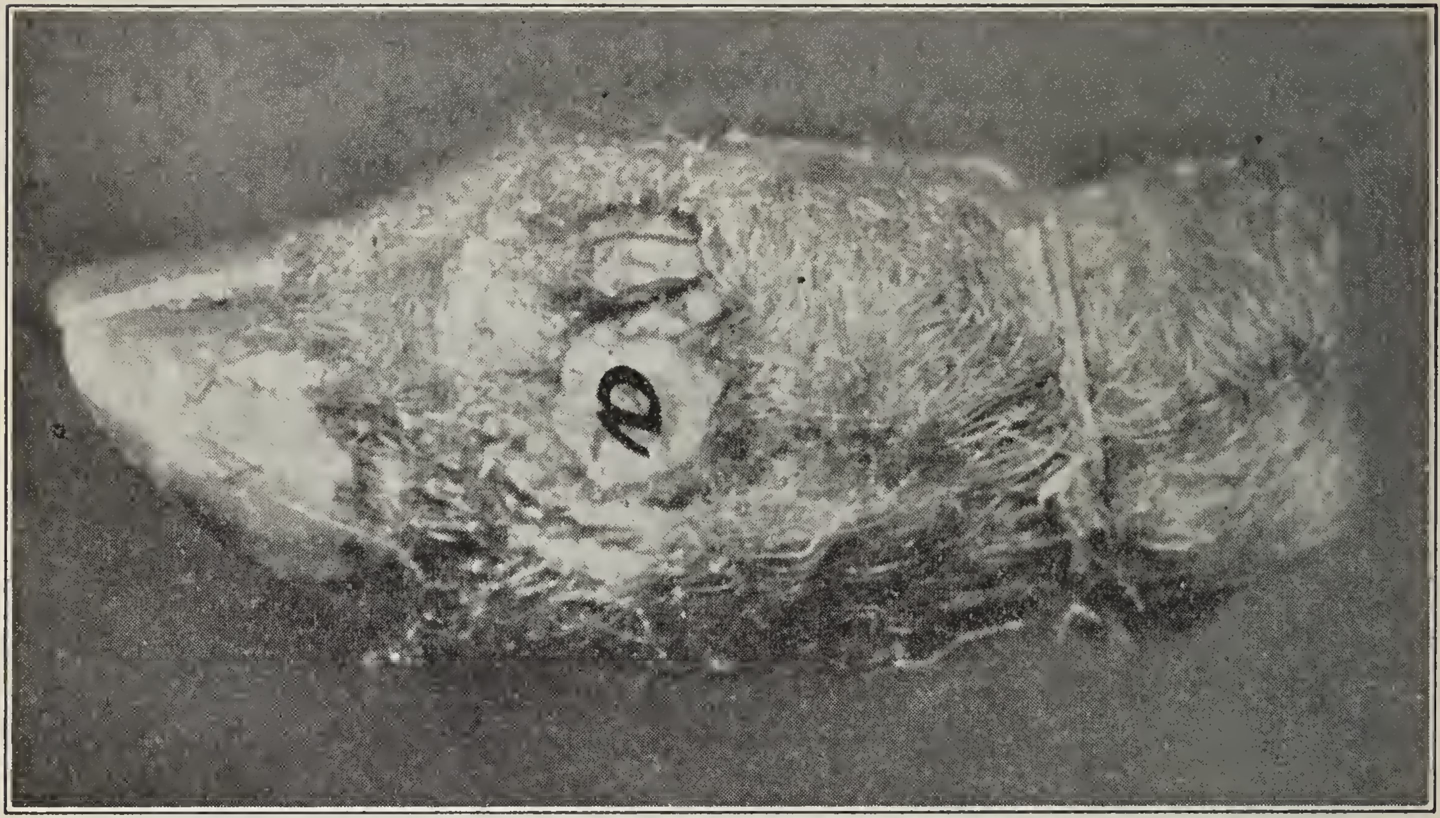

*Fig. 3. Ulcer on Foot of Pig due to Bacillus Necrophorous; a, the ulcer.*

Tincture of iodine and Lugol's solution of iodine have been used with excellent results. Five per cent carbolic acid is highly recommended as well as of creolin. Three per cent potassium permanganate is good. To get the best results the animals must be treated daily for about a week. Dipping did not prove as satisfactory as the hand dressing and is not now much used.

## BACILLUS NECROPHOROUS IN OTHER CONDITIONS.

This organism has been found in a large variety of diseased conditions in animals, such as Foot Rot of cattle and sheep, Quittor and Scratches in horses, Necrotic Anovulvitis in cattle, and in fact as a secondary invader in many wounds. No matter where found it always has the distinctive odor and is easily destroyed if it can be brought into contact either with air or antiseptics. Just why it assumes more virulent form in our Western States, we do not know, but such seems to be the case.

71 b

Bulletin 198 June, 1914

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

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## THE ONION IN COLORADO

BY

E. R. BENNETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station

FORT COLLINS, COLORADO



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# THE ONION IN COLORADO

E. R. Bennett*

Onions may be grown in nearly all parts of Colorado but, so far, they have been grown commercially in only a few districts. These are in order of their importance,—the Uncompaghre Valley with Olathe as the center, Greeley, Denver, Pueblo, Rocky Ford, Canon City, and, to a less extent, near the other towns of the irrigated districts. The requirements for commercial onion growing are, first, a fairly long growing season; second, a soil that can be made fine and that will work easily, a great quantity of available plant food, and a sufficient water supply.

## SOILS

Quite a variety of soils are used for onion growing. In the east the most common soil is that known as muck, or peet, bottom lands. These soils are rich in nitrogen, hold moisture readily and when fertilized with ashes or other commercial fertilizers containing phosphoric acid and potash, grow good crops of onions, providing they are not handicapped by either too much or too little rainfall. Practically no soils of Colorado are of this class. The next most common soil for the culture of the onion is the loose soil of the river bottoms. These range from light sandy loam with considerable humus to the heavier adobes. In the east few onions are grown in the uplands, but this is largely a matter of availability of moisture. In Colorado this makes comparatively little difference where irrigation is given and onions are grown successfully on the heavy clay mesa soils. Ordinarily, the onion is not well adapted to light, dry gravelly soils, as it is difficult to get a sufficient yield to make the growing of onions a paying proposition.

## PREPARATION OF THE LAND

Too much attention cannot be given to the preparation of the land. Probably the best method of preparing land for onions is to plow up clover or alfalfa soil and grow some hoed crop that requires a great amount of cultivation, as the potato or sugar beet. Soils which have been planted to potatoes following alfalfa or clover are in excellent condition for onion growing. They always need, however, a heavy coat of well decomposed stable compost. For this reason, onion growing is largely confined to close proximity to the small towns or cities where stable compost can be hauled to the land without great expense. The most successful growers use from ten to twenty tons of this compost each year on their onion lands. If this can be distributed in fall and plowed in, so much the better. In fact, fall plowing for onions is to be desired, particularly on soils that are inclined to be somewhat lumpy. In many cases, the manure is hauled onto the land during winter and plowing is done in February or March as soon as the frost is sufficiently out of the soil to permit the working of the land. In our districts of little rainfall, as in the Uncompaghre Valley, this may be depended on in the majority of years. The important thing in the preparation of the land is to have it so thoroughly levelled that water may be distributed over the whole field in shallow ditches or by flooding without getting too much in any one place or leaving spots with insufficient water. Thorough preparation of the land by harrowing and flooding is necessary. This should be done until a perfect seed bed is made.

So far, no particular rotation of crop has been practiced. The probabilities are that in time some rotation will need to be adopted to prevent the ravages of fungous diseases and insect pests, as the mildew, thrip, etc. The trouble with rotation in onion growing is the same as that for other intensive crops, that good onion lands are usually high in price and the grower feels that he cannot afford to give the land up for a year or two to such crops as clover or peas, as those crops will not, during those years, bring a good interest on the value of the land.

*Former Horticulturist of Experiment Station.

## PLOWING

Plowing may be done in either fall or spring. If plowed in fall, it may be done to a depth of eight inches. Where it is left till spring it is possibly better not to plow quite so deeply, or if deep plowing is done, packing the soil should be accomplished in some way so as to make a firm seed bed. It seems to be the concensus of opinion among our most successful growers that six inches is about the right depth for plowing. The plow should be followed by a harrow. Most growers alternate between the harrow and a float made from plank, using these tools until a perfect, smooth seed bed results.

The system of planting used will depend on whether the onions are to be irrigated by flooding or by ditches. Where flooding is done, the onions are sown in rows about twelve inches apart. The more common practice is to first make shallow ditches with a hand plow about 26 inches apart. These furrows are sometimes made, then followed by a light floating of the land to level the surface, leaving sufficient depressions in which to run water across the field. This leaves the land so that the spaces between the furrows are slightly raised. The seed are then sown, making two rows between the ditches. These rows are 12 to 14 inches apart respectively, the wider space being the ditched row. Considerable care is necessary in marking out the land and in sowing to keep both ditches and rows straight and even. The usual practice is to run a marker where the fissues are to be made. These markers are simply home-made, wooden frames with three or four legs that will make marks 26 inches apart when hauled across the field by one man. Several types of seeders are used, as the Iron Age, Planet Junior, etc. There seems to be considerable difference of opinion as to the relative merits of the different seeders, but as each kind is championed by different growers, it is evident that they all have their advantages and are probably nearly equal in efficiency. Where the rows of onions are made to conform with the ditches previously made, there is less danger of getting the rows out of line, as each ditch aids as a correction on the seeder. Seed are sown from one-half to five-eighths inches deep. From three to four or four and a half pounds of seed are used per acre.

## THE IMPORTANCE OF GOOD SEED

The importance of good seed cannot be over-estimated. Our experiments and observations in the field have demonstrated quite conclusively that no one factor will make for the success or failure to so great an extent as that of quality of seed and varieties adapted to conditions. In both the Olathe and Greeley districts the majority of growers are producing their own seed. There is probably a great deal in the acclimatization of seed for Colorado conditions as to its real value to the grower. At Olathe we found the most successful growers had been producing their own seed for from ten to sixteen years. These strains were the results of careful selection of bulbs for seed stock so that for these series of years nothing but the very best types of the variety had been saved. The results of this selection for acclimatization were shown when last year in making a test of these seed at the Experiment Station gardens at Fort Collins, in comparison with the best strain of seed obtainable from eastern seedmen. These seed, which were what is known at Olathe as the Yellow Globe Danvers, but what is probably a cross between Yellow Globe Danvers and Brown Australian, were sown at the same time as varieties of Red Globe, Yellow Globe, Danvers Red Weathersfield, White Globe and Prizetaker. The season of 1912 was rather unfavorable in the Fort Collins district, as the temperature averaged lower than usual with rather heavy precipitation, which made the onion crop late and produced a large percentage of so-called thick-necks. In the fall we found a difference of more than three weeks in time of maturity in favor of Colorado grown and selected seed. Another factor in favor of home grown seed is that the grower may be absolutely sure, not only of the purity of his seed, but of the variety, where if the seed are purchased from any of the seedmen, there is a chance for a mistake in variety, which may make a serious difference in the yield or the value of the crop. It is without a doubt cheaper, so far as cost of seed is concerned to buy seed from seedmen than to produce it on a small scale for home use, but when all things are considered, it is doubtful if any grower of onions can afford to take chances in buying seed unless he is able to buy from some neighbor who is doing good work in that line.

## GETTING A STAND

In the northern Colorado districts there is seldom any trouble in getting the onions to germinate and make a good stand from the moisture already in the soil. Because of this, most of the growers have used the flooding system rather than the furrow irrigation system, and in this case it would be difficult to irrigate the onions up. In the west slope districts and in the Arkansas Valley districts there is more danger of drying weather in early spring; consequently it is not safe to depend on getting a stand from the moisture in the soil. Most growers plan to irrigate shortly after the seed are sown. By running a small quantity of water in each of the furrows and leaving it in a sufficient length of time, the ground may be sufficiently moistened to bring up the seed without flooding or packing the surface. This brings a very even percentage of germination and stand.

## CULTIVATION

As soon as the young plants are large enough to be seen in the rows, cultivation is begun. This is begun almost entirely with the hand wheel hoes. Shallow, frequent cultivation is essential to success. The oftener this is done the better. Three or four times is probably the minimum number for hoeing. Weeding is one of the expensive operations, but must be attended to, as it is impossible with tools to keep the weeds entirely out of the rows. If the hoeing is done early and thoroughly done, it will very materially decrease the labor of weeding. The ditch system of irrigation also tends to cut down the labor of weeding, as there is less tendency for the weed seed to germinate in the row than when flooding is done.

## IRRIGATION

The number of irrigations must depend entirely on the type of soil, location, and the season. At Greeley, irrigation in the early part of the season is usually avoided. One of the most successful growers there begins in the latter part of June or early July and irrigates by flooding about once a week, probably making seven or eight applications. In the west slope districts, the irrigation is begun soon after the seed are sown and continued whenever necessary until early in August, when no more water is applied, so as to allow the onions to mature. There is undoubtedly a tendency among growers to over-irrigate. The aim should be to keep the ground in such a condition as to promote the most rapid growth during the early part of the season. Too much water tends to produce a heavy top and ultimately to make what is known as a thick-neck or a scullion. These thick neck onions are always present to a greater or less extent and any factor that tends to produce them should be avoided, as they are absolute waste.

After the onion is two-thirds grown, it is rooted sufficiently so that even if the top soil is quite dry it will still come to full maturity and produce an onion of better shape and keeping quality than if more water is given. The great difficulty in all Colorado onion growing districts is to secure the required size and still have the onion mature early. Late maturing onions are in more or less danger from freezing, and are more difficult to handle in harvesting and marketing.

We have had many inquiries as to the feasibility of rolling or breaking over the tops of the onions in the latter part of the season to cause them to ripen off. Experiments have not shown that this practice is necessary or particularly beneficial. If the weather is such as to allow the onion to mature normally, the top should stop growth early in August and soon tip over and be well shriveled in time for harvesting. It is possible in some cases that breaking down the tops by hauling a pole or light roller over the field may aid this process of ripening off, but our experiments so far have not demonstrated the efficacy of the practice.

## THINNING

It is quite possible that thinning of onions might be practiced with profit, but so far our growers in Colorado have not made a practice of thinning. Where good, reliable home grown seed is used and conditions permit the control of germination, it is not essential to sow much more seed than can be brought to maturity; consequently, thinning has never become a general practice.

## A NEW SYSTEM OF ONION CULTURE

Up to the present time the so-called new system of onion culture has never been practiced to any extent in Colorado. Our experiments for two years here at the experiment gardens have led us to believe that this system could be practiced in Colorado with considerable profit. The system consists of growing planted seed in flats or hot beds in February so as to have plants four or five inches high to set in the field as soon as the weather will permit in spring. These plants are thinned in drills an inch and a half or two inches apart in the hot bed and the plants grow rapidly, but with plenty of ventilation, till time of setting in the field. About 150,000 plants are required to set an acre, setting the plants 3 in. apart in the row with rows 1 ft. apart. The so-called Spanish onions, as the Prizetaker or Giant Gibralter, are most commonly used for this purpose. The other varieties, as Yellow Globe Danvers and Red Globe, may be used but will not produce the immense size that is desired. In our trials we found that it was not difficult to grow onions that would average from eight to twelve ounces and many specimens were produced that weighed from sixteen to twenty-one ounces. Even larger bulbs than these have been produced. This system insures a heavy yield of large onions and gets them ready for market early in the season. For special markets these onions will bring an average of from one-half or more to double the price of the ordinary onion crop. The cost of transplanting will probably not be less than $10 per acre and may amount to $20 and the work of producing the plants in the hot beds must be a considerable item. Much labor will be saved, however, in the weeding and hoeing, as the plants will have the advantage of good size before the weeds can possibly start. The yield in this case, also, will be much greater than onions sown in the field; consequently, for the man who has a small area of land we believe that this system has great possibilities. In setting the plants the ground must be marked out in somewhat different manner from that for sowing the seed. Either one or two methods may be adopted. A small shallow furrow may be made for each row with the plants set in the edge of the furrow, or a broader furrow may be made and a row of onions set each side of this furrow. In this case, it is well to make the ditch so that the two rows of onions may be about eight inches apart with a wider space between the double rows. This space may be used later for the ditches for irrigation.

## HARVESTING

In harvesting, the onions are first lifted by an implement known as an onion lifter. This is simply an implement shoe or bar of iron about two feet wide, drawn by a horse, that will run under the onions, cutting the roots and loosening them from the soil. This tool is sufficiently wide to raise two rows of onions at a time. After they are lifted, the onions are topped. This work must be done by hand. The toppers follow the rows, cutting off the tops with a knife and discarding those bulbs which are not marketable. The good onions are drawn in crates, and in cases where the onions are thoroughly ripe are emptied into sacks which are left in the fields from ten days to two weeks to cure. Where sufficient crates are available these are left in crates rather than sacks for the curing. The roots are not usually cut from the onion as the roots soon shrivel and are broken off from the bulbs in handling. The sacks used are practically the same as those used for potato growing, 115 pound Liverpool returns, or centrals. When the market is such as to make it possible, the larger part of the crop is shipped direct from the field. Our growers are coming more and more to storing a part of the crop, for in average years the price is considerably better some time during the winter than at harvesting time. This does not always prove true, however, and sometimes growers find that while the market is fair in the fall there is practically no market in winter or spring and the crop is sometimes lost. The market for onions is practically the same as that for potatoes. Sometimes they are shipped to Chicago or Kansas City but more often to Texas and other southern points. The great drawback to the onion growing is the variability of the market price. There are several reasons for this variability. The consumption of onions is somwhat limited as compared with our other staple crops. Production is probably rather more variable than any of the other crops; consequently, the price is controlled largely by the production in the east, which always depends on whether the season is normal or abnormally wet or dry. Owing to the climatic conditions of Colorado, it is probable that our production is more uniform from year to year than that of the eastern states, but as the bulk of the crop is grown in the east, the yield here has little influence over the market price. As nearly as can be estimated, the price at selling time in the fall has been in the neighborhood of $1.00.

## COST OF PRODUCTION AND YIELDS

It is a noteworthy fact that comparatively few of our growers seem to know the cost of production of their crop. As a business proposition, onion growing as well as other crops must be carefully considered from the standpoint of cost as well as that of production and market values if we are to make a successful business. Various growers with whom we have talked have made various estimates of this cost. One of the most successful growers and one who has been in the work for fifteen years has given the cost of production as follows: (This cost is based on a five-acre unit, or that which is considered to be what one man can handle during the season.)

| | |
|---|---|
| One man, six months | $360.00 |
| Manure for the land | 75.00 |
| Plowing and harrowing | 15.00 |
| Sacks for harvesting | 225.00 |
| Seed | 60.00 |
| Lifting | 5.00 |
| Hauling to market | 35.00 |
| Total | $775.00 |

The weeding, irrigating, and other labor is considered in the wages of the one man for six months. This gives us a total cost of $805, or $161 per acre. This is based upon a production of 350 sacks of 115 pounds each per acre. While this may be a little high for the average cost over the state, it is probable that it is not far from correct and does not include taxes, interest on investment, or depreciation of tools, although the latter item is of comparatively small importance, as one of the factors in favor of onion growing is that comparatively little machinery or horse power is required for onion culture. This leaves the grower $241.50 per acre from which must be deducted the taxes, interest, and depreciation. While this looks like a big income per acre, one must remember that the limit of the acreage per man is decidedly low. Some growers estimate that a man can take care of six or seven or even eight acres. It is doubtful in most cases if it will pay one man to attempt handling over five acres without extra help. The real factor in the business that must be considered by anyone contemplating onion production on the market, is as to whether all conditions are fovorable to get a maximum crop at a maximum price and at a minimum cost of production. It must be remembered that the cost of production will not vary to any considerable extent. If the land is situated a long distance from railroad, the item of hauling will very materially increase, or if bad roads are to be contended with. All the factors as to adaptability of soil and availability of stable compost, length of season, seed, and variety must be considered and, while we believe that for the man with all conditions favorable the onion crop has great possibilities, we would not recommend anyone to attempt the culture of this crop without carefully considering all sides of the question.

## SEED PRODUCTION

The production of seed for home use and for market is becoming more and more of a business each year. The first essential is to decide as to the variety most in demand. In the western slope districts the Yellow Globe Danvers, or a type of that veriety, is grown more than any other, although Red Globe, White Globe and Prize Taker are grown to some extent. In the Greeley district, the varieties are divided about equally between Yellow Globe Danvers, Red Globe Danvers, with White Globe, Prize Taker, and Red Weathersfield grown to some extent. In the fall when the onions are harvested, the best bulbs are carefully selected from the field. In making this selection, the first essential is to have in mind the most desirable type of that variety; then the selecting must be done by someone who will discard everything which does not conform to the desired type. These bulbs are usually placed in the crates and stored in a cool onion cellar. These should be kept as cool and dry as possible till the following spring. Early in the spring the ground is prepared and these bulbs set in the field a few inches apart in the row with rows from 2½ to 3 feet apart. About 90 sacks of medium sized bulbs are required to set an acre. In setting the trenches are made four or five inches deep and the bulbs placed by hand with the stem ends up, then the soil is replaced over the bulbs. These bulbs send up a stem 2½ to 3 feet high and will blossom in July. As the seed matures the seed stalk is cut by hand and placed on canvas to dry. After the seed head is sufficiently dry to thresh, the seed are separated from the fiber either by threshing or with the flail and the seed passed through a fanning mill to remove the chaff and light, worthless seed. The onion seed industry in Colorado gives promise of becoming of considerable importance. Up to the present time the seed growers of Colorado have received considerably more for their produce than the price obtained by the seedmen of the east and our growers have learned that even while the seed costs twice as much, it is more profitable than that procured elsewhere. A rigid selection is necessary if we are to keep up the type and yield of our bulbs. Dishonest seed growers who plant culls will produce as good looking seed as those from selected bulbs, but the inherence is necessarily bad and cannot result other than in an un-uniform type of onion and many scullions. After the seed are taken from the field, the plants will produce seed stems the second year. Growers tell us that these second year seed are not as desirable as those produced from the plants the first year.

## STORAGE ONIONS

The onion is rather difficult to store satisfactorily. There is always a tendency for the bulbs to start growth, which spoils them for market purposes. The storage house must be frost proof and as nearly dry as possible. To accomplish this end, it is usually necessary to build more nearly above ground than for the ordinary potato cellar. Great care must be exercised in providing for ventilation. Onions are better stored in crates or in racks in the storage house. If the onion can be kept dry and at near a freezing point, it may be carried till February or March when the market is in good condition.

Bulletin 199 August, 1914

# The Agricultural Experiment Station

OF THE

## Colorado Agricultural College

# Vegetable Growing In Colorado

## Hot Beds and Cold Frames

BY

R. A. McGINTY

# Common Insects of the Garden

BY

C. P. GILLETTE

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station
FORT COLLINS, COLORADO

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# Vegetable Growing In Colorado

By R. A. McGINTY

In the days of the eary settlers, it was thought that many vegetables which grew to perfection in other parts of the country would not grow well in Colorado, on account of the high altitude. But we have gradually learned by experience that the larger number of our cultivated vegetables can be produced in as high a state of perfection in Colorado as elsewhere. Many vegetables, as cabbage, celery, onions, peas, and tomatoes, to say nothing of potatoes, are now grown commercially in this state. On account of the short season, it is often advisable and sometimes necessary to start plants having a long growing season in hotbeds or greenhouses, but the majority can be planted outside, in the ordinary way.

Some vegetables, as tomatoes and egg plants, which cannot be grown profitably in some sections for market, may well be grown in the home garden for the family table. They may require extra care, but the satisfaction of having fresh homegrown products rather than other kinds, together with their economic value, makes the home garden worth while.

The Experiment Station is constantly receiving inquiries as to the method of culture for different vegetables, indicating a general demand for more information on the subject. It is with the idea of giving this information that this publication is issued.

*Soil.*—The soil for general vegetable growing should be a rich, friable, well drained loam. One containing some sand is desirable, since such soils warm up earlier in the spring. However, much heavier soils may often be modified by the addition of stable manure and the turning under of green crops so that they will serve. A southern or eastern slope is preferable.

*Preparation of the Soil.*—The ground should be plowed to a depth of ten or twelve inches in the fall and left in a rough state during the winter. Cross-plow again early in the spring and harrow smooth.

*Fertilizers.*—Many of the Colorado soils are deficient in organic matter, so that the best fertilizer is well rotted stable manure. This should be applied before plowing in the fall at the rate of 20 to 30 tons per acre. The turning under of green crops is also advisable.

*Irrigation.*—While the various vegetables require different amounts of water, it is thought advisable to treat the matter in a general way at this point to avoid useless repetition. Vegetables contain from 85 to 90 per cent 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 deep into the soil and economizes 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. Sprinkling every day or two will cause the plants to be shallow rooted.

## ASPARAGUS.

*Soil.*—Asparagus will grow well on a variety of soils, the one condition to be avoided being that of too much moisture. If earliness is desired, a rich sandy loam with a southern or eastern exposure is best. Such a soil will warm up earlier in the spring than a heavier one.

*Preparation.*—In the fall preceding the planting, the land should be well plowed to a depth of ten or fourteen inches and left to the action of the weather during the winter. In the spring twenty or more tons of well rotted stable manure per acre is applied and plowed under. This is followed by a thorough harrowing which puts the soil in the best condition for planting. This thorough preparation is very necessary to the success of the crop. New land should not be used for asparagus culture.

*Plants and Planting.*—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 the seed. It has been shown by experiment that the staminate plants produce the larger 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 five 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 rapid 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.

In the spring, the soil is loosened up by plowing to the depth of a few inches and cultivation 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.

In local markets, asparagus is often sold loose, by weight, bringing a good price, but in the city markets, bunched asparagus is desired. It is of first importance that the bunches be of uniform length and size, containing stalks of the best quality only, and neatly tied. There are several styles of bunchers on the market, in which the stalks may be placed, the uneven ends cut off and the bunches easily tied. These simple devices greatly facilitate the bunching of asparagus, secure uniformity, and are a necessity to the grower who sells any considerable amount of his crop.

*Forcing Asparagus.*—Asparagus may be forced by putting three or four-year-old roots in soil under the benches in the greenhouse or by placing them in hotbeds where the temperature is about 65° or 70°. The roots must undergo hard freezing for about three weeks before this is done, so that ordinarily they cannot be taken in before the latter part of December.

The plants will begin to grow in about a week. Shoots may be cut for a month or more, after which the plants are thrown away.

*Varieties.*—Some of the best varieties of asparagus are Conover's Colossal, Palmetto, and Columbian (Mammoth White).

## BEANS.

*Types of Beans.*—There are several types of beans, but the two of 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. Kidney beans are divided into green-podded and wax-podded types, while both kidney and Lima beans are divided into dwarf and pole varieties. The dwarf varieties are ordinarily planted for the early crop, while the later crops come from the pole varieties.

*Soil for Beans.*—While beans will produce well on a wide range of soils, a rich clay loam is probably best adapted to the plant. A soil rich in potash and phosphoric acid is desirable. The nitrogen content of the soil is relatively unimportant, as beans are capable of taking nitrogen from the air and appropriating it to their needs.

*Planting and Cultivation of Snap Beans.*—Beans are tender plants and cannot be planted until danger of frost is past. Plow the soil from six to eight inches deep in the spring and immediately smooth and harrow it to prevent evaporation of moisture. When ready to plant, make the rows two and a half feet apart and plant the seed three or four 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 a half inches is better.

Shallow cultivation should be given frequently during the growing period of the crop.

*Planting and Cultivation 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. The usual method is to plant four or five seed in hills, eighteen to thirty-six inches apart, with the rows about three and a half feet apart. After danger from cold and insect enemies is past, they are thinned to three plants in a hill. Shallow cultivation is given and a trellis of some kind is usually provided for the pole varieties. Beans should not be cultivated when the plants are wet from dew or rain, as this may cause the plants to become diseased.

As with most all vegetables, the soil for beans should be well fertilized, but a fertilizer containing high percentages of potash and phosphoric acid and a low percentage of nitrogen may be used to advantage, since beans are nitrogen gatherers.

## 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.

*The Soil and Its Preparation.*—A rich sandy loamy soil is best adapted to beets. If a very early crop is desired, the land should be deeply and thoroughly plowed in the fall. The ground should be broken eight to twelve inches deep, so that the root system will not be restricted.

*Planting.*—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. 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 marketable size, say one and a half to two inches in diameter, when they are removed to make room for the others. Since the beet is a relatively hardy plant, the seed may be planted about the same time as radishes or lettuce.

*Cultivation.*—Beets should never be allowed to become checked in their growth so that frequent cultivation, particularly in the early stages of the crop, should be given to conserve moisture and keep down weeds, which might hinder the growth of the beets.

*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 the plants in the row.

Swiss Chard is a vegetable which deserves to be more extensively cultivated than it is at present.

## BRUSSELS SPROUTS.

Brussels Sprouts is the name given to one of the variations of 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.

*Cultivation.*—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. In severe climates the plants may be lifted at the approach of winter and set in moist sandy loam in cool cellars and used as needed. Set the plants in the field at about the same distance as cabbage and give the same culture. Brussels Sprouts are usually sold by the quart and bring about the same price as strawberries.

## CABBAGE.

*Soil.*—While cabbage will thrive on most any soil used for growing ordinary farm crops, it prefers one that is cool, moist and deep. The soil should be rich and the plants never allowed to become stunted. Cabbage is often used as one of the factors in a rotation of farm crops following clover or alfalfa.

The soil should be well fertilized with stable manure, and in locations where the soil is somewhat sandy and has been under cultivation for a long period, commercial fertilizer may be used to advantage. It should be applied at the rate of about 1200 to 1500 pounds per acre and the mixture should contain a high per cent of nitrogen and potash.

*How Plants Are Obtained.*—The seed may be sown in the field where the crop is to mature, but this is not the best plan. For the early crop, the seed should be sown in the hotbed in February or 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. In milder climates where the temperature does not go below zero, the seed may be planted in cold frames in the fall. They spend the winter in the frames in a dormant state and are ready for planting out early in the spring.

The seed for the late crop may be planted in beds outside when winter is over and the plants are transplanted to their permanent positions when they have attained sufficient size.

The best time for transplanting plants of any kind is just before a rain and one of the worst times is right after a rain. Transplanting may be done to advantage in cloudy weather or late in the afternoon, and if the soil is dry, it is necessary to apply a small quantity of water around the roots of the plants when they are put out.

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 cut the stems.

*Planting.*—For the early crop, plants are set in the field in rows two and a half to three feet apart and fifteen to twenty-four inches apart in the row. For the late varieties the plants should be set three feet apart each way, as they require more room for development. This also permits cultivation in both directions.

*Cultivation.*—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.

*Storing.*—In storing cabbage for home use they may be kept in a cool, well ventilated cellar, or they may be stored in the ground as follows: Dig a trench or plow out a deep furrow eighteen inches wide and ten to twelve inches deep on a slight ridge or some well drained location. The cabbage heads are pulled up, roots and all, and placed heads down in this trench. The first layer will consist of two rows of heads and a second layer of one row of heads may be put on top of the first, placing the heads between the roots of the first layer. Straw may be placed next to the cabbage and the whole covered with a light layer of soil which is gradually added to as the weather becomes colder so as to prevent alternate freezing and thawing.

The cabbage should be in good condition when put into storage. Any water contained between the leaves ought to be drained out and diseased leaves removed. When stored in a cellar or other storage house, the temperature should be kept as near 34 degrees F. as possible.

## 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.

*Cultivation.*—Carrots are given much the same culture as beets. The seed is sown thinly, about one-half inch deep, in drills eighteen to twenty-four 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.

When the crop is harvested, the tops are removed and the roots may be stored in a celler the same as potatoes, or they may be put outside in conical heaps, containing twenty to thirty bushels, and covered with straw and earth.

## CAULIFLOWER.

This is another variation of the cabbage and is grown for the thickened flower stems or curd which forms a white compact head.

*Soil.*—The soil for cauliflower should be practically the same as for cabbage. A rich, sandy loam which can be cultivated in the cooler part of the year is preferable. The plant is a gross feeder and the soil must be well fertilized with stable manure of commercial fertilizers.

*Cultivation.*—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 cold weather is past. The distance between plants should be about eighteen inches in the row, and about two and a half to three 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 to never 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.

If the vegetable is to be sold, the outer leaves are trimmed off so as to project about one inch beyond the head, and the heads are usually wrapped in paper and packed in ventilated barrels or crates. Cauliflower may be forced profitably in the greenhouse. It requires about the same temperature as lettuce, with a high degree of humidity.

The seed is always expensive, but it pays to secure the best obtainable.

## 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 three or four 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.

*Fertilizers.*—The soil on which celery is grown must be rich in vegetable matter. This is best supplied by stable manure, applied at the rate of 30 to 40 two-horse loads per acre. Commercial fertilizer may sometimes be used to advantage. When used, it is usually applied at the rate of 1000 to 1500 pounds per acre.

*Seed Bed.*—The growing of 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. The seed may be planted rather thickly in drills or broadcasted. For the early crop the seed should be planted in hotbeds the first or second week in March, while the seed 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 watered with a fine spray. 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 two inches between plants each way. This method gives much more stocky plants and a much better developed root system. Sometimes the cost of transplanting is prohibitive and a different method is substituted. One method is to shear off the tops of the plants once or twice in the bed, while in other cases, a knife, mounted on wheels, is run under the plants so as to cut the roots, especially the tap root, causing the development of a better 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 sprinkling 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 three methods of blanching employed. The most common method is that where the plants are banked up with earth. In this case the rows are made five or six feet apart and the plants set six inches apart in the row. Sometimes double rows six inches apart, with six 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 five feet between the rows. Another method used quite extensively with the early crop is to blanch the celery with boards about twelve inches wide and sixteen to twenty feet in length. When this plan is followed, the rows are made three feet apart and the plants set six inches apart in the row. A heavy paper is now being manufactured which can be used instead of boards. With proper care this will last two or three seasons and is more easily handled than boards.

"The New Celery Culture" is a term applied to the growing of celery so close together as to cause self-balancing to a greater or less extent. By this method the plants are set eight by eight inches over the entire area. This crowding together causes them to grow tall and the shading keeps the stems from growing green. Its disadvantage lies in the fact that the plants are more subject to disease and more hand labor is required in cultivation.

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 withhold water 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 usualy 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 bank 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.

*Harvesting, Storing and Marketing.*—If the plants have been blanched with earth, they are taken up by means of a digger, having a U-shaped blade which runs under the plants and cuts the roots, slightly lifting them at the same time. The plants can then be easily lifted.

If blanched with boards, the plants can be cut slightly below the surface with a large knife.

When the plants are to be shipped long distances, they are not trimmed, but packed in crates or put into cars in bulk. If the celery is to be sold in a near market, the plants are trimmed and washed and tied in bunches of one dozen plants each, after which they are packed in crates and sold.

Celery can be stored in an ordinary cellar by placing the roots in moist sand, giving proper ventilation and maintaining a temperature of from 33 to 35 degrees.

Another way is to select a well-drained spot in the field and make an excavation about two and a half feet deep, four or five feet wide and as long as necessary. A permanent hotbed can be cleaned out and used for the purpose. Have three or four inches of loose soil in the bottom, in which to place the roots of the plants. The celery is put close together in the pit and then well watered. When the leaves are dry, boards are put over the pit, leaving openings for ventilation. As freezing weather comes on, straw is thrown on the boards and later, a layer of earth over the straw. The holes left for ventilation should be closed tightly in very cold weather. The plants must not be allowed to wilt between the time of digging and removal to the place of storage. All diseased plants or parts of plants must be thrown out. Provide against the eating of celery by mice and rabbits, but do not poison mice, as celery absorbs odors very easily and the whole lot may be ruined.

Celery can be kept in storage for two to three months. If it drys out during storage, apply water to the roots of the plants, keeping the tops as near dry as possible.

## SWEET CORN.

Sweet corn is less adapted to Colorado conditions than many other vegetables, but is a profitable crop in some sections, especially at the lower altitudes of the southern part of the state. The nights at the higher altitudes are ordinarily too cool for its best growth. However, a small amount of the early maturing sort may be satisfactorily grown for home use.

*Soil and Fertilizers.*—A warm, well drained loamy soil is best suited for corn growing. It is a rapid growing plant and therefore requires a liberal quantity of available plant food. It is impossible to make the soil too rich and large quantities of manure may be used to advantage.

*Planting.*—The soil should be more thoroughly prepared than for field corn because the seed require better conditions for successful germination and the young plants, when they appear, are less vigorous than field corn.

Rows are laid off from two to three feet apart and the seed planted so as to have the plants eight to ten inches apart in the row. Another method is to plant in hills three feet apart each way, leaving about three plants in a hill. The seed are planted one to one and one-half inches deep. Growers often take a chance with early corn and plant earlier than the normal season. Then, if the crop escapes frosts, 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, 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 more than two or three hours before it is to be 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.

## CUCUMBER.

*Soil and Climate.*—The best soil for cucumbers is a sandy, gravelly, or clayey loam. For early crops the sandy soils are best, while the clayey loam is better suited for the main crop. The cucumber, being a semi-tropical plant, will not grow to its greatest perfection in Colorado on account of the cool nights, but by starting the plants early good yields can be obtained. The plants are less susceptible to disease in this climate than in the east and this compensates to a large extent for the smaller yield.

*Planting.*—Since the cucumber is a tender vegetable, the seed cannot be planted until after danger of frost is past. The soil should previously be well prepared and fertilized with stable manure. Rows are laid off about six feet apart and the seed planted in hills three 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 secure plants early, thus allowing for a longer growing period, the seed may be planted in strawberry boxes in the greenhouse or 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 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.

*Cultivation.*—Clean surface cultivation should be given cucumbers. If planted in check rows, the crop may be cultivated both ways, thus saving much hard work. All weeds must be kept down and the soil stirred after each rain or irrigation.

*Picking.*—In order to keep the vines growing and bearing, the cucumbers must not be allowed to ripen. For slicing, they are picked when six to eight inches long, 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.

## 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 three feet apart and eighteen to twenty-four 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 wherever possible.

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 similar manner.

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 eighteen inches apart. The plants should later be thinned to stand six to eight 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 one and a half to two 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 curly-leaved or cutting lettuce. The latter will probably give more general satisfaction in this climate.

*Soil and Climate.*—Lettuce is a comparatively hardy plant and grows best in the cooler parts of the growing season. A rich, well drained, sandy soil is best, but the crop can be grown on heavier soils.

*Planting.*—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. In cold frames, the plants should stand about eight inches apart each way. Plants may be set in the field the latter part of April, and in this case the rows should be eighteen inches apart and the plants six to eight inches apart in the row. Lettuce transplants readily and if properly handled the plants wlll be only slightly checked.

*Cultivation.*—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. Transplanting should be carefully done and the plants given surface culture frequently during the growing period. The surface of the soil should be kept as dry as possible at all times, though the roots of the plants must not be deprived of the proper moisture. Lettuce is very susceptible to disease and particularly so when the surface of the soil and the foliage of the plants are kept moist. In applying water, precautions should be taken to keep the leaves from getting wet and this is especially important when the crop is grown in greenhouses, hotbeds, or cold frames.

*Forcing Lettuce.*—Lettuce is the most uniformly profitable vegetable that is grown under glass. It can be found on the market of large cities at all seasons of the year. When grown in greenhouses the plants are commonly set in solid beds slightly raised above the general level of the floor of the greenhouse. The plants are started in flats and when large enough to handle, are transplanted to other flats or small pots in order to give them more room. They are later transplanted into the permanent beds, being set about eight to ten inches apart each way. Great care must be used in watering to keep the leaves dry and not allow the surface of the soil to become too wet. By using a deep soil containing a large per cent of sand and organic matter, trouble is avoided in growing lettuce under glass. A soil properly prepared will sometimes produce a crop of lettuce in the greenhouse with one good watering. Sub-irrigation, by which water is applied beneath the surface, is often used to advantage in greenhouses. This method greatly lessens the danger from disease which may destroy the whole crop within two or three days.

In addition to being forced in greenhouses, lettuce can be grown to maturity in hotbeds. Both hotbeds and cold frames can be used to advantage for bringing lettuce to maturity in the fall or early winter and for starting them early in the spring.

## 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 in this state. The Rocky Ford section and the type of melon grown there are well known throughout the country.

*Climate and Soil.*—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 one or two 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.

*Planting.*—Rows are laid off six feet apart each way and eight to ten seeds planted at each intersection. The seed are covered to a depth of about one inch. They may be planted either by hand or with one of the many types of planters. After planting it may be necessary to irrigate in order to cause the seed to germinate. If this is the case, the water should be run in furrows parallel to the rows and four to six inches from it. By this method, the water soaks through to the seed, but leaves the surface above the seed dry. If the soil over the hills should become dry and crusted before the seed germinate, it should be raked with a garden rake in order to allow the young plants to come through more easily.

*Cultivation.*—Thorough and frequent cultivation should be given. During the early stages of the crop the ground is stirred rather deeply and close to the plants, but as the vines spread, the cultivation should be more shallow and further away from the plant. Light, frequent irrigations have proven to be of more advantage than heavy soakings given at considerable intervals.

*Picking.*—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. The proper stage can be more clearly determined by cutting a melon occasionally.

## ONION.

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 distant markets.

*Soil.*—The soil is one of the most important factors affecting the growing of onions. It is necessary that the soil be in workable condition early in the spring, so that heavy clay land is not suitable. The light sandy or gravelly soils do not hold moisture well. and are not the best for onion growing. The best soil is one between these, a retentive sandy loam. On account of the heavy yields per acre, a large amount of available plant food should be present. This may be supplied by heavy dressings of stable manure which should be plowed in in the fall. If the land was planted to some hoed crop like potatoes or beets, it will be in much better condition for onions.

*Preparation.*—For best results the land should be plowed in the fall to a depth of eight inches and in the spring the surface soil thoroughly pulverized. If preparation is delayed until spring, six inches will probably be the best depth. The soil for onions should not be too loose and when spring plowing is done, it should be compacted by using a roller or clod crusher. When planting time arrives. the ground should be in the best of tilth. Young onions are small and delicate and the work is largely done with hand power implements, so the soil must be free from lumps and easy to work.

*Planting.*—There are two methods of planting. By the first method the seed are planted in early April in rows twelve to fifteen inches apart. The seed 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 three to six 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 flats in the greenhouse or in hotbeds six weeks to two months before time to put the plants in the field. 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 three to six 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 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 or 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.

*Seed.*—The gardener should use good judgment in the selection of seed. Poor seed will produce a large number of small bulbs and scullions or "thick necks." Buy the best seed, even though the price is high.

*Cultivation.*—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 per cent 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 more 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.

*Harvesting.*—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 cut off about a half 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.

*Storing.*—In storage, they are either put in crates or placed on racks in layers eight or ten inches deep. A dry frost-proof storage house is necessary. The temperature is kept just above the freezing point, or if the bulbs can be frozen at the beginning of winter and not allowed to thaw out again until spring, and then very gradually, they will keep very well. When stored, onions should be very carefully handled or they will not keep well. They must not be handled while frozen and even the jarring of the building should be guarded against.

*Seed Production.*—Some growers in Colorado have found it to their advantage to produce their own seed. The method followed is this: At harvest time, the best bulbs of the desired variety are selected in the field and put in storage. The following spring these bulbs are set six inches apart and four or five inches deep in rows two and a half feet apart. They are given clean cultivation and in July send up flower stalks two and a half to three feet high. As the seed mature, the stalks are cut and placed on canvas to dry, after which they may be separated by using a flail and then running through a fanning mill to remove the chaff and light worthless seed.

## 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 one inch deep. The plants should be thinned to stand three or four inches apart in the row when well up. Cultivate frequently during the growing season, keeping down weeds and maintaining a surface mulch.

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.

## PEAS.

The growing of peas for canning purposes is of considerable importance in Colorado. They are adapted to most all sections of the state and are grown extensively in the northern part of the state to supply the canning factories at Greeley, Loveland and Longmont.

*Soil.*—Peas do well on a variety of soils. For the early crop a sandy loam is best, while a clayey loam is perhaps more suitable for the main crop. The soil should be deeply prepared and liberal quantities of stable manure applied.

*Planting.*—For the home garden, peas are often planted in double rows six inches apart with two to two and a half feet between the double rows. 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. The seed are 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 four or five inches deep. For the home garden, successive plantings should be made in order to have them in edible condition for a longer period.

For canning purposes, the seed may be sown with an ordinary grain drill. The crop is allowed to mature with no special attention or cultivation other than thorough preparation of the soil. The vines grow at will and are not provided with trellises or supports. When the greatest percentage of the pods are in the proper condition, the vines are cut with a mowing machine and run through specially prepared threshing machines which separate the peas from the pods. They are then washed and graded, after which they are ready to be canned.

*Types of Peas.*—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.

## PEPPER.

Pepper requires about the same conditions as the egg plant and 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 two to two and a half feet apart. The subsequent cultivation of the crop consists in keeping down weeds and stirring the soil from time to time.

## POTATOES.

For many years, Colorado has ranked among the leading states of the Union in growing potatoes, and though the growers in some sections, at the present time, are confronted with serious problems as regards diseases and soil conditions, yet the state will doubtless continue to maintain her position in the production of this valuable crop.

*Soil.*—In general, the best soil for potatoes is a deep sandy loam underlaid by a porous subsoil. The character of the subsoil is important. Even the heavier soils are often productive when the subsoil below is gravel or porous clay. Heavy clay soils which easily become puddled are not suitable for potatoes. The soils in the immediate vicinity of Fort Collins are largely of this character, and growers have not been successful in producing a profitable crop. It is possible that the addition of large quantities of stable manure will so lighten up the soil as to give better results.

*Preparation of the Soil.*—The preparation of the soil for potato growing is of great importance, as the tubers must have a congenial medium in which to develop. Potatoes should always be grown as a factor in some system of crop rotation. Very often they are planted to follow alfalfa. In turn they are followed by peas for canning, sugar beets, small grain or alfalfa. Wherever possible they should not be grown on the same soil more than once in four or five years, and, especially where diseases are prevalent. Where stable manure can be obtained, a liberal dressing should be applied in the fall and turned under. Cross-plow the land again in the spring, a short time before planting, and follow with a thorough harrowing. Do not plow or harrow the land while wet, as it will destroy the texture and leave the soil lumpy.

*Planting.*—Planting may be done by hand on a small scale, but when large areas are devoted to potatoes, a mechanical planter is necessary. These are of two types—the "picker" and "non-picker" planters. The former requires one man who thoroughly understands his business to operate, while the non-picker type requires two men to operate. Both have been satisfactory in Colorado.

The rows are made three to three and one-half feet apart and the seed pieces dropped eight to fifteen inches apart in the row. The closer distances are used with the early varieties. The seed is covered to a depth of four or five inches.

Some growers prefer to use whole seed rather than cut seed, and this is advisable where there is much disease. In this case the smaller potatoes should, of course, be used, as it would not pay to use the larger sizes. Where cut seed is used, as is most commonly the case, the pieces should contain one or two good eyes each, and should be large enough to nourish the young plant until it takes hold of the soil. The growth of the young plant from germination until a root system is formed is dependent entirely on the stored food contained in the seed piece.

*Cultivation.*—Cultivation should begin soon after the crop is planted—sometimes before the plants are up. The soil becomes packed during planting, and immediate cultivation is advisable in order to conserve moisture and aerate the soil.

Before the crop is up the ground should be well harrowed with a spike-tooth harrow. This may be profitably repeated after the plants are well up, and without any injury to the growing crop. The next two cultivations should be deep, and close to the rows. This leaves a loose medium for the potatoes to grow in. After this, surface cultivation which keeps down weeds and maintains a soil mulch, should be the rule.

*Irrigation.*—It is usually unnecessary to irrigate during the early stages of the crop, as there is enough rainfall, ordinarily, to cause the seed to germinate and bring the plants to the stage where the tubers begin to form. From then until about the time the crop matures, irrigation is necessary. The number of irrigations needed will, of course, vary with the weather conditions. The general tendency seems to be to give too much, rather than too little water. The water may be allowed to run down every other furrow the first irrigation and down alternate furrows the next time.

In dry seasons, however, 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.

It is sometimes necessary with varieties which set their tubers shallow, to employ protective ditching, by which soil is thrown over the hills, in order to protect the potatoes from frost. This is accomplished by running through the middles some implement which makes a narrow, straight-sided ditch, throwing the soil from the ditch over the hills. Of course, none of the tubers must be disturbed by this operation.

*Harvesting.*—The dates after which it is dangerous to leave potatoes in the ground vary with the altitude, from October 1st to

October 20th, the latter date corresponding to the lower altitudes. Therefore the crop should be harvested by this time.

On large areas, potatoes are harvested by means of elevator diggers, which are very satisfactory. However, these are too expensive for the small grower, and he usually digs his crop with a "shaker digger," costing about $12.00, or with a turning plow. Regardless of the method used, the potatoes should be cut or bruised as little as possible, as this injures their market value and keeping quality. They should be moved to market or into the storage cellar immediately to avoid possible frost injury. It is advisable to let the potatoes become thoroughly dry before they are placed in storage or before being sacked and shipped to market.

*Storing.*—A good storage cellar is essential where potatoes are grown for market. The grower does not always find it profitable to sell directly from the field, and in order to hold the crop, some kind of storage is necessary. The most common type of cellar in Colorado is one where an excavation is made and this roofed over with straw, earth, etc.

The storage cellar should be located on a slight knoll, if possible, or on level ground. The nearer the house it can be placed the better, as attention can be given much more easily than when situated farther away. If the walls and ends can be constructed of concrete, the cellar will be more permanent. Provision should be made for light and ventilation. This can be done by having from four to six shafts running through the roof. Light is necessary for sorting over the potatoes and desirable for greening seed potatoes in the spring before planting. Ventilation is necessary in maintaining the proper temperature. If the cellar is divided into two compartments, one can be kept dark for table potatoes and the other light when necessary for seed potatoes. A driveway with doors at each end of the cellar, so that a wagon may be driven through, will greatly facilitate loading and unloading. Tight double doors should be provided to keep out cold and heat. Two or three thermometers should be hung in the cellar to indicate the temperature, which should be kept as near 33 or 34 degrees F. as possible. To do this, careful attention is necessary, particularly in the fall and spring, when the cellar must be kept closed during the warm hours of the day and opened in the cooler hours of evening. By doing this the temperature can be kept about right in the cellar.

In addition to potatoes, other vegetables, such as turnips, cabbage, celery, etc., may also be stored in the cellar and kept for use during the winter.

*Potato Diseases.*—There are three fungous diseases which are of considerable importance in Colorado. These are *Fusarium*, *Rhizoctonia* and *Scab*. Other diseases, as early blight, which is a leaf trouble, sometimes attack potatoes over the state, but it is rarely necessary to employ preventative measures against these.

Fusarium gains entrance to the plant from the soil, and, by growing in the stem, shuts off the water supply, causing the vine to wilt. If a section of the stem is cut, the sap wood will show a darkened appearance not found in healthy plants. Areas where the trouble occurs should not be planted to potatoes again for four or five years, thus starving out the fungus. In addition to damaging the growing crop, this disease also causes dry rot of potatoes in storage.

Rhizoctonia also attacks the plant from the soil, and works on the lower portion of the stem. It restricts the downward flow of food material which has been prepared in the leaves, thus preventing the development of the tubers. Rotation, together with the use of clean seed is the only remedy.

Scab is another fungus trouble and causes unsightly, rough spots on the tubers, reducing their value on the market. One of the most common preventatives against scab is seed treatment. The uncut tubers may be soaked for two hours in a solution of four ounces of corrosive sublimate in thirty gallons of water. This solution is very poisonous and care must be used so that animals will not gain access to either the solution or the tubers which have been soaked therein. Crop rotation should also be practiced. Greening of the seed for a time, before planting, has also been recommended.

*Seed Potatoes.*—The question of pure seed is of vital importance to the potato growers of the state. Not only should the seed be true to type but they should be free from diseases. It is also important that in choosing the variety for a given section of the state attention must be paid to the question of maturity, as some of the standard varieties will not mature in some districts of the state and it would be useless to plant them. Then due attention should be paid to one or two standard varieties. In order to secure a favorable market, enough should be grown of each variety to insure carload shipments. The question of importing the seed from year to year is of especial importance to the older potato growing districts. These sections are now more or less infested with diseases that preclude the using of their own crop for seed the following year and seed must be obtained from other portions of the state or outside of the state where the disease is not known. There should be a correlation to mutual advantage between the potato growers in the mountain section and the potato growers in the valleys or on the plains, so that the latter can obtain their seed from the former.

There are a number of locations in the state where high-grade seed potatoes can be grown and these localities should take advantage of their location and furnish high-grade seed for the other districts not so favorably located.

Potatoes grown on a field known or found to be infested with Fusarium or Rhizoctonia diseases should under no circumstances be used for seed, nor should land so infested be planted to potatoes for at least four years, but be planted to alfalfa.

There is considerable controversy and difference of opinion as to the relative value of seed grown in the state or seed grown in Wisconsin and Minnesota. Experience has shown that seed grown in the last named states do not yield as heavily the first year as the second; in other words, it appears that the potato requires one year to become adapted to the conditions of Colorado. This adaptation does not seem to be necessary in the case of seed obtained from the mountain valleys and from higher altitudes in Colorado, but yield a maximum crop the first year. We would recommend the use of Colorado grown seed, for the cost of transportation, under most conditions, is much lower than the freight rate from Minnesota or Wisconsin.

In order that the potato seed growing industry in the state may prosper, it will be necessary that the growers pay particular attention to the varieties and types; in other words, the selection of typical plants and best yielding hills should be practiced, for experience has shown that by the hill selection system, we can greatly increase the yield of our present varieties and at the same time obtain a market.

## 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 seeds are planted in hills eight 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.

## RADISHES.

The radish is one of the most popular spring vegetables on account of its hardiness, quick return and agreeable crispness and flavor.

*Soil.*—For early radishes, the soil should be "quick," that is, it should be a sandy loam containing plenty of humus. The soil should be deeply cultivated late in the fall and left in slight ridges which allow it to warm up earlier and dry out sooner in the spring.

*Planting.*—The surface is harrowed and smoothed early in the spring and the seed planted in rows fifteen to eighteen inches apart. About 30 or 40 seed are 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.

*Forcing Radishes.*—This vegetable is often forced in hotbeds, cold frames, muslin frames, and sometimes in greenhouses. Seed are usually planted in the hotbed or cold frame very early in the spring in rows about six inches apart with 30 or 40 seed to the foot. Grown in this manner the crop will reach maturity in three to five weeks. In a good hotbed a crop of radishes may be grown in the middle of winter. In the greenhouse, they may, of course, be grown at any season of the year, but spring conditions must be imitated as far as possible. Radishes are comparatively hardy plants and naturally grow in the cool parts of the year. Therefore when grown in greenhouses or 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.

## RHUBARB.

Rhubarb, or pieplant, is found in almost every garden. It is grown for its thick leaf stalks which are used in making pies. The stalks are also cut in cubes and canned for use as occasion requires. Rhubarb does best in northern climates.

*Soil.*—The soil should be deeply plowed and given a heavy dressing of decomposed stable manure. It is difficult to make the soil too rich.

*Planting.*—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 four or five feet apart and the plants set rather deeply, two or three feet apart in the row. The crowns of the plants are covered two or three 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.

*Cultivation.*—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 given 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.

*Forcing Rhubarb.*—Rhubarb may be forced in greenhouses, cellars or hotbeds with very little trouble. One thing, however, is necessary before this can be done. The roots must have a rest period and it is better if they can be thoroughly frozen for three weeks or more. Regardless of the method of forcing, strong, vigorous roots should be used.

When forced in greenhouses the roots are placed as close together as possible on the ground and covered with soil. In a short time the leaf stalks appear and are soon ready for harvesting. Light is not necessary for the growth of rhubarb under such conditions, but when grown in the dark, the stems are inclined to be long and slender. For this reason excellent rhubarb can be grown under the benches in a greenhouse where the benches are used for other plants, or in a cellar.

When grown in a cellar, the roots are simply placed in sand or soil and moisture applied in proper quantity. A temperature of from 45° to 60° Fahrenheit is best for forcing this vegetable.

When a hotbed is used, one that is comparatively cool is desirable.

## SALSIFY.

This vegetable which is popularly known as "Oyster plant," is grown for the fleshy roots which are sent to the table boiled. It is quite hardy and the roots may be left in the ground during the winter for use early in the spring.

The seed are sown in the spring at the same time as early radishes in a deep rich soil. They are planted in drills fifteen or eighteen inches apart and the plants later thinned to stand two or three inches apart in the row.

Salsify may be harvested at any time during the winter when frost will permit, but if a supply is wanted for the winter, a part of the crop should be harvested late in the fall and the roots stored in sand in the cellar.

## SPINACH.

This is a plant grown in 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.

The soil best suited for spinach is a rich sandy loam. 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.

## 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 northern Colorado, but the winter kinds can be grown.

*Soil.*—For early squashes, a quick sandy loam is best, while the late varieties grow best on rather retentive clayey soils. The soil should be well fertilized with stable manure and thoroughly plowed and harrowed before planting time.

*Planting.*—Squashes are planted about the same time as corn. Rows are laid off in checks, four to eight feet apart each way, depending on variety, and 6 to 10 seeds planted at each intersection of the check marks. The seed are covered about one 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 greenhouse or hotbed, as suggested for cucumbers, and transplanted to the open after danger of frost is past.

*Harvesting and Storing.*—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 so as 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.

## SWEET POTATOES.

Sweet potatoes, while not adapted to all parts of the state, can be successfully grown at the lower altitudes in the southern part of the state.

*Soil.*—A rich sandy loam is desirable for growing sweet potatoes. The soil should be well prepared and fertilized with stable manure. In the south, low ridges are usually thrown up and the sets planted on this, but the ground may be left flat.

*Planting.*—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 three inches of sandy soil. The potatoes are placed on this just far enough apart not to touch and covered with three 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 six 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 fifteen inches apart in rows three and a half or four 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 recent 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 degrees 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 degrees 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 has come to be one of our most important vegetables and is now universally cultivated in the gardens of this country. There are three types of tomatoes grown. They are the current type, the cherry type, and the commercial type. The first two are rather weak-growing, small-leaved, small-fruited plants, while the commercial type is the one commonly found on the markets. This type makes a sturdy growth and has large leaves and fruits.

*Soil.*—While the tomato will grow well on a variety of soils, a warm sandy loam is preferable.

*Securing Plants.*—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 in the greenhouse or in the hotbed from March 1st to March 15th. As soon as the plants are large enough to handle, they are transplanted to other flats or 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 six-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. If handled properly, however, they will not be checked in their growth.

*Setting the Plants.*—The plants should be set about four 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.

*Cultivation.*—When the plants are set four feet apart each way, they can be cultivated almost entirely with horse-drawn implements. The objects of cultivation are to keep down weeds and maintain a surface mulch in order to preserve moisture.

When tomatoes are grown on a large scale for canning they are usually allowed to grow at will and are not provided with supports. On a small scale, however, the plants are trained to stakes two to three feet high. In this case the plants may be grown to a single stem or two or three stalks may be allowed to develop, and these are tied to the stakes in order to keep the fruits and foliage off the ground and expose them to the sunlight.

*Forcing Tomatoes.*—Tomatoes are forced quite extensively in greenhouses. When so grown, they must have a day temperature of from 70° to 80° F. and a night temperature of 60° to 65° F. Tomato forcing houses are usually constructed with solid benches with no provision for bottom heat.

The plants for forcing are secured in about the same way as suggested for early field planting, except the seed are sown in August instead of March. The plants are transplanted two or three times, being put into 4 to 6-inch pots the last time. When they have filled these pots and flower buds are beginning to appear, they are ready to place in their permanent positions in the bench about eighteen inches apart each way.

In the greenhouse tomatoes are commonly grown to a single stem which is supported by twine stretched between two wires.

Hand pollination is necessary when this crop is grown under glass. This is accomplished by brushing the stamens with a small camel's hair brush and then brushing the end of the pistil. Or the pollen may be shaken on a watch glass and the stigma of the flower dipped into the pollen. Another method is to use a small sharp-pointed stick. This is run between the stamens and a few grains of pollen will adhere. These are applied to the stigma. By using one of these methods a large per cent of the flowers can be made to set fruit.

## 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.

A rich sandy or clayey loam is best for turnips. The crop grows rapidly and must have a good supply of available plant food.

The seed for the early crop are sown in March or April in rows fifteen to eighteen inches apart. The seed are covered to a depth of three-fourths of an inch. When the plants are well up, they are thinned to stand four to six inches apart in the row. After they have attained edible size, they are bunched and sold the same as beets.

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 sold or 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.

## WATERMELONS.

Watermelons are much less widely cultivated in Colorado than the muskmelon, but with proper care they can be grown in most any part of the state.

*Soil.*—Watermelons thrive best on a warm sandy soil, while the cool nights and short season of northern Colorado are not conducive to the best development of the crop. The abundance of sunlight during the summer offsets this to some extent. The soil should be thoroughly prepared and well fertilized with stable manure.

*Planting.*—The watermelon is a tender plant, so that planting must be delayed until danger from frost is past. The seed are planted in hills about eight feet apart each way and covered one 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 the seed in pots, strawberry boxes, or on pieces of sod placed in the hotbed or greenhouse. 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 the growing plants can be protected at the most critical stage from insects and other troubles when in the greenhouse or hotbed, much more easily than if they were scattered over a field.

*Cultivation.*—The best culture possible should be given the crop early in the season so that the least amount possible will be required later when the vines begin to cover the ground.

# Hot Beds and Cold Frames

*By R. A. McGINTY*

Everyone who plants a garden should have a cold frame or hotbed in order to have early plants for the field. These are either temporary or permanent structures used for starting plants early in the season, carrying half hardy plants over the winter, and for growing quick maturing crops out of their ordinary season. In the hotbed, heat is supplied by fermenting manure or other means, while there is no artificial heat in the cold frame. Plants like radishes and lettuce may be grown to maturity in hotbeds, even in midwinter, while others, like cucumbers, tomatoes, and cabbage, may be started in the hotbed early in the season and transplanted to the open after danger of frost is past.

Cold frames are used for hardening off tender plants such as tomatoes and cucumbers: that is, they are transplanted from the greenhouse or hotbed into the cold frame in order to allow them to become more gradually accustomed to outside conditions. Cabbage, pansies and other semi-hardy plants may be started in cold frames late in the fall and carried over the winter so as to be ready for transplanting to the open very early in the spring. Tender perennial plants like geraniums and some of the roses can be successfully wintered in cold frames.

*Location.*—The hotbed or cold frame should be located on a well drained spot with a southern aspect. If protected from the prevailing winds by a hedge, board fence or building, so much the better. The hotbed, particularly, is best located on a walk between the house and barn or other outbuilding to insure that it will not be neglected in the matter of ventilation, protection, etc.

## HOTBEDS.

*Permanent Hotbeds.*—In preparing a permanent hotbed, an excavation about two and one-half feet in depth, six feet wide, and any length desired, extending east and west, is made. This may be walled up from the bottom with brick or cement. In this case the walls are made to extend about twelve to fifteen inches above the surface of the ground on the north side of the bed and five or six inches lower than this on the south side, thus giving a slope to the south. If it is preferred not to use brick or cement, a frame made from planks two inches thick will serve. However, the plank does not extend to the bottom of the excavation, but just a few inches below the surface of the soil. Wooden or iron stakes are used to hold the boards in place.

*Manure for Hotbeds.*—The heating material most commonly used is fresh manure from grain-fed animals—horses or mules. It is better to secure it from a livery stable, as larger quantities can be gotten within a short time. As much as one-third or more of the manure may consist of straw or litter used in the bedding. If the manure has less straw or litter than this, it will be too dense and will not heat well and if it contains too much, the period of heating will be shortened. The manure is taken from the stable and placed in a flat-topped pile four or five feet high and as long and wide as necessary. If the manure is dry, it should be moistened by sprinkling, but must not be made too wet. Under normal conditions, it will start heating in four or five days. If the weather is cold, it may be necessary to sprinkle a part of the pile with hot water in order to start fermentation, or a small quantity of hen manure placed in one part of the pile will sometimes cause it to begin heating.

When fermentation has progressed for a short time the pile is turned in order to make the heat uniform throughout. It may be necessary to turn the pile two or three times. When it is steaming uniformly throughout, the manure is ready to be put in the hotbed. The period between the piling of the manure and the time when it is ready to put into the bed is ordinarily about two weeks.

In putting the heating material into the hotbed, the amount used depends on the outside temperature. If zero or colder weather is expected, manure to the depth of 18 to 30 inches should be put in the bed. For milder temperatures less can be used, and where there is only three or four degrees of frost, six or eight inches will be sufficient. The material is best put in by layers, each layer a few inches deep, and well tramped down with the feet before the next layer is put in.

When the necessary amount of heating material has been put in and well packed down the bed is then ready for the soil. Soil made of one-fourth sand, one-fourth well rotted manure, and one-half good garden soil will answer very well. It is spread over the heating material to a depth of five to seven inches, the greater depth being desirable for radishes and other root crops. If plants in pots or boxes are to be put in the hotbed, sawdust or sand may be used instead of soil. Plants in pots are plunged to the rim in the sawdust, while boxes are simply set on it, the sawdust or soil, either of which can be used, being only three inches deep in this case.

*Temporary Hotbeds.*—A temporary hotbed may be made as follows: Construct the walls of the hotbed of one-inch instead of two-inch plank, but make them of the same dimensions otherwise. An excavation is often made somewhat wider and longer than the ordinary dimensions of the bed and the heating material put in. The boards forming the walls are then set on top of the manure. By this plan the heating material extends somewhat beyond the edges of the bed and there is less danger of the temperature falling too low. Glass sash or muslin may be used for covering. The board walls of the hotbed are easily removed after they have served their purpose and the ground may be cultivated as desired.

Another plan that is often followed in making a temporary hotbed is to place the heating material on top of the ground instead of in an excavation. The pile of manure is made somewhat wider and longer than the frame which is set directly on top. Manure may also be banked up around the boards in order to further protect the bed from cold; a layer of soil is put over the heating material and the hotbed is ready for planting. The frames may be removed after they have served their purpose and the rotted manure removed scattered or plowed into the soil.

*Sowing the Seeds.*—The manure will ordinarily heat very vigorously for a few days after being put into the bed and the temperature may go up to 130° to 140° F. Soil thermometers should be thrust through the earth to the manure and the frame kept tightly closed with sash. After a few days the temperature will begin to decline. When it has declined to 90° the seed may be planted. The soil should be loosened before planting and the rows made four to six inches apart, usually crosswise the bed.

*Covering for Hot Beds.*—The most common covering for hotbeds in the ordinary glass sash 3x6 feet. The sash cost, glazed, about $1.75 to $2.00 each. In addition to the glass sash, straw mats or some such covering is necessary during very cold weather. These can be bought for 50 cents to $1.00 per sash, or straw, or home-made covers can be used instead. A very good cover can be made by stuffing old sacks (not too full) with straw. In addition to mats it is well to bank manure or soil up around the walls of the bed to help keep out the cold.

A covering which is used on hotbeds considerably instead of glass after the middle of March is made by dipping muslin in linseed oil and letting it dry. The muslin is then tacked to light frames and makes a very serviceable covering in weather that is not too cold. The linseed oil makes it more impervious to moisture and semi-transparent.

*Care of the hotbed.*—In the management of the hotbed there are two things which must be given especial care. They are watering and ventilation.

It is better to water the bed with a watering pot than with a hose because there is less tendency to pack or puddle the soil. The bed should not be watered toward night, as this tends to lower the temperature when the outside temperature is falling. Too much water checks the heating of the manure and must be avoided. Wet the soil thoroughly (but not too wet) and then do not apply any more water until the plants show that they need it.

Ventilation is particularly important. On warm days, the combined heat of the sun and fermenting manure will be enough to destroy the plants unless the hotbed is properly ventilated. Ventilation can be given by sliding down the sash or by propping it up a few inches. When the time approaches for setting the plants in the open, the sash should be removed entirely when the weather permits. In this way the plants become accustomed gradually to a lower temperature and the normal conditions of the atmosphere. Whenever the air in the hotbed is so moist that drops of water collect on the panes, ventilation should be given if the temperature will permit. Plants which are kept in a close moist atmosphere tend to grow too tall and soft.

In very cold weather or during snowstorms it may be necessary to keep the sash and mats over the hotbeds for several days at a time. In this case, the plants are in the dark and tend to become soft and tender, so that care must be used in admitting light after this period, as they are likely to be scalded by the sunlight.

The hotbed should not be started too soon. If it is to be used for starting plants which are to be transplanted to the field early in the spring, it should be made from five to eight weeks before time to set out the plants. If they have to be held back on account of the cold weather and not transplanted, they will become stunted. The average life of a hotbed is about two months. A good size for the ordinary garden is 6x12 feet, requiring four 3x6 sash. It is a good idea to fill the pits with litter of some kind in the fall. When the time for making the hotbed arrives, this litter may be pitched out, leaving an unfrozen area for the making of the hotbed.

## COLD FRAMES.

Cold frames may be either temporary or permanent structures. If temporary, they are boarded up with the same material as the temporary hotbed, that is, one-inch plank. Cold frames are made the same size as hotbeds and have a slope to the south. Glass sash and mats are used for covering them, or the muslin cover described under hotbeds may be used after about the 20th of April.

When the cold frame is to be used for growing lettuce or for hardening off plants such as tomatoes or cabbage, it is not necessary to make an excavation unless to make room for a few inches of good soil. The soil in a cold frame may be the same as that for a hotbed, or a good sandy, loamy garden soil will be sufficient.

If the cold frame is to be a permanent structure, the sides should be made of heavy plank two inches thick or of brick or cement. If it is desired to use it for carrying half hardy flowers in pots over the winter an excavation three feet deep may be made and the walls and bottom cemented. Sawdust is then put in to a depth of a few inches and the pots are plunged in this to the rim.

Hardy plants like cabbage, kale, and cauliflower can be carried through the winter in cold frames in order to have them for early transplanting in the spring. The seed are sown in the open in the fall in time to develop three or four true leaves before freezing weather comes on. When the plants are transplanted into tne cold frames they should be as stocky as possible. All weak or poorly developed plants should be discarded, as they will hardly survive the winter. When freezing weather comes on, the frames are covered, but they should be left open as late as possible in order to make the plants more hardy. The sash is first put on and later the covers are used. The plants do not grow during the winter. They gradually freeze, but if proper care is exercised that the sun does not strike the frozen plants and thaw them out too quickly, they will come through unharmed. They may stand for several days under a cover of snow on the sash without injury with the ground frozen, but if the ground should thaw out, they should not be kept in the dark for more than a day or two at a time. When warm weather comes, the plants are thawed out as gradually as possible and the sash is removed on bright warm days.

The proper age and condition at which plants should go into the cold frame can be determined only by experience. If the plant is too old when put into the cold frame, it is apt to run to seed when planted out in the spring, and if it is too young it will not be likely to survive the winter.

Such plants as pansies, carnations and daisies may be kept over winter in the ordinary cold frame without any trouble.

The best use to which cold frames can be put in this climate is that of hardening off plants in the spring. If tomatoes, cucumbers and other tender plants are started in the hotbed or greenhouse, it is better to transplant them into a cold frame for a short time before they are finally put in the field. By this means they are gradually accustomed to a lower temperature and yet may be protected on cold nights.

## MODIFIED HOTBEDS AND COLD FRAMES.

Hotbeds, instead of being heated by fermenting manure, may have smoke flues, steam or hot-water pipes running through them to furnish the necessary heat. In such cases the pipes, flues, etc., are run beneath the soil in the beds.

A device which serves the purpose of a miniature cold frame is the forcing box which is used in small gardens to place over a plant or a hill of plants in order to protect it in the early spring. The forcing box is made about 10 inches wide, 12 inches long, and 6 inches deep, without top or bottom. Provision is made whereby a pane of glass may be slid into the top. The box is so made that this pane of glass slopes toward the south when it is placed in the field. The boxes are placed over the plants in the early spring and protect them during cool weather, particularly at night.

# Common Insects of the Garden

*By C. P. GILLETTE*

## CORN.

### *Striped Corn Rootworm* (*Diabrotica virgifera*).

This insect is becoming very abundant in some of the market gardens and home gardens in Eastern Colorado. The female, in the adult stage, is a small striped beetle, easily mistaken for the striped cucumber beetle. The male beetle is almost wholly black. This is a comparatively new pest, having been first recorded as injurious to corn by the writer in *Journal of Economic Entomology, Vol.* 5, *page* 364, 1912.

The beetles lay their eggs about the roots of the cornstalks during late summer and in the fall. The eggs remain over winter and hatch the following spring, and if corn is planted upon the same ground the following year, it is sure to be attacked. The little grubs, upon hatching, burrow into the roots and crowns of the corn, causing the stalks to become stunted, and they often fall over of their own weight, and are specially prone to do so at a time of wind and rain.

*Remedy.*—There is one very efficient means of preventing the injuries of this insect, and that is to avoid planting corn upon the same ground several years in succession.

### *Corn Ear-worm* (*Heliothis armigera*).

This insect is very destructive, especially to sweet corn, in Colorado, by eating into the ears and feeding upon the kernels at any time during the summer months. It is known as the cotton boll-worm in the Southern States and is a rather general feeder, often eating into tomatoes and string beans when it is present in large numbers.

The eggs are laid upon the tassels, silk and leaves of the corn and the little worms burrow their way into the ears of corn and are most commonly found near the tips of the ears.

There are several broods a year in the Southern States, and in Colorado the worms are found throughout the summer.

*Remedies.*—There is no satisfactory remedy for the control of this insect. Probably the best one for the garden is to destroy the worms by hand as they eat into the ears of corn. Po.sonous sprays are of very little effect and are dangerous, as they render the corn fodder unfit for stock food.

## CABBAGE AND CAULIFLOWER.

*Green Cabbage Worm* (*Pieris rapae*).

Cabbage, cauliflower and allied plants are nearly always seriously attacked in Colorado by the common green cabbage worm, which feeds upon the cabbage leaves, and, when abundant, often eats deeply into the cabbage heads, ruining them for market.

The adult insect is a white butterfly, which deposits its eggs, one in a place, upon the leaves of the plants attacked. If one w.ll watch these butterflies over a cabbage patch, it will be no trouble to notice the butterflies occasionally descending and touching the tip of the abdomen to a leaf. In doing this an egg is deposited. The eggs hatch in a few days and the little worms begin at once to feed upon the leaves near where they hatch.

*Remedies.*—One of the most efficient remedies for this insect is the use of arsenical poisons. Perhaps the most satisfactory one to use is Paris green, though arsenate of lead may be used with satisfactory results. One of the best methods of applying the Paris green is to mix a teaspoonful of the poison in about one pint of common wheat flour and then dust the mixture over the infested plants through a cheese cloth sack. The application is best made early in the morning when there is no wind and when a little dew is still upon the leaves. A very light dusting is all that is necessary for good results. If arsenate of lead is used, dilute one pound of the lead paste, or one-half pound of powdered lead, in twenty gallons of water and thoroughly spray the leaves. The application should be begun as soon as the butterflies begin to deposit their eggs, and should be repeated once every week or ten days until the cabbages are nearly grown.

Insect powder, or Pyrethrum, may be used either in the form of a spray, one ounce to three gallons of water, or may be lightly dusted over the infested plants for the destruction of the worms.

This insecticide is not poisonous to man or higher animals, but is very destructive to most insect life. This powder is best applied with a small bellows that will drive it deeply into the cabbage head, as the powder must come in contact with the insect's body in order to kill it.

If the poisons above mentioned are used, the leaves will not be fit for stock food, but there will be no danger of poisoning people who eat the cabbage heads, as all of the outside leaves that catch the poison are removed when the cabbages are cooked. These arsenical poisons must not be used on cauliflowers after the heads have begun to form, and should not be used on cabbage nearer than two weeks to the time when the heads are to be gathered.

*Cabbage Louse (Aphis brassicae).*

The green cabbage aphis is often very abundant upon the leaves of cabbage, cauliflower and closely allied plants. The surface of the body of this louse is covered with a fine powder which will shed water and ordinary insecticide poisons, unless the application is made with a good deal of force so as to cause the liquid to wet through the powder. It is better still to wash the lice off the leaves. Strong soapy mixtures (a pound of whale oil or fish oil soap to each eight gallons of water), nicotine preparations such as Black-leaf 40, or oil emulsions, will be found efficient in the destruction of this louse if used as a forceful spray.

## BEANS.

*Spotted Bean Beetle (Epilachna corrupta).*

This insect is very destructive to garden and field beans in the area adjacent to the eastern foothills of the Rocky Mountains, from Wyoming to Southern Colorado and far into New Mexico. The insect belongs with the lady beetles, but has acquired the habit of feeding upon plant tissues instead of plant lice and insect eggs. Its occurrence is not known in the states farther east. The adult insect is of a rusty yellow color with a number of small black spots upon its wing covers. The eggs are yellow in color and are laid in patches, usually of twenty or more, on the under side of the bean leaves and can hardly be distinguished from egg patches of the Colorado potato beetle.

The grubs or larvae that hatch from these eggs are light yellow in color and are covered with stout branched hairs or spines. There is only one brood of the insect during the year, but it continues upon the bean foliage throughout the season.

*Remedies.*—The use of insecticides for the control of this insect have not been very satisfactory. After much experimentation we have come to the conclusion that the best methods of control are picking the adult beetles and their eggs from the plants early in the summer, and brushing the insect in all stages of development from the leaves upon the hot ground later in the season. To do this work successfully the day must be hot with the sun shining brightly, and only two or three hours of the warmest part of the day can be used.

Arsenical poisons applied to the leaves will usually do more injury to the plants than to the bean beetles.

## SQUASH AND PUMPKIN.

### *The Squash Bug (Anasa tristis).*

This large dark colored squash bug, often designated as "stink bug" because of its very disagreeable odor, has been credited with a great deal of injury to winter squashes in Colorado. I have been noticing its presence upon squash vines in Colorado for many years but have never yet seen a plant that I thought was seriously injured by it. When abundant enough to do serious harm, the bugs, in all sizes, accumulate upon individual leaves in sufficient numbers to cause them to wilt and die.

*Remedies.*—The application of insecticides for the control of this insect, is not satisfactory. The best remedies are hand picking and destruction of the adult insects and their eggs early in the season, and collecting the bugs later in the summer in a pan of water with a spoonful of kerosene on top. The latter method is most successful early in the morning when the bugs are inactive.

The destruction of squash vines by the squash root maggot mentioned below is commonly attributed to the squash bug.

### *The Squash Root Maggot.*

During the middle of the summer, almost any time after the winter squash vines have begun to run, they will sometimes wilt and die within a day or two. If these vines are examined, it will usually be found that the plants are being attacked at the crown, or root, by maggots, causing them to decay. As soon as the maggots are fully grown they leave the plants and burrow into the ground about the roots, where they undergo their transformation and later emerge as two-winged flies, very similar to our common house fly, but somewhat larger.

*Remedies.*—When the plants die, the dirt immediately around the crown should be removed and the maggots or their pupae destroyed, which can easily be done by stamping the earth under foot. The flies may be prevented from depositing their eggs about the plants by placing a collar of tar-paper close about the crown. This should be done just before the vines begin to run. Part of the plants that can be spared should be left without the collar to catch the eggs and so serve as traps.

It is quite often that the vines of winter squash or pumpkins wilt down quickly as mentioned above, when the crown and roots of the plants are apparently sound. In such cases the plant will nearly always be found to be attacked by a bacterial organism which causes the interior of the stem to change to a yellowish color, and usually there is considerable exudition of an amber-colored fluid from portions of the vine, and especially near the root. If insects are abundant on the squashes, they are liable to carry the disease organisms upon their mouth parts from vine to vine until the entire patch is destroyed. To prevent the spread of this disease, pull and burn all dying plants as soon as they are noticed and reduce the insects that are attacking the squashes to the smallest possible number.

## MELONS AND CANTALOUPES.

### *The Melon Louse (Aphis gossypii).*

The little green melon louse which attacks the foliage of melon, cantaloupe and cucumber vines, is perhaps the most destructive pest that these plants have in Colorado. The melon aphis usually attacks, at first, but very few plants scattered through the patch. Upon these plants the lice increase rapidly in numbers, some of them acquiring wings, and then the insect spreads rapidly over the field, and may become so numerous as to almost destroy the crop.

*Remedies.*—It is sometimes the case that the lady beetles and other natural enemies of these lice are abundant enough to keep them in check, but it is not safe to depend upon the insect enemies to do this work, as a rule. Probably the best artificial remedies are either burning or burying the first infested vines of the year. In order to be successful in this work, the melon raiser must keep very close watch of his plants and as soon as any of them are found infested, the treatment should be made promptly. The burning is done by throwing a small forkful of straw or hay upon the infested vines and burning it. The plants are buried by throwing a few shovels of dirt upon them, which, however, must be sufficient to prevent the escape of any of the lice. All of the infested leaves should be buried under, at least, one or two inches of earth, and then it is well to tramp down the dirt. The lice cannot burrow out.

The ordinary insecticides for the destruction of other plant lice will kill the melon louse also, so far as they can be thoroughly applied to them. These insecticides are seldom effectual, however, because of the difficulty of making an application that will thoroughly reach the lice on the under side of the curled leaves. Fumigation of the plants under wash tubs may be carried on successfully, but I believe this is too expensive a method for practical purposes in the field.

*Striped Cucumber Beetle* (*Diabrotica vittata*).

This is one of the oldest and best known enemies of melon and cucumber vines. The adult insect is a small yellow beetle with three narrow black lines upon the back, or wing covers. It is very similar in appearance to the corn rootworm mentioned above, but shows the stripping much more plainly than that insect. The beetles usually appear about as soon as the second leaves start upon the cucumber plants. They often come in a single day in sufficient numbers to destroy the plants. The beetles have the habit of going in swarms, so that they often destroy certain hills completely without attacking others. While this insect is not generally distributed in Colorado, it has become rather abundant in the melon growing sections of the southeastern portion of the state.

*Remedies.*—Insecticides are often of little avail for the control of this insect. Pyrethrum powder, when thoroughly dusted over the plants early in the morning, while the insects are still dormant, will usually give good results. The plants should be disturbed enough to cause the insects to drop to the ground, so the powder can be thoroughly applied to them. Any very fine powder, such as fine road dust, ashes, slaked lime and the like, when thoroughly applied to the plants, will help some to reduce the injuries of this beetle. The application of arsenical poisons will do some good, but is seldom very efficient. The beetles may be kept away from the plants by putting mosquito netting over the vines and holding it down by means of dirt, stones, or wooden pegs.

Wherever this insect is abundant, it is advisable to plant plenty of seed, so that many of the plants may be sacrificed and still enough remain to produce a crop.

## ONIONS.

*The Onion Thrips.*

The onion thrips, sometimes spoken of as a louse, is a very minute, active insect that commonly attacks onion tops in Colorado, causing them to turn white, and often to wilt and fall to the ground. This insect is so small that it is often overlooked by the gardener, even when it is present in large numbers. When fully grown these minute insects have wings and will readily fly from the plants when disturbed, which makes it somewhat difficult to apply insecticides effectively.

*Remedies.*—The onions should be closely watched and when grayish or whitish places begin to appear upon the tops, it is quite certain that this insect is present and beginning its injuries. If the tops seem to be bleaching rapidly, it is advisable to apply some insecticide for the destruction of this insect. The best remedies are either some strong tobacco extract, such as Black-leaf 40, in the proportion of one part to 700 or 800 parts of water; or one of the oil emulsions, or miscible oils, in the form of a spray. The application is best made early in the morning while the air is quite cool and before the insects have become active. If the application is made by means of a pump and spray nozzle and with sufficient force the thrips can be washed from the onion tops and thoroughly drenched, which will destroy a very large proportion of them.

## RADISHES.

### *Flea-beetles.*

Little black beetles of more than one species, which jump readily when disturbed, often are very severe pests to radishes early in the season. Sometimes the first leaves are almost entirely eaten as soon as they break through the ground. The injury is always done by the adult insects. The characteristic manner of feeding is to eat small holes, hardly larger than a pin hole, through the leaves and when these are very abundant, the entire surface of the leaf will often die and turn brown. The same flea-beetle also attacks tomatoes, potatoes and other garden crops.

*Remedies.*—Any fine dust, such as road dust, ashes, slaked lime, and land plaster may be freely used upon the plants with some good results, but none of these are very effective if the insects are present in large numbers. The arsenical sprays, such as Paris green and arsenate of lead will also destroy some of the beetles, but are not considered satisfactory. Bordeaux mixture such as is commonly used for the control of fungus, diseases, if thoroughly applied to the plants, is often very effectual and prevents serious injury. I have had the best results, however, from the free use of insect powder, or Pyrethrum, applied freely by dusting it through a cheese cloth sack very early in the morning. The beetles should be brushed from the leaves so that they may be well covered with the powder.

### *Cut Worms.*

Perhaps the cut worms, of which there are several species in Colorado, are the most destructive pests to the average garden. These worms burrow just beneath the surface of the ground, where they remain in quiet during the daytime, but during the night or upon cloudy days it is their habit to come to the surface of the ground and feed upon a great variety of plants, having the peculiar habit of eating just at the surface of the ground, where they often cut the stem of the plants completely off; hence the name, cutworm.

The adult insects are dark-colored moths, expanding about one and a half inches when their wings are fully spread. These moths are often troublesome about the lamps in the evening on account of their habit of flying to the light in the night time. The moths are more or less common through the summer, but are usually most abundant in Colorado during the latter part of May and June. When the worms become fully grown, they burrow into the earth, change to the pupal or resting stage, and later emerge in the moth stage mentioned above.

*Remedies.*—In large fields, the method of control is to plow the ground during the summer and keep it cultivated and free from all vegetable growth until winter. This will prevent the moths laying eggs and will nearly always result in freedom from cutworm injuries the following spring.

If it is impossible to keep the garden tract free from vegetation late in the season, it is necessary to depend upon other means of control. One of the best of these remedies is to watch for the appearance of the plants that have been cut off during the night, and dig out and destroy the worms that are doing this work. Individual plants, or hills, of any plants in the garden that are liable to be attacked by the worms, may be protected by surrounding each plant or hill by a collar made of stiff paper, or tin. Tin cans may be cut in suitable sizes by means of tin shears and be used from year to year. A good size for the protection of a single plant is a strip of tin or paper three inches wide by five inches in length. The strip is curled in the form of a cylinder and placed about the plant and then pressed into the ground so that the top of the cylinder will project one and a half or two inches upon the surface of the ground. The worms will almost never climb over one of these cylinders to attack the plants. Care should be taken not to enclose the worms within the cylinder when it is placed about the plant.

Small weeds between the rows of plants in the garden are also a great protection from cut-worm injuries. When the cultivated plants are small, the worms feed as freely upon most of the garden weeds as upon the cultivated plants. If the weeds are all hoed out, the worms are compelled to feed upon the few cultivated plants that remain. It is bad advice, without doubt, to recommend allowing weeds to grow in the garden, but this can often be done judiciously for a week or two early in the season when the plants are tender and easily destroyed by the worms. As soon as the plants become woody and resistant to the worms the garden, of course, should be freed from all weeds and kept in as good condition as possible for the growth of the cultivated crops.

## POTATOES.

*The Colorado Potato Beetle* (*Leptinotara 10-lineata*).

The striped Colorado potato beetle is too well known to need description. The remedies are also quite generally known and are as follows: Early in the season collect as many of the adult beetles and their eggs as is possible and destroy them to prevent injury from the brood of young that would otherwise destroy the potato tops. If the eggs have been allowed to hatch and the young beetles are numerous upon the potatoes, the best remedy is the application of one of the arsenical poisons. Paris green may be used in the form of a spray in the proportion of one pound of the powder to each fifty gallons of water. If arsenate of lead is employed, dilute two pounds of the powdered form or four pounds of the paste to each fifty gallons of water. If a second brood appears, repeat the treatment for them.

*The Potato Tuber Moth* (*Phthorimaea operculella*).

This very destructive insect has been introduced into Colorado from infested districts in Southern California and Texas, but so far as I am able to determine, it has not as yet become established in any portion of the state.

This insect is an importation from China and bids to be one of the most serious enemies to potato growing in the the southern potato growing sections of the United States. Attention is called to this insect here chiefly for the purpose of warning growers of the possibility of introducing it in their communities and to ask for prompt information from anyone who suspects this insect to be attacking his crop.

The adult insect is a small, dark colored, narrow winged moth, which measures about one-half of an inch from tip to tip of its wings when they are spread. The eggs are laid upon the tubers, or upon the leaves or stems of the potato plant. The light colored worm, upon emerging from the egg, burrows into tuber, stem, or leaf, as the case may be, and feeds until it is fully grown, when it is about one-third of an inch in length. There are several broods during the year. The greatest injury is usually done to potatoes in storage, and especially if the temperature is high enough to be favorable for the development of this pest.

*Remedies.*—About the only remedies to be suggested are the burning of the potato tops when the insect is found to be burrowing into them, the careful gathering of all of the cull potatoes from the field at digging time, and the fumigation of cellar and storage rooms where the tubers are being kept.

Bulletin 200 Aug. 1914

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

# SILOS AND SILAGE IN COLORADO

*By* H. E. DVORACHEK

Dairy Barn and Concrete Silo, Colorado Agricultural College, Fort Collins

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# SILOS AND SILAGE IN COLORADO

*By* H. E. DVORACHEK

## PREFACE

Although the silo could be found on American farms nearly four decades ago, its use in Colorado agriculture dates back only a few years. It is true that there have been a few silos built in the state previously, but the number was too small to have even a pioneering influence towards present interest in silo construction. Eastern and middle western farmers came to Colorado and brought with them their experience with silage, and it was they who built our first silos. The plain-stave and wooden-hooped types were used most, as they were the common silo during the early days. The pit silo is of more local origin.

In the fall of 1909, the Dairy Division of the U. S. Department of Agriculture, stationed one of their senior dairymen, Mr. A. K. Risser, in Colorado to look over the field with a view of placing a man permanently to co-operate with the Animal Husbandry Department of the Agricultural College in developing interest in dairying and silo construction. From this time dates the beginning of active interest in the silo in Colorado.

During the three years of co-operative work, some seventy concrete silos were constructed under the supervision of the U. S. dairymen or college men. Other work, such as silo meetings and silo trains, did much to stimulate interest. Mr. P. V. Maris, one of the U. S. dairymen, published a bulletin on "Silage Feeding and Silo Building" in 1912. So great has been the demand for this bulletin that it has long been exhausted, and because of the constant and growing inquiries for information on this subject it was deemed advisable to issue another; therefore this bulletin on "Silos and Silage in Colorado."

This bulletin will set forth some of the advantages of silage as they apply to Colorado conditions, and the essentials to be considered in the selection of a suitable silo. Various types of silos commonly used will be discussed as to their merits from an unprejudiced viewpoint. The crops commonly used will be taken up only from the standpoint of their adaptability for making a silage of good quality. The making of silage will be treated in a manner which will enable the reader to get at the cost and economical utilization of labor. The essential principles of silage making will also be set forth. The feeding of silage to various farm animals will be discussed with a view towards encouraging the practice with other farm animals than the dairy cow. Finally, this bulletin will contain instructions for the building of the monolithic, solid-wall, concrete silo and also instructions for pit silo construction.

## ADVANTAGES OF SILAGE.

1. It is a well known fact that field curing is a wasteful method of preparing the forage crops for livestock feeding. Our dry climate and frequent winds make it especially so. Experiments show that at best only about 50 per cent of the crop is ultimately saved. Through the silo about 90 per cent can be saved, the waste occurring in the surface spoilage and fermentation processes which take place in silage formation. With most of our dry land farmers it is of vital importance to save all the forage possible, as it is not too plentiful.

2. The plant remains in a form which is not only nutritious, but also succulent and therefore palatable. Most of our farm animals do best on good, green pasture, and so the more nearly we can imitate that condition, the better should be results. Silage is also eaten without waste.

3. The crop is stored in a convenient and compact form. About four times as much dry matter in forage crops can be stored in a given space in the silo than by field curing and storing in the mow. The silo can be so located as to make it very convenient for feeding silage to stock. Then regardless of weather conditions the feed is at hand, leaving the fields clear for other farm operations.

4. Putting corn into the silo is the most economical method of harvesting the crop unless it be harvesting it with livestock. Practical farmers find they can put corn into the silo cheaper than husk it in the field. Besides the grain, the forage is harvested during the same operation.

5. The silo makes it possible to save the abundance of favorable years to be utilized during the years of scarcity. This advantage alone should justify the building of a silo on every one of our farms, because we are bound to have good and bad years. Silage can be kept in properly constructed silos for several years at least; how long has never yet been demonstrated to the author's knowledge.

6. Silage is the best supplement for pastures, which in the case of dry land sections are entirely inadequate, especially for the

dairy cow. Soilage may give as good results, but it is more expensive. Even in our irrigated sections pastures get short at certain seasons of the year. Silage may even take the place of pasture on high-priced land, but our experience at this college is that it would be more expensive.

7. The addition of silage to the ration makes it more palatable and therefore improves the whole ration. During severe weather, silage tends to keep up the appetite of stock and also supply large amounts of water which would not be taken in a cold condition. Shrinkage in gains or milk production is not likely when silage is fed during periods of storm. The animal can better utilize the balance of its ration.

8. The cost of the ration is materially reduced by feeding ensilage with all classes of livestock. Considering the cost of silage, its nutrient content and its beneficial effect upon the utilization of the balance of the ration fed, cheap gains are reported from many of our experiment stations with beef cattle. With the dairy cow, silage has long been recognized as practically a necessity for profitable winter dairying. Lamb feeders in Colorado are finding silage a cheap roughage for fattening lambs and, during periods of low market prices, those feeders who reduced the cost of fattening by the addition of silage were the only ones who reported a profit.

9. The silo will make it possible to put Colorado agriculture on a sounder financial basis. It is a fact that Colorado farmers must diversify more than they do. The one crop system has shown its weakness in many sections of the state. What we need is more livestock on the farms, and the silo will make it possible. Forage crops which can be grown with certainty every year must replace the special crops which are very frequently failures.

## ESSENTIALS OF THE SILO.

*Shape.*—The silo should be built cylindrical in shape, or nearly so. The surrounding wall thus incloses the greatest amount of space and there are no corners so that silage can be packed firmly around the wall, insuring less spoilage. The wall should be perpendicular and smooth to permit of even settling without leaving air pockets.

*Efficiency.*—The silo is a large tank or cistern for preserving chopped-up green feed in a succulent form. There is one fundamental principle which must be observed in silage making. The feed must be kept away from air, otherwise it will mold and decay. The silo will keep the best silage whose walls are the nearest air-tight. It is a proven fact that air-tight walls can be constructed from a variety of materials. The water of the green feed or added water aids in this exclusion of air, so that the walls should be so constructed as to make them not only air tight but also water-tight. If the walls absorb large quantities of moisture, they draw out moisture from the silage and allow mold to develop around the walls.

*Durability.*—The material used for silo walls should not only be of a character which will insure efficiency in silage keeping, but should also be of a durable nature. The silo is rather expensive in any material, so that the material which will last over the longest period of years and give satisfaction will be cheapest in the end, even though the first cost will be slightly greater. A silo which is weather, storm and fireproof is a great asset, as farm buildings as a rule are not generally insured heavily, if at all, and the risk of loss is great, due to lack of fire protection. Such a structure, with nothing about it to decay and need replacement after a few year's use, will require much less care and attention, which would add much to the satisfaction, and decrease expenses of the owner. A permanent structure of any kind is a good indication of the judgment and foresight of a business farmer.

*Cost.*—The silo which will give the most and best service for the least money is, of course, the kind to buy. First cost is, however, only one of the factors to be considered. Cost of upkeep and period of usefulness should also be figured on. It is therefore possible that some types of silos, although their first cost may be greater, are really a better investment, if their annual cost of upkeep is small and their period of usefulness, due to durable material used, extends over a long period of years. Upkeep is quite a factor when we stop to consider that the silo is generally empty during the most trying season, and when labor is scarce due to urgent farm work. It is work that is too often put off or forgotten. Such neglect proves expensive with silos, which demand attention.

*Convenience.*—The above ground types of silos are generally considered more convenient than the below ground types. It is easier to throw silage down than to throw or elevate it up. The continuous door is also more convenient than the intermittent, since the opening is always nearer the level of the silage and therefore requires less pitching up over the door. It is not desirable with above ground silos to go more than 5 feet below ground or to exceed 18 to 20 feet in diameter for convenience sake.

*Attractiveness.*—Any properly constructed silo adds to the attractiveness of the farm and enhances its value. Like other farm buildings, if in a delapidated condition, it is an eyesore and a good sign of shiftlessness and poor judgment on the part of the owner. Nevertheless, the silo which will be attractive and remain so with the least expense and effort is the one that will be "A thing of beauty and a joy forever."

*Dimensions.*—The inquiry is often made: "What size of silo shall I build?" The diameter depends upon the number and class of animals to be fed. To keep silage perfectly fresh, two inches should be removed daily from the entire surface during the summer months, and at least an inch to an inch and a half during winter months. This rule holds more particularly to above ground silos, as the spoilage of silage is not so rapid in below ground silos in this state. This makes it practical to build pit silos for smaller herds than above ground silos. It is not generally considered practical to build above ground silos for less than ten to twelve head of cows, while many pit silos are being built and successfully used with as few as four or five cows. The cause of poor silage is often nothing more than too large a diameter of silo for the amount of stock fed.

The following table shows the number of animals which should be fed from silos of various diameters in order to remove two inches of silage daily when various quantities are fed:

*Relation of Herd to Diameter of Silo.*

| Diameter of Silo | Pounds Removed | Number of animals feeding various quantities — 40 lb. per head | 30 lb. per head | 25 lb. per head | 20 lb. per head | 15 lb. per head | 5 lb. per head |
|---|---|---|---|---|---|---|---|
| 10 ft. | 523 | 13 | 17 | 21 | 26 | 35 | 105 |
| 12 ft. | 754 | 19 | 25 | 30 | 38 | 50 | 151 |
| 14 ft. | 1,030 | 26 | 34 | 41 | 51 | 69 | 206 |
| 16 ft. | 1,340 | 33 | 44 | 54 | 67 | 88 | 268 |
| 18 ft. | 1,685 | 42 | 56 | 67 | 84 | 112 | 337 |
| 20 ft. | 2,100 | 52 | 70 | 84 | 105 | 140 | 420 |

The amount fed varies with the class of animals to which it is fed. The following table shows the quantities of silage commonly fed to various classes of livestock:

| Kind of Stock— | Pounds daily. |
|---|---|
| Dairy cows | 25 to 40 |
| Stock cattle | 25 to 40 |
| Fattening cattle | 15 to 30 |
| Breeding ewes | 3 to 5 |
| Fattening mature sheep | 3 to 4 |
| Fattening lambs | 2 to 3 |
| Horses and mules (work stock) | 4 to 5 |
| Horses and mules (yearlings) | 8 to 10 |
| Horses and mules (mature, idle) | 20 to 40 |

The depth of the silo depends upon the length of the feeding period. Knowing the daily amount of feed per animal and the length of the feeding period, one can figure out how much silage will be needed for the entire herd. In general, the depth should be at least twice the diameter. The following table shows the capacity of silos of various depths and diameters:

*Capacity of Silos.*

| Depth of Silo, Feet. | Inside Diameter of Silo 10 ft. | 12 ft. | 14 ft. | 16 ft. | 18 ft. | 20 ft. | 22 ft. | 24 ft. |
|---|---|---|---|---|---|---|---|---|
| 20 | 26 | ... | ... | ... | ... | ... | ... | ... |
| 24 | 37 | 54 | 73 | 96 | ... | ... | ... | ... |
| 26 | 40 | 58 | 80 | 104 | ... | ... | ... | ... |
| 28 | 44 | 63 | 86 | 112 | ... | ... | ... | ... |
| 30 | 47 | 68 | 92 | 120 | 152 | 188 | ... | ... |
| 32 | 50 | 73 | 99 | 128 | 162 | 200 | 243 | 290 |
| 34 | 55 | 78 | 107 | 139 | 176 | 218 | 263 | ... |
| 36 | 59 | 85 | 115 | 150 | 190 | 235 | 285 | 339 |
| 38 | 63 | 91 | 124 | 162 | 205 | 254 | 307 | ... |
| 40 | 68 | 98 | 134 | 175 | 221 | 273 | 330 | 393 |
| 42 | ... | ... | 143 | 187 | 237 | 293 | 354 | ... |
| 44 | ... | ... | 150 | 196 | 248 | 309 | 371 | 417 |
| 46 | ... | ... | ... | 205 | 259 | 320 | 388 | ... |
| 48 | ... | ... | ... | 214 | 270 | 334 | 405 | 482 |
| 50 | ... | ... | ... | 223 | 281 | 348 | 422 | 502 |

It is often desirable to compute the amount of silage in a partially emptied silo. In order to do this it would not be accurate to figure the depth of silage as if it were the total amount put in. The silage at the bottom of course is more firmly packed and therefore a cubic foot weighs more than at the top. The following table gives the number of square feet of surface area in circles of various diameters:

| feet Diameter | Square feet Surface Area | feet Diameter | Square feet Surface Area |
|---|---|---|---|
| 10 | 78.54 | 16 | 201.06 |
| 12 | 113.10 | 18 | 254.47 |
| 14 | 153.94 | 20 | 312.16 |

The following table gives the weight of silage per cubic foot at different depths and the total weight of one square foot of area to a given depth:

| Depth of Silage, feet | Weight per cu. ft. at different depths, lbs. | Total weight 1 sq. ft. area to given depth, lbs. | Depth of Silage, feet | Weight per cu. ft. at different depths, lbs. | Total weight 1 sq. ft. area to given depth, lbs. |
|---|---|---|---|---|---|
| 1 | 18.7 | 18.7 | 19 | 45.0 | 619.7 |
| 2 | 20.4 | 39.1 | 20 | 46.2 | 665.9 |
| 3 | 22.1 | 61.2 | 21 | 47.4 | 713.3 |
| 4 | 23.7 | 84.9 | 22 | 48.5 | 761.8 |
| 5 | 25.4 | 110.3 | 23 | 49.6 | 811.4 |
| 6 | 27.0 | 137.3 | 24 | 50.6 | 862.0 |
| 7 | 28.5 | 165.8 | 25 | 51.7 | 913.7 |
| 8 | 30.1 | 195.9 | 26 | 52.7 | 966.4 |
| 9 | 31.6 | 227.5 | 27 | 53.6 | 1,020.0 |
| 10 | 33.1 | 260.6 | 28 | 54.6 | 1,074.6 |
| 11 | 34.5 | 295.1 | 29 | 55.5 | 1,130.1 |
| 12 | 35.9 | 331.0 | 30 | 56.4 | 1,186.5 |
| 13 | 37.3 | 368.3 | 31 | 57.2 | 1,243.7 |
| 14 | 38.7 | 407.0 | 32 | 58.0 | 1,301.7 |
| 15 | 40.0 | 447.0 | 33 | 58.8 | 1,360.5 |
| 16 | 41.3 | 488.3 | 34 | 59.6 | 1,420.1 |
| 17 | 42.6 | 530.9 | 35 | 60.3 | 1,480.4 |
| 18 | 43.8 | 574.7 | 36 | 61.0 | 1,541.4 |

With the two tables given above, one can easily figure the capacity of a partially emptied silo. For example, a 12x36 silo is emptied until only 20 feet of silage remains. Figure the amount of silage in the silo. One square foot of area through 36 feet in depth weighs 1,541.4 pounds, but the top 16 feet, which weigh only 488.3 pounds, have been removed, leaving in the silo 1,053.1 pounds for every square foot of area. A 12-foot silo has 113.10 square feet of area; therefore there would be 113.10 times 1,053.1 pounds, or 119,105.61 pounds, or approximately 59½ tons of silage left in the silo. Partially filled silos, of course, have a capacity equal to a silo whose depth would be the same as the depth of the silage. If a 12x40 silo were filled to only 26 feet, the weight of that silage would be the same as that of a full 12x26 silo.

*Floor.*—A cement floor is not necessary in the silo under ordinary clay soil conditions. Where there is danger of seepage into the silo a floor should be put in. Where the soil is very gravelly so that the drainage from the silo would be very rapid, it would be advisable to lay a floor in the silo.

*Roof.*—A roof on a silo adds greatly to its appearance; giving it a more finished appearance. A tight roof also helps to decrease freezing and adds to the comfort of the feeder during the periods of storm. However, a roof is not entirely essential.

*Chute.*—A chute should be built on all above ground silos, as without it a great deal of waste of silage would result. Silage would be scattered over considerable space by throwing it down from the top of a silo without a chute, especially during windy weather.

## TYPES OF SILOS USED IN COLORADO.

The types of silos used may be divided into two general classes, the above and below ground. To the former class belong all types, regardless of material used, which are built entirely above ground or nearly so. To the latter class belong the pit, bank, and trench silos.

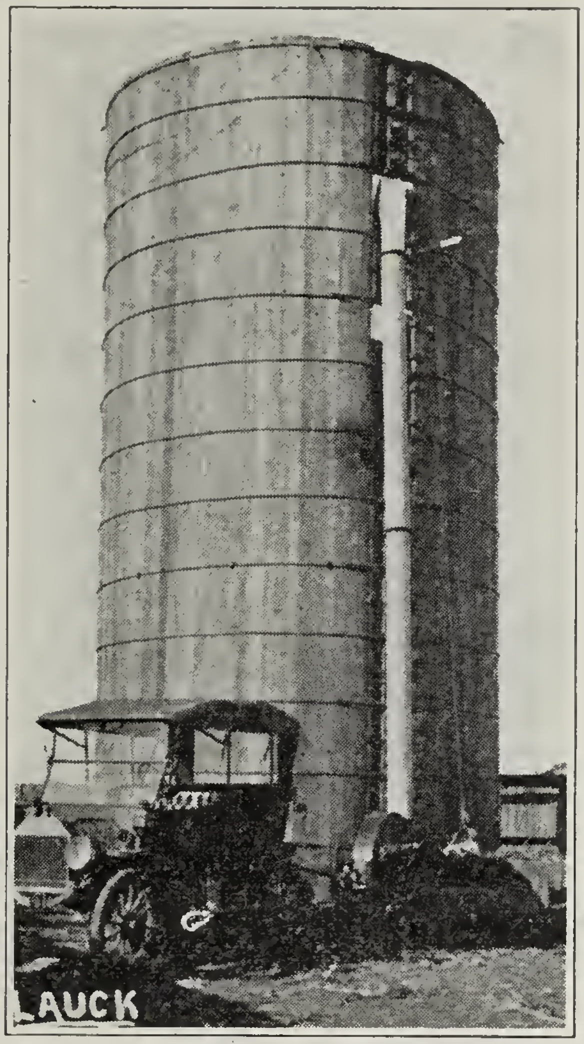
### *Above Ground Silos.*

*Home-Made Stave Silo.*—This type was perhaps the first to be built. The earlier ones were built of plain staves, often not even beveled on the edge to make them fit in a circle. Many failures resulted, as poor lumber was selected and the shrinkage was great. Knots dried up and dropped out. They were generally a costly experience. It is quite common at the present time for farmers to build their own stave silos, but tongue and groove material is used instead of the plain stave. When lumber of good quality is used, a very serviceable silo can be built at a moderate cost. Mr. A. C. Cauble, of Holyoke, built two home-made stave silos, and following is quoted his letter of endorsement:

"I built my first silo in the fall of 1911 from material purchased of the lumber yard in our city. The material was 2x8, 20 feet long, beveled and dowel-pinned, not tongue and grooved. I also made a pit seven feet deep with a seven-inch concrete wall, placing the 20-foot staves on this pit, making my silo 14x27 feet. Seeing that this silo paid me so well, in the fall of 1912 I built another of the same material and size. My success has been above my expectations. I would not think of trying to keep any great amount of stock without a silo. While the wood stave silo is not just the silo for this dry climate, it is far ahead of no silo. The cost of my silo was $120.00 each, including labor of excavating and placing concrete."

The capacity of these silos would be about 83 tons each.

*Patent Stave Silo.*—As it is now put on the market, the patent stave silo is made of tongue and grooved material, with larger tongues and grooves than are commonly used in home-made silos. The material used should be of the best grades and quality. Conclusions drawn from Bulletin No. 100, Iowa State College, place the merits of wood for silo use as follows: 1, redwood; 2, cypress; 3, Oregon fir; 4, tamarack; 5, white pine; 6, long leaf yellow pine. There is no doubt whatever that the stave silo is a thoroughly established success, but its measure of success depends largely upon the method of construction, quality of material used, and the care and attention given the silo. The life of the stave silo varies from five to twenty years, depending upon the requirements stated above. For Colorado conditions, nothing but the single-piece stave should

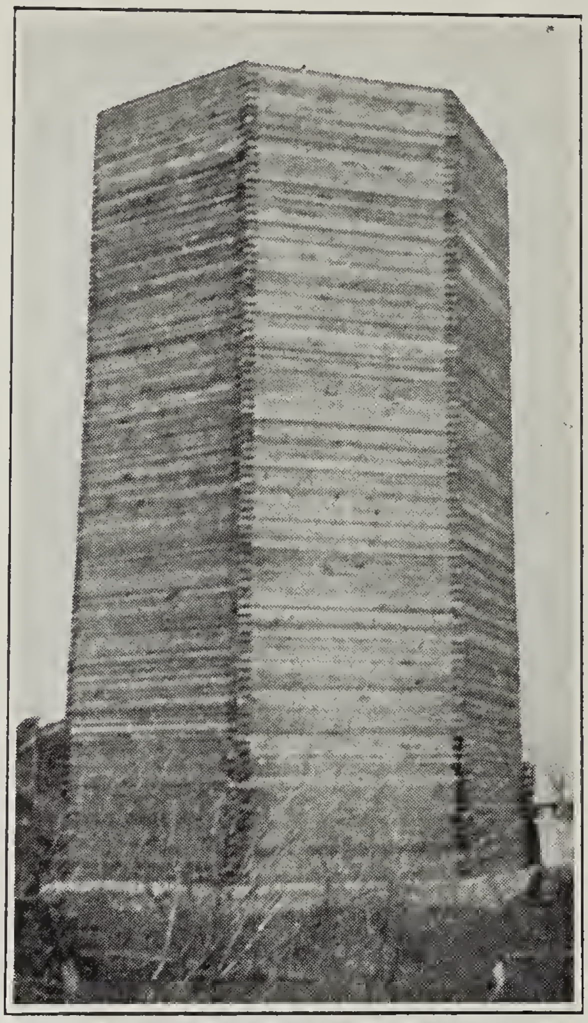



Hinge-Door Patent Wood-Stave Silo in El Paso County (Photo by Lauck).

be used. The dry climate and frequent winds make it more imperative to use good material and to give the silo more care and attention than is necessary in more humid sections. Unless it be securely anchored and kept tight it is sure to get racked out of shape, or blow down.

For the tenant, the stave silo has the advantage of being movable. As far as cost is concerned, when built of good single-piece staves, it is not the cheapest silo even for first cost. It has been and is used very largely in the East and Middle West and gives perfect satisfaction there, but our conditions are somewhat different.

*Common-Sense Silo.*—A few silos of this type have been built in this state, but have not been in use long enough to allow one to judge of their success. They are made octagonal in shape out of two by fours laid flat side and nailed one to the other, lapping at the corners. The inside surface is either coated with tar pitch or covered with tar felt. The faults thus far disclosed have been excessive shrinkage causing cracks to open and thus breaking the in-



Common-sense Silo on the Farm of Mr. Roberts, LaSalle, Colo. (Photo by Barr.)

side coating. The cost is relatively high unless poor grades of lumber are used.

*Tung-Lok Silo.*—A recent invention of a silo similar to the Common-Sense is the Tung-Lok. The material is milled into the desired lengths with mortises at the corners. If the material used is of good quality and could be treated with some wood preservative, it should be a satisfactory silo, but would cost considerable, due to the thickness of the wall.

*Wooden-Hooped Silo.*—This was also one of the early types, and is still being built. Hoops are made of several layers of thin material of the desired size. They are then tacked to a temporary framework about two feet apart and then sheeted inside and outside with matched flooring, setting the flooring perpendicular and nailing it securely to the hoops. The advantage of having a dead air space is not great except in our high altitudes, as the freezing is not very great ordinarily. When properly built so as to make the walls perfectly tight it makes an efficient silo.

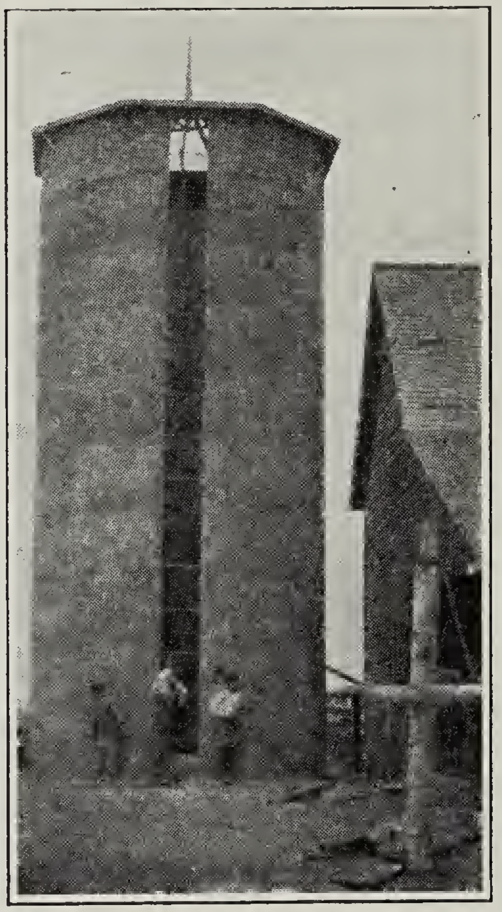
*Wisconsin Silo.*—The author has seen but one silo of this type in the state, and it was built a number of years ago and was still giving good service. This silo was built with two by four uprights two feet apart and sheeted on the outside with one thickness of shiplap on tar paper, and on the inside with two layers of matched flooring laid horizontally with tar paper between. It would be rather an expensive structure at present prices of lumber.

*Gurler Silo.*—The Gurler silo is much on the same order as the Wisconsin silo, except that the lining on the inside is a plaster of cement or wall plaster on wooden or metal lath. Such a silo should be very satisfactory, particularly if metal lath of good quality is used and several coats of rich cement plaster are applied. The framework should be rigid, otherwise the plaster is likely to crack.

*Concrete Silo.*—Cement is coming to be used more and more for construction work on the farm. This is only in keeping with progress made in concrete construction along other lines. A great many objections are made to concrete as a suitable material for silo construction. Besides a number of others, the following are some of the most common: Concrete walls allow mold and decay around the walls, are affected by the acid of silage, and they cannot be built to keep them from cracking and thus leak air. These statements, of course, come from competing builders, mostly stave silo people. Observation of concrete and stave silos standing side by side shows that the freezing is no greater in one than the other. By coating the walls with a wash of neat cement or tar pitch they can be made perfectly air, water and acid proof. If properly reinforced and made of suitable material they should not crack any more than does other concrete work. There have been failures in all types of silos, but it is safe to say that the percentage of failures is less in concrete silos than in most other types. That they are a success has been demonstrated beyond a doubt by those built not only in this state but other states as well. Silos of this type are known to have been used successfully for eleven years without the least sign of deterioration, or loss of silage through spoilage.

The common causes of failure in concrete construction are: (1) Insufficient reinforcement, (2) dirty sand and gravel, (3) too lean a mixture or insufficient amount of cement used, (4) poor mixing of cement with sand and gravel, (5) poor placing of mixture within the building forms, (6) washing out of cement by excessive water.

*Solid Wall Concrete Silo.*—This type has been thus far the favorite among concrete silos, and in fact among all silos for Colorado conditions. The reason for this is that one can be built by anyone of ordinary intelligence, with unskilled labor, with but little advice or aid. Sand and gravel can be secured conveniently in most any locality at a low cost, making the cash outlay small for such



Solid Wall Concrete Silo on the Farm of Nelse Anderson, Niwot, Colo. (Photo by Risser.)

construction. Because it meets all requirements of a good silo, is a permanent structure, and costs less for construction than any other type of silo suitable to this climate, unless it be the pit silo, it is to be strongly recommended. The solid wall concrete silo will give more efficient service for a dollar invested than any other above ground silo on the market today.

*Cost of Concrete Silos Built in* 1911.

Data collected and compiled by P. V. Maris.

| Dimensions | Capacity | Cost of Forms | Rental of Forms | Cost of Materials | Cost of of Labor | Estimated Total Cost | Actual Cash Exp'ded |
|---|---|---|---|---|---|---|---|
| *10x29 | 45 | $ 25.10 | $...... | $ 96.45 | $ 60.00 | $181.55 | $122.15 |
| †12x25 | 52 | 33.80 | ...... | 60.85 | 74.25 | 146.35 | 115.00 |
| †12x27½ | 59 | ...... | 11.25 | 61.90 | 104.00 | 177.15 | 111.00 |
| †12x28½ | 62 | ...... | 11.25 | 62.40 | 94.00 | 167.65 | 111.65 |
| §12x28½ | 62 | ...... | 10.00 | 102.20 | 110.35 | 222.55 | 160.55 |
| †12x31½ | 72 | 33.80 | ...... | 65.30 | 102.00 | 184.20 | 106.90 |
| †12x31½ | 72 | ...... | 4.40 | 54.95 | 106.00 | 185.85 | 117.35 |
| †12x40 | 100 | ...... | 10.00 | 156.96 | 88.00 | 259.96 | 359.96 |

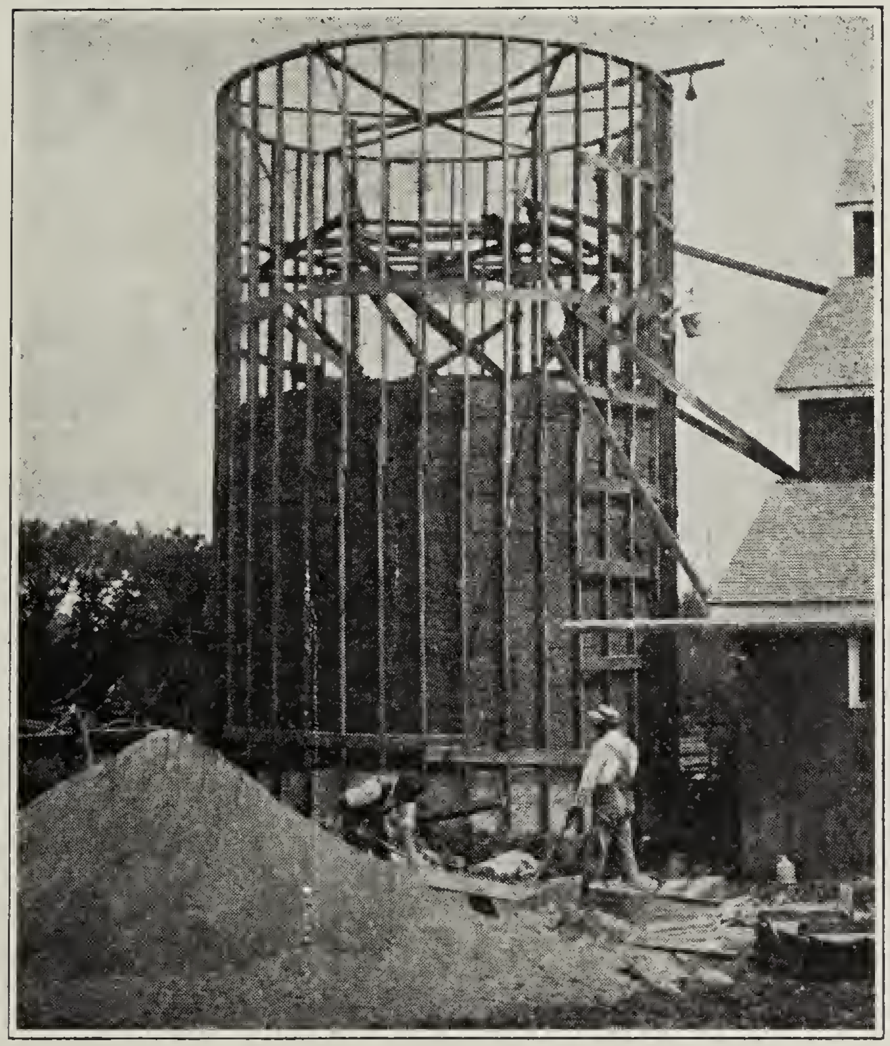
*Cost of Concrete Silos Built in 1911—Continued.*

| Dimensions | Capacity | Cost of Forms | Rental of Forms | Cost of Materials | Cost of of Labor | Estimated Total Cost | Actual Cash Expended |
|---|---|---|---|---|---|---|---|
| †14x31½ | 98 | 28.03 | ...... | 146.80 | 70.00 | 244.83 | ...... |
| *16x24 | 90 | ...... | 21.36 | 120.39 | 121.30 | 263.05 | ...... |
| §16x34 | 143 | ...... | 3.00 | 144.98 | 148.50 | 293.48 | 112.00 |
| †16x34 | 143 | 42.00 | ...... | 173.66 | 142.00 | 320.66 | ...... |
| *16x39 | 174 | ...... | 48.00 | 224.50 | 182.00 | 444.50 | ...... |
| *16x48½ | 231 | ...... | ...... | 209.28 | 217.95 | 434.23 | ...... |
| †18x36 | 196 | 41.57 | ...... | 171.90 | 140.00 | 353.47 | 323.47 |
| †18x36 | 196 | ...... | 19.00 | 182.50 | 181.00 | 381.50 | 371.00 |
| †16x32 | 131 | Contracted | | | | 300.00 | 250.00 |
| †16x32 | 131 | Contracted | | | | 300.00 | 250.00 |

§ Includes cost of roofing.

† Includes neither labor nor material cost of roofing.

* Includes roofing material, but not labor of roofing.



Plastered Cement on Metal Lath Silo in process of construction.
(Photo by Hinman.)

## *Cost of Concrete Silos Built in* 1912

Data collected and compiled by W. A. Barr.

| Names and Addresses of Builders | Dimensions | Capacity | Cost of Forms | Cost of Materials | Cost of Labor | Total Cost | Cost per ton Capacity |
|---|---|---|---|---|---|---|---|
| Matt Wencel, Lyons ........ | 16x38 | 131 | $ 25.20 | $157.60 | $120.00 | $ 302.80 | $2.31 |
| W. E. Day, Masters......... | 16x30 | 119 | ...... | ...... | ...... | * 300.00 | 2.52 |
| Tracey Decker, Fort Lupton. | 12x20 | 46 | ...... | ...... | ...... | § 120.00 | 2.60 |
| A. S. McKinney, Fort Lupton. | 12x30 | 70 | ...... | ...... | ...... | § 180.00 | 2.57 |
| E. A. Bromley, Brighton.... | 16x40 | 180 | ...... | ...... | ...... | * 367.50 | 2.04 |
| Wm. Schneider, Brighton.... | 16x40 | 180 | ...... | ...... | ...... | * 367.50 | 2.04 |
| Wheeler Kelsey, Fort Lupton. | 16x40 | 180 | ...... | ...... | ...... | * 410.00 | 2.28 |
| Harry Ewing, Fort Lupton... | 16x40 | 180 | ...... | ...... | ...... | * 410.00 | 2.28 |
| Henry Lowell, Castle Rock... | 18x36 | 196 | ...... | 168.40 | 90.00 | 258.40 | 1.31 |
| W. A. Dickens, Longmont... | 2 16x39 | 174 | 20.00 | 225.00 | 150.00 | 395.00 | 2.15 |
| J. R. Nichols, Fosston....... | 14x30 | 92 | 20.00 | 136.00 | 80.00 | 236.00 | 2.56 |
| J. E. Church, Denver....... | 2 20x42 | 600 | 85.00 | 700.50 | 481.00 | 1,266.50 | 2.11 |
| J. W. Purvis, Berthoud...... | 12½x37 | 97 | 7.50 | 179.40 | 173.15 | 360.05 | 3.71 |
| Adolph Kunze, Elbert....... | 14x31 | 96 | 23.90 | 158.90 | 112.50 | 295.30 | 3.07 |
| W. M. Sullivan, Fort Collins. | 12½x35 | 85 | 10.00 | 95.65 | 123.50 | 229.15 | 2.69 |
| Thos. Christensen, Castle Rock | 2 14x34 | 218 | 15.00 | 293.00 | 190.00 | 498.00 | 2.30 |
| J. H. Kennedy, Johnstown... | 12½x36 | 94 | 10.00 | 130.95 | 125.00 | 264.95 | 2.82 |
| J. W. Whowell, Johnstown... | 16x35 | 150 | 20.00 | 163.10 | 120.00 | 303.10 | 2.15 |
| W. A. Purvis, Johnstown..... | 16x35 | 150 | 20.00 | 161.00 | 90.00 | 312.00 | 2.08 |
| Jake Spohr, Johnstown...... | 12x34 | 80 | 7.50 | 160.00 | 94.00 | 261.50 | 3.28 |
| Worth Abbey, Franktown.... | 14x36 | 118 | 10.00 | 147.00 | 103.00 | 237.50 | 2.12 |
| A. F. Reynolds, Elizabeth... | 14x36 | 118 | 10.00 | 151.00 | 99.00 | 237.[illegible] | 2.12 |
| B. F. Williams, Fort Collins. | 12½x36 | 94 | 12.00 | 125.72 | 82.00 | 207.72 | 2.20 |
| Joe Hammerly, Fort Collins.. | 12½x29 | 68 | 15.00 | 118.00 | 85.00 | 203.00 | 3.98 |
| C. L. Vollmar, Platteville.... | 2 14x36 | 236 | ...... | ...... | ...... | ** 796.40 | 3.22 |
| H. D. Parker, Greeley...... | 2 14x36 | 236 | ...... | ...... | ...... | ** 805.50 | 3.49 |
| Charles R. Adams, Greeley... | 14x36 | 118 | ...... | ...... | ...... | ** 400.80 | 3.59 |
| S. M. Wilson, Greeley....... | 14x36 | 118 | ...... | ...... | ...... | ** 400.00 | 3.61 |
| W. R. McClellan, Greeley.... | 14x36 | 118 | ...... | ...... | ...... | ** 405.00 | 3.43 |
| Fred Hart, Denver......... | 3 18x42 | 700 | ...... | ...... | ...... | 1,116.70 | 1.74 |
| George Evans, Boulder...... | 16x38 | 167 | 15.00 | 152.00 | 193.00 | 360.00 | 2.15 |
| Erdman Bros., Holyoke .... | 14x32 | 100 | ...... | ...... | ...... | ...... | .... |
| Allen Tedman, Fowler....... | 10x30 | 48 | ...... | ...... | ...... | ...... | .... |
| A. L. Johns, Larkspur....... | ‡15x35 | 90 | ...... | 42.00 | 80.00 | 122.00 | 1.35 |
| B. D. Godfrey, LaSalle...... | 16x32 | 131 | 22.50 | 150.00 | 100.00 | 272.50 | 2.08 |
| Alex Chapman, LaSalle...... | 16x34 | 143 | 22.50 | 165.00 | 144.00 | 331.50 | 2.32 |
| A. E. Abbey, Franktown..... | 15x36 | 136 | ...... | ...... | ...... | ...... | .... |

‡ Pit silo.

§ No roof nor chute contract.

* Complete contract.

** Contract by Bell.

Thirty-nine silos. Average cost per ton capacity for season, $2.48.

Omit the last silo in determining cost per ton capacity. (Pit silo.)

*Hollow-Wall Concrete Silo.*—Owing to the fact that freezing is not very serious with silos in Colorado, few if any hollow or double-wall concrete silos are built. The greater cost and more difficult construction than of solid walls are no doubt the chief causes of so few being built. Where severe freezing occurs they should prove very satisfactory.

*Cement Plastered Silo.*—Those who have built this type of silo are strongly in favor of it. A framework of upright two by fours, placed two feet apart, is erected in a circle the size of the silo to be built. Expanded metal lath is tacked on the inside. Two to three coats of rich cement plaster are applied on the lath with a finishing coat of cement wash, or plaster containing water-proofing material. When sufficiently cured, the framework is pulled off and two or three coats of plaster are applied on the outside. This leaves a solid wall three to three and a half inches thick with the metal lath in the center for reinforcement. Where a good quality of material is used and good, rapid plasterers are employed, this makes a splendid silo. As a general thing, they are more expensive than the solid wall silo built with forms. More cement is necessary and the metal lath in good quality is quite expensive. More skilled labor needs to be employed.

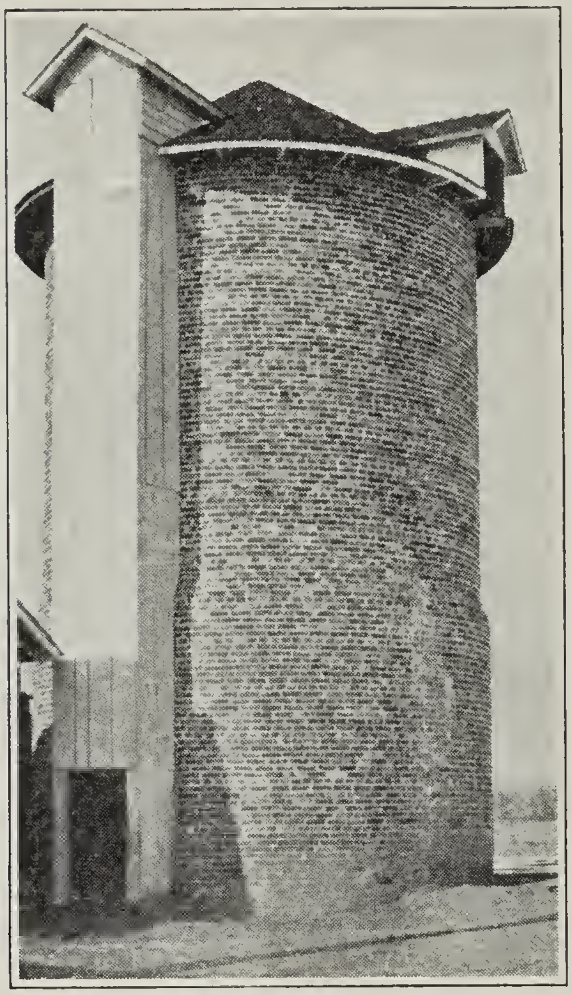
Following is a statement of cost of a plastered metal lath silo built by Mr. John E. Painter on his ranch at Roggen, Colorado.

"My silo is 18x34 feet in the clear, and 4 feet in the ground. On account of seepage I have had to plaster the bottom with cement. I think it the best silo I have ever seen and it is in perfect condition. We kept the walls watered for about two weeks, so got a complete crystallization in the cement work. I should estimate about $450 as the cost, exclusive of roof, chute and floor, which I have added since."

This silo would have a rated capacity of about 205 tons.

*Cement Block Silo.*—The home-made block silo is favored by many because it does away with expensive forms. Home-made molds can be made cheaply, and the blocks can be made at odd times, and, when all made and cured, laid in the wall in cement mortar. The blocks should be made with a groove on one side to allow proper place for reinforcement. When well made blocks are used and are reinforced at least every second course with heavy wire (No. 6) or steel, they make a very durable and attractive silo at a cost which is not much greater than the solid-wall type. More labor and cement would account for the greater cost. Great care should be taken to get all joints tight, and a coat of plaster washed with neat cement should be put on the inside to make a perfectly tight wall.

*Cement Stave Silo.*—This silo has been but recently introduced. The staves are two and a half inches thick, made of rich cement in a mold for the purpose. They are tongued and grooved on the edges so as to fit more securely when in place. They are surrounded with strong, flat iron hoops at every joint. The inside is then treated with an acid and waterproof wash. If a thin wall is any advantage over a thick one, they may have some merit. When one builds something permanent, it seems it would be advisable to get away from hoops which may cause trouble.

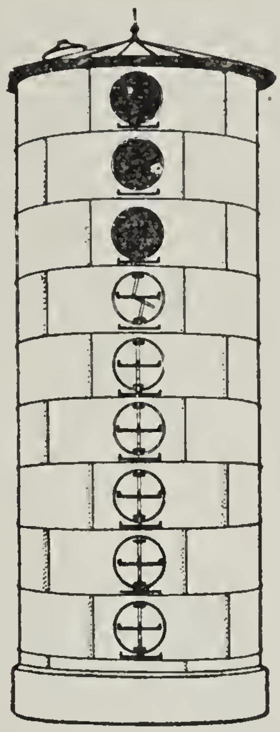


Brick Silo on the Farm of Nelson Bros., Pueblo, Colo. Silo 16x32 cost $350. Brick used was second-hand within two hundred yards of the silo site. (Photo by Barr.)

*Brick Silo.*—When brick can be obtained cheaply, a very good silo can be built at a moderate cost. Estimates show that when brick sells for $8.00 per thousand, a brick silo costs about $4.00 per ton capacity. Silos are being built both out of ordinary brick and hollow brick. Aside from the high cost, they are a very desirable silo.

*Vitrified Hollow Tile Silo.*—A silo made of vitrified hollow tile of good quality, reinforced between every course of tile with steel, and properly laid up, might well be pronounced the best silo made. It embodies every factor which goes to make a perfect silo. However, the cost is almost prohibitive to all but the well-to-do or wealthy farmer. In a 100-ton capacity size one company quotes a price of practically $4.50 per ton capacity f. o. b. buyer's station. To this would have to be added the cost of foundation, erection, roof and chute. This would run the cost up to nearly $5.50 per ton capacity for a silo of 100-ton capacity.

*Stone Silo.*—Thus far but one stone silo has been built in the state. This proved a very expensive structure, although stone was cheap and handy. Because of the thickness of the wall required, the amount of labor required was enormous, making the cost too high to be practical.



Columbian Metal Silo. (Courtesy L. A. Watkins Mdse. Co., Denver.)

*Metal Silo.*—This is also a new type of silo, but should prove more successful in warm climates, as the freezing would be excessive even in this temperate climate. The objection made is that the acid of silage will attack the metal, but this can be overcome by coating the walls each year, which makes a regular cost of upkeep. As yet they are rather expensive for farmers to care for them much.

The following prices have been submitted by the L. A. Watkins Merchandise Co. of Denver, who are Colorado agents for the Columbian Steel Tank Co. of Kansas City:

*Standard Sizes of Columbian Metal Silos.*

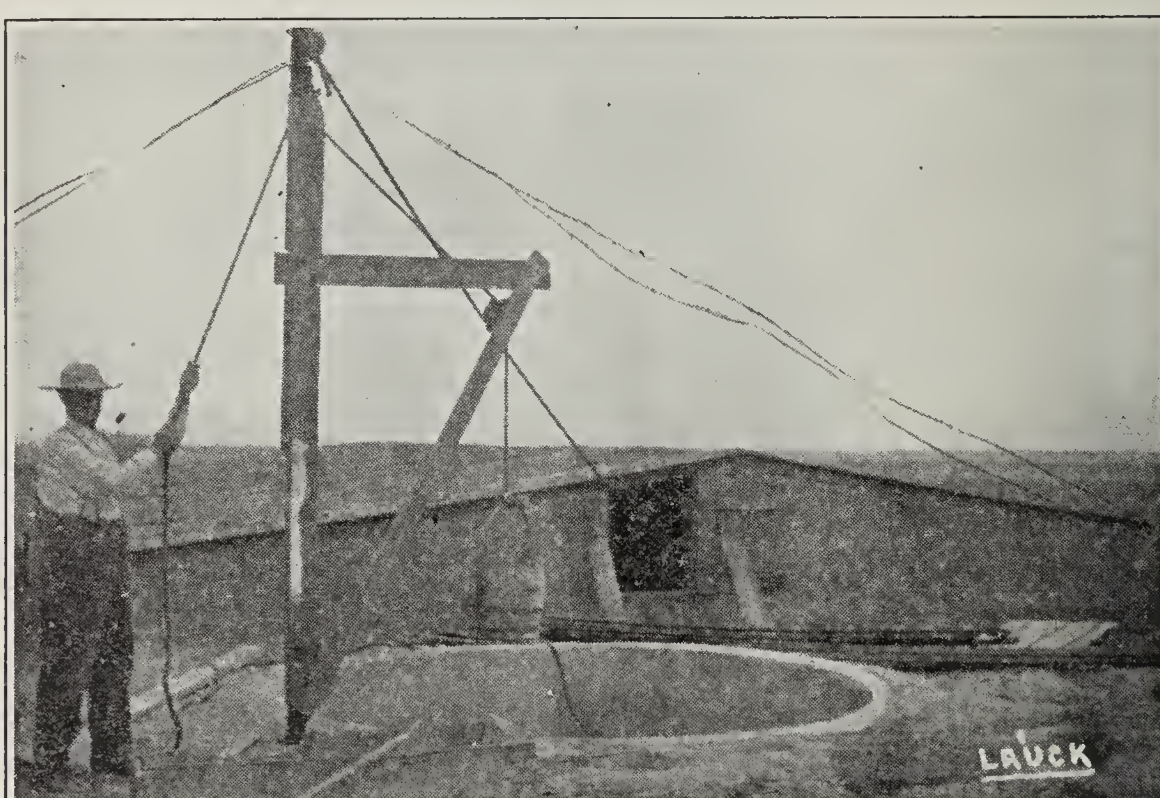
| Diameter | Height | Estimated ton capacity | Estimated weight | Acres of corn (45 bu.) required to fill | Price |
|---|---|---|---|---|---|
| 12 ft. 3 in. | 25 ft. | 65 | 3,600 lbs. | 6 | $ 425.00 |
| 12 ft. 3 in. | 30 ft. | 73 | 4,200 lbs. | 7 | 505.00 |
| 12 ft. 3 in. | 33 ft. | 80 | 4,500 lbs. | 8 | 515.00 |
| 14 ft. 9 in. | 30 ft. | 110 | 5,200 lbs. | 11 | 552.00 |
| 14 ft. 9 in. | 33 ft. | 126 | 5,700 lbs. | 13 | 600.00 |
| 17 ft. 3 in. | 30 ft. | 150 | 6,000 lbs. | 15 | 635.00 |
| 17 ft. 3 in. | 33 ft. | 165 | 6,700 lbs. | 17 | 690.00 |
| 19 ft. 8 in. | 30 ft. | 190 | 7,100 lbs. | 19 | 725.00 |
| 19 ft. 8 in. | 33 ft. | 220 | 7,600 lbs. | 22 | 760.00 |
| 22 ft. 2 in. | 30 ft. | 258 | 7,900 lbs. | 26 | 800.00 |
| 22 ft. 2 in. | 33 ft. | 280 | 8,500 lbs. | 28 | 840.00 |
| 22 ft. 2 in. | 36 ft. | 305 | 9,000 lbs. | 31 | 900.00 |
| 24 ft. 6 in. | 36 ft. | 390 | 12,000 lbs. | 36 | 1,200.00 |
| 29 ft. 6 in. | 40 ft. | 636 | 15,200 lbs. | 57 | 1,486.00 |

The above are inside measurements.

Quotations on larger sizes may be had on application.

## BELOW GROUND SILOS.

*Pit Silo.*—The pit silo is the poor man's silo with hardly a competitor. For the money invested, it is by far the best silo used. It has its limitations, however, to conditions where the soil is of such a nature which will permit of digging without too much caving, where water is not too close to the surface and where digging is not too difficult due to rocky formations in the soil. Where the soil is sandy and gravelly, and a retaining wall of several inches would be needed instead of a thin coat of plaster, one could better afford to build above ground, as the cost for material and forms would not be much greater and the labor of digging the pit would be saved. The advantages of the pit silo are not such as would warrant its building under such unfavorable conditions.

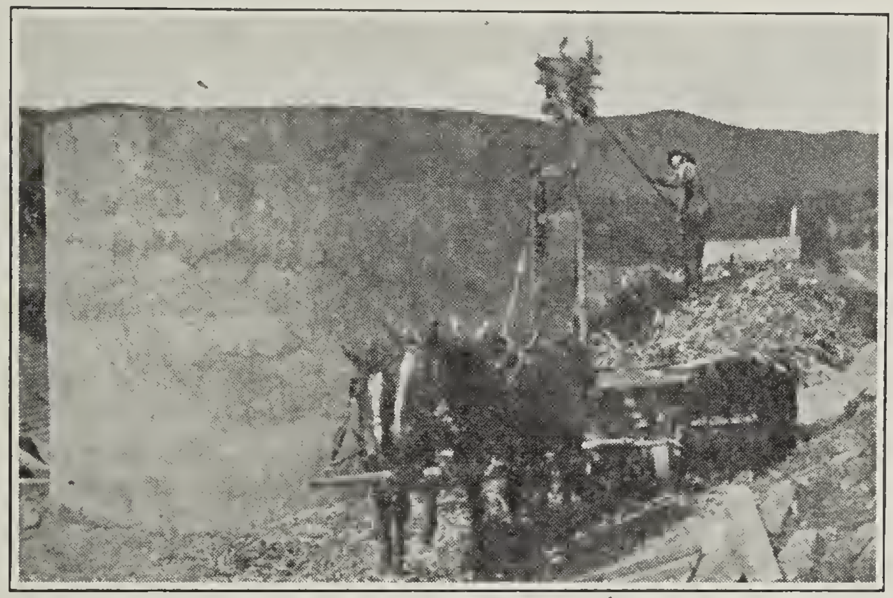



Pit Silo in Eastern El Paso County. (Photo by Lauck.)

Mr. J. W. Adams, Superintendent of the Plains Substation of the Agricultural College at Cheyenne Wells, Colorado, may well be called the father of the pit silo in Colorado. It was through his efforts and experiments that the pit silo, and the methods for its construction have been perfected to their present degree of perfection. His report on the building of the pit silos on the Substation Farm are published in this bulletin. The advantages of the pit silo, its cost, and the best methods of construction are ably set forth in this report.

*Bank Silo.*—Where the location makes it possible, this type of silo is very convenient. Where a basement barn is built in rather a steep hill, a silo can be built almost entirely below ground. The only difference between this and the pit silo would be that a continuous door and chute are built which connect with the barn below. The freezing is overcome and the necessary equipment for filling is less expensive because elevating is not necessary. The cut shows a bank silo on the farm of Mrs. Ed Dwyre of Monument, Colo. This silo has now been filled three years with uncut corn. The corn is short, and a sample taken from the silo this spring was a perfect specimen of good silage. The silo is 16x24 feet with a 6-inch wall. This silo should give splendid results for an indefinite period of years. This silo, with a rated capacity of ninety tons, cost $263.05, the cost being divided into the following items:

| | |
|---|---|
| Cost of forms | $ 21.36 |
| Cost of material | 120.39 |
| Cost of labor | 121.30 |
| | $263.05 |



Bank Silo on the farm of Mrs. Ed. Dwyer, Monument, Colo.
(Photo by Maris.)

These figures include the cost of material for roofing, but not the cost of labor for roofing. The cost per ton capacity with this silo would therefore be approximately $3.00.

*Trench Silo.*—A trench can be easily built in a side hill or even on level ground very cheaply, with a team and slip-scraper. The walls should be trimmed smooth. Any sized trench can be dug. This trench filled with green forage and well packed, covered over with a foot of straw, and weighted down with about two feet of dirt, should give good results. The German method of siloing beet leaves and tops in alternate layers of five to six inches with straw in a trench silo built in this way, is a practice which could be very economically adopted by Colorado farmers for the preservation of their tops and leaves as well as forage crops.

## SILAGE CROPS.

*Corn.*—Where corn can be grown to advantage, even though it does not mature or even form many ears, but grows an abundance of forage, it is pre-eminently the best silage crop. On our plains dry land farms, there are a number of varieties which will mature. The White Australia is one commonly used, but it is a small yielder of forage and rather difficult to harvest. White and Yellow Dent, and Calico varieties are also successfully grown. One should grow a variety which does best in his locality from seed which has become acclimated. An average yield under dry farming conditions is from four to six tons per acre. In the irrigated sections the Yellow and White Dent varieties are most commonly used. The Eureka silage corn is coming to be used more extensively. It grows a great amount of forage with little, if any, grain. However, when it is desirable to fill a silo with succulent forage from a small area, its use is to be recommended, as it will furnish the cheapest succulent roughage. Concentrates can be purchased, while succulence cannot very conveniently at times when most needed. Ordinary varieties of corn yield from ten to fifteen tons per acre under irrigation, while records show Eureka silage corn as yielding as high as twenty-six tons and even more per acre. The planting may be done as for grain growing, except where sufficient moisture will permit; planting more closely in the row is to be recommended, as a larger yield of total dry matter per acre is then harvested. Eight to twelve inches apart in the row is common for silage corn. The custom of drilling thickly, so as to get thin leafy stalks with little if any ears, has changed, as it is a recognized fact that silage from well eared corn has more nutritive value.

*Sweet Sorghum.*—Sweet sorghum or sugar cane has not been used much for silage. There exists a prejudice that it makes a very sour silage, due to the large amount of sugar it contains. This has been disproved at the Kansas Station and the cause of sour silage laid to harvesting the crop too early. If cut when mature for seed production it made a silage containing less acid than corn silage. The bagasse or refuse from cane mills has been used for silage in the South, but makes a rather inferior silage, as the leaves are generally stripped before taking it to the mill. However, it is a by-product which can be greatly improved by putting into the silo.

*Non-Saccharine Sorghums.*—Milo, Kaffir, and Feterita are becoming very popular in the dry land sections. The yield per acre is generally greater than with corn, averaging from six to ten tons. Experiments at the Texas Station, Bulletin No. 13, shows the analyses of kaffir silage almost equal in nutritive value to corn silage.

At the Kansas Station, Circular No. 28, tests were made with dairy cattle where corn, kaffir and cane silage were compared for milk production. Each lot of cows was fed alternately on two kinds of silage for periods of thirty days with an interval of ten days between these periods. Following is the table showing results:

LOT I. KAFFIR SILAGE vs. CORN SILAGE.
Six Cows—Thirty-day Periods.

| Period. | Milk. | Butterfat. | Body Weight, lbs. |
|---|---|---|---|
| 1. Kaffir silage in ration | 3,373 | 142 | 6,010 |
| 2. Corn silage in ration | 3,383 | 140 | 5,994 |
| 3. Kaffir silage in ration | 3,339 | 139 | 6,021 |
| Av.—First and third periods, kaffir silage | 3,356 | 140 | 6,015 |
| Av.—Second period, corn silage | 3,383 | 140 | 5,994 |
| Difference | 27 | | 21 |

LOT II. CANE SILAGE vs. KAFFIR SILAGE.
Five Cows—Thirty-day Periods.

| Period. | Milk. | Butterfat. | Body Weight, lbs. |
|---|---|---|---|
| 1. Cane silage in ration | 2,384 | 107 | 4,852 |
| 2. Kaffir silage in ration | 2,492fl | 112 | 4,879 |
| 3. Cane silage in ration | 2,139 | 98 | 4,927 |
| Av.—First and third periods, cane silage | 2,261 | 102 | 4,890 |
| Av.—Second period, kaffir silage | 2,492 | 112 | 4,879 |
| Difference | 231 | 10 | 11 |

LOT III CORN SILAGE vs. CANE SILAGE.
Four Cows—Thirty-day Periods.

| Period. | Milk. | Butterfat. | Body Weight, lbs. |
|---|---|---|---|
| 1. Corn silage in ration | 1,953 | 89 | 3,743 |
| 2. Cane silage in ration | 1,832 | 86 | 3,747 |
| 3. Corn silage in ration | 1,852 | 85 | 3,755 |
| Av.—First and third periods, corn silage | 1,902 | 87 | 3,749 |
| Av.—Second period, cane silage | 1,832 | 86 | 3,747 |
| Difference | 70 | 1 | 2 |

Following are some of the conclusions drawn from the experiment:

1. Corn silage is slightly superior as a milk producer.

2. Kaffir silage ranks second and cane silage third as a feed for milk cows.

3. Cattle gained more readily in live weight on cane silage than on either kaffir or corn silage.

4. Although kaffir and cane silage were shown to be slightly less valuable than corn silage, there are other factors that must be considered; namely, yield and adaptability to local conditions. Without doubt the greater yield of cane and kaffir will offset the slight increase in feeding value obtained from corn silage. Kaffir and cane are drouth-resistant crops and can be grown over a wider territory than corn, and from one-third to one-half more tonnage per acre can be obtained.

5. The average acidity for the three different kinds of silage was as follows: Corn 2.03 per cent, cane 1.46 per cent, and kaffir 1.43 per cent.

6. The kaffir silage was perhaps the poorest on account of being immature, as a heavy frost forced an early harvest.

7. The cane silage seemed the most palatable.

8. The silage was stored in wooden-stave and in cement silos. It kept equally as well in cement as in wood.

9. The time of cutting cane and kaffir for silage is all important. The crops should be practically mature; that is, the seed should be mature.

Kaffir is claimed by some to be the heaviest yielder, but we find that this varies greatly with conditions, seed, and variety used. Another factor which should encourage the making of silage from sorghums is that silage made from stunted or frosted sorghum does not have the poisoning effect on stock which the green fodder is known to have. The prussic acid seems to be dstroyed during silage-making.

*Alfalfa.*—A great many inquiries come asking whether it is advisable to put alfalfa into the silo. As a rule, it is a practice which is being generally discouraged, except under unfavorable weather conditions when it is impossible to cure it into hay without great loss of leaves and soluble nutrients. It is true that greater losses occur in the silo with proteid than carbonaceous feeds. A poor quality of silage is also reported, but this is likely due to improper packing and cutting the crop too young. Many practical dairymen report silage of excellent quality from alfalfa when cut quite mature and put into the silo immediately after cutting. Filling the silo with first crop of alfalfa for summer use is really a thing to be encouraged, as it is a more economical practice than soilage. What has been said of alfalfa would apply equally as well to clovers.

*Peas.*—The common field pea, when grown with either barley or oats, is being used very extensively for silage purposes in sections of Colorado where corn and sorghums cannot be grown successfully. Samples taken from silos filled with this mixture, showed a silage of very fine quality, and reports of results obtained are very favorable, coming thus far mostly from lamb and sheep feeders. The cowpea and soybean, when planted with corn, are giving very good results in Eastern and Middle Western states. Pea cannery refuse has been successfully siloed.

*Small Grains.*—Summer silage of winter rye, cut when well headed, is giving satisfaction. Early crops of this kind could be used to advantage. Great care should be taken to cut it very fine and pack the material firmly, as it is more difficult to completely exclude the air because these plants have hollow stems.

*Russian Thistle.*—Mr. H. B. Hassig, of Cope, Colorado, was perhaps the first to try Russian thistles for silage purposes in 1911. He writes as follows regarding his experience:

"I had twelve feet of silage made of Russian thistle on top of corn silage. I covered this with dirt, but not as much as I shall after this, as the air penetrated the earth and spoiled about two feet of the silage. The balance was well preserved and relished by the cattle." He adds that the cattle consumed corn silage with greater relish than the thistle silage.

The thistle should be cut at about the same time as it is cut for hay, which is when it is quite young and therefore not too woody. Where thistles are found in corn fields they are often put in along with the corn. Those trying this practice claim it is the only way to get even with the thistle by putting it through an ensilage cutter. The stock does not discriminate against it in the corn silage and eat it up clean.

*Beet Leaves and Tops.*—The present method of utilizing leaves and tops is wasteful, to say the least. Besides, there is no small element of danger connected with the practice, as animals gorge themselves with the moldy and decayed material and death is often the result. A large percentage of the feed is also tramped under foot and soiled so that it is lost for stock-feeding purposes. The practice of curing the tops in the field and feeding them in limited quantities is very successful. The silo should be a means of conserving their feeding value in even a better form. Ware in his book, "Cattle Feeding with Sugar Beets, etc.," gives the German method as given in connection with the trench silo.

The college here put some beet tops and leaves into their silo in 1911. They were in bad condition when put in, which will be the general condition of most tops, as farmers are too busy with the harvesting of beets to stop to dispose of the tops and leaves. Cows did not relish the silage as well as the corn silage. In fact, it was difficult to get them to eat as much as twenty-five pounds daily. Ware recommends the addition of ten to twenty pounds of lime to every ton of tops and leaves to render insoluble the oxalic acid, which is present in large quantities. The leaves and tops when properly preserved are a very valuable feed.

*Beet Pulp.*—Thus far the feeding of beet pulp has been confined to the vicinities surrounding the sugar factories. The feeding is done in the fall and winter so that the pulp is fed either fresh from the factory or from the factory's silos, which are nothing more than large, shallow bins to hold the pulp. In these silos the pulp loses much of its moisture and forms a cheesy mass of higher feeding value than the fresh pulp. The silos are provided with drains to remove this surplus moisture, as the retention of this water seems to have a bad effect on the pulp. Bacteria develop which, according to French scientists, cause serious intestinal disorder with stock. Silos for beet pulp should therefore be drained. Ware also recommends the addition of from five to nine pounds of salt per ton of pulp, stating that the salt helps destroy the bacteria. Very little pulp has been put into above-ground silos, but it should be a success if proper precautions are observed, and should make a good form of succulent feed for summer use.

## SILAGE MAKING.

*Time to Harvest.*—When the silo was first introduced, it was thought necessary to cut corn in the milk stage. As a result, more complaint of sour silage was heard then than now. Corn should be in the denting or glazing stage; about the time it would be cut for shocking is about right. Sorghums should be cut when the seed is mature. A few of the lower leaves may have started to turn brown, but these will regain moisture in the silo. In case of severe frost, the corn or sorghum should be cut as quickly as possible, as drying and loss of leaves will soon cause great loss.

*Harvesting the Crop.*—Cutting by hand is a very expensive way to harvest the crop. Whenever possible, it is best to use a corn binder, as the crop is then bound in bundles and is easier to handle. Where corn is very short, the sled is a very rapid and efficient implement. This sled consists of a V-shaped platform narrower in front than the width between rows and wider behind, mounted on three wheels and drawn by one horse between rows. A knife is attached on each side close to the ground. This cuts two rows. One man drives while the other gathers in the fodder. When an armful is gathered, the horse is stopped and the corn laid aside in piles. When a steady horse is used, both men can gather the fodder. This is a very good method because it is rapid, all the fodder possible is saved and the ears are not broken off. It is advisable to have the cutting commence at least a half day before the filling in order to cause no delay, where a silage cutter of large capacity is used. Rain will not injure the fodder for silage-making after it is cut or before cutting.

*Handling the Crop.*—Ordinary hay racks are generally used, although it means more labor loading. Two men in the field should keep six or seven wagons loaded unless the distance to haul is short, when less wagons can be used and an extra man put in the field.

For economy's sake it is best to keep the silage cutter going at full capacity. It may be that better silage is possible with a slower fill, but it would prove too expensive to be practical. If a steam engine is used, one man will be required at the engine, one man at the cutter, and one or two in the silo completes the crew. Such a crew, with a 16 or 18-inch cutter with plenty of power, should put in 100 to 150 tons of green fodder daily, barring accidents, and would therefore be adapted only for filling silos of 100 tons capacity or more. For smaller silos, a 10 or 12-inch cutter with a capacity of 4 to 6 tons per hour would require only one man in the field and half the number of teams. One man in the silo could easily distribute and tramp thoroughly that amount of green material.

*Silage Cutters.*—There are two types of cutters on the market commonly used. One type has the knives and fan-blades fastened on the flywheel in the blower-drum. Cutters of this type as a general thing require less power but are run at greater speed. Because of the high speed they are more dangerous, cases having occurred where the flywheel burst when foreign material got under the knives or through mechanical imperfection. The other type has the knives arranged on a cylindrical head with the blower operating separately. Cutters with blowers or carriers are used, although the blower has about replaced the carrier for filling above-ground silos. For filling pit silos, cutters with or without carrier are used. The power required for a cutter with a blower is about a third greater than for one with a carrier, while a cutter without either carrier or blower requires only about half the power required for cutter and blower.


Utilizing the Automobile as Power for the Silage Cutter.
(Photo by Lauck.)

*Power for Cutters.*—Steam and gasoline engines are both used for this purpose. The common mistake made is when engines are bought to be used for this purpose they are not bought with enough power. It seems that the manufacturers' estimates are too low for power required to run their cutters. Enough power should be provided so that the cutter can be run at full capacity with steady speed, otherwise the extra cost of a larger cutter is wasted. As a rule one should figure on from a fourth to a third more horsepower when puchasing a gasoline engine than a steam engine. Of course, power varies with work done, and it seems that when a cutter with a blower elevating thirty feet is run by a steam engine, the power required would be about one horsepower for every ton of green fodder cut and elevated per hour.

*Length of Cutting.*—Short, whole corn has been put into silos with reasonable success, but it is a practice not to be recommended. It is difficult to pack such material compactly enough to insure perfect exclusion of air. It is advisable to cut all forages in lengths not to exceed three-fourths of an inch, and one-half inch is better. Not only will such lengths pack more thoroughly, but the stock will eat it up more completely than when put in uncut. Cut silage is also more easily removed.

*Distributing and Packing.*—The man in the silo really has the most particular job to perform. Upon his efforts depends largely the quality of the resulting silage. The silage distributor used with blowers is a great help, as it adds to the comfort of the man and decreases the amount of labor necessary to move the silage, allowing more time for packing. Packing should be thorough over the entire surface of the silo, but more so around the walls. The surface should be kept saucer-shaped with the higher edge at the wall. This, when thoroughly packed, will prevent the settling away of silage from the walls, and letting in air. If the silo is filled in one day, it is sure to settle five or six feet in the course of a few days. It is then best to remove any decayed silage on top and refill in order to utilize the full capacity of the silo.

*Adding Water.*—Where the fodder has been severely frosted or burned, or has been allowed to mature so that the leaves and husks are brown, water must be added in order to thoroughly wet the fodder and make it pack more easily and to help exclude the air. The amount required depends upon the condition of the fodder. There is not much danger of adding too much water, but there is serious danger of using too little. The fodder should come from the blower in a thoroughly wet condition. The best method of adding water is to run it directly into the blower. In this way the silage is more evenly wet down than by taking the hose into the silo. Where water with pressure is not available, a barrel or tank fitted with a faucet emptying into the blower is a handy arrangement for adding water. After the silo is filled, it is a good practice to thoroughly soak the top silage and tramp it well, as it will reduce surface spoilage.

*Adding Salt.*—Many inquiries received ask whether or not salt should be put into silage during filling. The only reason for this would be to increase palatability, which is unnecessary, or to check fermentation, which is not advisable. In putting beet pulp into the silo, it is recommended to add salt to help destroy harmful bacteria which develop in the juices. This is not necessary with silage crops.

*Sealing the Silo.*—When a silo is filled, the top eight or ten inches mold and decay into an airtight layer which seals the mass below. Various means have been employed to save these top eight inches. Straw is often cut fine, soaked down with water and packed. This lessens spoilage but does not prevent total loss. In pit silos, the covering of the top with earth is commonly practiced, but total prevention of spoilage is seldom if ever reported, as earth is porous. Some cover the top with a tarpaulin and earth, but canvas will not last long with such treatment and so this is an expensive method. Sprouting oats on the surface is often done, but unless the feeding commences early enough so that the green oats can be fed before it decays, it is really an expensive system, as the oats required for the purpose has more value than the silage saved. Besides, this is only a partial preventive against spoilage. The cutting of weeds on top is not to be recommended, as the silage is liable to be tainted for several feet. The most practical method is to snap the ears out of the last two or three loads of corn put in, thus saving the grain, and after soaking and packing the surface, allow the top layer to spoil and seal the silo.

*Opening the Silo.*—Feeding, of course, commences from the top, so the decayed silage should be removed from the entire surface. Be sure to remove all of it, and its use as fertilizer on the field is the safest method of disposing of it. "How soon can one feed after filling the silo?" it is often asked. One could commence at once, but of course fermentation sets in quickly and the silage for some time would be like green corn which has been piled up and allowed to heat. It spoils quickly when exposed to air, and gets a bad odor and flavor. Professors Dox and Neidig of Ames College state, in Research Bulletin No. 10, that "Esten and Mason have shown that fermentation proceeds very rapidly after filling the silo and that the changes are practically complete at the end of two weeks;" so that after that time would be the best time to commence feeding the silage

*Co-operation in Filling.*—If every silo owner owned his own cutter and engine, he could fill his silo whenever he chose or when his crop was ready, instead of trying to borrow his neighbor's when he is using it himself. This is hardly practical, as the cost of machinery considering the amount it is used is too great to be borne economically by each farmer. Four or five neighbors who get along peacably can form a company for the purchase of machinery and for the silo filling to good advantage. It can be agreed at planting time in what order the filling shall be done and the corn planted at intervals of a few days apart in the same order so that all the corn will not be in the best condition for silage at the same time. If it is possible, it is economical to hire a threshing engine for power, saving expense, unless one cannot be hired during such a busy season of the year. The silos can all be filled and then refilled in the same order, thus allowing about a week for settling. Always remove all decayed silage before adding fresh fodder. Companies of this kind are greatly reducing the cost of their silage and also overcoming the obstacle of finding sufficient hands by exchanging labor.

*Silage From Cured Fodder.*—It often occurs that cured fodder is on hand after the silo is empty. It has been proven by numerous instances that such cured fodder can be converted into a good grade of silage by running it through a cutter, soaking it thoroughly and packing it well in the silo. Such cured fodder will of course absorb a great amount of water to restore it to a succulent form. After filling, water can be turned on the silage from the top and soaked well and tramped. In one case where all the corn was cut in advance, and through a serious breakdown in filling machinery, was shocked in the field and allowed to cure and subsequently put into the silo, good silage resulted. This silage was fed in almost unlimited quantities to horses with excellent results, so that its quality can scarcely be questioned.

*Cost of Silage.*—Three factors are of prime importance in controlling the cost per ton of silage; namely, first, cost of raising the crop; second, cost of putting the crop into the silo; and third, the yield per acre of the crop. All factors are sufficiently influenced by the personal capability of the farmer, so that various costs are reported under very similar conditions. As a general thing costs per ton of silage under both dry land and irrigated conditions run right around $2.00 per ton in the silo.

## FEEDING SILAGE.

*To Dairy Cattle.*—Silage was perhaps first used by dairymen, and some people are still of the opinion that it is a feed fit only for the dairy cow. It is a fact that dairymen consider it a feed which is practically indispensible to profitable dairying, but such are not its limitations. For winter dairying it is much cheaper and slightly more efficient than most of our common root crops. As a summer feed it is cheaper than soilage and quite as efficient. Pasture is, under most conditions, a cheaper feed, but a higher production of milk is possible where cows are fed silage. Silage should always be on hand to supplement pasture during the summer-time when pastures get dry and short. The addition of silage to the dairy ration stimulates appetite, increasing consumption, and therefore production, reduces the cost of the ration, reduces the quantity of concentrates necessary in the ration, and in general keeps animals in a healthier and thriftier condition.

*To Beef Cattle.*—Experiments at a number of our experiment stations have shown conclusively the value of silage for both breeding and fattening beef cattle. This data is too familiar to most of our stock men to be repeated here. Yet silage must occupy a more important place in our beef industry than it does at the present time. Cattle are too high priced and range is becoming too scarce, especially in the winter, so that we can economically run three-year-old and four-year-old steers on the range. In order to cut down this period, it will be necessary to take better care of our calves so that they are kept growing during the winter instead of losing weight and quality, so that they may be turned off as finished beef as long yearlings and two-year-olds. Silage, supplemented with a rich proteid roughage or concentrate, offers a very cheap wintering and growing ration. For fattening steers, silage will soon be a strong rival of our cheap beet pulp.

*To Horses and Mules.*—One hears a variety of reports on the value of silage to horses and mules. One farmer reports the loss of a number of valuable horses, while his neighbor reports very satisfactory results where he hauled the silage out in a beet wagon and spread it out on the ground and allowed his cattle and horses to eat all they chose. The conclusion would be that silage for horses and mules must be in perfect condition. The fact that they eat it with a relish is not a sign by any means that it is good silage. Silage for horses should not be as acid and should be fed in small quantities until the animals become accustomed to the feed. It is too washy to feed to work stock except in very limited quantities. It is not safe to feed to brood mares unless one has had sufficient experience with silage to know when it is free from mold and in the best possible condition. The layman better not feed it at all to mares.

*To Sheep.*—As with horses, reports vary on the feeding of silage to sheep. For breeding ewes and rams, silage has been used for many years in a winter ration with excellent results, but for fattening lambs it has not been used much in this state prior to the fall and winter of 1911. Those feeders using silage during this feeding period reported profits, while most feeders lost money on account of unfavorable markets. The addition of silage cheapened the ration and therefore gains. Other feeders report that the sheep is too much of a "mincer" to feed profitably on silage. It is true that silage for sheep should also not be too acid. Many feeders are putting in silos, and a few years more of experience along this line will bring out valuable information on the feeding of silage to fattening lambs.

*To Hogs.*—For breeding stock, succulence is very valuable in the winter ration, but silage is too bulky for the nutriment it contains to be fed to advantage to fattening hogs. Rich concentrates are necessary to put on a good finish in a short time. For growing fall litters, silage in small quantities would partly take the place of pasture which is our cheapest growing feed.

*To Poultry.*—Silage for laying hens in the winter is being strongly advocated. In fact, some silo companies are now putting out a special poultry silo. The economy of the practice must yet be more thoroughly demonstrated before it is adopted very generally by poultrymen.

*Frozen Silage.*—There is always some frozen silage in all above ground silos even in Colorado. Heavy feeding of such silage is not to be recommended, as it causes scouring. Such silage also spoils very quickly on thawing out. The best method of feeding is to mix it with the unfrozen silage and let it thaw out in that way before feeding. It is a better plan to keep the frozen silage fed out than to let it remain on the walls, as such silage seems to have a refrigerating effect in the silo and freezing increases. Freezing is not so great that all frozen silage cannot be fed out with the unfrozen in the manner indicated above.

## BUILDING INSTRUCTIONS FOR CONCRETE SILOS.

*By Paul V. Maris, Field Representative in Dairying, Animal Husbandry Department, Colorado Agricultural College.*

Note.—These building instructions are based upon work done by Mr. Maris, while Junior Dairyman for the United States Department of Agriculture, in co-operation with the Colorado Agricultural College.

Drawing No. 1, showing the detail of the forms and scaffolding, was prepared by Mr. A. K. Risser, of the Department of Agriculture, who had charge of the work of that division of this territory. The photographs from which cuts Nos. 5, 6 and 7 were prepared were also furnished by Mr. Risser. The drawings upon which figures 1 to 11 are based were prepared by Mr. Maris.

The cuts used in illustrating these instructions were loaned by The Colorado Farmer.

*Laying Off Ground for Excavation.*—Figure 1 illustrates the manner in which the ground may be laid off preparatory to excavation for the silo. The center stake (a) should be well set into the ground and a straight stiff scantling (b) long enough to reach past the outside wall of the silo should be spiked to this with a nail that will not bend easily. The nail marks the center of the silo. From this center nail measure the distance to the outside of the silo wall and mark across the scantling at this point. Nail a block (c) flush with this mark. A sharpened board (d) may then be held against this block and be raised and lowered to meet the irregularity of the ground as the circle is described. The scantling (b) should be kept level while the circle is being described.

In case the silo is to be 16 feet in diameter the point of the sharpened board should mark off a circle just 8 feet and 6 inches from the center nail, the 6 inches being allowed for the silo wall. The dirt inside the circle thus described may then be thrown out to the desired depth.

*Depth of Excavation.*—The bottom of the silo should not be more than 5 feet below the ground level on the side in which the door is to be placed. A greater depth will cause inconvenience in removing the silage from the bottom of the silo. Care should be taken to keep the walls smooth and perpendicular in excavating. Irregularity in the dirt walls will result in either large cavities that must be filled with concrete or narrow places in the wall. When a team and scraper are used in excavating, an exit driveway should be left at one side. Hand shovels should be used around the walls of the excavation. When the team and scraper have been used as long as possible the driveway may then be thrown out by hand.

Care should be taken to level the dirt floor of the excavation. A spirits level and plumb which will be needed throughout the construction of the silo, should be used for the purpose and it should also be used as a guide in keeping the walls perpendicular while excavating.

*Footing for Wall.*—The walls of the silo should rest upon a solid foundation or footing extending below the frost line. The size of this footing will be regulated by the nature of the dirt in which the excavation is made. One foot and a half deep by 16 to 20 inches wide at the bottom will be sufficient in case the dirt is solid. If the soil is loose and sandy a larger footing should be made. Larger rocks may be used in the footing than in the wall above.

Fig. 2 shows the manner in which a trench may be dug around the bottom of the excavation and filled with concrete to form the footing. It also shows the manner in which the surface of the footing may be leveled by resting one end of a straight edge board upon a center stake and the other end upon the surface of the footing.

When the inside form is set up it rests upon this footing. The form is so constructed that when set upon a level base the sides will be plumb. Hence if the footing is not level, the wall of the silo will not be started plumb and difficulty will follow.

Figure 3 shows a cross section of the silo wall and footing after the inside form has been set upon the footing and the six-inch space between the form and the dirt wall has been filled with concrete. It will be seen from this cut what the effect of an irregular dirt wall would be.

*Excavating in Loose Sandy Soil.*—In case the soil is such that the walls of the excavation cave and give way it will be necessary to excavate from a circle considerably larger than the silo so that the outside form may be set up around the inside form to take the place of the dirt wall. The footing in this case will be made by digging a trench, about two feet wide and from one to one and a half feet deep and filling it with concrete. The footing should be laid out so that the silo wall may be started upon the center of it. This may be done by describing two circles in the manner shown in Fig. 1. The circles should be separated by a distance equal to the desired width of the footing.

*Reinforcing Foundation.*—The foundation should be well reinforced. This may be done by laying strands of barb wire three or four inches apart in the concrete as the trench is being filled.

*Reinforcing Wall Under Ground.*—The wall under ground should be reinforced in the same manner and with the same woven wire that is used above the ground.

*Setting Up Forms.*—At the first setting, the inside form rests upon the footing. The diameter of the inside form should be taken after it is set up and in case it has been forced out of circle shape it should be drawn back again.

After the forms have been filled and allowed to set over night. they are ready to be raised for the first time. Before this is done the scaffolding must be started.

*Scaffolding.*—Proper scaffolding is a very important feature of concrete silo building. No outside scaffolding is used. An idea of the scaffolding arrangement can be gained by reference to cuts

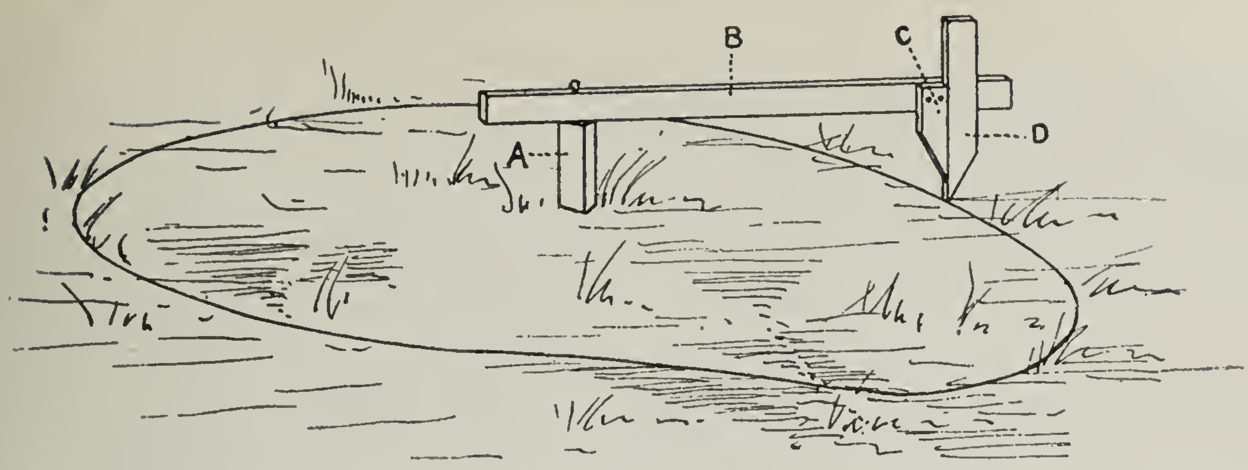



FIG. I.

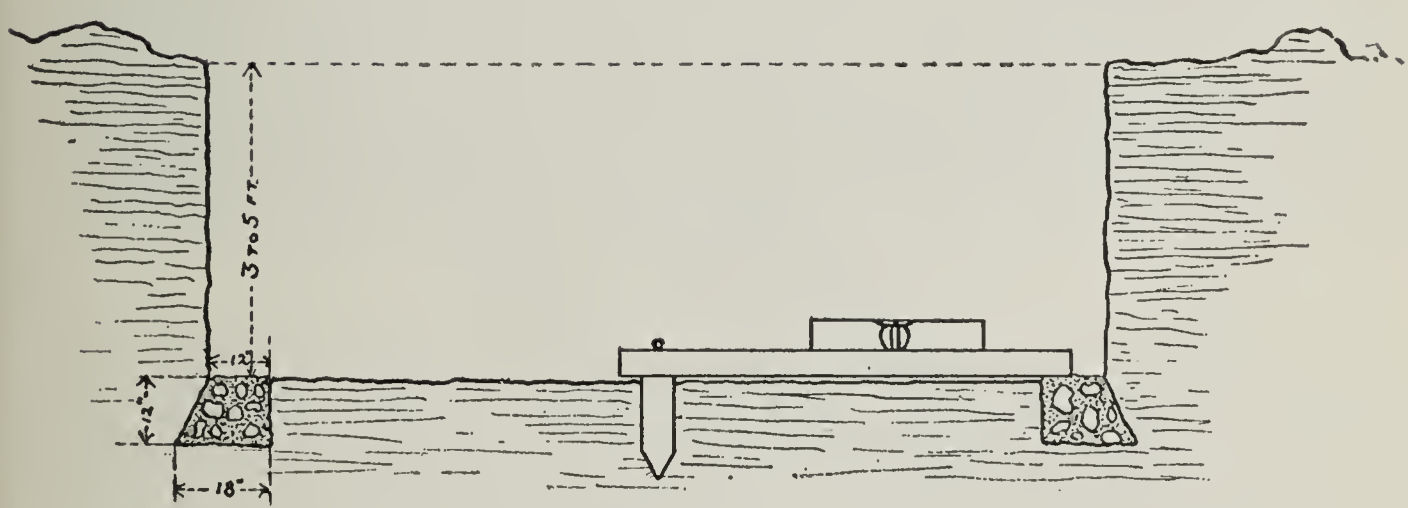



FIG. II.


FIG. III

5, 6 and 7, showing photographs of silo building. The exact arrangement is shown in drawing No. 1.

A center 2x4 is first set a few inches in the ground and made plumb by temporary braces. Quarter posts (2x4) are then set at right angles to this center post about eight inches from the silo wall. These are held perpendicular to the silo wall by overhead cross arms (2x4), joining them to the center post, and they are prevented from leaning by side braces. These four cross arms are used for attaching the pulleys that raise both the inside and the outside forms and they should extend a few inches over the outside of the silo wall. Pulleys are shown hanging to these cross arms in the cuts 6 and 7.

In silos fourteen feet in diameter or smaller, one 2x4 is set between each quarter post, making eight outside scaffolding posts in, all around the center post, each one being set plumb and 8 inches from the silo wall. Each of these outside posts are joined to the center post by overhead cross-arms just as the quarter posts are. They will not be required to support weight and 1-inch material may be used. Short boards should join the outside posts together as shown in cut 6.

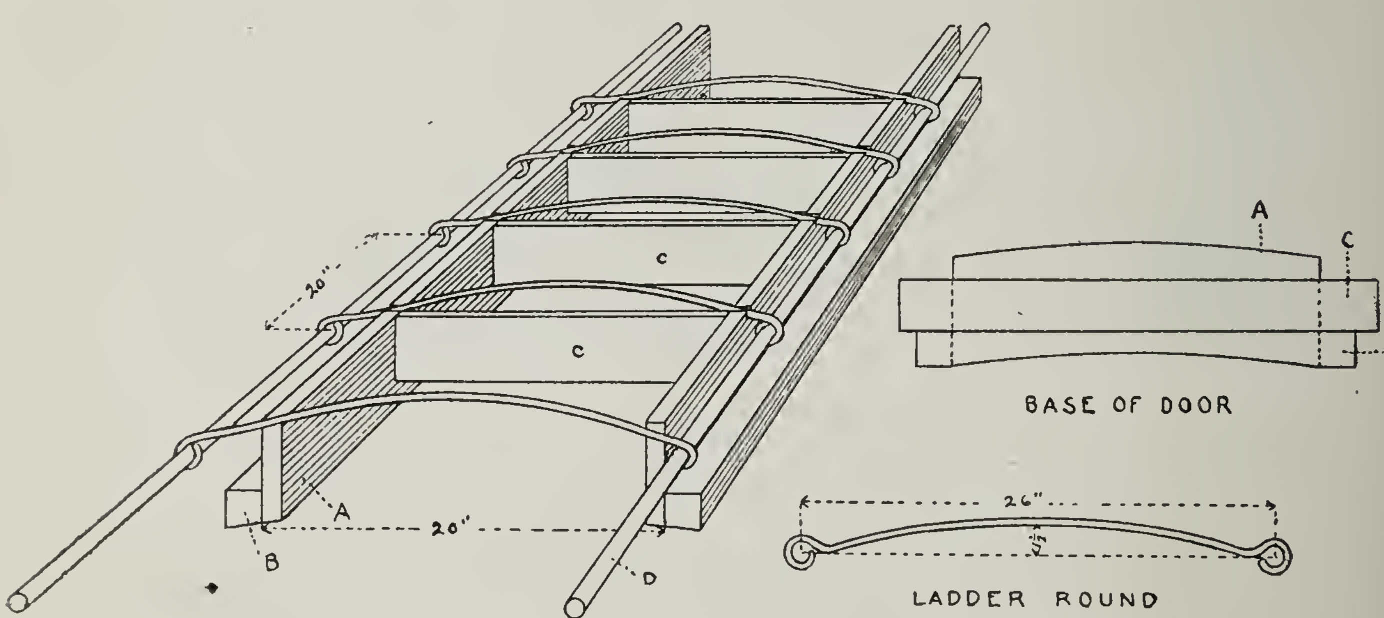



FIG. IV

In silos over fourteen feet in diameter, two posts are set between each of the quarter posts, making a total of twelve around the center post. After the scaffolding has been cross-braced so that it cannot twist under the weight of the forms, the forms may then be raised.

*Raising the Inside Forms.*—The first step in raising the inside form is to draw it in, by using the adjusting bolts, so that the sheet iron will be free from the concrete wall at all places. The ropes from the pulleys hanging from the quarter arms may then be attached to short boards nailed across two studs of the inside form. One man should manipulate each pulley rope from inside the silo.

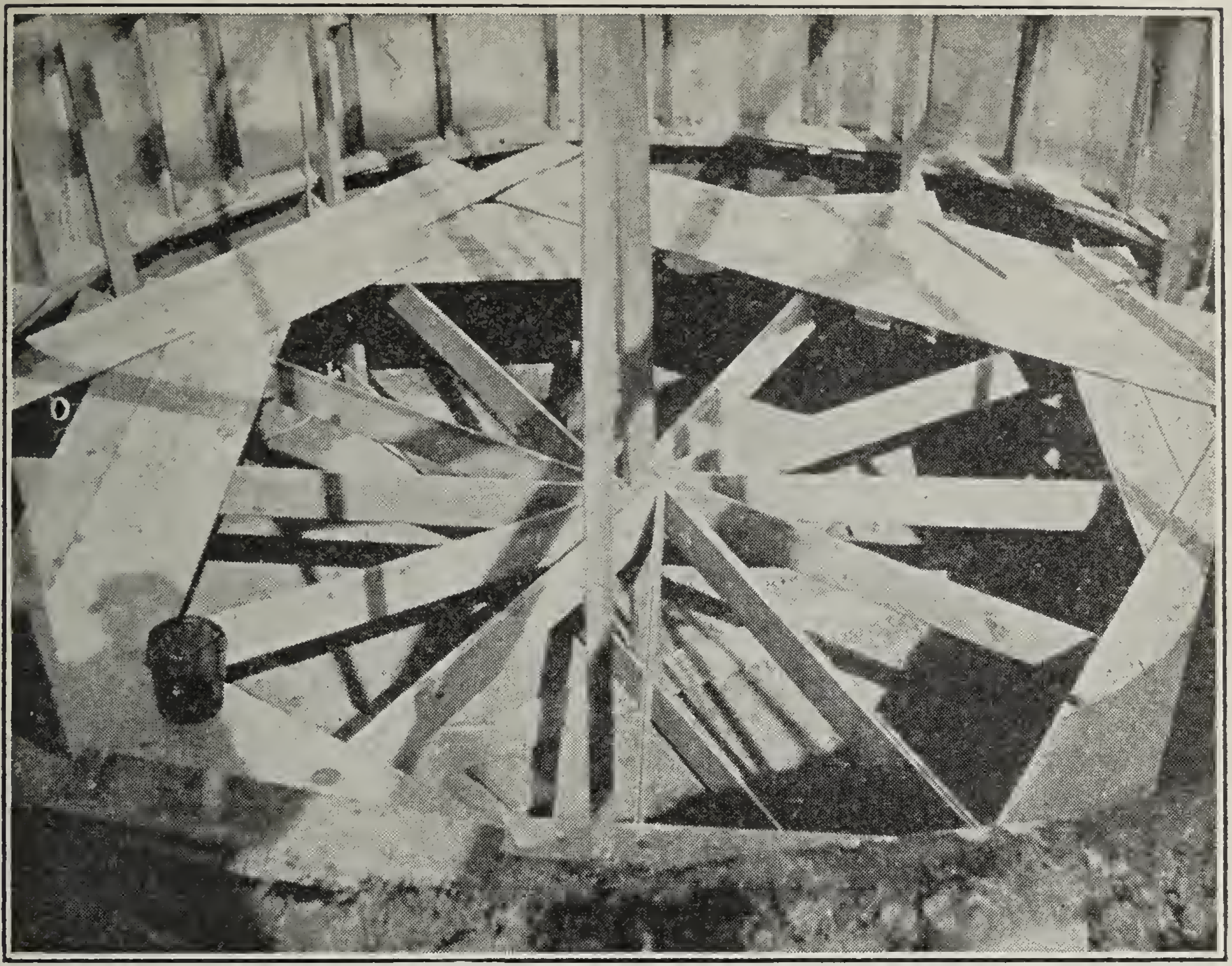


Fig. V.

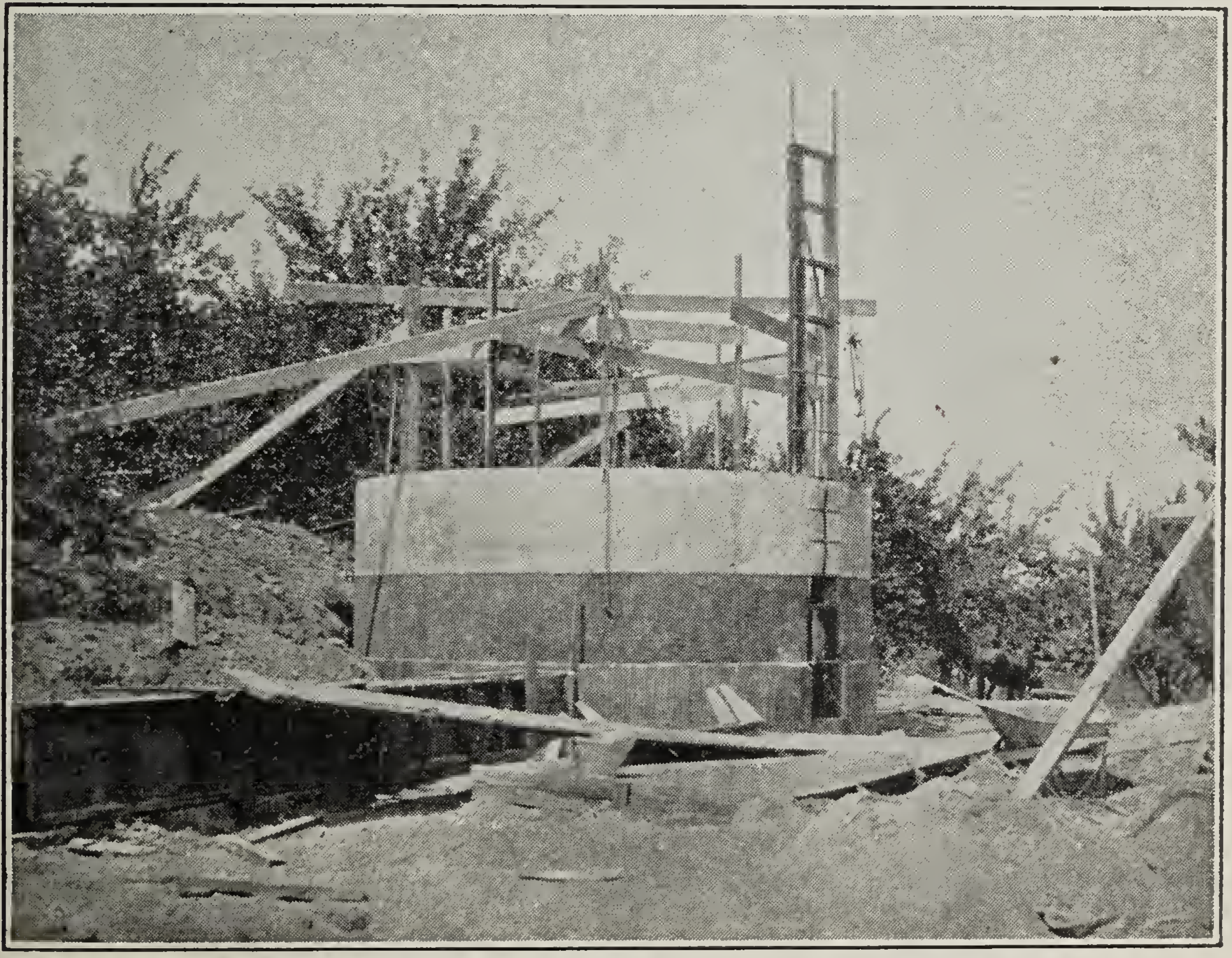


Fig. VI.

The inside form is raised above the level of the finished wall and allowed to hang from locked pulleys. Cut 5 shows how a level rest is then made that the forms may be lowered upon.

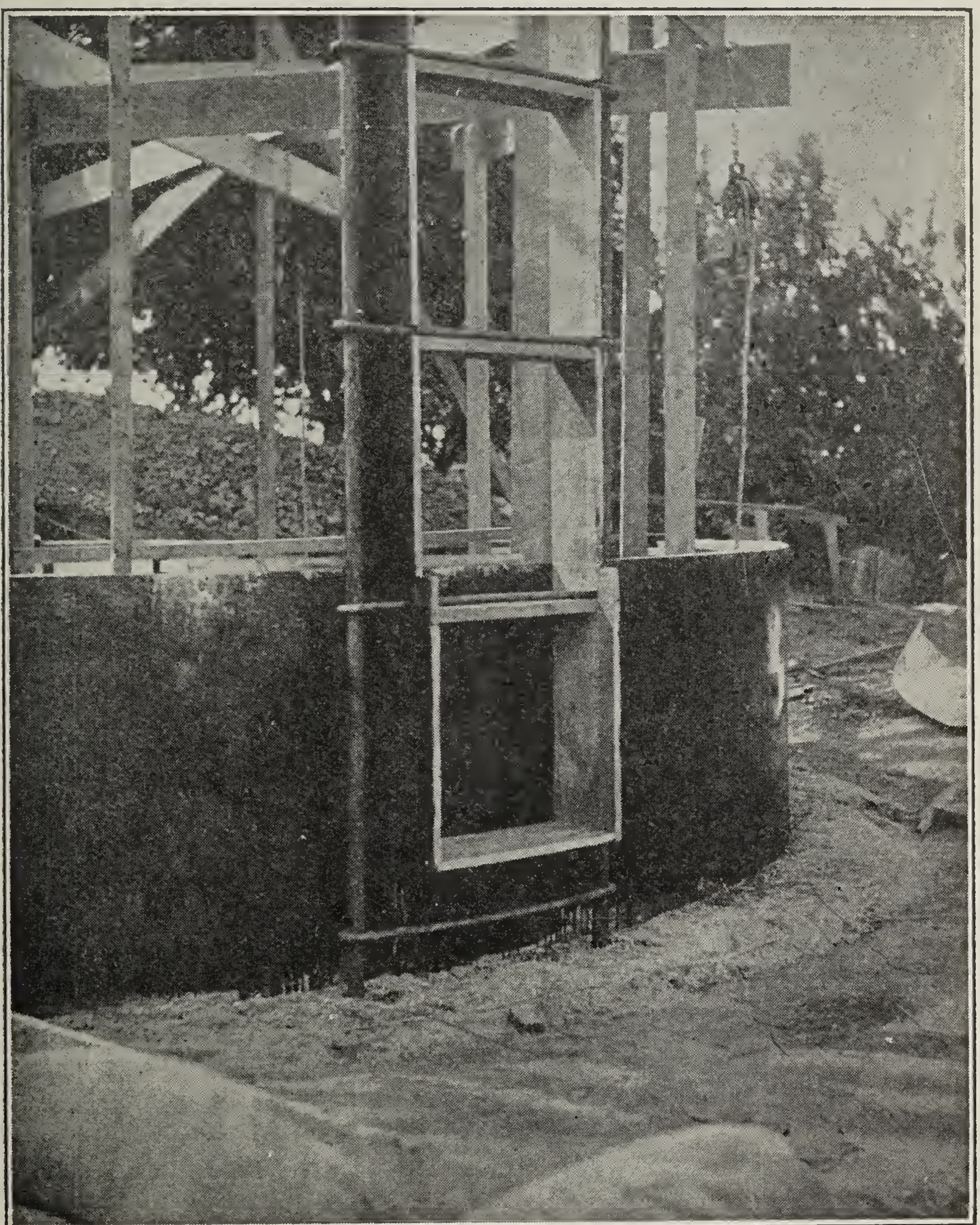
A mark is drawn around the center 2x4 just two inches below a point level with the top of the finished wall. Arms are then run, on the level of this mark to the wall of the silo, one such arm being nailed to each of the eight or ten (as the case may be) of the outside legs of the scaffolding. These arms should each meet the concrete wall. In cut 5 you are looking down upon the scaffolding after these arms have been placed, the working platform laid and the inside form lowered to position. When the inside form is lowered upon these arms it should be perfectly level and should lap two inches below the finished wall. The form should then be spread to its normal diameter by manipulating the adjusting bolts. It will thus be forced out tightly against the wall at all points.

The form should be made plumb each time it is set, but in case difficulty is encountered in spreading it to its proper diameter, in other words, if the circle of the silo seems to be growing smaller, the top of the form may be flared outward slightly to overcome this tendency.

*Reinforcing.*—After the inside form is set, the reinforcing is then put in place. Use hog wire with 6-inch stays. Cut 7 shows the inside form raised and set and ready for reinforcing. In the courses below the door, the reinforcing will reach entirely around the inside form and will be tied at the point of meeting. About nine inches should be allowed for tying in this case. After the door is started the reinforcing will be tied to the pipes on either side of the door. The allowance for tying will be doubled in this case for the two ties. The reinforcing after the door is started will, therefore, be cut long enough to go around a circle of one foot greater diameter than the silo, plus 18 inches for tying, minus the 26 inches between the door posts. The distance around the circle may be determined by multiplying the diameter by 3.1416. Each strand of the wire should be tied to the door pipe. This cannot be done after both forms are raised and care must be taken to have the reinforcing the proper length when tied.

*Position of Reinforcing.*—The reinforcing is set at the outside rather than in the center of the concrete wall. It is held in place by boards (spacers), 5 or 6 inches wide (according to the thickness of the wall), set edgewise at intervals of about 2½ feet between the inside form and the wire. These same spacers also hold the outside form in position. The reinforcing and the outside form are held in contact by the spacers. If instructions are followed in tamping the concrete, the reinforcing will not show when the outside forms are raised. The spacers are raised and kept above concrete as the forms are filled.

Before the outside form is raised it is well to set the spacers to determine whether or not the reinforcing has been tied the right length. If the reinforcing is drawn tight when the spacers are set at intervals of 2½ feet, it is the proper length.



Cut VII.

*Raising the Outside Form.*—A hole may be punched through the sheet iron of the outside form about one inch from the upper edge, just under each raising pulley, and a ring of baling wire may be tied in this hole to form a pulley attachment. Before the lug bolts of the outside form are loosened, the pulleys should be attached to these wires and locked to prevent the form from dropping. After the bolts are loosened the sheet iron should be freed from the wall at all points. The outside form may then be raised by men at each pulley rope inside the silo. The outside form should be brought to a level with the inside form, having a lap of two inches over the finished wall. The form is then tightened by drawing the lugs together. The spacers should be so set that the distance between the inside and the outside form will be uniform.

It is customary to raise the inside form first, but the system may be reversed if it becomes desirable to clean or grease the outside form. It is important that the outside form be tight at the time the inside form is forced out against the green wall.

*Silo Door.*—The silo door should be started on the level of the floor or ground upon which the silage is to be delivered and for convenience this should not be more than five feet above the bottom of the silo.

Cut 7 shows a photograph of the silo door frame just placed in position against the inside form. It shows one ladder round which will be imbedded in the concrete under the door and shows how the iron pipes will be imbedded in the concrete on either side of the door.

*Constructing the Door Frame.*—The door frame made up and ready for raising is shown in Fig. 4. The wooden framing is first constructed. The door jambs are made of 5 or 6-inch boards according to the thickness of the concrete wall. 2x2 pieces, which may be ripped from straight 2x4's, are nailed on the outside of and what will be the front of these jambs as they stand against the inside form. Spreaders (c) (Fig. 4), 1x4's or 2x4's are set between the jambs at intervals of about two and a half feet so that the jambs will stand twenty inches apart outside measure. In Fig. No. 4 one spreader is shown under each ladder round. Notches for the ladder rounds are then cut in the door jambs at intervals of twenty inches. The notches should be made about two and a half inches deep. The iron ladder may then be laid over this frame and the rounds placed in the notches prepared. The space between the pipes or ladder legs (d) and the jambs should be made equal on either side. The ladder may be held in position by wiring a few of the ladder rounds tightly to the jambs where the rounds pass the notches.

*Ladder Rounds.*—The ladder rounds should be carefully made. Three-fourths inch rod iron should be used. The eye at either end need not be welded, but should be made to fit over an inch pipe. The distance from the center to the center of the eye should be twenty-six inches. Unless all rounds are uniform in this respect they cannot be placed over the iron pipes. One-inch pipe is used for the ladder legs.

*Base of Door.*—A board (a) the length of the spreaders (c) and the width of the silo wall forms the base of the door frame. This must be sawed to the circle of the silo on either edge. A 2x2 twenty-four inches long (b) and sawed on one side to the silo circle should be nailed to this bottom board, so that the shoulder formed by the 2x2 pieces on the door jambs may also extend across the bottom of the door. An iron strip (c) should be tacked on the under side of the bottom board flush with the straight-edge of the 2x2. This will form an iron sill at the bottom of the concrete door when the wooden framing is removed.

*Door Made in Sections.*—The door should be made up in sections 10 or 12 feet long, since longer sections cannot be erected or held plumb without great difficulty. Cut 6 shows a door standing in position. When the wall is completed to the height of this section another section will be erected. The pipes should be provided with shoulders and threads for the unions made where the door sections join.

*Bolt Holes for Chute Attachment.*—In case a chute is to be attached after the silo is complete it will be necessary to bolt 2x4's on either side the door for the chute framing, ¾-inch bolt holes should be made in the silo wall at the time of construction for this purpose. They should be placed just outside the ladder pipe on either side the door, one about six feet above the other. These bolt holes may be made by laying blank bolts, as long as the wall is thick in the concrete and then driving them out after the forms are raised. The bolts should be well greased with axle grease or some heavy grease, so that they may be driven out easily. Perhaps a better method than using the blank bolts is to use ⅝-inch gas pipe, plugged at either end with mud, so they will not fill with concrete. These are left in the wall and the chute bolts are run directly through them.

*Plate Bolts.*—If the silo is to be roofed, plate bolts must be set in the top course of the concrete wall. Two bolts should be set equally distant apart for each of the eight plate pieces used in building the octagon roof. The bolts should be left about three inches in the clear and be embedded eight inches in the concrete. The end embedded in the concrete should be bent to "L" shape to prevent its working loose. The entire bolt will, therefore, be about fourteen inches long. Rod iron may be threaded and used for this purpose.

*Working Force.*—The silo forms should be filled each day.

This will require a working force of four men. After setting over night they may be raised and filled again the next day. Four men will be required to accomplish this labor of raising and filling. Since four men can fill the forms, no time is gained by increasing the size of the force. A day's time is lost, however, when the forms are not filled each day.

*Material.*—The selection of proper sand and gravel and determining the proportions in which cement shall be mixed with the sand and gravel are vital factors in concrete silo building.

The sand and gravel commonly used is found in mixed form in banks or creek bottoms. The fine sand and coarser gravel may be present in this mixture in the right proportion for making good concrete, but there is generally quite an excess of sand. This mixture may be tested by passing it over a ¼-inch screen. There should be five parts of the coarse material to three of the finer. When this proportion prevails generally throughout the gravel bank, the two materials need not be separated but may be mixed with the cement at the rate of one part of cement to five of the bank mixture.

If the proportion is undesirable as it comes from the bank, the sand and gravel should be separated and remixed. It should be borne in mind that one part of the cement is to be used for each three parts of sand, regardless of whether the coarser aggregate is present or not. Good walls can be made when there is not sufficient gravel to make the full five parts, provided the one part to three relation is maintained between cement and sand. Care should be taken that the sand does not contain dirt or clay.

The desirable concrete mixture for concrete silos consists of one part cement, three parts sand and five parts crushed rock or gravel.

It should be remembered that when one cubic foot of cement, three cubic feet of sand and five cubic feet of crushed rock or gravel are mixed together, the total is not equal to nine cubic feet. The cement fills the voids between sand particles and the sand particles fill the voids between the coarse aggregate or gravel. A strong mortar is made by mixing one part cement and three parts clean, coarse sand. This mortar will fill the voids between and cover five parts of rock or gravel. If the five parts of gravel are not present one part of cement must still be used for each three parts of sand. A cheaper wall is obtained when the full five parts of gravel or rock are present, since in this case less cement will be used. In certain cases, however, the gravel or rock are not obtainable.

*Sand.*—Sand for concrete work should be coarse and free from clay, dirt and vegetable matter. If it is dirty it must be washed over a screen before being used.

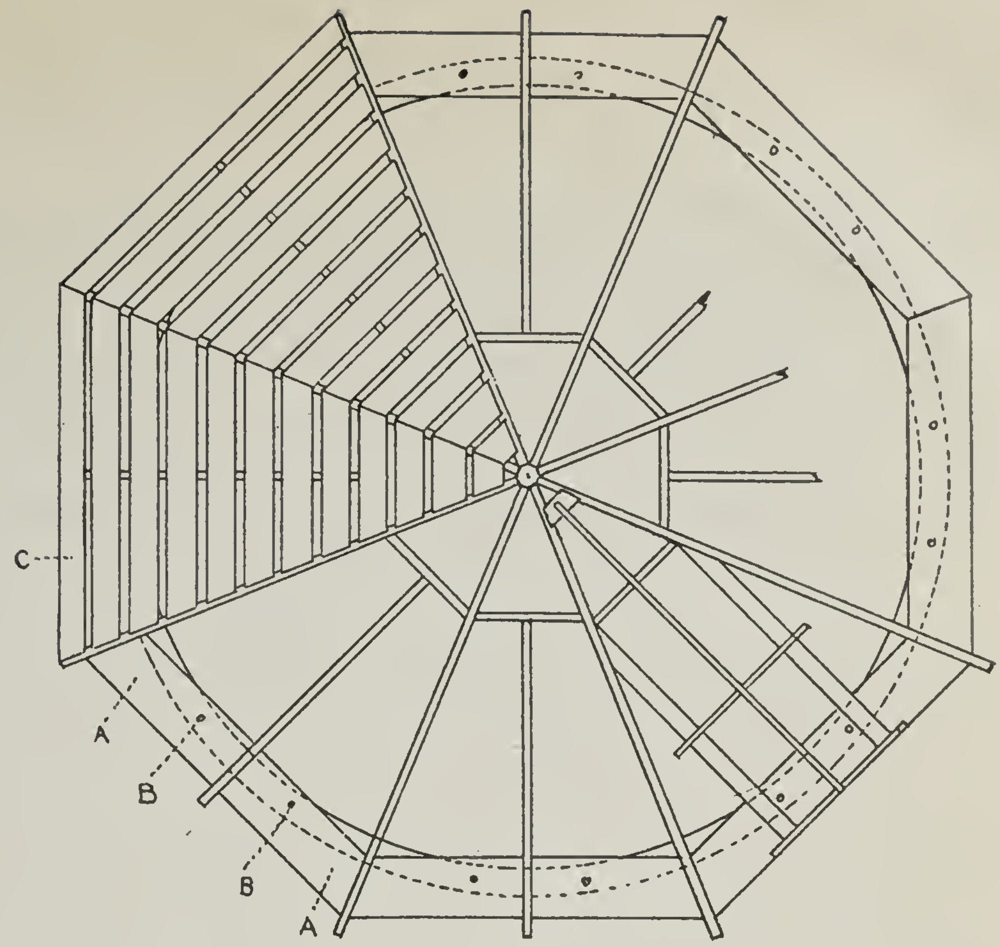



FIG. VIII.

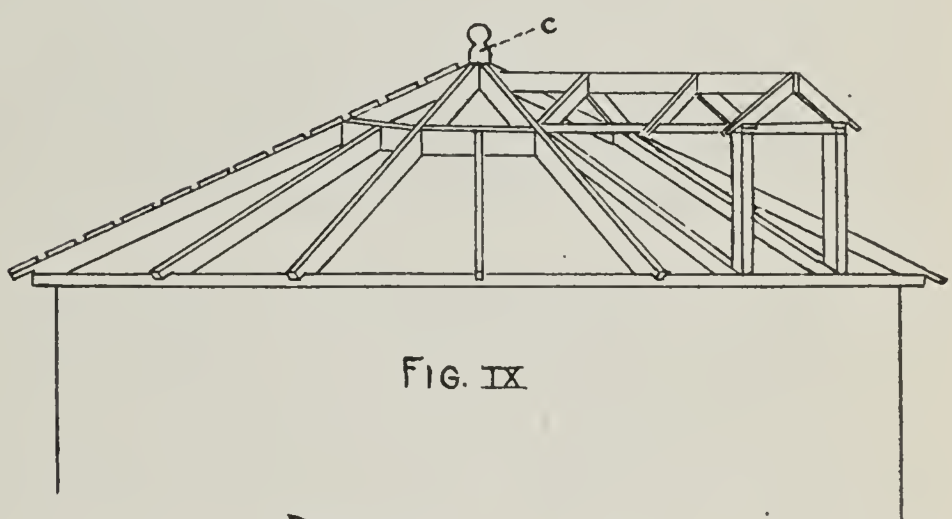



FIG. IX

PLATE FOR 12 FT. DIA SILO

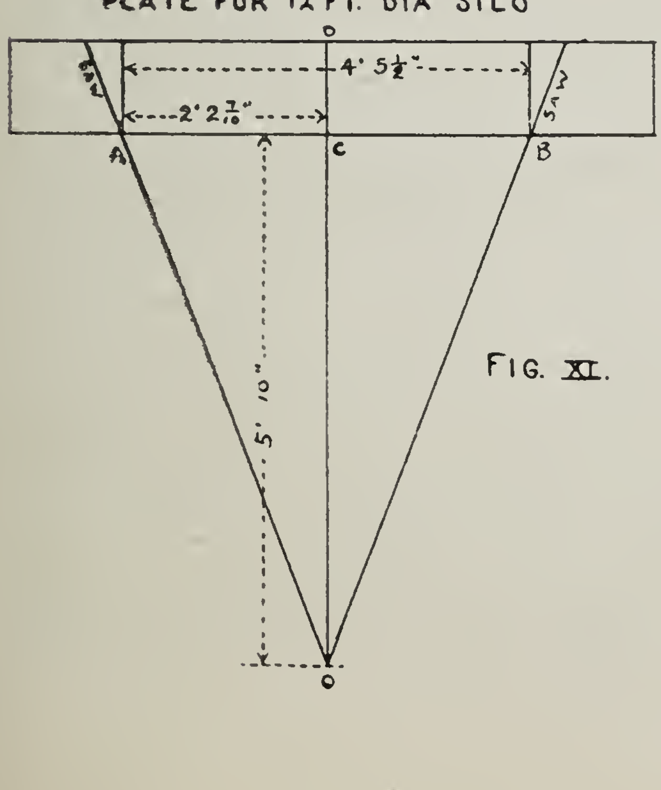



FIG. XI.

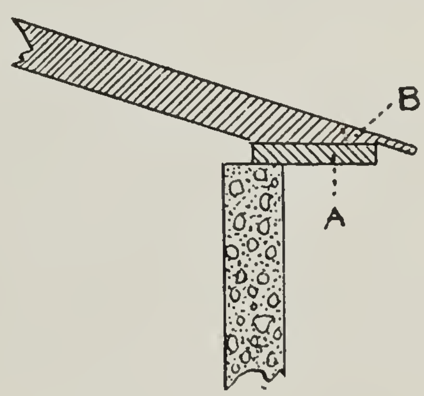



FIG. X

The statement that one part of cement mixed with three parts of sand makes a strong mortar, contemplates the use of coarse sharp sand. If the sand is fine, one part of cement to three parts of sand is not sufficient. One to three mixture of cement to sand is permissible only if the sand is suitable, but if the sand is other than the most desirable, the mixture must be made richer. This is regardless of whether the full five parts of rock are present or not.

*Gravel.*—Gravel should consist of aggregate varying in size from grains just too large to pass through a ¼-inch mesh screen up to rocks that can be passed through a 2-inch diameter ring.

*Bank Sand and Gravel.*—Practically all builders will have occasion to use bank sand and gravel ready mixed. This must first be examined to see that it is free from dirt and vegetable matter.

Before the proportion of cement can be determined the relation between the sand and gravel in the bank must be ascertained by passing it over a ¼-inch mesh screen set at an angle of 45 degrees. If a relation of three parts of sand to five parts of gravel prevails quite uniformly throughout the bank and the sand is coarse, clean and sharp, a mixture of one part cement to five of the bank material may be used. If excess gravel is present the sand and gravel must be separated and the excess gravel discarded.

Ordinarily the bank gravel contains an excess of sand. In this case the quantity of mixed sand and gravel to use may be determined as follows:

Screen the sand from the gravel until three measures of sand are obtained. Then remix the gravel with these three measures of sand, and measure the two combined. This will represent the quantity of the bank material that may be mixed with one measure of cement.

*Kind of Measure.*—The mason's wheelbarrow which is filled level full with two sacks of cement is the most convenient measure to use in mixing materials. A cement barrel which holds just four sacks of cement may be used by knocking out the bottom and nailing boards on the sides for handles. A box without a bottom and with the sides extending to form handles may be easily constructed if a barrel is not obtainable. The size of this box may be determined as follows: One sack of cement contains .95 cubic feet. It is desirable to mix two-sack batches, hence a box holding 1.9 cubic feet should be built. The following dimensions would give the capacity 1 foot high by 1 foot wide by 1.9 feet long. If the mixed sand and gravel are suitable for a one to five mixture, this box will be filled five times with the sand and gravel and two sacks of cement will be spread over it upon the mixing platform. If the barrel is used the two sacks will fill it but half full. Five half barrels of sand and gravel (or $2\frac{1}{2}$ barrels) would make a one to five mixture, etc.

*Caution.*—It must be borne in mind that in all cases the proportion of cement to sand and gravel will depend upon the character of the sand and gravel in each particular bank. To use a certain mixture without knowing how much sand is present may result in faulty concrete. The proportion of cement must be increased when sand is fine. Dirty sand and gravel may be rendered usable by washing but not by increasing the proportion of cement.

It will be understood, therefore, that a mixture of one part of cement to five parts of the mixed sand and gravel, ordinarily found in the gravel banks in this state, is the widest mixture that is permissible when all materials are satisfactory.

*Mixing Platform.*—A tight level mixing platform about ten feet wide by 14 or 16 feet long should be constructed. A smaller platform than this will not be ample for the four men who should work at mixing.

*Manner of Working.*—The work is accomplished most advantageously when all four men work together in mixing a batch of concrete. Two men then remain on the platform. One of them fills the buckets, while the other elevates them to a man above. One man inside the silo receives the bucket and empties it into the forms. The fourth man uses the tamper continuously while the batch is being placed in the forms.

*Sizes of Batches.*—A batch in which two sacks of cement at a time are used is a desirable size. This may be handled nicely upon the platform and placed in the forms before it begins to set.

*Manner of Mixing.*—The sand and gravel are first placed upon the mixing platform and spread out evenly. The two sacks of cement are then emptied over this and spread evenly. The same gravel and cement are then thoroughly mixed together while dry. Two men should stand at either end of the pile and shovel it over outward. It may then be turned back together. This procedure should be repeated once more. No rule will be given for the number of times this should be turned. The cement should be so thoroughly mixed that no streaks will show and the color of the entire mass will be uniform throughout. Partial mixing should not be done with the idea that it will be made thorough when water is added.

*Adding Water.*—The dry mixture should be spread out and the center hollowed out, thus forming a crater. Water may be poured in this crater and the dry mixture from the edge may be gradually worked in. Square cornered shovels will be found the best tools for both wet and dry mixing. Care should be taken not to permit the water to run off and carry cement with it while mixing. When made wet enough the entire mass can be shaken by patting it in the center with the shovel. It will be wet enough to deliver from the bucket into the forms nicely.

*Elevating.*—An extra pulley attached to one of the quarter arms of the scaffolding is used in elevating the concrete. One man stands upon the ground and pulls this up. No saving in time or men can be effected by the use of a horse in hoisting cement. The one man draws it up as rapidly as it can be handled above.

*Tamping.*—Thorough tamping of the cement in the silo forms is a very important matter. The man who fills the forms should work gradually around the silo, filling to a depth of about six inches as he goes. He should be followed closely by the man who does the tamping.

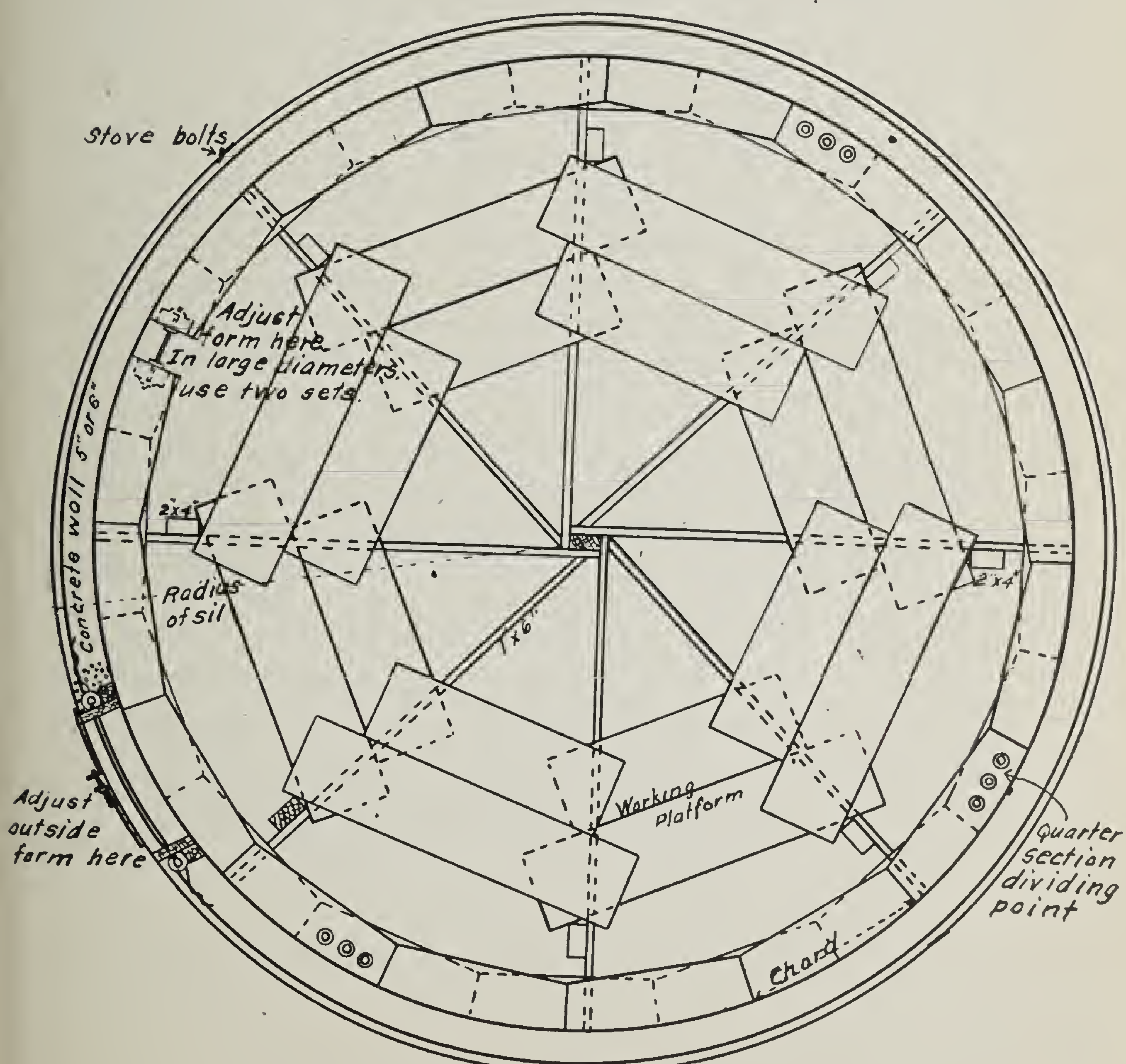
*Tamper.*—A desirable tool for a tamper is made by straightening the shank of a hoe until the blade is straight with the handle. With this sharp edge the concrete can be thoroughly tamped. It is desirable to run the hoe blade between the outside form and the reinforcing. Although the reinforcing is against the outside form, it will be covered with concrete if this precaution is taken. Very careful tamping should be done around the door jambs. When the concrete is properly tamped it will be smooth and soft on top and if the proper amount of water has been added, the concrete will jiggle as the tamping is done. A little water will soon raise to the surface of the concrete. If this collects in excess and runs out of the forms too much water has been used in mixing. When water runs out of the forms in this manner it washes the cement off the rocks and sand and weakens the wall.

*Wetting the Surface.*—Each day before the first concrete is placed in the forms, water should be thrown upon the surface of the wall completed the day before, and a few handfulls of dry cement should be sprinkled over the moistened surface. This will result in a more perfect union between the different courses.

*Tarring the Silo.*—The inside surface of the silo wall should be rendered air and water tight by the application of a coat of No. 7 soft tar pitch.

The pitch should be melted in kettles until it is thin enough to be applied smoothly and readily. When only partially melted, an excessive quantity will be used. The pitch may be applied with swabs. The swabs are made by attaching rags or mop material securely on the end of a handle, such as a broomstick handle. The swab will have the appearance of an ordinary mop except that the free end of the swab material will not be over five or six inches long. The hot tar will melt the glue in brushes if they are used. The tar should fill all the pores of the concrete and give the wall a smooth appearance. The mere painting of the wall with tar paint or thin gas tar does no good.

*Cement Washing.*—The washing of the walls of concrete silos with a cement wash of cement and water, about the thickness of paint, has proved just as efficient to make them air and water tight as an application of tar. The wash should be put on with a white-wash brush on the green walls as soon as the forms are removed. The cement wash is cheaper than tar and does not need to be applied as often.




Drawing I.

## BUILDING MATERIALS.

The following table shows the quantity of cement, rocks and reinforcing required for the foundation and main wall of silos of different dimensions. When the sand and rock are obtained together in gravel form, the quantity will slightly exceed the number of cubic yards of rock designated. Theoretically the sand should just fill the voids between the rock particles without increasing the bulk, but it is well to add one-sixth to the cubic yards of rock when sand and gravel are obtained together.

BUILDING MATERIAL REQUIRED.

| Dimensions of silo in feet | Thickness of wall in inches | Tons capacity | Cubic yards in wall and foundation | Sacks cement | Cu. yds. rock | Cu. yds. Sand | *Rods Reinforcing |
|---|---|---|---|---|---|---|---|
| 10x25 | 5 | 36 | 14.1 | 70 | 13 | 8 | 19 |
| 10x28 | 5 | 42 | 15.6 | 75 | 14 | 9 | 20.4 |
| 12x28 | 5 | 61 | 18.6 | 90 | 16 | 10 | 25 |
| 12x32 | 5 | 74 | 20.4 | 100 | 18 | 11 | 26.5 |
| 14x32 | 6 | 100 | 28.7 | 136 | 26 | 16 | 32 |
| 14x34 | 6 | 109 | 30.4 | 145 | 27 | 17 | 30 |
| 15x34 | 6 | 126 | 32.5 | 156 | 29 | 18 | 40 |
| 16x34 | 6 | 143 | 35.5 | 166 | 32 | 20 | 43 |
| 16x40 | 6 | 180 | 38.4 | 195 | 36 | 23 | 45.5 |
| 18x36 | 6 | 196 | 42.0 | 200 | 37 | 23 | 58 |
| 18x40 | 6 | 229 | 46.3 | 217 | 41 | 25 | 65 |
| 20x40 | 6 | 281 | 51.2 | 240 | 45 | 28 | 72 |

* Reinforcing doubled in lower two courses of 15x34-foot silo; in lower three courses of 16x34 and 18x36-foot silos; in lower four courses of 16x40 and 18x40-ft. silos.

*Sheet Iron Forms.*—Building forms are constructed of eighteen or twenty gauge black sheet iron, thirty-six inches wide. Each set of forms consists of an inside and an outside band. The inside band is made up of four sections of equal length. The iron is kept in stock in 8-foot lengths and special request should be made to have it made up into the required length at the factory. This applies particularly to the four pieces for the inside form. The outside band is either riveted or bolted together with stove-bolts into one long sheet. This may be done easily on the farm and hence for the outside band the 8-foot sheets may be ordered, with a short extra piece when required to make up the total length. The cutting with ordinary farm equipment is difficult, however, and for this reason inside pieces should be made up at the factory.

One set of forms can be used in building several silos and the farmer should ascertain by correspondence with this college (see preface) whether or not there are available forms in his community before he himself builds.

The following chart shows the lineal feet of sheet iron needed for both inside and outside forms for silos of different diameter.

SHEET IRON FOR FORMS.

| Diameter | Circumference | | Sheet Iron. |
|---|---|---|---|
| 10 feet | Inside | 31.41 ft. | —4 pieces 8 ft. long. |
| | Outside | 34.03 ft. | —4 pieces 8 ft. long, 1 piece 2 ft. 8 in. long. |
| 12 feet | Inside | 37.70 ft. | —4 pieces 9 ft. 8 in. long. |
| | Outside | 40.22 ft. | —5 pieces 8 ft. long, 1 piece 1 ft. long. |
| 14 feet | Inside | 43.98 ft. | —4 pieces 11 ft. 2 in. long. |
| | Outside | 47.12 ft. | —6 pieces 8 ft. long. |
| 15 feet | Inside | 47.12 ft. | —4 pieces 12 feet long. |
| | Outside | 50.27 ft. | —6 pieces 8 ft. long, 1 piece 3 ft long. |
| 16 feet | Inside | 50.27 ft. | —4 piece 12 ft. 9½ in. long. |
| | Outside | 53.4 ft. | —7 pieces 8 ft. long. |
| 18 feet | Inside | 56.55 ft. | —4 pieces 14 ft. 4 in. long. |
| | Outside | 59.69 ft. | —7 pieces 8 ft. long, 1 piece 5 ft. long. |
| 20 feet | Inside | 62.8 ft. | —4 pieces 15 ft. 11 in. long. |
| | Outside | 65.97 ft. | —8 pieces 8 ft. long, 1 piece 3½ ft. long. |

(For incidental material and scaffolding obtain building instructions.)

## REPORT ON CONSTRUCTION OF PIT SILOS AT THE PLAINS SUBSTATION.

*By J. W. Adams, Superintendent.*

During the summer of 1912 two pit silos were made at the Plains Substation, located at Cheyenne Wells. These silos are ten feet in diameter, one is twenty-three feet deep and the other is twenty-eight feet deep.

It was the purpose to make these silos as cheaply as was consistent with efficiency, durability and safety.

To insure durability and efficiency, a concrete ring was put at the top of the ground and great care was taken to keep the walls smooth and perpendicular. Care was also taken to do a good job of plastering and brush coating the walls. To make the pits safe, that is, to prevent the danger of stock or people falling into them, we built a wall of adobe ten inches thick and three feet high around each. These adobe walls are cemented and form a part of the silos. (For method of making adobe walls see Bulletin No. 174 of this station entitled, "Adobe as a Building Material for the Plains.")

These silos have proven so satisfactory in every way that two more were put in the past winter (1913-1914). These are twelve feet in diameter and twenty-six feet deep.

### *Method of Construction.*

In constructing these silos the first operation was to bore with a test auger a hole in the center of silo as deep as the silo was to be. A pipe was put in the hole and using it as a center, two circles were marked on the ground. The inner circle was the diameter of the silo plus one inch, one inch being allowed for plaster. The outer circle was 6 inches outside of this. Then with a tiling spade we dug out the space between these two circles to a depth of 1 foot, taking care to keep the inner side of the trench thus formed smooth and per-

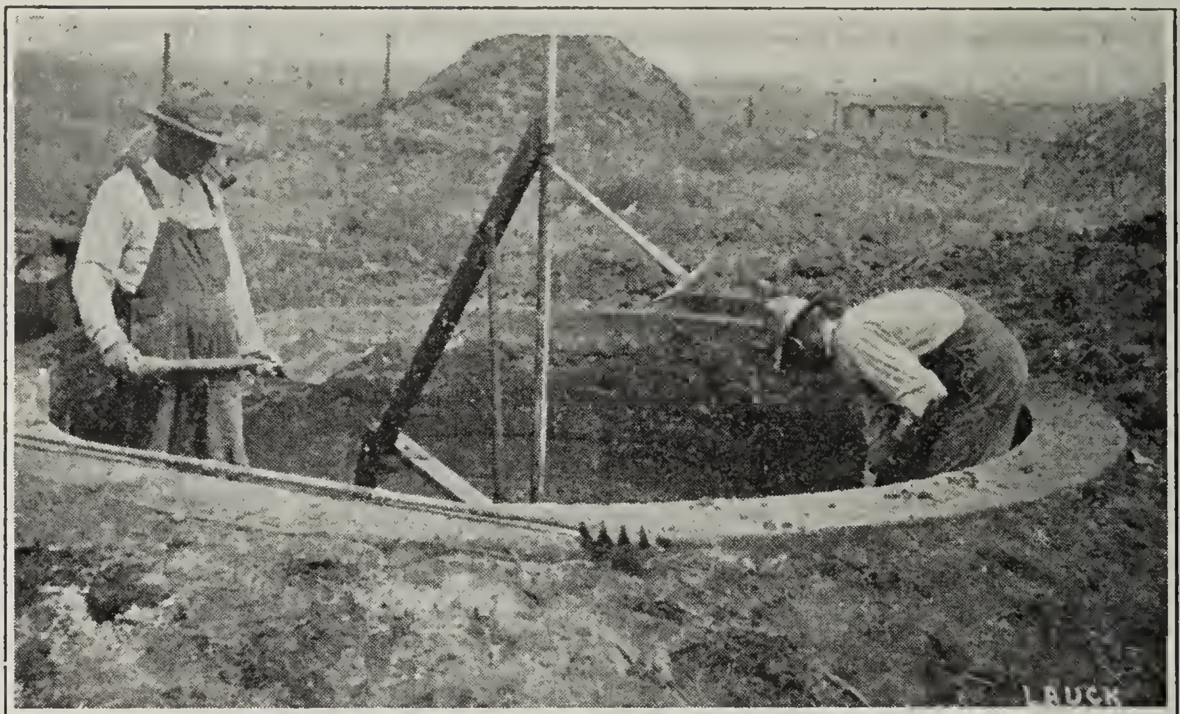


Fig. I. Digging a pit silo. Note the concrete ring at the top of silo. Also the trimmer tool in place on the pipe. The test auger for sinking a hole for the pipe is shown at the left. (Photo by Lauck.)

pendicular. This trench was then filled with concrete. We now built the adobe walls on this concrete ring, trimming the inside of adobe walls with the same tool we used for trimming walls of the pit. (See illustration of tool used for trimming walls, Cut 1.) The adobe walls should be 10 inches thick. The concrete ring being only 6 inches thick, the adobe will lap onto the ground on the outside. In digging, we left an inch or two on the outside to be cut down with the trimming tool. This tool was made by bolting an "L" shaped knife on the end of a 2x4, then measuring from the knife half the diameter of the silo, plus one-half inch, to allow for plaster, on the 2x4 and bored a hole to fit on the pipe in the center of the silo. Then, by bracing in the manner shown in Cut 1, the 2x4 is held in a horizontal position and by swinging it around the pipe the walls will be trimmed perfectly smooth and perpendicular. The edge of the knife should be set to draw into the wall slightly. If the ground is very dry and hard, some difficulty will be experienced in making the knife cut, but in ordinary soil the trimming is an easy job. If you should find the ground too hard to trim with the knife, then use it as a guide to trim with the pick. We were obliged to do this the last four feet of our last silos.

For hoisting the dirt, we erected a crane (See Cut 2) and placed it so the arm would swing over either of the two silos and then swing outside to deposit the dirt. We used a tub made from a half of a coal oil barrel in which to hoist the dirt. We had the blacksmith put a heavy band of iron under the tub extending up three-fifths of the way on each side. The ends of this band were formed into eyes for the bail. The bail was made from ¾-in. round iron and was made large enough so that the tub could turn bottom up inside of the bail. If the bail is properly attached, the tub can be emptied with little effort. We attached a hook to the back of a road scraper so we

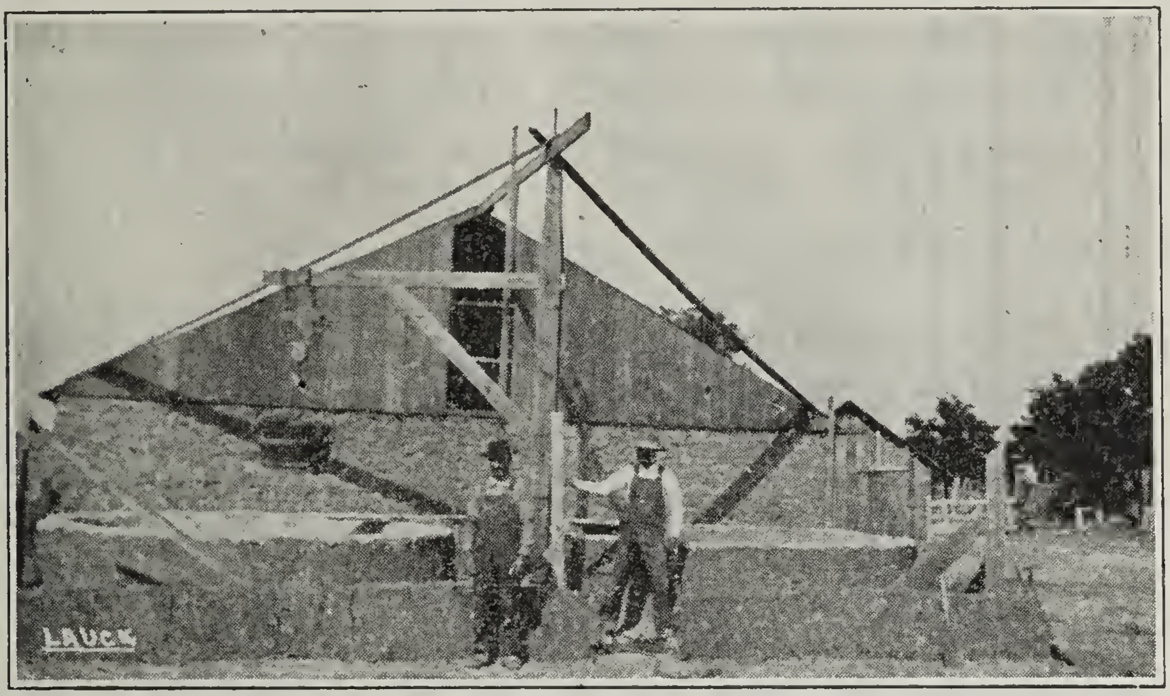



Fig. II. Two pit silos on the Plains Substation Farm at Cheyenne Wells, built by Superintendent J. W. Adams. Note the plaster on the adobe walls, the hoist for elevating dirt and silage, and the half-barrel bucket. This shows a desirable location of silos. (Photo by Lauck.)

could use the same team to haul away the dirt that we used to hoist dirt out of the silos. We would load the scraper, then attach the rope to the hook on the back of the scraper, then drive the team up until the tub was above the silo, then swing the tub out and dump it, swing it back over the silo, release the rope from the scraper and let it down by hand. The team will learn very quickly what is expected of them so they will not need a driver while hoisting the tub. The loaded scraper will relieve the team of the necessity of holding the tub while it is being emptied. In this way one man and team can keep two men busy digging even when the dirt spades easily. If the digging is hard, one man can haul the dirt considerable distances and still keep two men busy. We used the dirt to fill in the low places in our barn yard.

When we made our first silos we completed the digging before we plastered. This necessitated making staging. This we did by making a round platform and hanging it from the top. The last silos we plastered as we went down. We would dig six or seven feet and then plaster and then work in the other silo while the plaster was setting. We mixed the plaster one of cement to three of sand. We would plaster three or four yards and then go over it with the second coat. This is in effect two-coat work, but by putting both coats on at once it makes better work. When the plaster is hard enough so it will not be marred by the brush we gave it a brush coat of pure cement and water mixed about as thick as paint. This was applied with a whitewash brush. The brush coat should be applied before the plaster is too hard to absorb the water from the cement. The particles of cement are thus drawn into the pores of the plaster and makes a much stronger plaster, besides being much more impervious to water or air. The plaster should not be allowed to dry for several days. If it dries too soon it will not be so hard and is liable to crack.

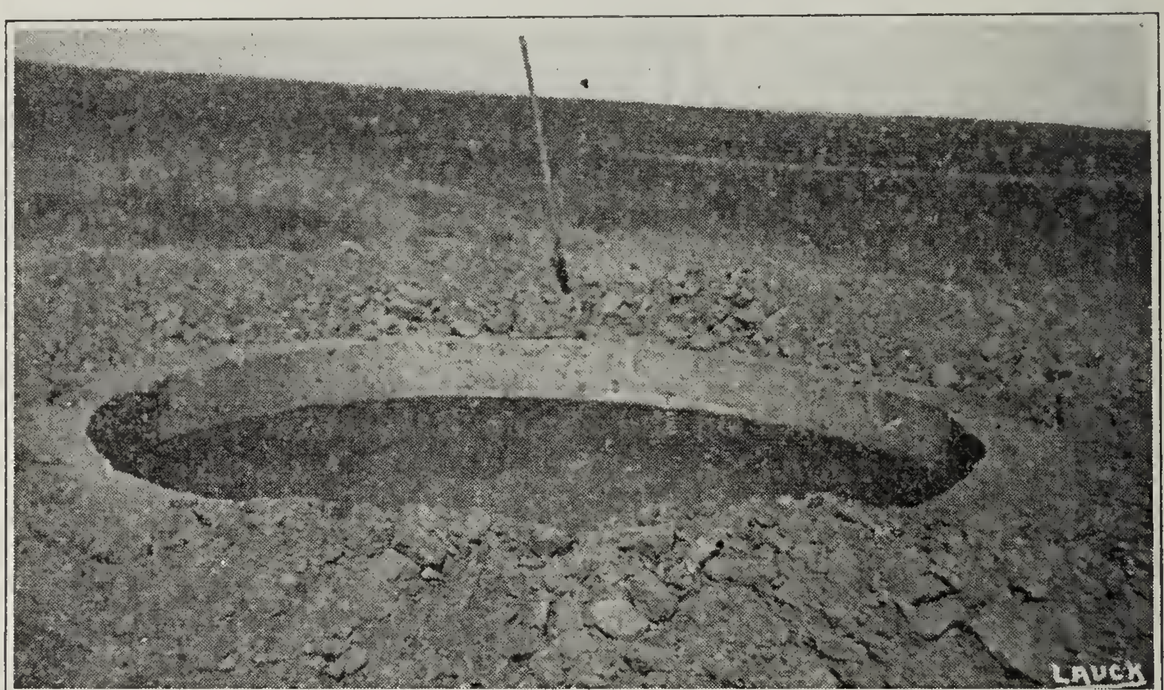



Fig. III. Pit silo in El Paso county, showing the concrete ring and a smooth wall ready for the plaster. (Photo by Lauck.)

The adobe portion should be thoroughly dried before the plaster is applied, otherwise it will crack. If the walls of the silos are dry it is best to sprinkle them before plastering. In cold weather the silos should be covered to prevent the fresh plaster from freezing. A few very cold nights we put an oil heater in our silos when plaster was green. We did not plaster bottoms of silos.

*Removing Ensilage.*—For removing the ensilage from silos we attached a windlass to the same crane we used for hoisting dirt. We have the crane so placed so that the arm will swing over any of the four silos. We made an ensilage cart with a sheet-iron box in which to hoist the ensilage. This cart will hold over five hundred pounds of ensilage or sufficient to feed twelve or fourteen cows a full day's feed. We lower this cart into the silos, fill it, and then draw it up by means of the windlass. On the cement feed-way, it is no trouble to push this cart in front of the cows. We enter the silos by means of an extension ladder. The cow barn has been extended over the silos so they are all under the same roof.

*Cost.*—Cost of material of two silos built in 1912 is as follows:

| | |
|---|---|
| 38 sacks cement | $19.00 |
| Crane and tub for hoisting dirt | 10.00 |
| Ensilage cart | 8.00 |
| Windlass attached to crane | 2.00 |
| Total cost of material | $39.00 |
| Labor at $2.25 per day for man labor and $3.00 per day for man and team | 137.20 |
| Total | $176.20 |

The combined capacity of these two silos is eighty tons.

The cost of the two silos completed in 1913-1914 is as follows:

| | |
|---|---|
| Cost of material | $ 51.10 |
| Cost of labor at $1.25 and $1.50 per day for man labor, and $2.00 per day for man and team | 125.96 |
| Total | $177.06 |

Total capacity of these two silos is 120 tons. These figures include foundation and adobe walls of extension of cow barn to cover silos, but does not include roof.

There has been a number of silos put down in this vicinity the past year that have cost much less than the ones here described. As we have said before, these silos were made as cheaply as we consider was consistent with efficiency, durability and safety. By omitting the concrete ring at the top of the ground and the adobe walls above the ground and by giving only a skim coat of plaster, the cost for material would be reduced, and by taking less care in digging to keep the walls true, the time required to make silos would be reduced, but we do not believe this would be economy.

*Efficiency.*—The first silos have been filled and emptied the second time. The ensilage has kept perfectly. The plaster has not cracked nor peeled off nor has it showed any indication that the acids of the ensilage has affected it in any way, so for keeping the ensilage it must be conceded that silos built in this way are as good as can be built. The first cost of silos of this type will not exceed but one-third that of high silos of similar dimensions. The cost of cutter is reduced one-third, as a blower is not required. The power required is reduced one-half, as it is estimated that it requires as much power to operate a blower as is required to cut feed. With the equipment we have, the additional labor required to feed twelve or fourteen head of cows does not exceed two minutes per day over that required to feed the same number of cows from a high silo.

Assuming a feeding season of two hundred twenty days, the additional labor would be but seven hours for the season, or for twenty-four cows it would be but fourteen hours. At twenty cents per hour for labor, the extra cost of feeding twenty-four cows would be but $2.80 for the season. This would go but a little way towards paying interest on the extra money invested in high silos and equipment for filling them.

Fig. IV. County Agriculturist W. H. Lauck of El Paso county, helping build pit silos on farms in that county. Digging the trench for the concrete ring. Note the method of describing the circles. (Photo by Frear.)

*Advantages.*—Pit silos have some advantages over high silos besides their cheapness. First, it is practical to make a silo of very small dimensions. The ensilage will keep without drying or freezing. This recommends the pit silos to those who wish to keep only five or six cows. Second, there is no trouble from feeding frozen ensilage even in the coldest weather. Third, after the ensilage has thoroughly cooled it is possible to feed off as little as one inch per day without danger of spoiling, even in warm weather. The pit is so cool that fermentation does not begin quickly. Fourth, the pit silo will recommend itself to those who are short on money and long on time. By three such persons working together they can make silos at very little cost.

*Gas.*—There has been a great deal said about the dangers of gas in pit silos. I am thoroughly convinced from my own experience and from the experience of others that there is no danger from gas except at filling time or while the ensilage is going through the heat. While the ensilage is going through the heat there is a large amount of carbonic acid gas formed which is forced out of the ensilage by the settling of the ensilage, and as it is heavier than air it accumulates on the surface until disturbed with something to cause it to mix with the air. When the silo is partly filled, no one should enter until the cutter has started. The falling ensilage will quickly drive out any gas that may have collected.

*Conclusion.*—Where the ground formation is suitable and there is no danger from seepage, the pit silo is perfectly practical and is within the reach of many who cannot afford a high silo.

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Bulletin 201 November, 1914

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

# Some Colorado Mushrooms

By B. O. LONGYEAR

The Common Mushroom---Edible

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station

FORT COLLINS, COLORADO

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# Some Colorado Mushrooms

*By B. O. LONGYEAR*

Mushrooms and toadstools. What contrasting emotions of pleasure and repugnance these two terms convey to most persons. One suggests a wholesome, appetizing and nutritious article of food, while the other conjures up an idea of some noxious, dangerous or poisonous growth. The popular idea, moreover, that the two may be readily mistaken one for the other deters a great many people from using any of these plants for food in this country; consequently a large part of the annual crop of native edible fungi goes to waste for lack of a familiar knowledge of the different species by the public.

## POPULAR IDEAS ABOUT MUSHROOMS.

Probably no other class of plants is so little understood by the public as the fungi and especially those fleshy forms commonly called mushrooms and toadstools. Perhaps the most common idea is that there are just two kinds of fleshy fungi. Mushrooms, edible, and toadstools, poisonous; hence the usual query is, "How do you tell a mushroom from a toadstool?" This question suggests the popular notion that there is some test or arbitrary rule which if applied at random to such fungi as one may come across will enable the finder to distinguish which are edible and which are poisonous. There also prevails quite generally an idea that there is no certainty in the recognition of the edible kinds without the use of some such rule and therefore the matter of eating fleshy fungi is extremely hazardous except by those who hold the secret formula.

The botanist does not classify the fleshy fungi in this way, but calls them either mushrooms or toadstools and recognizes the poisonous species among them by their botanical characters.

No dependence should be placed upon such tests as the blackening of a silver spoon in cooking, the salt test, the avoidance of bright colors, whether the caps will peel or not, and such general rules as are sometimes recommended. Another popular notion about certain of these plants is that toads have something to do with their origin and growth. This is purely a superstition and has no foundation in fact, as determined by a scientific study of these plants.

## THE TRUE TEST OF EDIBILITY.

The scientific way of testing the fungi one finds is to learn to know the species according to their botanical characters so that the same plant can be recognized wherever it is met with. By acquiring this knowledge it is then possible to learn the qualities of the fungus by reference to books or bulletins on the subject or by submitting the matter to a botanist or other person who has this information. Any person with average powers of discernment may soon come to know several species of edible fungi at sight just as the different vegetables in the garden are recognized. This means that the botanical characters of these plants should be studied and that they be known by these characters rather than by some general and uncertain test or rule.

## FEW POISONOUS SPECIES.

When compared with the large number of edible or harmless species of fleshy fungi which occur in our state, the number of poisonous or dangerous species is very small. Almost all of the latter, moreover, grow only in timbered places or in recently cleared woodlands so that there is almost no danger in using the species found outside of such areas.

It is advisable, however, for persons who desire to gather the fleshy fungi extensively for food to learn to know the poisonous or harmful species as well as the edible ones.

The only general test which has been advocated for persons who care only to know if a certain fungus is edible or not is the physiological test. This consists of tasting a very small fragment of the fungus without swallowing any of the juice. If no unpleasant symptoms arise within the next twenty-four hours, a slightly larger piece may be chewed and a part of the juice swallowed. After another twenty-four hours a still larger piece may be eaten, providing no poisoning symptoms appear. If a piece the size of a small pea is thus used, no serious results will occur even when a poisonous species is being tested, although symptoms of poisoning would be sure to arise if that were the case. While this method is perfectly safe when followed by a careful person whose imagination is under good control, it is recommended principally for the person who possesses the courage to try any plant's properties upon himself.

## THE NATURE AND GROWTH OF FUNGI.

Mushrooms and toadstools belong to that great class of lowly plants known as Fungi. While they differ widely in size, structure, and habits of growth, all species of fungi have certain characters in common. They are without flowers and are entirely destitute in all stages of growth of the green coloring matter, chlorophyll, found especially in those plants which bear true foliage. On account of the absence of this chlorophyll, the fungi are dependent plants and must gain their livelihood either at the expense of other living plants or must feed upon the dead remains of such plants.

In the first case they are parasites, such as the smuts, rusts, mildews and other disease-producing organisms of the higher plants. The mushroom fungi belong mainly to the second division, those which live upon dead and decaying organic matter, such as

No. 1. A mass of decaying leaves covered with delicate filaments of some fungus which is causing their decay.

leaves, wood, straw, and manure, or similar substances. In fact, the decay of such material is largely due to the presence of these fungi in their vegetative stage of growth.

During this early vegetative period of a fungus, it consists of delicate, cobweb-like filaments or threads which are almost too slender to be seen with the unaided eye unless they are very numerous and massed together, when they give a moldy appearance to the material upon which they are growing. Under the high powers of the microscope these delicate filaments are seen to be thin-walled tubes which branch and unite to form an intricate network somewhat like the root system of a flowering plant. This network of minute tubular threads, known as mycelium, grows rapidly under proper conditions of moisture and heat and dissolves and absorbs the nutritive substances in the material upon which it grows. If this happens to be a mass of fallen leaves, a pile of manure or a piece of wood, these materials soon show the signs of decay. Most fungi require an abundance of moisture to enable them to grow. For this reason, the mushroom crop is especially abundant during or following a period of wet weather and it is a matter of common knowledge that vegetable matter will not decay as long as it is kept dry.

After a fungus has grown in its vegetative stage until it has accumulated a supply of reserve food material and has formed a well developed mycelial system, it may begin to produce its fruiting stage in the form of the mature mushroom or toadstool. A great

No. 2. Root-like strands of mycelium of the common cultivated mushroom giving rise to the button stage of the fungus. This shows how the little mushrooms are formed in the mushroom bed.

many of the little threads of mycelium may unite to form root-like strands which in turn give rise to small globular bodies, the future mushrooms. This process usually takes place a little below the surface of the soil, the mass of leaves or other decaying vegetation, or upon the surface if it is a decaying log or stump. These little bodies rapidly increase in size until they are prepared to expand into the mature mushroom. In some species of fleshy fungi this last stage of growth is very rapid so that these plants appear to spring up in a night, while in others it requires several days for the complete unfolding of the fruiting part.

## SPORES.

During this period of expanding to full size, the mushroom is also maturing an abundance of spores. Spores are the minute bodies by means of which the fungus is able to start a new generation elsewhere or to reproduce itself. They are so small that in some fungi a compact mass of spores as large as the head of a parlor match could contain as many as ten millions of these microscopic bodies, enough to cover an acre and a half at the rate of one spore to each square inch of surface. Their minute size enables

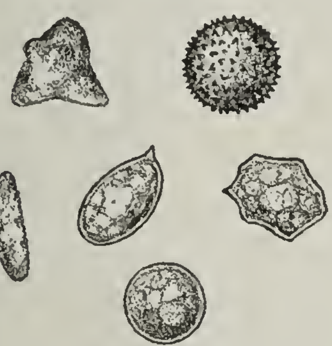


Fig. 3.

Fig. 4.

No. 3. Fungous spores showing a variety of shapes as found in different kinds of fungi. Highly magnified.

No. 4. Spores of the common mushroom germinating. Each one is sending out a thin-walled tube which is the beginning of the network of mycelium of the fungus. Highly magnified.

them to float readily in the air like the finest particles of dust and it is only when large numbers of them are thrown into the air at one time, as from a mature puff ball, that we are able to see them as a miniature cloud of smoke. The enormous number of spores which even one mushroom may shed readily accounts for the ease with which these plants find every suitable place in which to grow.

When the spores of fungi fall into a suitable condition of moisture and heat and with the proper food supply at hand, they may germinate by sending out a slender germ tube. This germ tube begins at once to gather nourishment from the material suited to its growth and in this way a new colony of the fungus is soon established. Frequently a period of drought may set in after the mycelium has reached a considerable growth. In such a case it may dry up for a time to be started into activity again when the moisture supply is renewed. This is the condition in which mushroom spawn is sold for the starting of mushroom beds, the so-called bricks or flakes being compact masses of half decomposed manure filled with the mycelium of the cultivated variety of the common meadow mushroom.

## STRUCTURE AND CLASSIFICATION OF FUNGI.

In their structure the tissues of a fungus are much simpler than those of other plants. If a small fragment of the flesh of a

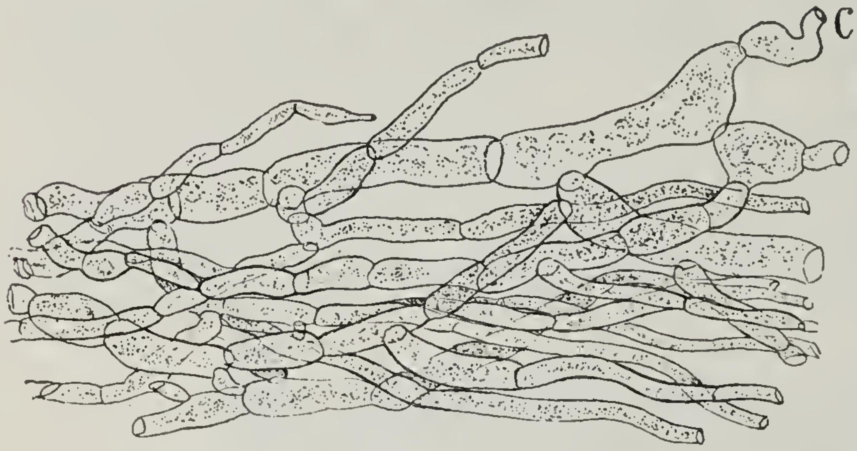


Fig. 5.

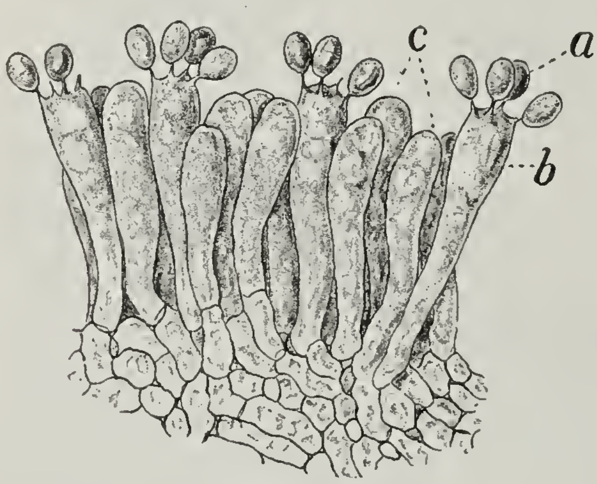



Fig. 6.


Fig. 7.

No. 5. Small portion of the tissue of a mushroom showing the tubular filaments which go to make up the flesh of the softer part of the fungus. Highly magnified.

No. 6. Small portion of the spore-bearing layer of one of the fungi belonging to the class Basidiomycetes. The spores (a) are produced on the ends of little stalk-like projections of the basidia; (b), (c), sterile cells intermingled with the basidia. Highly magnified.

No. 7. Small portion of the spore-bearing layer of a Morel. The spores (a) are produced inside of long thin-walled cells or sacs called Asci; ;(b), (c), sterile cells intermingled with the spore-bearing cells. The spores are discharged by the breaking open of the ends of the asci, as at (c). Highly magnified.

mushroom is examined under the higher power of a compound microscope it will appear to be made up of interwoven thin-walled, freely branched tubes which are divided at frequent intervals by thin cross-walls into more or less elongated cells. Thus the body of the fungus is found to be made up of the same filaments which form its mycelium; in fact, it is a continuation of the mycelial threads thickly interlaced and partly grown together. In the denser parts of some hard and woody fungi the cells of the tubular filaments are thick-walled, short and entirely grown together, while in the soft kinds the mycelial tubes are loosely interwoven, thin-walled, and have fewer partitions.

The cells thus formed contain varying amounts of water and protoplasm, the living substance of the plant. This protoplasm is usually nearly colorless and appears minutely granular, with larger particles of food material floating in contact with it.

All the larger, fleshy fungi are divided into two classes, depending upon the manner in which they bear their spores: (1) The Basidiomycetes; (2) the Ascomycetes. In the first class, the spores are produced upon the ends of certain elongated cells called basidia, while in the second class the spores are formed within similar cells.

In most fungi of the mushroom type only a certain limited part of the fungus produces these spore-bearing cells which are thickly crowded together to form a continuous layer known as the *hymenium*. The form of the fungus and the shape of the parts upon which the hymenium or spore-bearing layer of cells is spread are some of the principal characters by which a fungus is recognized by the botanist. Fortunately it is not necessary for a person to determine these matters by the use of a microscope in learning the names of the more common edible species of fleshy fungi, but it is necessary that one be able to recognize the location of the hymenium and that the shape of the parts which bear it be noted in order that accurate work in identification be done.

## SPRING MUSHROOMS.

While some species of mushrooms occur during only a limited part of the growing season, there are others which may be expected to appear almost any time during the warmer part of the year, especially soon after a period of rainy weather.

Among the earliest mushrooms to be looked for in spring are the Morels. They appear principally during the month of May and then disappear during the remainder of the season. Apparently these fungi complete their growth of mycelium during summer and autumn and are then ready to produce the fruiting part early in the following spring. They belong to the class *Ascomycetes* in which the spores are produced within the fertile cells of the hymenium or spore-bearing layer.

Upon examining a mature specimen two parts are noticed:

No. 8.. Specimens of the common Morel (Morchella esculenta).

(1) A hollow stem; (2) a head or cap borne at the top of the stem and known botanically as the pileus. While at least five species of

Morels occur in this country, only one has been found in Colorado by the author.

The hymenium in the Morels covers the sides of wrinkles or variously branched ridges upon the surface of the pileus or cap and the spores are discharged into the air by the breaking open at the tips of the cells which contain them.

*The Common Morel (Morchella Esculenta).*

This is the most familiar mushroom to many persons who often call it the "sponge mushroom" from the resemblance of its pileus or cap to a small sponge. It grows in small groups or scat-

No. 9. The Stinkhorn fungus. A cluster of three eggs and two mature specimens. This is the only fungus liable to be mistaken for the Morel. It is readily distinguished, however, by its powerful carrion-like odor when mature.

tered individuals especially on the grassy land and among the cottonwoods, which border our streams and the lover of mushrooms soon learns to look for them each spring in the same haunts. It loves the leaf mold which gathers among broad leaf trees in particular and has been found at times in favored places upon undisturbed soil near the shade trees of a vacant city lot.

The color of the stem is nearly white, while the cap is grayish or leaden when young but acquires a buff tint as it matures. The usual size of the plant is from two to four inches in height, although larger specimens are sometimes found.

The only fungus at all likely to be mistaken for the Morel is the Stinkhorn fungus which not infrequently appears along sidewalks and ditch banks, bordered with cottonwood trees and even in gardens and lawns or wherever there is decaying wood in the soil. The latter fungus, however, while not dangerous, is readily recognized by the taller stem which bears a small bell-shaped pitted cap coated at first with a dark grayish green slime possessing a strong carrion-like odor. This ill-smelling fungus is at first entirely covered by a tough membrane, in which condition it somewhat resembles a small, soft-shelled egg. When about to push above ground the fungus bursts through this covering which is left in the ground at the base of the stem. Sometimes a whole nest of these fungous eggs may be unearthed if the soil is dug up where they occur and in this condition they are considered by some persons to be edible.

### *The Puffballs.*

Puffballs are among the most interesting members of the fleshy fungi. They occur almost everywhere, on open grassy

No. 10. A purple-spored puffball commonly found growing in meadows and pasture land.

ground, sometimes in dooryards and frequently in woodlands. Some grow only from the earth, while others may be found attached to much decayed wood.

When young and fresh they are nearly always white in color throughout, the interior being firm and in appearance much like cottage cheese. In this condition they are prime for eating and should never be destroyed. As they mature, however, the interior portions acquire a yellowish, brownish or purplish color and a soft and watery consistency, which unfits them for food. In a few days' time the moisture dries out leaving the tougher outer part filled with a cottony mass of fibers mixed with dark colored, dusty spores. In this condition they are fit objects for the small boy with a stick who delights in making them puff out smoke-like clouds of spore dust.

The spores of puffballs are produced in clusters at the ends of the fertile cells of the hymenium or spore-bearing layer which lines the walls of small, irregular cavities within the fungus. As the puff ball matures, these walls partially melt and cause the watery condition of the interior, while the spores are left mixed with thread-like cells of the walls. The fact that the puffballs are so easily recognized in every stage of their growth and that none of them are poisonous or harmful, so long as they are firm and white inside, makes them especially desirable and safe for the novice to collect for food.

*The Cup-Shaped or Purple Puffball.*
(*Calvatia lilacina variety occidentalis.*)

This is perhaps the commonest of our larger puffballs and is at the same time one of the best for the table. It may be looked for in meadows and in grassland that is used for pasturage. When full grown it is about once or twice the size of one's fist and has the form of a flattened sphere with a narrowed base.

At first the outer covering (*peridium*) is white and nearly smooth, but as the fungus matures it becomes slightly cracked into very irregular areas and acquires a purplish color. As the inside moisture evaporates the peridium gradually flakes away, exposing the purple spore-mass within. In time the wind scoops out the spores, together with the cottony threads and scatters them far and wide, leaving the hollowed-out base of the fungus attached to the ground.

*The Giant Puffball* (*Calvatia gigantea*).

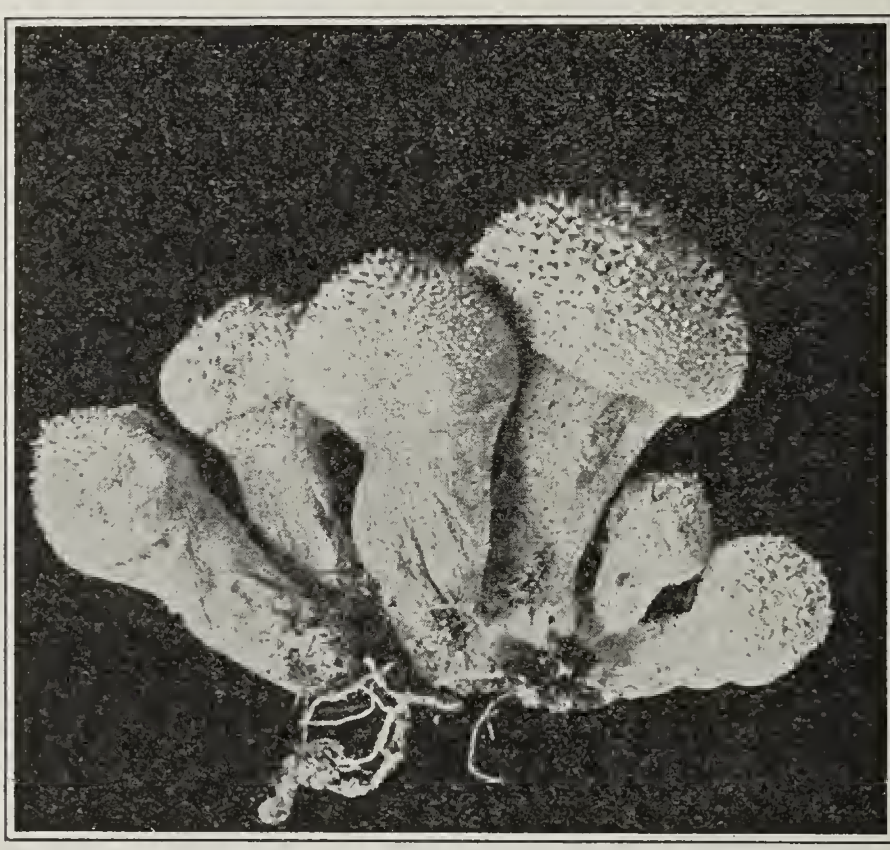
This fungus is not only the Goliath of its tribe, but when well developed has no rival in size among the fleshy fungi. It frequently attains the size of a football while specimens nearly sixty inches in circumference and weighing fifteen pounds have been seen by the writer. While this fungus occurs not infrequently in the humid sections of the United States, it has been rarely found in Colorado. It should be sought for in grasslands, especially of our mountain parks. A single well developed specimen is capable of furnishing a fungus omelette for a whole neighborhood.

The surface of this puffball, when young, resembles white kid leather, while its resemblance to a large rounded mass of freshly raised bread dough is quite striking. A specimen much too large to be used by a family at one meal has sometimes been utilized during several days, or so long as no discoloration appeared, by slicing it off as desired for cooking.

The spore mass of the giant puffball is olive brown in color and is discharged as in the preceding species.

*The Gemmed Puffball (Lycoperdon gemmatum).*

The name of this little puffball was suggested by the fact that its surface is thickly studded with little pointed warts which fall away at maturity and leave the surface of the peridium marked with slight indentations. While the size is small, one or two inches



No. 11. A cluster of the gemmed puffball. This little puffball often occurs in large numbers on mossy ground in woodlands.

high, it makes up for this to some extent by its numbers. It grows usually in clusters of three or four to several dozen in number, and occurs in woodlands usually about decayed wood lying on the ground.

The shape of this puffball is more elongated than that of the preceding species and instead of breaking irregularly, to discharge the spores, it opens by a small rounded mouth at the extreme top of the plant. A mature dry specimen when suddenly pressed between the fingers, will give off repeated puffs of smoke-like spore dust and thus illustrates unusually well the origin of the common name of "puffball" applied to the plants of this character.

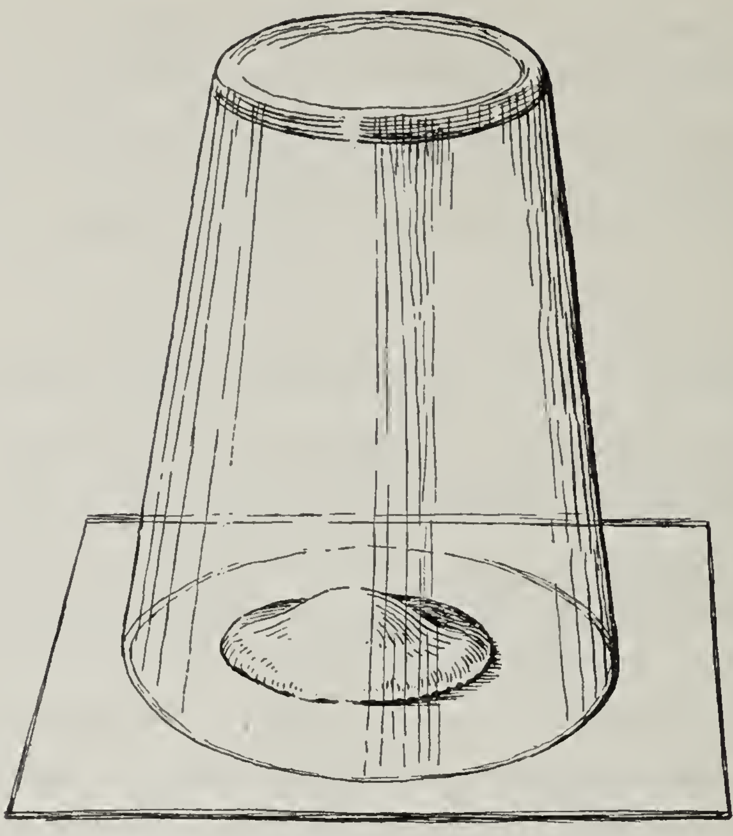
## GILL-BEARING MUSHROOMS (*Agaracineae Agarics*).

The fungi composing this family are characterized by having the spore-bearing layer spread on the surface of thin, radiating plates or gills attached to the lower surface of a more or less expanded or flattened part, the cap or pileus. In the simpler members of this family, the pileus is shaped much like one of the valves of a clam shell attached by one edge to whatever the fungus is growing upon. In the more highly developed members the pileus is bell-shaped or inverted saucer-shaped and is raised upon a central stalk with the gills radiating from its upper end toward the margin of the pileus. When very young or in the button stage the pileus is mostly rounded in shape and the stem is very short, in which condition the whole plant is often egg-shaped. As the fungus is about ready to mature its spores, the stem rapidly lengthens lifting the pileus into the air, where it soon opens out and allows the spores to drop from the gills attached to its lower surface.

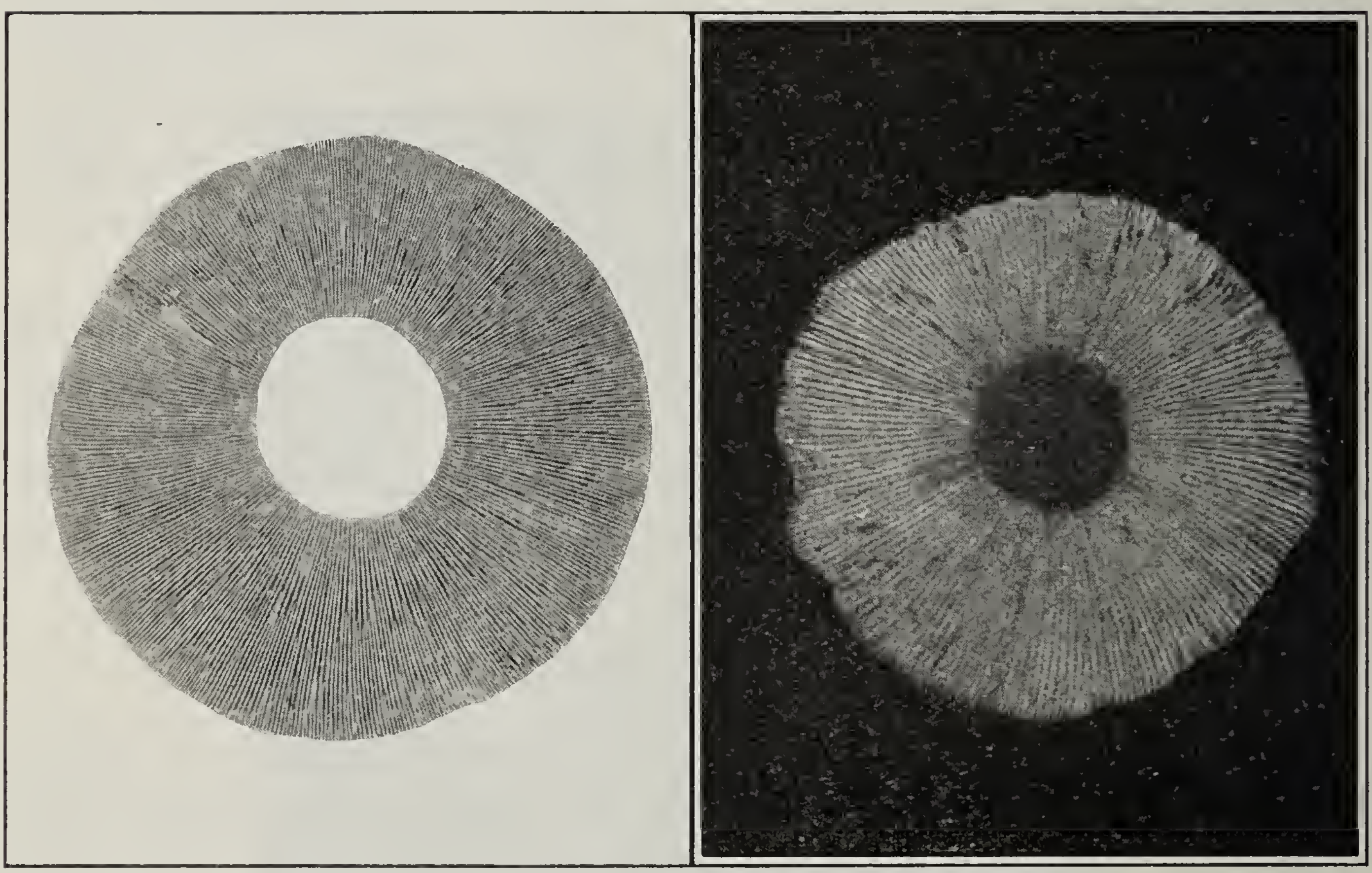
The spores of the gill fungi are borne upon the ends of cells called basidia the same as in the puffballs. Instead of being enclosed by the outer walls of the fungus, however, they are exposed to the air as soon as the cap or pileus expands and are thus readily cast off and wafted away by the gentlest breeze.

## SPORE PRINTS.

In order to identify with certainty the members of the gill fungi or agarics, it is necessary to know the color of the spores. While this can often be told by a careful examination of the gills which are usually powdered with the dustlike spores, it is determined most surely by making a spore print. If the cap is carefully removed from the stem and placed gills down upon a piece of white paper and covered with a tumbler or bell jar, the spores will settle upon the paper and form a spore print (Figs. 12-13). This process may require from one-half to three or four hours, depending somewhat upon the freshness of the specimen. If the spores are white, they can hardly be seen except by looking across the paper. If black paper is used for those species which have white gills, the



No. 12. Making a spore print.



No. 13. Spore prints of common mushroom and smooth Lepiota.

spores will show very distinctly and if the paper is first coated with a very thin layer of mucilage the spores will be held in place and the spore prints are thus made permanent.

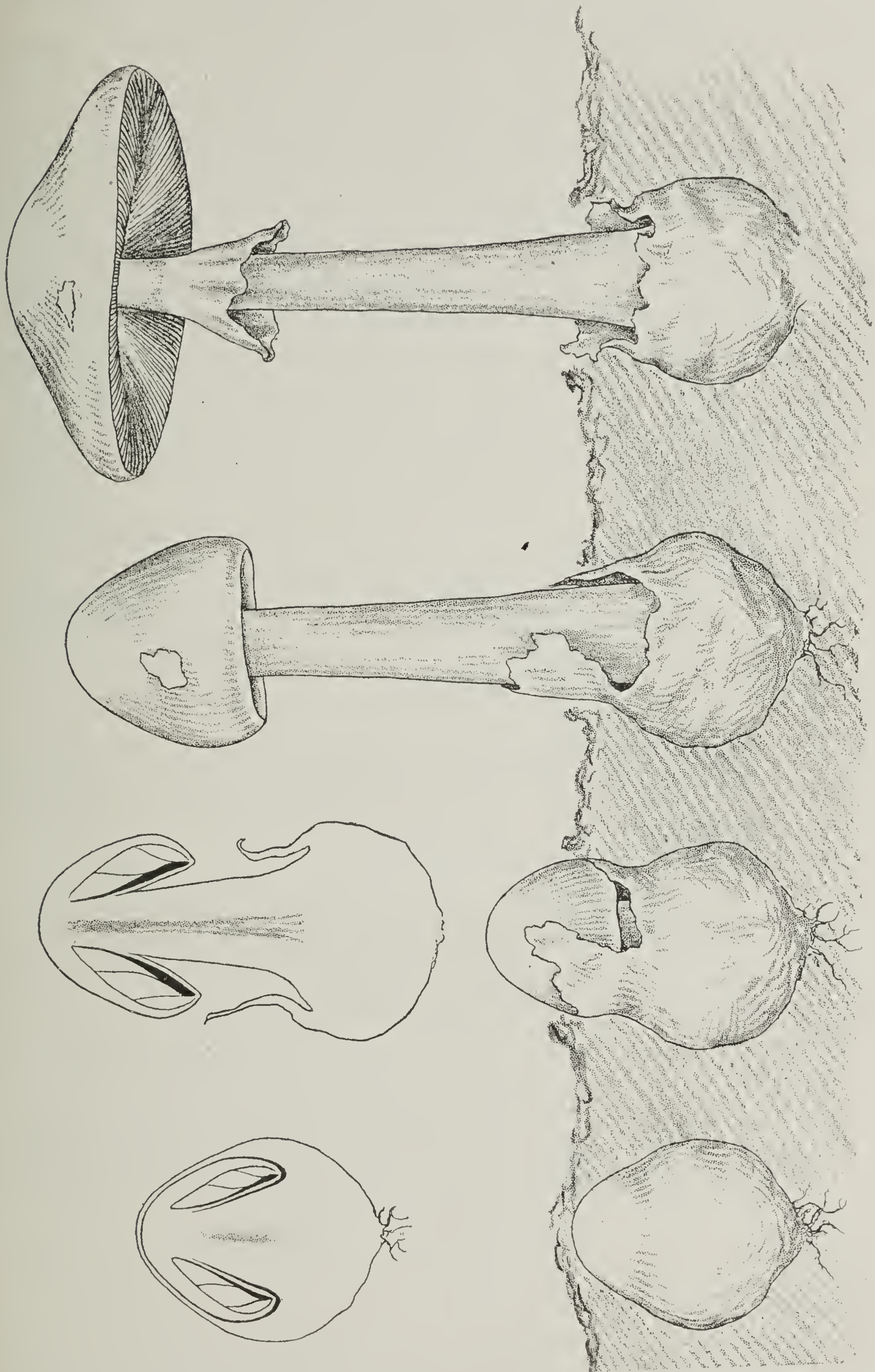
## THE AMANITAS.

The Agaricus family is the only one which contains the deadly poisonous species of fleshy fungi, the Amanitas. The Amanitas are umbrella-shaped mushrooms which in the early or button

Fig. 23

Fig. 24

stage are in the form of egg-shaped bodies which begin just below the surface of the soil or decayed leaves where the fungus grows,



No. 14. The Deadly Amanita. From a drawing showing the fungus in several stages of development from the egg to the mature plant (Amanita phalloides).

Each egg consists of one fungus enclosed by a membrane or coating which splits open as the mushroom is ready to appear above the ground. The remains of this covering, known as the volva, forms a sheath or coating of loose scales around the base of the stem after the fungus is full grown, but as it is usually hidden under the surface of the soil, the base of the stem should be carefully dug up in order to show this character. In some of the Amanitas, moreover, small portions of the upper part of the volva remain as loose patches or warts upon the top of the cap and thus help in the identifying of the specimen.

Just as the fungus emerges from the volva, by the rapid lengthening of the stem, a second or inner membrane may be seen which joins the margin of the cap or pileus to the upper part of the stem and covers the gills from view. By the spreading of the pileus, this membrane is torn loose from its margin and clings as a loose ring upon the upper part of the stem, where it may be found in most species as long as the fungus lasts.

The following descriptions refer principally to the mature plant.

*The Deadly Amanita (Amanita phalloides)—Poisonous.*

*Cap*—Two to three inches broad; varying in color from nearly pure white to smoky brown in different varieties; smooth, often with one or more small patches of the whitish volva sticking to it.

*Gills*—Wide, numerous, white.

*Spores*—White.

*Stem*—Three to five inches high, enlarged at base, white or tinged with the color of the cap, pithy or hollow.

*Ring*—Curtain-like, near upper end of stem.

*Volva*—Cup-like or sheath-like, white or yellowish white.

Occurs in woodlands or recently cleared ground where leaf mold abounds. While this fungus has not been seen in this state by the author, it should be looked for and carefully avoided, as it is one of the most poisonous plants known, when eaten.

*The Fly Amanita (Amanita muscaria)—Poisonous.*

(See colored plate.)

*Cap*—Two to four inches broad, bright orange or light scarlet, thickly sprinkled with small, yellow-white warts or fragments of the volva which stick closely to the smooth surface.

*Gills*—Usually white or sometimes faintly tinged with yellow, broad, numerous.

*Spores*—White.

*Stem*—Three to six inches long, enlarged and coated with scaly fragments of the volva at the base, pithy, becoming hollow white or tinged with pale yellow.

*Ring*—Soft and clinging, often breaking and disappearing in old plants, yellowish white.

*Volva*—Soft, breaking up into scales or fragments which cling loosely to the enlarged base of the stem and sometimes disappear in old plants.

Occurs almost entirely among trees in moist places in gulches and mountain parks or in forests of Lodgepole pine. It is not uncommon, but is so striking in appearance with its brilliantly colored cap adorned with whitish warts that it can scarcely be mistaken for any other fungus. While perhaps not quite so deadly as the first species, it is very dangerous when eaten and has taken its toll of lives in almost every country of the world. The common name, "Fly Amanita," which has been applied to this plant, is due to its poisonous effect upon flies. The writer has seen specimens of this mushroom, left to dry in the open air, which were surrounded by a circle of dead flies that had fed upon this natural fly poison.

Undoubtedly, other species of Amanitas occur occasionally in our state, but any person who becomes familiar with the two described should have little or no difficulty in recognizing them as belonging to this genus. Any umbrella-shaped fungus which has *white* spores, a *ring on the stem* and a *volva at the base of the stem* is an *Amanita* and should not be eaten. These characters, together with the fact that these fungi are confined to woodlands or the near proximity of trees or recently cleared forest should make it readily possible to entirely avoid them.

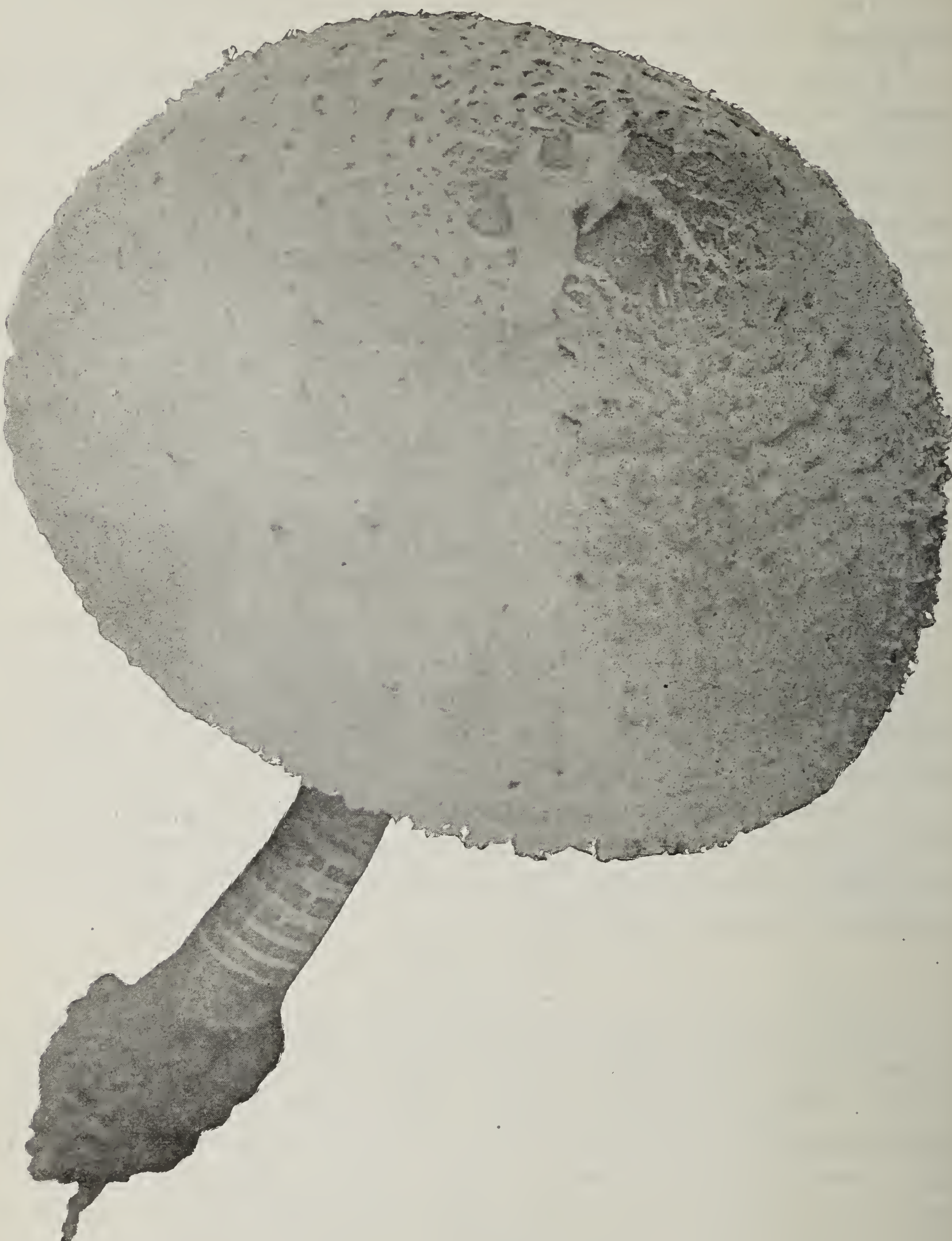
### *The Lepiotas.*

The Lepiotas closely resemble the Amanitas in certain respects, as they have white spores and a ring on the stem, while the cap is in most species scaly at maturity. The volva, however, is entirely lacking and this furnishes the most important distinguishing character between the two genera. The scales on the cap of a Lepiota, moreover, are part of the cap itself, the outer layer of which becomes broken up as the cap enlarges. The ring, also, is better developed than in the Amanitas and in some species becomes free from the stem and capable of being moved up and down.

### *Morgan's Lepiota (Lepiota Morgani)—Dangerous.*

*Cap*—Four to eight inches broad, sometimes larger; rounded and later flattened; whitish with numerous brownish or yellowish scales, thicker at the center.

*Gills*—Crowded, not quite reaching the stem, whitish at first then becoming greenish in color.



No. 15. Morgan's Lepiota (Lepiota Morgani) showing upper surface of a large specimen.

*Spores*—Dirty yellowish green.

*Stem*—Tapering upward from a somewhat swollen base, tinged with brownish, smooth or sometimes the surface becomes slightly cracked as in the specimen figured.

*Ring*—Thick and large, movable on the stem. Occurs mostly in open ground, in meadows or pastures, usually several or many individuals growing near together, sometimes forming a large ring or circle.

This fungus, while attractive in its large size and pleasing appearance, has the reputation for making at least half of the number of persons who eat it very sick for a time and should be avoided as dangerous. It is so unlike any other known mushroom which occurs in open ground in the color of its spores that it can be very easily shunned by taking care to determine this matter.

### *Smooth Lepiota (Lepiota naucina)—Edible.*

*Cap*—Two to five inches broad, rounded, usually smooth and white, sometimes brownish and scaly, as in one of the specimens figured; flesh thick, white, or pinkish when old.

*Gills*—Numerous and crowded, white, later pinkish or brownish.

*Spores*—White, or pale pinkish in mass.

*Stem*—Two to four inches tall, tapering upward from the somewhat swollen base; white or colored like the cap; may be readily separated from the cap by bending it to one side.

*Ring*—Narrow, sometimes free on the stem.

Occurs occasionally in groups in rich lawns and in the vicinity of trees or hedgerows where leaf mold has accumulated.

This is one of the most desirable of the umbrella-shaped fungi and is equal in every way to the cultivated common mushroom. It

No. 16. The smooth Lepiota (Lepiota naucina). Edible.

appears usually during the latter part of summer and early autumn and should be known to every lover of mushrooms.

*Oyster Mushroom (Pleurotus sapidus)—Edible.*

*Cap*—Two to six inches broad, shell-shaped, often quite irregular, smooth, smoky or wood brown in color. When young moist and rather tough.

*Gills*—Not crowded, extending down onto the short stem, white.

*Spores*—White on black background, pale grayish or lavender on white background.

*Stem*—Very short or sometimes wanting, attached to one edge of the cap.

Grows in crowded masses or clusters, often of many individuals upon decaying stumps or logs of cottonwood, poplar and similar wood. This fungus can often be found year after year in the

No. 17. The oyster mushroom (Pleurotus sapidus). Edible. A large cluster growing upon the trunk of a dead cottonwood.

same places and occurs almost throughout the season when the moisture conditions are favorable. The caps should be used while comparatively young as they become tough with age and are also apt to be infested by insect larvae if left for some time.

No. 18. The oyster mushroom (Pleurotus sapidus). A small cluster from a cottonwood stump.

*Elm Tree Pleurotus (Pleurotus ulmarius)—Edible.*

This species closely resembles the preceding one except that it usually has a longer stem which is more nearly central in attachment to the cap and the color of the fungus is white or yellowish. It grows mostly upon dead elm wood and is usually solitary. Like the other species of pleurotus the flesh is rather tough.

*Small Hypholoma (Hypholoma incertum)—Edible..*

*Cap*—One to two and à half inches broad, broadly conical or bell-shaped, with thin wavy margin to which fragments of white

No. 20. The small Hypoloma (Hypholoma incertum), growing in profusion in a lawn around an old cottonwood stump. Edible.

No. 21. A cluster of the small Hypholoma. Natural size.

membrane are attached; dull yellowish or brownish white, showing purplish tinge near the margin; flesh very thin and tender.

*Gills*—Narrow, crowded, joined to the stem; nearly white at first, becoming purplish brown.

*Spores*—Purplish brown.

*Stem*—One to three inches tall, slender, hollow, white.

Occurs in lawns and moist grassy places. While the individual specimens are small and the flesh thin; this is usually compensated for by the large numbers which often grow together as shown in the photograph.

*The Coprini or Inky Caps* (*Coprinus*).

These plants form a very characteristic group of the gill fungi. They are often very abundant during or following rainy weather and are familiar objects to everyone. Evanescence is one of their chief characteristics. Some of them literally spring up in a night, spread their fragile caps for a brief period, and vanish at the sun's touch. Others are more enduring, remaining for a day or two, but seldom longer, soon drooping into a slimy mass of inky dejection very aptly suggestive of the common name "inky caps."

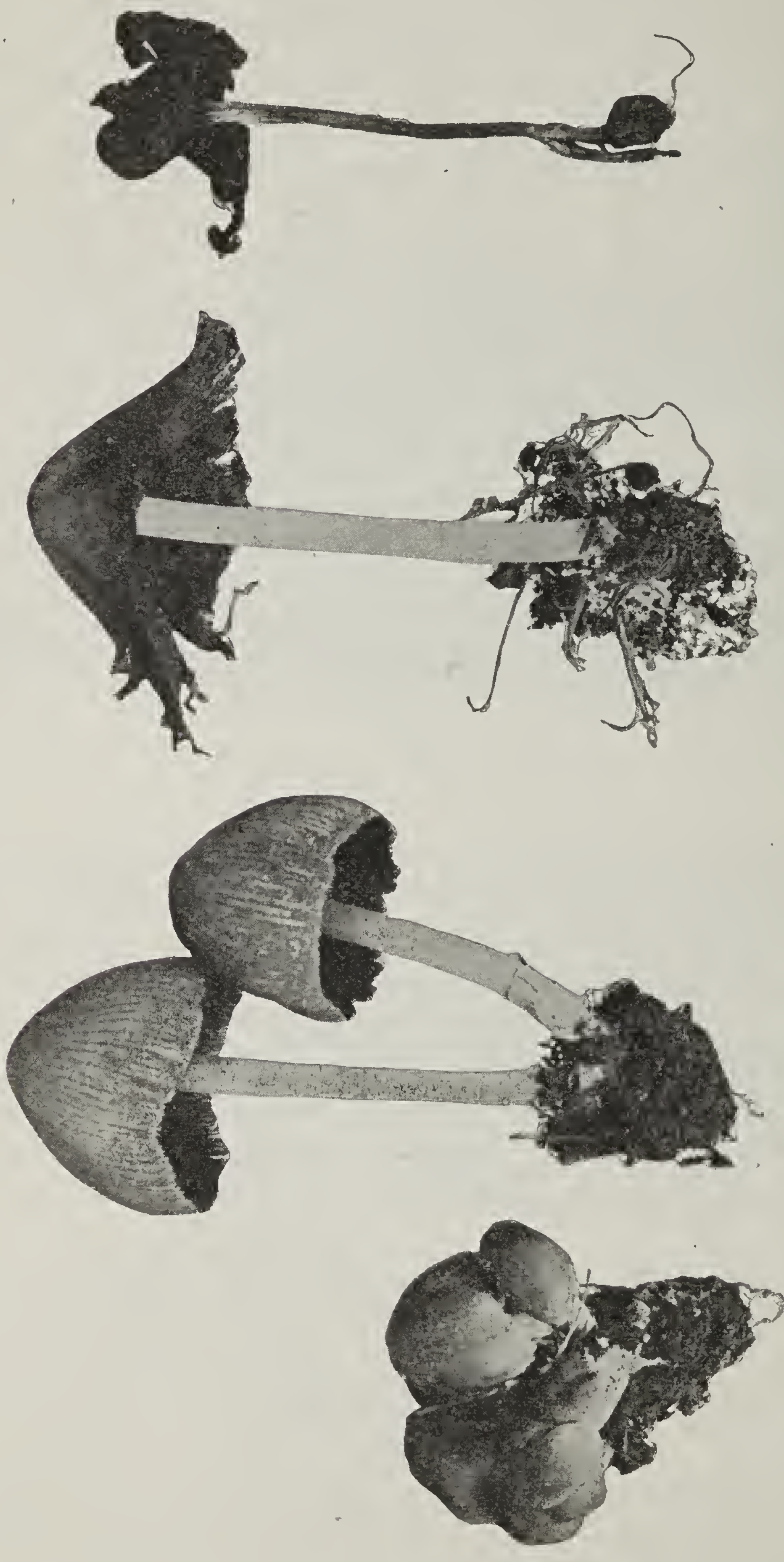
In this condition of sodden collapse they are not calculated to prove very inviting to the mushroom collector, but if gathered before the caps expand and while the gills are still light colored, they are excellent eating. Furthermore, none of the species are known to be poisonous and are easily distinguished from any of the poisonous fungi.

The caps of these fungi when young are folded close to the stems with the thin, delicate gills packed closely together. The gills are white or light colored, at first, but soon become darker, passing through various shades of pink, purple, and brown, to black, finally melting into an inky liquid. The color of this liquid is due entirely to the black spores which it contains and which are largely set free in this way.

The three species described are the most abundant and desirable kinds for food.

*The Glistening Coprinus* (*Coprinus micaceus*).

This mushroom often grows in dense clusters of many individuals at the base of decaying trees or stumps, near an old door step, or at the edge of a sidewalk. Sometimes it appears in the open lawn, but this is usually an indication of the presence of buried wood in the soil. The caps when folded are conical, oblong or egg-shaped, with fine grooves running lengthwise. The color is yellowish, brownish yellow, or tan, while the surface is frequently sprinkled with glistening, mica-like particles that give this mushroom its name. These shining particles do not always appear on the caps, however. In young specimens the margin of the cap is at first



No. 22. The Glistening Coprinus (Coprinus micaceus) showing four stages in the development of this mushroom.

slightly attached to the steam near the base and leaves an encircling ridge where it breaks away. The stems are quite slender, smooth, white, with a narrow hollow and are easily broken. The

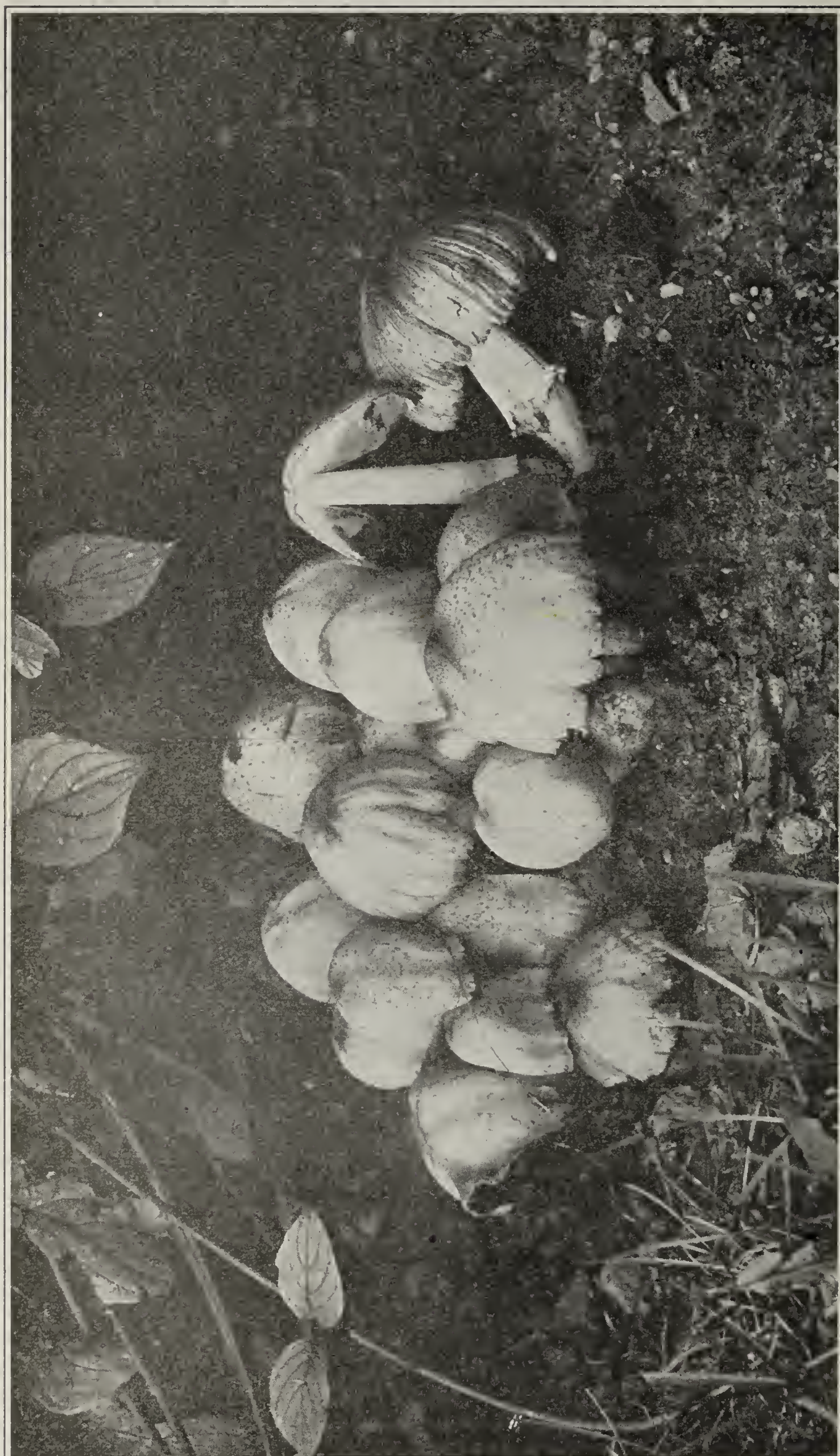
No. 23. The Glistening Coprinus. A cluster growing in a lawn where a cottonwood tree has been removed.

gills, at first white, change through brownish purple to black and in rather dry weather they shrivel and dry up instead of melting into ink.

The Glistening Coprinus occurs mostly during late spring and early summer, but is not infrequently found during the autumn following rainy weather.

*Inky Cap* (*Coprinus atramentarius*).

This is a somewhat larger mushroom than the glistening coprinus and is readily distinguished by the shape and color of the caps. It usually occurs in grassy places where the soil is rich, many often crowded together, the short stems being almost hidden from view. The caps are from one to two inches high, oval or egg-shaped, sometimes slightly indented at the top, and of a gray or brownish gray color. The caps have fine lines extending to the margin, some of them being quite deep grooves and in consequence the margin is apt to be rather irregular. It leaves a rather prominent ridge where it was attached to the stem. The surface of the caps is frequently quite scaly, due to the breaking up of the surface during growth, while in other forms the longitudinal striations or fine grooves are alone present. The caps when open assume a flattened bell-shape with the margin usually upturned and rolled back. The stems are white, smooth above and somewhat scaly or rough below the ridge-like ring and are comparatively short at first, but lengthen as the caps expand, often reaching a height of six inches. It is oftenest found during summer and autumn



No. 24. The Inky Cap mushroom (Coprinus atramentarius). Edible

No .25. The Shaggy Mane mushroom (Coprinus comatus), showing the different stages in the development of the fungus. Edible.

### *The Shaggy-Mane (Coprinus comatus).*

This is the giant of its group, occasionally growing eight inches high with the cylindrical pileus two and a half to four inches long. It grows in much the same places as the inky-cap mushroom, frequently appearing in profusion year after year in the same spot in some rich, moist lawn or grassy place where filling or grading has been done with fertile soil. It may appear in June, but is apt to be more abundant in the rainy part of autumn. The caps are longer than in either of the two preceding species, being nearly cylindrical or barrel-shaped when young. Their most noticeable feature, however, is the shaggy surface formed by the breaking up of the fibrous outer coat into tufts of delicate threads. These tufts are usually pointed at the lower part where they begin to separate from the cap and are sometimes tipped with brownish or blackish pieces, thus making them conspicuous on the white, fibrous layer beneath. The top of the cap is usually overlaid with a ragged piece of the same color. Although considerable variation in different plants may be found, they are so characteristic in appearance as to be unmistakable when once identified. As the margin of the cap breaks loose from the stem, by the rapid lengthening of the latter, it leaves the veil in the form of a narrow ring which unlike that of either of the above species, is free and movable on the stem. Soon after this occurs, the lower part of the cap and the gills begin to darken, the latter at first becoming a pinkish salmon color, gradually deepening to brownish and then black when the melting process begins. At this time, too, the cap gradually expands, assuming the shape of a bell, then becoming more flattened with the dissolving margin dripping with inky juice. At length, only a small portion remains but this, too, soon gives way, leaving the naked stem standing a slender monument to its final dissolution. The white stem when split lengthwise is seen to be hollow and to contain a strand of mycelial fibers extending through it.

### *Many Species Omitted.*

As it is impossible in the pages of an ordinary bulletin to describe and figure more than a small number of the fleshy fungi which occur in Colorado, only the more common and easily recognized kinds have been considered. Many other genera than those here treated are represented within our borders and our foothills and mountain forests at times abound in them. For the person who desires to know more about these interesting but largely unfamiliar plants, the reader will find such information in the following works:

"Mushrooms, Edible and Otherwise," *M. E. Hard.* The Ohio Library Co., Columbus, Ohio.

"The Mushroom Book," *N. L. Marshall.* (Doubleday, Page & Co.)

"Minnesota Mushrooms," *F. E. Clements.* (University of Minnesota, Minneapolis, Minn.)

"One Thousand American Fungi," *McIlvaine.*

"Principles of Mushroom Growing and Mushroom Spawn-Making," *B. M. Duggar.* (U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 85.)

## GATHERING FLESHY FUNGI FOR FOOD.

In collecting any of the fleshy fungi for eating, the same general precautions should be taken as with any other food materials. All specimens that are over mature or that are infested with the larvae of mushroom-eating insects should be discarded. Puffballs should be white inside when cut or broken open. Yellow or brownish stains near the base or in the center indicate approaching maturity and, although not necessarily poisonous in this condition, the fungus is apt to be bitter and unpleasant in flavor.

Care should be taken in removing the mushrooms from the soil so that adhering dirt will not be left on the specimens while carrying them. This will often obviate the necessity of washing the fungi before cooking and it is always very difficult to remove the soil from the gills of mushrooms which have been carelessly handled. An ordinary lunch basket is an excellent receptacle for carrying the mushrooms and it is desirable to wrap the larger specimens in thin paper before putting them in the basket.

## MUSHROOM COOKERY.

Almost as many culinary methods have been employed in the preparation of mushrooms for the table as for the various kinds of meats. In fact, they are adapted to almost any treatment given to meats, fish, fowl and eggs. Thus they may be stewed, baked, fried, broiled and escalloped, made into croquettes and patties or mixed with chopped meat and baked into a loaf, while they form a pleasing addition to thickened gravies and stuffing.

The tougher kinds, such as pleurotus, are adapted to stewing and require forty to fifty minutes. They are also readily prepared by grinding in a meat chopper and mixing with chopped beef for the filling of pattie shells or for the making of meat loaf. The puffballs are very daintily served by being sliced, dipped into egg batter, the same as for French toast, and fried in butter until lightly browned.

The very tender species, such as the Coprini or Inky-caps, are well suited to being served on toast after being stewed for fifteen to thirty minutes and thickened with a flour and milk sauce to which a little butter has been added.

Almost any of the various species are well suited to being baked with cracker crumbs after the manner employed in preparing escalloped oysters or tomatoes and a mixture of kinds can be utilized at one time in this manner. Almost any good cook book will be found to contain numerous recipes for mushroom cooking. only a few of which are mentioned here.

Bulletin 202 November, 1914

The Agricultural Experiment Station

of the

Colorado Agricultural College

# TESTING AND HANDLING OF MILK AND CREAM


BY

R. McCANN

Deputy Dairy Commissioner

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# The Agricultural Experiment Station

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# TESTING AND HANDLING OF MILK AND CREAM

By R. McCann, Deputy Dairy Commissioner

## Introduction

The use and understanding of careful, uniform methods of testing and handling milk and cream by the producer and receiver has led the advance of the dairy industry to higher planes and to broader fields wherever practiced. To secure uniform and accurate methods of testing and bring about a mutual understanding of the producer's and receiver's problems has been the aim of this bulletin.

The dairyman should know the requirements and rules of the receiving stations for his own protection and the advancement of his industry. The station operator should know and help solve the problems confronting the producers of the cream which he is handling.

Co-operation for the advancement of all concerned will work wonders in effecting changes of great economic importance to the dairy world of Colorado.

## HERD TESTING

Dairying, when properly conducted, is one of the most profitable lines of farming. But as a rule the average dairyman neither knows nor suspects the amount of profit or loss from each cow in his herd. It is not the large amount of money taken in, but the money that stays in the dairyman's pocket, which counts. Every cow must eat whether she produces much or little and she can bring no profit to the owner until she has first paid for her board.

To advance in dairying, herd improvement must go on. Elimination of low producing animals is without doubt the first step toward herd improvement, and this elimination cannot be successfully accomplished unless records of the milk production of each cow are systematically kept.

The only way to know how much a cow produces in a year is to weigh her milk at each milking and find its per cent of butter fat by the Babcock test. This should be done two days of every month, the middle two days of each month being preferable. Along with such records of production it is at least desirable, if not absolutely essential, that a record of food consumed be kept as well.

To facilitate the tabulating of such tests and weights as are necessary for the keeping of records, especially prepared sheets will be supplied upon application, either by the State Dairy Commission or the Dairy Division of the U. S. Department of Agricuture, Washington, D. C.

The equipment needed for running tests for a small dairy herd, with the cost, is given below:

| | |
|---|---|
| One automatic milk scale (30-lbs. capacity)........................ | $3.50 |
| On 4-bottle Babcock tester, with necessary glassware for milk...... | 5.00 |
| One dairy thermometer............................................ | .25 |
| Sulphuric acid................................................... | |
| | $8.75 |

A large covered tester may be had without glassware equipment at prices ranging from the 6-bottle size at $9.00 to a 12-bottle size at $14.00. Where many tests are to be run at once, it is a saving of time to have the larger machine.

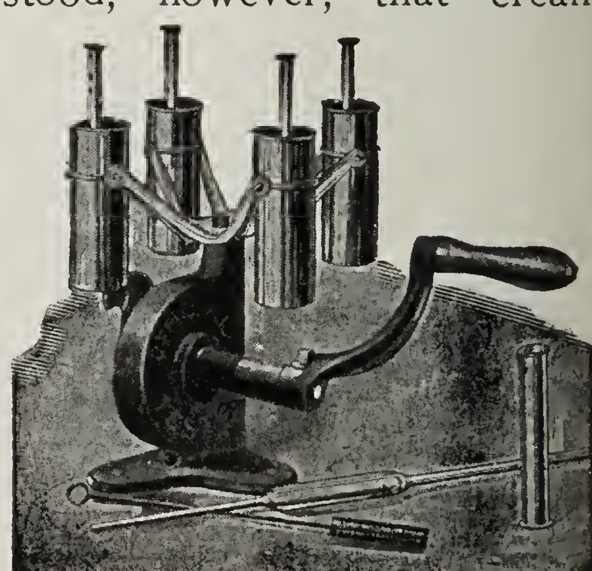
If cream is to be tested, scales for weighing the tests are required, which cost from $4.50 to $12.00 for the one bottle size. Cream bottles will also be needed. which will cost $1.00 for four, or additional glassware needed for making cream tests may be included in the order for the 4-bottle Babcock tester for an added cost of 50 cents.

Complete directions for running milk tests will be found on page 5.

Approximate cream tests may be made by measuring the cream into cream test bottles by the use of a 9 c. c. or an 18 c. c. pipette instead of weighing. In this case the pipette should be rinsed out and the rinsings transferred to the test bottle, or the test will be too low.

If cream is measured into the test bottles, care should be taken that the cream when measured is not in a foamy condition. Cream from the centrifugal separator should not be measured into the test bottle immediately after separation as such cream contains considerable foam. It should be understood, however, that cream tests made by measure are only approximate and are not as accurate as the weight measure tests. This method is given only for testing on the farm where cream is not bought or sold upon tests made, and test scales are not at hand. Such a method will serve as a rough check upon creamery tests, and then if sweet cream is sold for direct consumption, it is desirable to know the proper richness of the cream.

Milk scales


Babcock tester for a small herd

# MILK TESTING.

The method of operating the Babcock test when determining the amount of fat in milk, is here given in brief outline by steps:

1. Mix thoroughly sample of milk which is at 65 degrees to 70 degrees F.
2. Fill pipette to mark with milk at once.
3. Run milk into test bottle from pipette.
4. Fill acid measure to mark with acid and pour into test bottle.
5. (1) Mix milk and acid thoroughly by rotary motion; (2) let stand one to three minutes; (3) mix again.
6. Whirl four minutes at proper speed.
7. (1) Add water up to neck of bottle of 170 degrees F., whirl two minutes; (2) add 170 degrees F. water to within the two or three percent mark of top, and whirl one minute.
8. Read results at temperature of 120 degrees to 130 degrees F.

The sampling of milk is the most important operation of the test. Unless the sample is representative of the milk from which it is taken, the result of the test cannot be correct. Thorough mixing before taking a sample or a test from a sample, is absolutely necessary and always the first step toward accurate results in testing. Pouring from one vessel to another is the best method of mixing.

*Care of Milk Samples.*—Samples of milk should be placed in air-tight receiving jars, if the sample is to be left any length of time before testing. Tight sealing prevents evaporation. Should evaporation take place, the per cent of fat increases causing inaccurate tests.

Milk samples should not be permitted to sour before testing, as souring causes lumps of curd to form which require extra care in dissolving before testing. Souring may be prevented by keeping in a cool place or by use of some preservative, as formaldehyde or corrosive sublimate. When preservatives are added the sample should be shaken gently to insure mixing. One corrosive sublimate tablet will preserve one pint of milk for more than a week.

*Composite Samples.*—Composite samples of milk or skim milk are taken the same as for cream, and the tests run according to directions given for whole or skim milk.

### Method of Making the Test

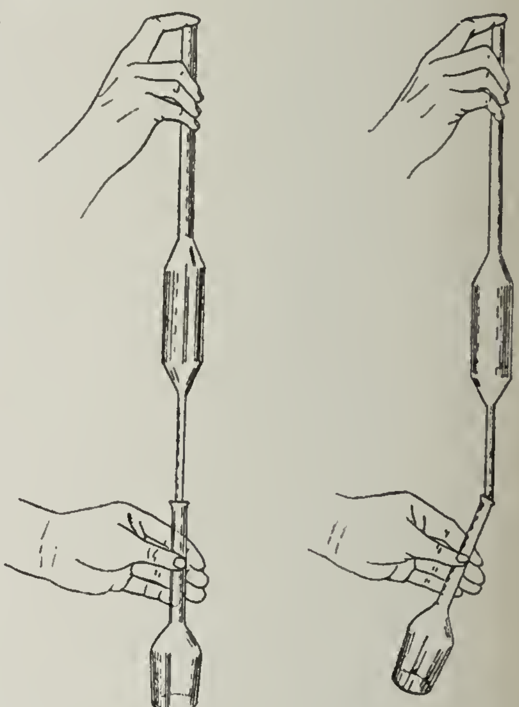
Samples in good condition may be brought to a temperature of 65 to 70 degrees F., thoroughly mixed, and the test taken at once, after thorough mixing and pouring. Samples that are sour or lumpy must be brought to a temperature of 110 degrees F. before mixing is attempted.

All tests should be made in duplicate so that one test will serve as a check on the other for accurate work. If both tests of a duplicate are not alike, some mistake has been made.

*Measuring the Milk.*—Milk is measured by the use of the milk pipette which holds, when filled to the mark on the stem, 17.6 c. c.

The milk is sucked into the pipette above the mark and the finger quickly placed on the upper end of the pipette and pressed firmly to keep the milk from running out of the pipette. The pipette is then held vertically, with the mark on a level with the eye, then by gently relaxing the pressure of the finger on the end of the pipette, air is admitted and the milk is allowed to flow slowly out until the top of the column of milk is level with the mark on the pipette.

*Running Milk into the Test Bottles.*—The point of the pipette is placed in the mouth of the test bottle, holding the test bottle in an inclined position. Removing the finger from the end of the pipette, the milk will flow out of the pipette into the test bottle. The object of inclining the test bottle is to allow the milk to run down the side of the neck of the test bottle, thus allowing an exit for the air in the bottle. If this precaution is not observed, the air will bubble out and cause some of the milk to overflow. Blow the last drop of milk out of the pipette before removing it from the bottle. Each bottle should be numbered with a lead pencil, giving the same number to each bottle as that corresponding to the name on the milk sheet.



The wrong way The right way
Manner in which the tests should be transferred to the bottle.

*Adding the Acid.*—The milk should be btetween 65 degrees and 70 degrees F. when the acid is added. 17.5 c. c. of sulphuric acid of a temperature of 65 degrees to 70 degrees F. should then be added to the test bottle, its specific gravity being 1.82 to 1.83 at 60 degrees F.

On pouring the acid into the test bottle, the latter should be held at an inclined position so that the acid will flow down the sides of the test bottle and not drop through the body of the milk in the bottle, the bottle being revolved so as to wash down all adhering particles of milk that may cling to the neck of the bottle. By observing this precaution, charring of the milk is avoided and also spilling of the acid.

If the acid has been properly added there will be distinct layers of acid and milk in the test bottle without any black layer of partially mixed acid and milk between.

Acid will eat holes in clothing wherever spilled on them. If any should be spilled on the skin or clothing, it should be quickly washed off with water. Color can be restored to clothing by treating the spots with ammonia water.

*Mixing the Milk and Acid.*—Mixing the milk and acid is done by giving the test bottles a combined rotary and shaking motion, being careful not to allow any curd to get into the necks of the bottles. Such mixing should be continued until all of the curd is dissolved and the color and body of the test appears to be uniform. The bottles may then be let stand from one to three minutes, given another gentle, rotary motion, and they are then ready for the tester.

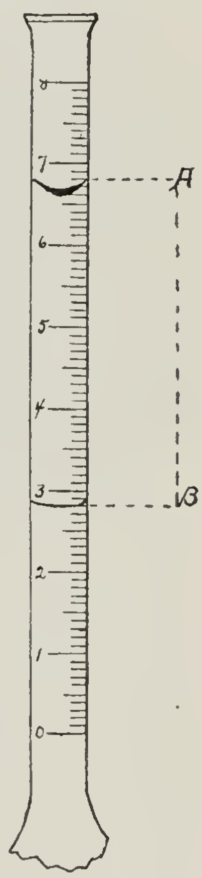
*Whirling.*—The test bottles, with the acid and milk properly mixed, are now placed in the tester.

The bottles should be arranged in pairs at opposite sides of the center so that they will balance when rotating.

First, whirl four minutes, at speed of machine indicated on the cover, then fill with soft, hot water to the bottom of the neck and whirl two minutes, fill the neck of the bottle with hot water of 170 degrees F. to within two or three per cent of the top, and whirl one minute. The periods of whirling given means the time during which the tester is run at full speed and does not include the time of starting and stopping.

*Reading the Tests.*—Milk tests should be read at a temperature between 120 degrees and 130 degrees F. This temperature may be best obtained by use of a five minute hot water bath before reading.

In reading the tests, hold the bottles perpendicular and on a level with the eye. Place one point of the dividers at the lower end of the fat column and the other point at the top of the meniscus or upper curved surface of the fat column. Then lower the dividers until the lower point is on the zero mark of the test bottle, the upper point will indicate the per cent of fat. Care must be taken to hold the dividers rigid while lowering.



Showing length of fat column to be read on milk tests, A to B

The following are a few precautions in making milk tests:

1. Always make tests in duplicate.
2. Make sure that the sample is a representative one.
3. Have the temperature of the milk and acid at 65 degrees to 70 degrees F. before mixing.
4. Use only acid of right strength, specifc gravity 1.82 to 1.83.
5. Mix milk and acid thoroughly as soon as acid is added, by gentle rotary motion.
6. Mix a second time after a short interval.
7. Make sure that tester does not jar.
8. Set bottles in water of 120 to 130 degrees F. five minutes before reading.
9. Read each test twice to make sure no mistakes have been made.

## Testing Skim Milk

The following changes should be made in testing skim milk from methods used in testing whole milk:

Skim milk bottles must be used; these bottles are graduated to be read to one one-hundredth of one per cent. More acid is needed than for whole milk, about 20 c. c. instead of 17.5 c. c. The speed of the tester should be increased 10 per cent and the tester kept as warm as possible. Skim milk always contains some butter fat, and should a test fail to reveal the presence of butter fat, it is an indication that the testing was poorly done and should be repeated.

Milk test bottle — Skim milk test bottle — Dairy thermometer — Dividers

## Variation of Fat in Milk.

The percentage of fat in normal milk varies a great deal. However, the fat content seldom falls below 2 per cent or rises above 7 per cent. The fat content of milk from a whole herd of cows varies only within comparatively narrow limits. The following are the chief factors which cause the fat conetent of milk to vary:

1. Individuality of cows.
2. Breed of cows.
3. Time between milkings.
4. Manner of milking.
5. Whether the milk is fore or after milk.
6. Age of cow.
7. Lactation period.
8. Surrounding conditions.
9. Condition of cow.

### Preparation of Milk and Cream Samples for Mailing

When a sample of milk or cream is sent to the Dairy Commission for testing, it must be received in good condition or an accurate test cannot be made.

The following suggestions will serve as an aid outline to be followed:

1. Secure a representative sample by pouring milk or cream from one can to another at least three times. Sample must be smooth, free from streaks and lumps.

2. Fill a clean sample bottle full, the bottle or jar should have a capacity of from two to four ounces. If the sample is not to be tested for adulterations or preservatives and is likely to be more than twenty-four hours in transit, add two or three drops of formaldehyde to prevent souring.

3. Seal the sample absolutely air tight. Test by inverting for an hour on white paper to see if the cover leaks.

4. Wipe the sample jar clean and dry, and pack well with plenty of soft, white paper in a small wooden or strong pasteboard box. Send by parcel post.

5. At the same time the shipment is made, send a letter stating what tests are desired. Give the name and address of the person that took the sample, of the person whose milk or cream was sampled, and of the person to whom analysis is to be sent.

If solids, adulterations or bacterial examinations are to be made special directions for sending will be mailed from this office upon application. All applications for directions for sending should give full information as to the kind of tests that will be required so that special instructions may be sent for securing the same.

Samples arriving in a leaky, unsatisfactory condition cannot be tested, but the sender will be notified of the probable cause of his trouble.

No charges are made for making tests.

About a week is required for making tests and reporting.

## CARE OF CREAM; AND CREAM QUESTIONS

Good butter cannot be made from poor cream. If a grade of butter can be produced that will bring the highest market value, better prices can be paid for cream.

The first step in the production of good cream is clean milking. This can be accomplished when barn, cows and utensils are clean. It is a good plan to dampen a cloth and wipe off the cow's udder and flanks each time previous to milking. Small top milk pails should be used. Cows should be kept in a good, healthy condition, economically but well fed and cared for. Then as soon as the milk is drawn it should be taken at once to the separator room, a room apart from the milking barns and free from all odors that may taint the cream in the least. As soon as all the milking is done, the cream should be separated at once and then cooled down to 50 degrees, or between 40 degrees and 50 degrees F. if possible. All utensils used must be kept clean and given plenty of sunlight and air when not in use. All strainers, pails, separator and separator parts must be washed and cleaned thoroughly after using.

Other important cream questions can be most concisely set forth by the following questions and answers:

1. Q. How thick should cream be skimmed?

A. Between 35 per cent and 40 per cent. Thick cream keeps better than thin cream, there is also not the waste in handling a smaller bulk of cream that there is in handling larger amounts, in the way of hauling and express charges. Moreover, the skim milk is kept on the farm for feeding the pigs and calves. If cream is skimmed thicker than 45 per cent, there is a loss in some of the cream going over into the skim milk, and there is also a considerable loss from the amount of cream that will adhere to cans and utensils.

2. Q. How can cream be skimmed near the same thickness each time?

A. (a) By using the same amount of water to flush the bowl of the separator each time.

(b) By keeping the cream screw the same.

(c) By running the separator at the same and a uniform speed. It is best to have the same person turn the separator at each skimming, if possible. By this means a more uniform speed will be obtained.

(d) By having the temperature of the milk the same.

(e) By keeping a uniform inflow to the bowl.

(f) By washing the separator thoroughly after each time it is used.

3. Q. How cool must cream be before it is mixed with other cream of previous skimmings?

A. Always cool cream down to between 40 degrees and 50 degrees F. before mixing with other cream and stir all cream thoroughly every time new cream is added.

Warm cream should never be mixed with previous skimmings.

4. Q. Under what condition should cream be kept?

A. Cream should be kept in a cool sanitary place, the temperature should be below 50 degrees F. Odors of vegetables, oils, etc., must not be present. A spring house or a building provided with cold, running water is best. A cellar or cave is not a good place to keep cream because the air is seldom pure and the temperature is not low enough in summer.

5. Q. Where should a cream separator be kept?

A. The separator should be kept in a separate room or building provided for that purpose.

6. Q. How often should a separator be washed?

A. The bowl and all parts of a cream separator which come in contact with milk or cream should be thoroughly washed and scalded after each separation. This requirement is necessary to secure uniform skimming each time the separator is used, and, furthermore, dirty utensils are classed as unsanitary by law and must not be used.

7. Q. How should cream be taken to the market?

A. During warm weather, cream should be protected from the sun, while delivering, by wrapping dampened blankets around the cans and over the tops. In severe winter weather cream should not be permitted to freeze while delivering.

8. Q. What causes cream to become sour?

A. The action of bacteria. The action of such bacteria may be delayed by keeping cream cool and clean.

9. Q. What are the chief causes of bad flavors in cream?

A. Strong-flavored weeds or feeds, unsanitary surroundings and undesirable bacteria.

10. Q. Can sour cream be tested.

A. Yes, but cream in a sour or bad condition is much harder to sample and test accurately than sweet cream.

11. Q. What standard of butter fat is required by the state law when cream is sold for table or private use?

A. 16 per cent butter fat.

12. Q. What is first grade cream?

A. First grade cream shall consist of cream that is clean to the taste and smell, free from all foreign matter and sweet or only slightly sour.

13. Q. What is the best breed of cows to keep when cream is sold?

A. Holstein, Guernsey, Jersey, and Ayrshire are the four best breeds. As to which of these four breeds should be placed first, depends largely upon the owner's individual liking and the conditions that must be met by way of climate and feeds.

14. Q. When should dairy herds freshen?

A. In the fall as much as possible, for it is through the winter months that cream brings the highest prices. Cream is more easily kept in good condition, and labor for caring for the herd is cheaper at this time than any other season of the year. Records also show that cows freshening in the fall produce from 25 to 40 lbs. of butter fat in a year more than the same cows freshening in the spring.

15. Q. Are silos an economical factor in feeding dairy cows?

A. They are in reality a necessity, but they must be properly made and filled.

16. Q. What is the best make of cream separator?

A. The one that will skim the closest, last the longest, run the smoothest and be the easiest to clean thoroughly. Too much attention cannot be paid to investigation before a purchase is made.

17. Q. Is the Babcock test accurate?

A. Yes, if the method of operation is understood and care is taken to work it carefully.

18. Q. What protection has the farmer against inaccurate testing?

A. He may make an occasional test of the cream himself at his own farm by following the instructions given in this bulletin. All station operators must pass an examination and hold a state license before they can sample or test milk or cream or other dairy products. In order to continue to hold this license, they must do accurate sampling and testing. Inaccurate testing or false reading of tests is a direct violation of the law and will be punished by law enforcement wherever found.

18. Q. Should cans be borrowed from cream stations or creameries?

A. Milk cans should not be borrowed from station operators or creameries, as in this way many cans are not only lost each year, but others are returned in damaged and unsanitary condition.

Station operators are hereby authorized not to loan milk cans to their patrons or others desiring them.

20. Q. When should a patron expect pay for a cream delivery?

A. When a cream delivery is made and the empty can of that delivery is ready for return by the operator, the check for the previous delivery should be expected together with a statement of the present delivery and the price being paid for butter fat. By this method of payment, the patron always has a check coming upon the day deliveries are made, excepting the first delivery at a station, and ample time is given the operator so that testing may be done accurately and carefully during hours that are not rushed with business.

Patrons should insist that operators take plenty of time to do their work accurately and follow this method of payment, as such a plan is decidedly to the advantage of both parties concerned.

22. Q. How should cream be cared for at the cream station?

A. Cream brought to the station is then under the operator's care, and it is his duty to keep it in the best condition possible, emptying the cream after sampling and weighing into clean, well aired cans. Cream of second grade or poor grade, should not be mixed with good, first grade cream, as such mixing will spoil the good cream in stock. Good cream must be kept free from additions of poor cream. Every time new cream is added, the entire amount should be thoroughly stirred. The lid of the can should not be closed tightly, but left open and protected from dust and flies. Cream held at the station should be stirred often. Stirring keeps it in better condition and the top will not become dry and crusted. The temperature should be kept between 40 degrees and 50 degrees F. The station must be in a sanitary condition and free from all odors such as oil, vegetables, etc.

## METHODS OF RECEIVING AND SAMPLING CREAM.

Nearly every person has a particular business method of their own which they follow, others never get the habit of having systematized work.

The following ten steps will serve as a guide and aid to all who are just taking up this work, and may also hold some worthy suggestions for older followers of the business.

1. Write the patron's name plainly upon the receiving sheet.
2. Balance scales and weigh the cream.
3. Record the gross weight of cream and can.
4. Sample as required by Colorado law.
5. Place the number of the sample jar opposite the patron's name.
6. Rinse the empty can.
7. Wash the can thoroughly, then drain it.
8. Weigh the empty can.
9. Subtract the weight of the empty can from the weight of the can and cream obtained in No. 3, then enter the remainder on the receiving sheet as the weight of the cream to be paid for.
10. Then when the patron calls for the can, give him the check for the previous delivery, and also a statement of the amount of cream just received and the price being paid for butter fat. This rule is a very important one. Show the patron that it is to his advantage not to receive payment for cream the same day of delivery, for the reasons that during the rush hours of the day an operator has not the time to do the accurate, careful testing that the patron should require. Hurried testing will not be permitted.

*Sampling Cream.*—It is always best, if possible, for the person taking the sample to do the testing. Accurate samples must be taken. The taking of inaccurate samples is just as much a violation of the law as improper testing.

Too much stress cannot be laid upon the need of thorough and careful mixing just before the sample is taken, and also before putting the final charge into the test bottle.

To secure an accurate and legal sample of cream, according to Colorado law, it shall be poured from one vessel to another at least three times before sampling, unless said cream is thoroughly stirred and sampled by the McKay sampler, or some other recognized sampler that will secure a representative sample. Always mix by pouring, unless the McKay or a similar sampler is used.

The ordinary stirring rod generally used will not get an accurate average sample unless pouring is resorted to in addition.

Cream that is frozen or lumpy should be heated to 110 degrees in a water bath and then thoroughly mixed, stirred and poured. It should remain in the water bath until the body of the cream has become smooth, free from lumps and of a uniform texture. After such cream has become free and smooth it may be sampled the same as other cream.

Milk may be sampled the same as cream, with the exception that only one pouring is required by law. However, additional mixing is often necessary and always beneficial toward securing an accurate sample.

*Composite Samples.*—"In sampling milk or cream, from which composite tests are to be made to determine the per cent of butter fat contained therein, such samples or sampling shall not be lawful unless a sample be taken from each weighing and the quantity thus used shall be proportioned to the total weight of the cream or milk samples." The sampling should be done the same as for taking samples for other tests, with the exception that the composite sample must be proportional to the quantity of cream from which it is taken. That is, take only half as large a sample from a half can of cream as from a full can. The samples taken from all the cans of cream should be mixed together and warmed in a water bath and a test made from them the same as from other samples. This test multiplied by the number of pounds of cream sampled, will show the number of pounds of butter fat in the total amount of cream sampled.

This method of making a composite test of each shipment of cream should be used as a check on the day's business, and as an aid toward checking out with the creamery. The amount of rinse water used in the cans will not affect the total pounds of butter fat, since the slight lowering of the test by the addition of the water will exactly compensate the increase in weight.

The value of such a check on shipments rests entirely upon the care given in taking the samples or sample, providing the test is completed by the usual methods.

*Care of Samples.*—If samples are allowed to stand any length of time before testing, they should be tightly covered in order to prevent evaporation. The use of common milk bottle caps in the tops of the small sample jars now generally used is an effective seal. Where it is absolutely necessary for tests to stand many hours, it is best to add some preservative to prevent souring and curdling. A few drops of formalin or corrosive sublimate is good, but all such preserved samples should be emptied in the waste as soon as tested, for corrosive sublimate is poisonous and formalin also if very much is used.

All samples should be kept until all the tests have been made and recorded, for occasionally something may happen to a test, and an additional quantity of the sample will be needed to run another test.

Considering the conditions under which most samples are handled and the length of time that they are sometimes kept, it is usually most economical to empty the small quantities of cream left in them into the waste rather than into the cream cans.

## CREAM TESTING

In describing the method of operating the Babcock test, when determining the amount of butter fat in cream, special attention will be called at each step to such difficulties as may occur, and emphasis will be laid upon precautions necessary to obtain accurate results.

In brief outline, the different steps may be stated as follows:

1. Heat sample to be between 100 and 110 degrees F.
2. Balance test bottle or bottles on scales.
3. Mix the sample thoroughly by pouring from one vessel to another.
4. Weigh test or tests.
5. Cool to between 60 degrees and 70 degrees F.
6. Add acid of same temperature.
7. Mix.
8. Add hot water of 170 degrees up to neck of bottle, whirl five minutes.
9. Add hot water of 170 degrees to within three or four divisions of the top and whirl two minutes.
10. Read at a temperature of between 120 degrees and 130 degrees F.

*Preparing samples of cream for testing.*—Cream samples should first be heated in a water bath at 100 to 110 degrees F. The cream must not be heated to more than 110 degrees F. or the fat will become liquified and the sample taken will not furnish an accurate test.

The bottle or bottles to be used for the test may be balanced on the scales in the meantime while the cream is heating. Mark each test bottle plainly with the same number given the corresponding sample jar.

Showing the height to which cream free from air bubbles must be raised in a pipette to get 18 grams of cream. It shows that to measure in a pipette is inaccurate in cream testing. (Modified from Iowa Dairy Com. 1903)

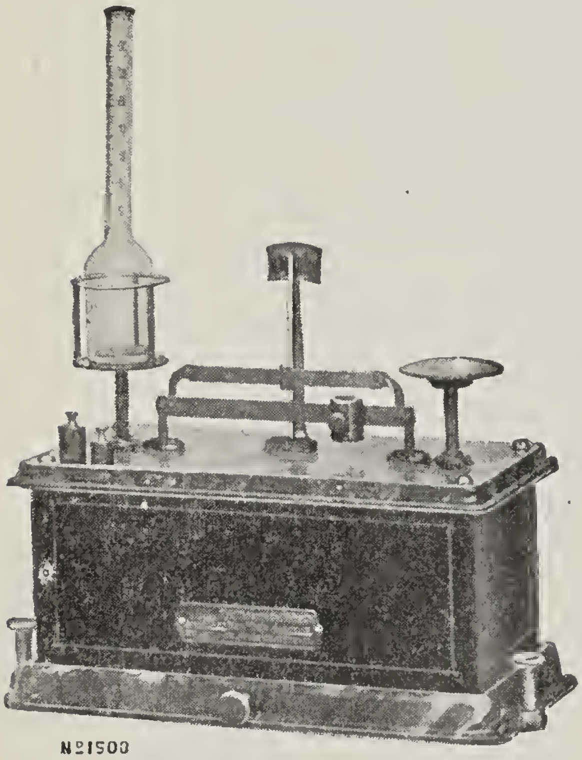
Mix the samples thoroughly by pouring from one jar to another until the cream is uniform in color, and smooth. Cream samples containing lumps or streaks must be classed as not thoroughly mixed, and should not be tested until all lumps and streaks have been dissolved.

To insure accuracy, all samples of cream should be tested in duplicate. If the results of the duplicate tests do not agree, there is an error somewhere and the work should be repeated. Then, also, if something happens to one test, the other is left.

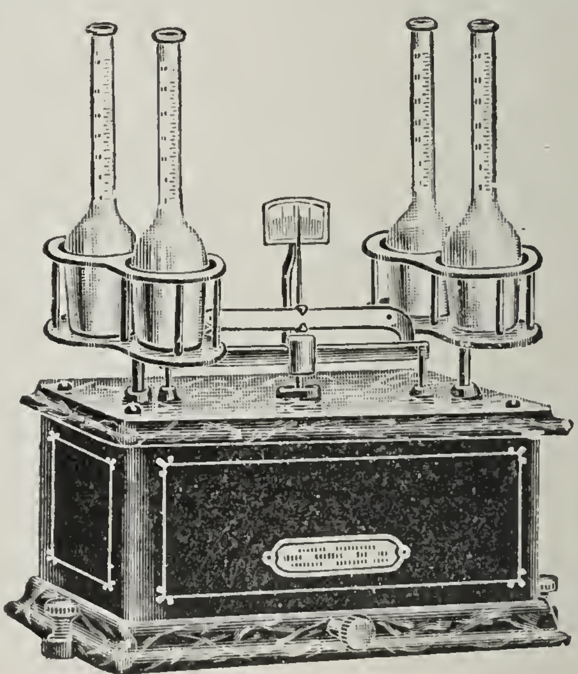
*Weighing the Test.*—After again making sure that the scales are level and balanced, weigh out the test immediately, nine or eighteen grams, using a large mouthed pipette to transfer the cream to the test bottle. No cream should be allowed to get on the outside of the bottle or in the scale pan while the weighing is done.

To lengthen the life of the scales, use the rest rod whenever adding weights or taking weights from either scale pan.

If too much cream should be added to the test bottle, the excess may be removed with a clean wire or glass rod. Be sure to get the weight accurate, as not quite enough or a little too much will not bring correct results.



One-bottle torsion balance scale


Four-bottle torsion balance scale

*Adding the Acid.*—Before adding the acid the cream should be brought to between 60 and 70 degrees F. by placing in a water bath of that temperature or colder until the cream has reached the desired temperature. Unless the cream and acid are brought to the above temperature at the time of mixing, the action of the acid may cause burnt or cloudy tests. In cold weather it will be necessary to warm the acid slightly in order to bring it to the desired temperature.

The proper measure of acid to be added will depend upon the size of the test, whether nine or eighteen grams, the strength of the acid and the richness of the cream. For a nine gram test, about 8.8 c. c. of acid may be used, for an eighteen gram test 17.5 c. c. of acid is the usual amount. While adding the acid, the bottle should be held at an angle and at the same time revolved so that the acid may wash down all adhering cream on the inside of the neck of the bottle. Acid should not be allowed to fall directly into the cream, as such a practice may cause black particles to appear in the fat column. There is also danger of the neck choking up and the acid overflowing on the operator's hands.

The contents should then be mixed by a gentle rotary motion, avoiding spilling or shaking curd particles into the neck of the bottle. The sample should then turn a dark chocolate color. After mixing, each bottle should be allowed to stand a short time, until the desired uniform chocolate color is obtained.

Commercial sulphuric acid of a specific gravity of 1.82 to 1.83 should be used. Such acid should not be left in an open container, as the action of the air will very soon cause it to become weak and unfit for use.

Rich cream will require a little less acid than thin cream, and sour cream will require a little less than sweet cream.

*Whirling.*—The tests having been let stand after mixing with the acid, as described above, a second gentle rotary motion should be given and hot, soft water of 170 degrees F. added in proportion to the amount needed as indicated by the color of the mixture, usually up to the neck of the bottle. Balance in tester and whirl at the proper speed of tester for five minutes.

Stop the tester and add soft water, 170 degrees F., to within three or four graduations of the top of the graduated scale on the neck of the bottle. Unless a steam tester is used, care should be taken to keep the tests at 170 degrees F. by inserting in a hot water bath of that temperature for five minutes.

Whirl two minutes.

All water added must be soft. If soft water cannot be obtained, hard water may be softened by adding a few drops of sulphuric acid before putting into the bottle. The use of hard water will cause air bubbles on the top of the fat column.

The periods of whirling given mean the time during which the tester is run at full speed, and do not include the time used in starting or stopping the machine.

The following table gives the necessary number of revolutions for different size testers.

| Diameter of Machine | No. of Revolutions per Minute |
|---|---|
| 10 | 1074 |
| 12 | 980 |
| 14 | 909 |
| 16 | 848 |
| 18 | 800 |
| 20 | 759 |
| 22 | 724 |
| 24 | 693 |

*Reading Tests.*—Having finished the last whirling, all tests shall be maintained at a temperature of between 120 and 130 degrees until read. If glymol is used, the test should be kept between 135 and 140 degrees until read. These temperatures are best maintained by the use of the water bath for ten minutes. The careful use of the water bath will contribute greatly in cutting down shortages caused by over-reading of tests.

The color of a test to be read should be a golden yellow, free from cloudiness, specks or curd. Any tests that have curd, dark specks or foreign matter at the lower portion of the fat column causing an irregular line, must be retested.

In reading the test, hold the bottle perpendicular and on a level with the eye. Place one point of the dividers at the lower end of the fat column and the other point in the middle of the meniscus formed on the upper curved surface of the fat column. Then lower the dividers on the graduated scale until the lower point is on the zero mark of the test bottle, the upper arm will indicate the per cent of fat. Care must be taken to hold the arms of the dividers rigid while lowering.

When glymol is used, the upper surface of the fat column is made straight and the reading may be taken from the top of the fat column, no allowance being made for the meniscus, as it has been overcome.

Cream test readings should always be made to the nearest half per cent or full per cent marks. Reading to the half per cents is necessary in order to check out closely with the creamery.

The reading completed should be entered opposite the patron's name, being sure that the number on the test bottle corresponds to the number given the patron's name.

*How to Clean Test Bottles.*—Empty the bottles while warm into the earthen waste jar, at the same time shaking the bottles to loosen the white deposits in the bottom, then wash in warm water using a washing powder and a small brush. Weak acid and washing powder will often remove sediment which water will not dissolve.

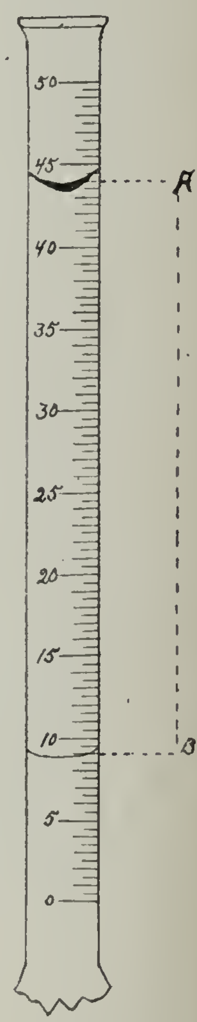



Fig. *

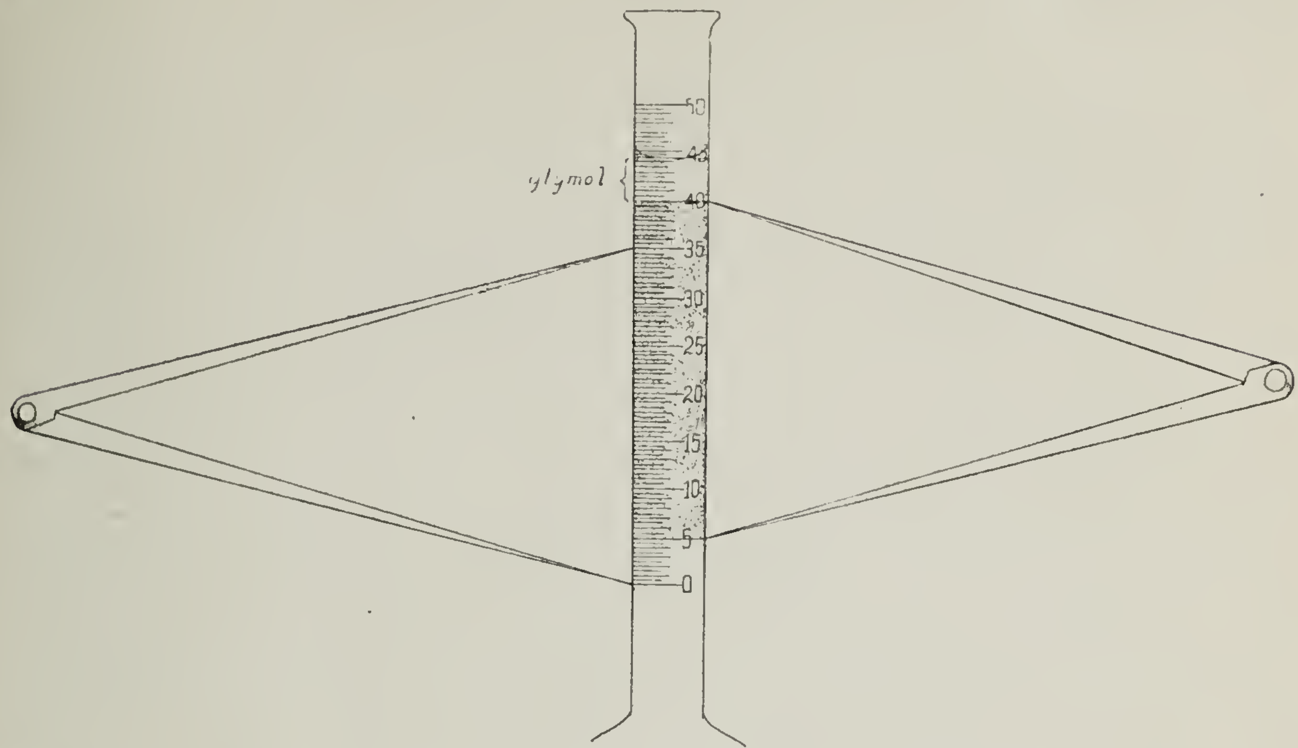
Test bottles should be inverted and allowed to drain until dry. If glassware does not drain clean after it has been thoroughly washed, too much washing powder has been used.

*Glymol and Its Use.*—Glymol is a white mineral oil and can be obtained at most drug stores. It serves its purpose better in making the fat column easier to read by coloring with akanet root. The akanet root may be wrapped in cheese cloth, an ounce to a quart, and left in the oil two or three days, after which time the oil will

Fig.* —Read the fat column for cream from A to B, or from the bottom of the column to half way up on the upper dark curved surface or meniscus.

be colored a cherry-red. A few drops of this dropped on top of the fat column will entirely remove the meniscus, leaving a straight line for the top of the fat column.

Tests on which glymol is used must be read at 135 to 140 degrees F. temperature in order to check with ordinary tests read at




Note the straight line on top of the fat column when glymol is used. The lighter portion at the top is glymol. The use of dividers is also shown in measuring the length of the fat column. (Missouri Bulletin)

from 120 to 130 degrees F. on account of the fact that the added heat is needed for the proper expansion of the fat column.

*Action of Sulphuric Acid on Milk or Cream.*—Sulphuric acid dissolves all milk solids other than fat, leaving the fat globules free to collect in a mass. Sulphuric acid liquifies the fat, due to the development of heat.

Sulphuric acid increases the specific gravity of the milk or cream mixture, the butter fat being much lighter, more readily rises to the surface of the heavy liquid.

*The Value of Cream.*—To find the number of pounds of butter fat in a certain quantity of cream, or in a delivery, multiply the number of pounds of cream by the test, point off two decimal places; this gives the number of pounds of butter fat. The number of pounds of butter fat multiplied by the price per pound paid for butter fat, will give the value of that quantity of cream, or the amount due the patron.

*To Find the Average Per Cent of Fat.*—In calculating the average per cent of fat from a number of cows, or the milk or cream furnished by different patrons, the mistake of adding the tests of all samples tested is often made. Milk or cream from different patrons or from different cows will always vary, some in quality and some in quantity, and in order to get a correct average test, both quantity and quality must be taken into consideration.

The wrong way:

| Sample | Cream Delivered | Per Cent of Fat |
|---|---|---|
| 1 | 100 lbs. | 30.0 |
| 2 | 50 lbs. | 30.5 |
| 3 | 300 lbs. | 40.0 |
| 4 | 200 lbs. | 45.5 |
| | | 4 ) 146.0 |
| | | 36.5 |

The correct way:

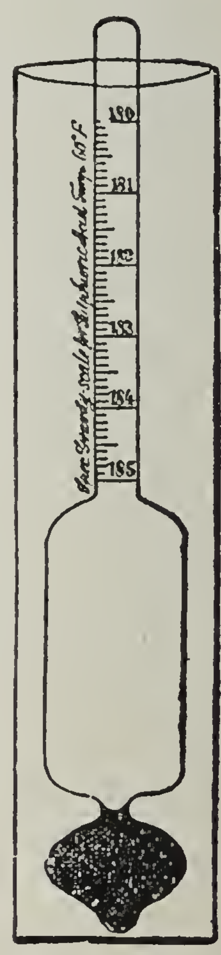
| Sample | Cream Delivered | Per Cent fat | |
|---|---|---|---|
| 1 | 100 lbs. | 30.0 per cent | 30.0 lbs. fat |
| 2 | 50 lbs. | 30.5 per cent | 15.3 lbs. fat |
| 3 | 300 lbs. | 40.0 per cent | 120.0 lbs. fat |
| 4 | 200 lbs. | 45.5 per cent | 91.0 lbs. fat |
| | 650 | | 650 ) 256.3 |
| | | | 39.4 per cent |

The average test as figured by the wrong method gives 36.5 per cent. Figuring by the correct method gives 39.4 per cent, the average per cent of butter fat.

If the percentage of fat or the number of pounds of milk is uniform, then it does not make any difference in the results as to which of the two ways illustrated above is used. Such uniformity seldom exists in practice, so that the only correct way of calculating the percentage is to find the total number of pounds of fat and divide it by the total number of pounds of milk or cream.


Combined acid measure makes work more rapid

Acid measure



Acidometer, showing glass tube in which the acid is tested for specific gravity.

## STATION PROBLEMS.

*Probable Cause of a Shortage.*—When the creamery reports a shortage of butter fat, the cause probably lies in one or more of the following reasons:

1. The number of cans shipped and net weight not agreeing with the creamery report.
2. Samples not having been taken according to directions as to securing a representative sample, or not kept tightly sealed and in a cool place.
3. Dirty test bottles having been used.
4. More than a 9 or 18 gram test having been taken.
5. An abnormal fat column.
6. Reading tests at a point higher than the center of the meniscus.
7. Failure to keep the tests at from 120 to 130 degrees F. until read, and from 135 to 140 degrees F. when glymol is used.
8. Hasty reading, or slipping of dividers.
9. Inaccurate glassware.

*Probable Cause of Excess.*—When the creamery reports an excess of butter fat, the cause probably lies in one or more of the following reasons:

1. The number of cans shipped and net weight not agreeing with the creamery report.
2. Samples not having been taken according to directions as to securing a representative sample, or not kept tightly sealed and in a cool place.
3. Less than 9 or 18 gram test having been taken.
4. Not running tester long enough periods or at high enough speed.
5. Reading tests at the base of the meniscus instead of half way up the curve.
6. Failure to keep the tests from 120 to 130 degrees F. until read, and from 135 to 140 degrees F. when glymol is used.
7. Hasty reading or slipping of dividers.
8. Inaccurate glassware.

Stations and creamery records should agree at the end of every month. The Babcock test is accurate, and careful and observing testers should agree in their work.

*Frozen Cream.*—Cream should not be permitted to freeze, but should such happen the cream should be thawed in a water bath of not over 110 degrees F. then sampled in the usual manner

*Cause of Air Bubbles in the Fat Column.*—When hard water is used in tests, air bubbles often form at the top of the fat column.

*A Milky Fat Column.*—A milky fat column may be caused by the mixing of the acid with the test when both are not near the same temperature, 60 to 70 degrees F. The acid used may be too weak, or enough may not have been used.

*Filling Cream Cans.*—The amount of cream in a can must be determined by the conditon of the weather and the cream. For average conditions a can should not be filled more than half way between the handle fastener and the top band of the can; second grade cream should not go above the top band especially during hot weather. Not filling cans over full will prevent waste and shortages. Foamy cream is especially likely to waste. A small piece of ice dropped into such cream just before shipment will prevent further foaming

*McKay Sampler.*—The McKay sampler is one of the most reliable samplers that can be found on the market. It takes a vertical sample of the cream for its entire depth and truly represents the richness of all portions and depths of cream so sampled.


McKay sampler

The amount of the sample is proportional to the depth or amount of cream in the can. The sampler consists of two tubes, one within the other. Each tube is provided with a handle and each tube has vertical slots on one side. By turning the handles, the sampler may be opened or closed.

In use, the sampler is plunged to the bottom of the can of cream to be sampled, with the slot closed. The handles are then turned to allow the contents of the can to run into the sampler, then the handles are turned to close the tube. The sampler is then withdrawn and the contents emptied into a sample jar by slightly pulling out the inner tube or opening the handles. If cream sampled is very thick, an inside plunger is needed for removing all the cream from the inside, or dip the sampler in warm water.

The best results are obtained when the sampler is kept warm. McKay cream samplers have wider slots than those intended for milk.

## THE CREAM STATION.

A cream station should be a building where sanitary conditions for the handling of cream may be maintained. It should not be located near obnoxious factories, yards or buildings, on side streets or alleys back of other buildings. Good drainage is a very important requirement both for the disposal of surface water and waste within the station. As dairying in Colorado is a growing industry, ample provision should be made for future growth.

The following sizes and capacities give a fair estimate of the size of building needed:

| | |
|---|---|
| 10 cans per week | 10 x 12 |
| 25 cans per week | 14 x 16 |
| 50 cans per week | 16 x 18 |
| 100 cans per week | 20 x 24 |

All empty cans should always be kept inside, not out exposed to the hot sun or other weather elements. Plenty of room makes work for the operater lighter and more rapid, especially on busy days. The hot water boiler should always be in an adjoining room to that where the cream is kept; thereby the dirt and dust made while firing is avoided, as is also the heat caused by the same during the hot summer weather.

The floor should be of close fitting, well matched boards, painted, if a cement floor is not available.

The ceiling and side walls should be of smooth, hard finish, so as to be easily kept clean. Paper should not be used for finishing, as it soon becomes torn or cracked leaving catching places for dust and insects.

Window space should be provided for one-fifth as much window space as floor space. Sunlight is necessary as a disinfectant and for the operation of efficient work. Good ventilation should also be provided for, as a cool room is essential for keeping cream, good and free moving air with plenty of light is one of the greatest aids toward keeping the room sweet and fresh at all times.

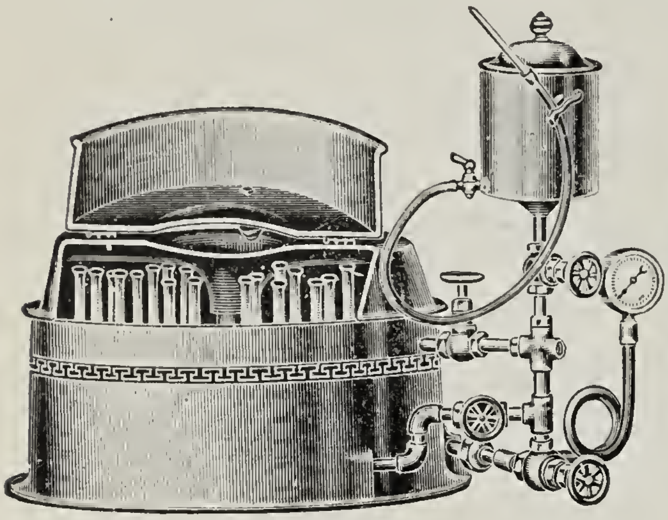
All doors and windows should be fitted with screens, either a canvas shade or a covered porch is very desirable for the principal door, as it is a protection against rain and the bright sunshine. If the station is a frame building it should be attractively painted.

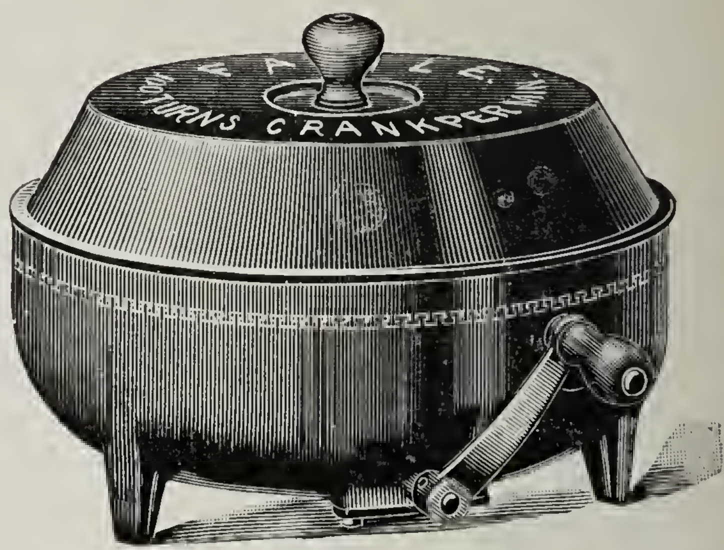
All stations of modern type will need primarily the following equipment:

1. Upright Tubular Boiler and steam fittings.
2. Wash sink with drain.
3. Babcock tester.
4. Can rack.
5. Weigh scale.
6. Cream sampler.
7. Cream scales.
8. Dividers.
9. Pipette.
10. Acid measure.
11. Sulphuric acid.
12. Water bath.
13. Test bottle brush.
14. Can brush.
15. Sample jars.
16. Test bottles
17. Dairy thermometer.
18. Washing powder.
19. Waste jar.

1. An Upright Tubular Boiler with steam fittings and connections is the best and most efficient means of securing plenty of hot water so necessary in every station. It also will provide steam for running the Babcock tester.

2. A wash sink made of half rounded galvanized steel large enough to hold a ten gallon milk can is considered best. The two compartment sink has the advantage of keeping wash water and rinse


Steam tester


Hand tester

water at hand at the same time. There should be a good drain connected with the sink; if a drainage system is not at hand to drain to, a fifty-foot tile drain four feet under ground leading to a stream, gully, or ditch, will serve the purpose.

3. The Babcock tester should set level and on a solid foundation in order that it may run smoothly. If it shakes it will cause a remixing of the fat, and consequently an inaccurate reading.

A twelve-bottle tester is large enough for the average station.

4. The law requires that milk cans or receptacles be inverted in pure air and cover removed. This is a very wise and necessary precaution, to keep the cans in a good, sweet condition, and can best be accomplished by the use of can racks made along the side of the wall. Substantial uprights and one by four or one by two crosspieces nailed with eight nails makes a very desirable and cheap rack.

The boards should be painted so as to be more easily kept clean.

Nails in the racks directly above the position of each can will serve as hangers for the lids.

5. Weigh scales should be accurate and sensitive to a quarter of a pound.

6. The most common and most accurate samplers, when used in combination with one another, are the stirring rod having the curved disk on the end, and the McKay sampler.

7. Cream test scales should be level when in use, and sensitive to a drop of cream. The Torsion balance is the most satisfactory form. It may be obtained with a capacity of from one to twelve bottles. Where a large amount of testing is done, the large scales are best as the work is more rapid. However, an error made in weighing one bot-

tle on the large scales causes an error for the next sample weighed in the same set of weighings.

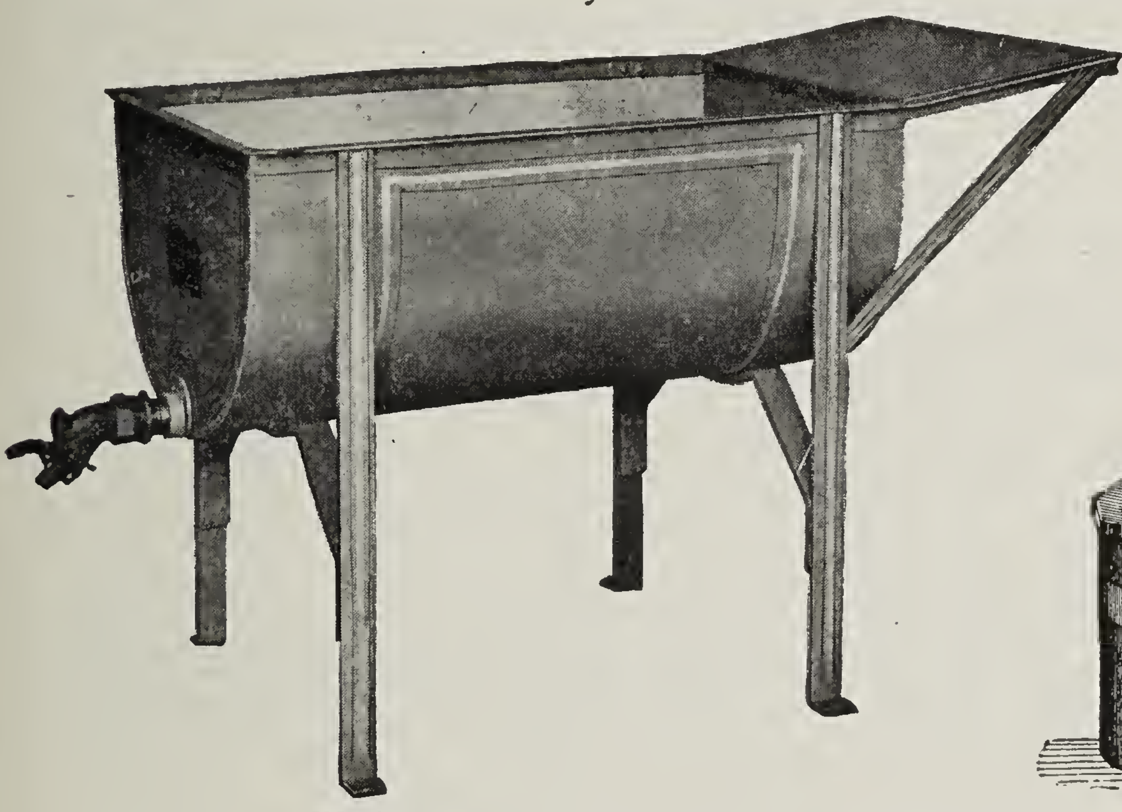
8. Dividers should be sharp-pointed and move with plenty of friction at the hinge. Dividers which are loose and likely to slip should be mended at once.

9. A pipette may be used to transfer a cream charge to the test bottle or for adding hot water to the test, but it must not be used to measure the cream test.

A wide mouthed pipette is better for cream, as it will not clog so easily as a narrow mouth.

10. An acid measure is a small glass cylinder marked at 8.8 c. c. capacity for 9 gram tests and 17.5 c.c. for 18 gram tests, used in measuring the proper amount of acid to be added to the cream charge.

11. Sulphuric acid of a specific gravity of 1.82 to 1.83 should be used, and care must be exercised to keep it tightly corked, as it absorbs moisture from the air and may thus become too weak for use.



Wash sink

Waste jar

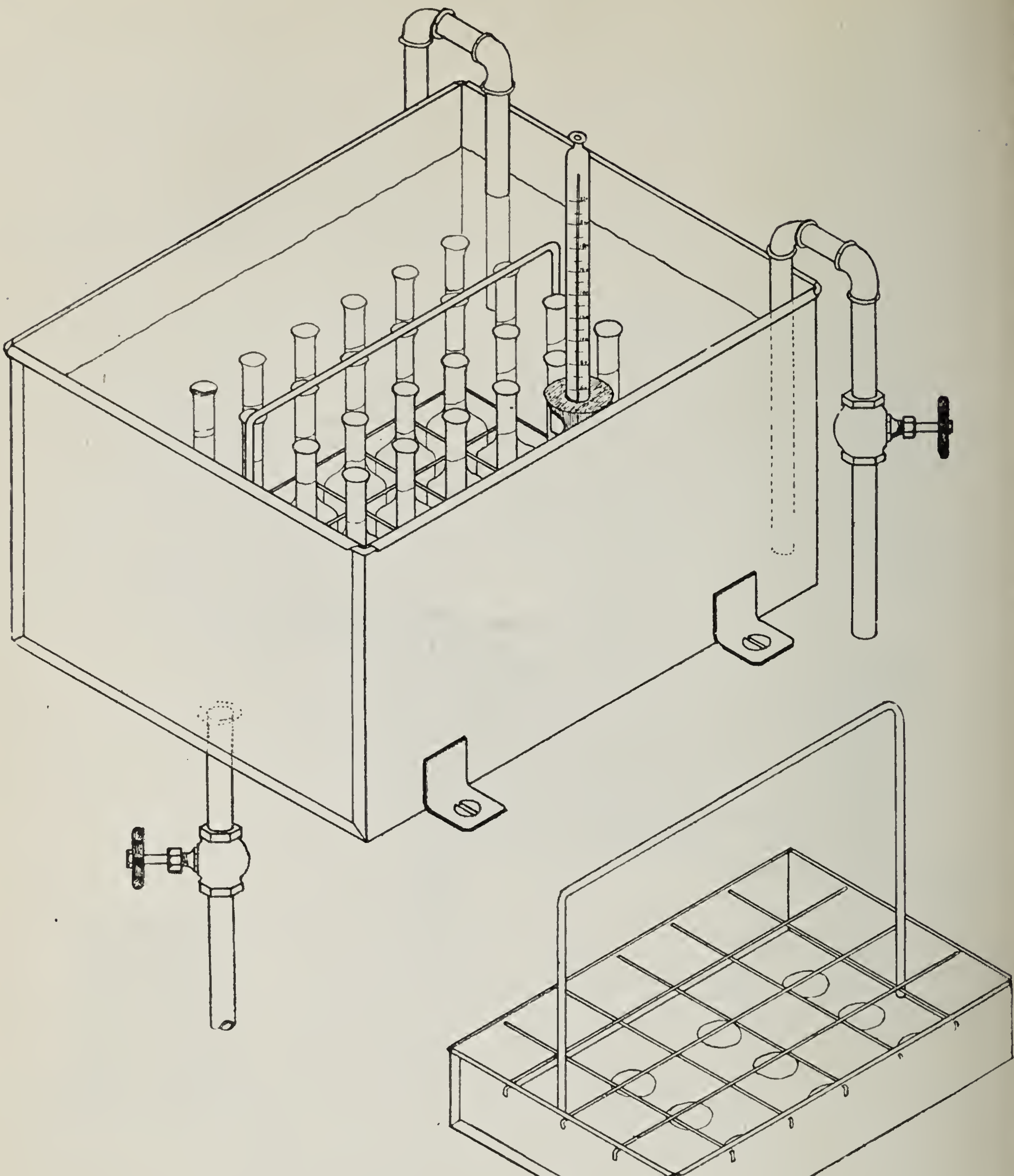
12. A water bath is necessary, especially so in case of hand testers, to maintain or bring the temperature of the tests between 120 and 130 degrees F. until read.

13. Test bottle brushes are necessary for cleaning bottles in which the dirt sticks badly.

14. Brushes for milk cans should be on hand so that all cans used and returned may be kept in a clean, sanitary condition.

15. Sample jars should have air-tight covers to prevent evaporation. As a matter of convenience they must be wide-mouthed and have a capacity for at least two tests. A half more jars are needed than the greatest number of patrons likely to deliver cream any one day.

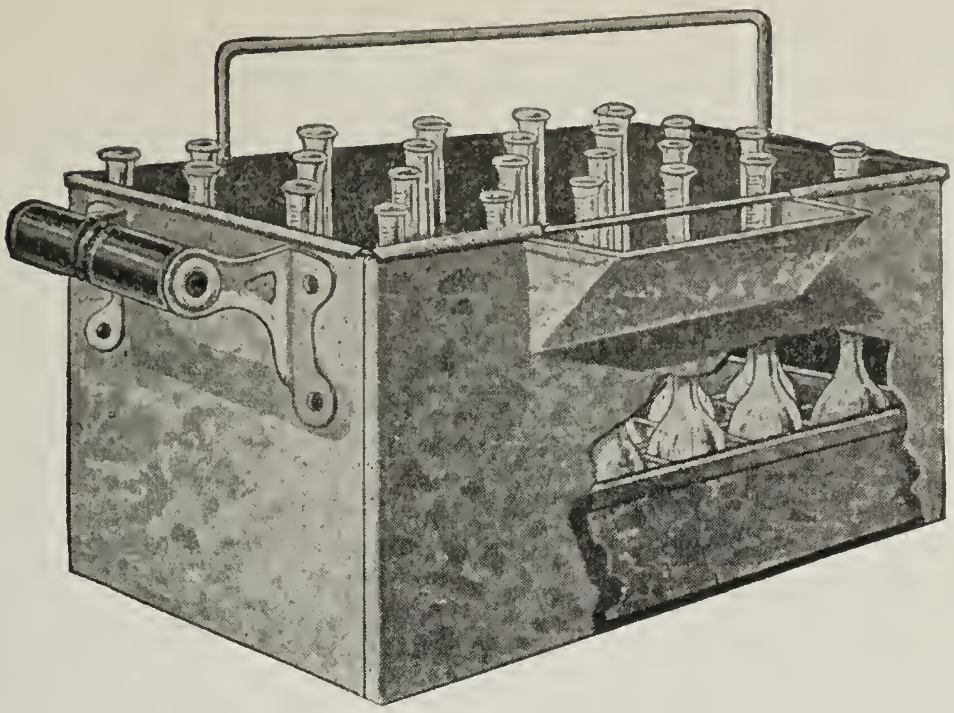
16. Cream test bottles are graduated to read the percent of fat according to their size; that is, 18 gram or 9 gram.



Improved water bath, showing water and steam inlet, drain, thermometer and basket holding twenty-four test bottles. Length, fourteen inches; width eleven inches; height, eight and one-quarter inches. The water should reach the top of the fat column in the test bottles.

The basket accomodating twenty-four test bottles. Length, nine and one-half inches; width six and one-half inches.

(Indiana Circular No 42.)



Water bath

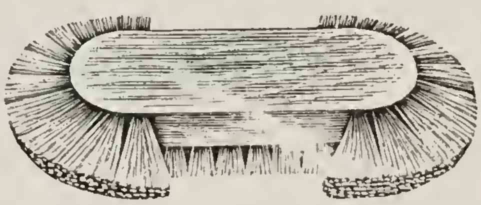
The best style of bottle is known as the "Standard Cream," since it is recommended by the Dairy Instructors Association and the U. S. Bureau of Standards. It is 6.5 inches high and has scale graduation to .5 per cent.

17. A dairy thermometer floats upright, being weighted on lower end, and generally reads 32 degrees F. up.

18. A mineral washing powder is the only effective cleaner for station work. Soap will not do the work required.

19. A waste jar provided with a wood cover bored full of ⅞-inch holes is the most convenient method of disposing of the test when

Bottle brush



Can brush

finished. The test bottles may be inverted by inserting the necks of the bottles in holes and left to drain. The jar should be of earthenware because the sulphuric acid will eat up or destroy all metals and enamels.

## LICENSES, EXAMINATIONS AND INSPECTIONS.

*(Procedure of the State Dairy Commission, Fort Collins. Copies of the state dairy laws may be obtained from the Commission.)*

In section 9 of the Colorado Dairy Laws provision is made requiring that any person desiring to sample or test milk, cream, or other dairy products for the purpose of determining the value of such products when bought and sold, must hold a license granted by the state dairy commissioner.

All newly employed operators, whether samplers or testers, must have their applications in to the state dairy commissioner's office not later than seven days from the date of starting operations, provided they do not already hold a license of this state.

*How to Make Applications for and Take Examinations.*—Write to the State Dairy Commissioner, Fort Collins, Colorado, giving the name and address of a Justice of the Peace or Notary Public, before whom the required examination can be taken. As soon as an application so made and directed has been received at the commissioner's office, a notice will at once be sent to the applicant to appear before the justice or notary named not later than seven days from the date given upon said notice.

As soon as the examination has been taken and the same returned to the justice or notary giving the examination, the papers will be gone over carefully and graded. If a passing grade is earned, a license will be issued and a notice of issuance of license and grade made will be sent on the same day the permit is mailed. If the grade is below passing, a notice of failure will be sent to the party failing, giving reasons and causes of failure. Another examination for testers license will not be given the same individual within 90 days of the date of failure.

Wherever a license has been issued, inspection may be expected to follow at a later date for the special purpose of gaining a knowledge of the operator's actual knowledge of the practical side of his work and methods used. Should such inspection show that the operator does not thoroughly understand his business, and that the station is unsanitary, or if the permit held is not in a conspicuous place, or if other provisions of the dairy law are violated, the permit will be cancelled and the station closed.

All applicants for examination must be at least sixteen years of age, and must have tested, prior to the time of their application at least twelve samples of milk or cream under the supervision of a person holding a license or a field superintendent and according to the directions printed in this bulletin.

Licenses are good for one year and may be renewed at the end of that time by application.

All applications for renewals of licenses must be accompanied by the number of the license held.

Licenses are not transferable; neither is it lawful for any person to sample and test under another person's license.

Examination questions will cover the contents of this bulletin.

*Substitutes.*—Whenever substitutions are made, the station operator is held responsible for the sampling and testing done, and in no case shall a substitute be allowed to test or sample for more than seven days from the date of starting operations without having his application for a license in the dairy commissioner's office within that time limit.

The best way of solving the substitution problem when substitution is made necessary by sickness or important business at a distance, is to have some member of the family or helper hold a license so that they may readily fill the vacancy made by such unexpected absence.

No fee is charged for the granting of a license.

*Inspections.*—Provision is made by law for the inspection of all places where dairy products are handled or produced. In making inspections of cream stations, a written report of conditions found, with recommendations, will be given the operator, a second copy of the inspection report will be sent the creamery or company represented, and a third will be kept on file in the commissioner's office.

As soon as possible a plan of scoring stations will be followed, similar to that now in use in many other states.* Following are the points considered in scoring:

**I. External Appearance. Points allowed, 10.**

The outside portion of the station should be neat and clean in appearance and provided with some sort of porch and platform. If a frame building, it should be painted.

*Kansas Bulletin No. 3.

**II. Neatness of Surroundings. Points allowed, 10.**

The surroundings of a cream station should be sanitary in every sense of the word, as cream readily absorbs any undesirable odors, and decayed substances harbor flies. Stations should not be located within fifty feet of chicken yards, hog pens or other objectionable buidings or open into rooms in which oils, poultry, eggs or other strongly flavored products are handled.

**III. General Equipment. Points allowed, 10.**

All necessary equipment for making lawful tests shall be provided for each station, and operator's license must occupy a conspicuous place on the wall.

**IV. Freedom from Flies. Points allowed, 10.**

Stations must be provided with protection against flies.

**V. Neatness of Interior. Points allowed 10.**

A well arranged, neat station facilitates the operator's work. Suitable places must be provided for bottles, scales, etc., and articles kept therein.

**VI. Walls and Ceilings. Points allowed, 10.**

Walls and ceilings should be finished with a hard surface cement when possible. Tight fitting boards painted in some light color are next in desirability. The surface must be kept clean and free from dirt.

**VII. Cleanliness of Floors. Points allowed, 10.**

The desirable station floor should be of cement, which can easily be kept clean. Tight-fitting, well painted boards are satisfactory, and must be kept free from dirt at all times.

**VIII. Cleanliness of Utensils. Points allowed, 10.**

All station utensils must be kept scrupulously clean at all times. No excuses will be accepted. Stirring rod, sample jars, bottles, and all vessels coming in contact with the cream must be washed thoroughly each day. The personal appearance of the workmen also figures here.

**IX. Ventilation and Light. Points allowed, 10.**

A station should have at least one-fifth as much window as floor space. Sunlight is an excellent disinfectant, and light is necessary if the operator is to do efficient work. Whenever possible the building should have openings on at least two sides. A cool room is essential for keeping good cream.

**X. Drainage. Points allowed, 10.**

A station should be located on a well drained, slightly elevated spot, sloping away from the station in all directions.

By the above method of scoring and inspection, which will also take into consideration the examination for license passed, cream stations will be graded into three classes. A clean, attractive station, provided with a full equipment and scoring 85 per cent or better at the time of inspection, will be graded "A Class", and the letter "A" will be so stamped in bold face type beside the seal upon the license.

If the station scores between 70 per cent and 85 per cent, it will be graded second class, or in class B, and the letter "B" will be stamped upon the license in the same position as given for letter "A." Should the station score less than 70 per cent, or show evidence of neglect or carelessness on the part of the operator, but show no violation of law, it will be rated third class, and the letter "C" will be stamped in bold face type upon the license.

All stations rated in C class will be given a written notice of a time limit set for them to make the A or B class. If, upon inspection after the time limit has expired, they do not make either of these two classes they will be closed.

Where the station is unsanitary, the license held is not posted in a conspicuous place, or other provisions of the dairy law are violated, the license will be cancelled and the station closed.

The purpose of this system is to improve the quality of Colorado cream by raising the standard of cream production and cream handling.

The dairies furnishing the cream going into these stations will be scored in much the same manner, and by building up the places of handling and the places of production of cream together, a far superior product of butter will be produced. The production of a high grade butter in this state means an increased demand, and in turn increased demands mean larger profits for all concerned in supplying such a market.

ACKNOWLEDGMENT

Acknowledgment is hereby made to The Wagner Glass Works, The Creamery Package Manufacturing Company, E. H. Sargent & Co., J. G. Cherry & Co. and A. H. Reid Creamery and Dairy Supply Company, for their kindness in supplying most of the electrotypes for this bulletin.

## INDEX.

Bulletin 203 December, 1914

# The Agricultural Experiment Station

OF THE

## Colorado Agricultural College

# FARM COSTS ON THE COLORADO AGRICULTURAL COLLEGE FARM

*By ALVIN KEYSER*

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

# The Agricultural Experiment Station

FORT COLLINS, COLORADO

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# FARM COSTS ON THE COLORADO AGRICULTURAL COLLEGE FARM

*By Alvin Keyser.*

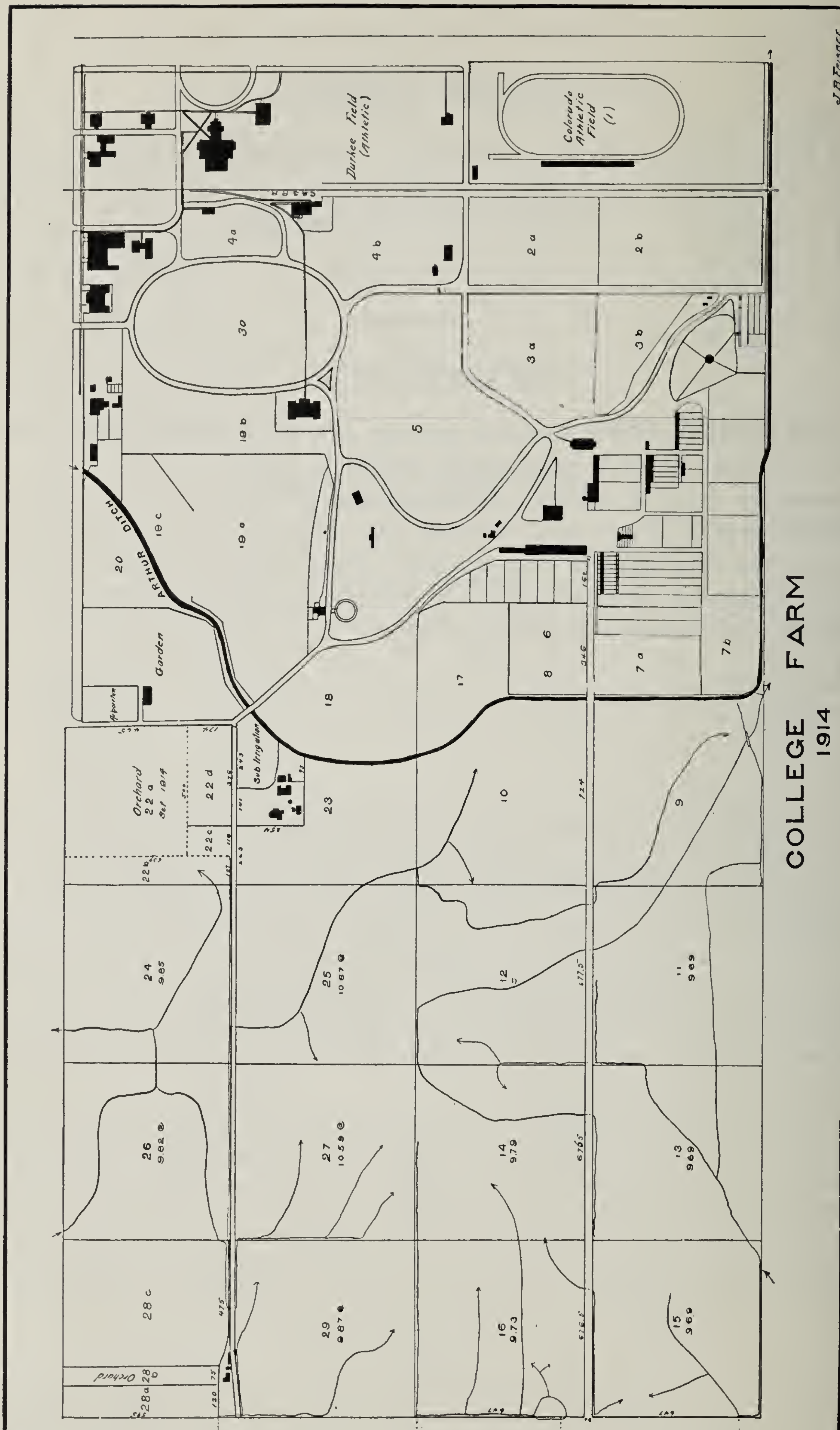
## INTRODUCTION.

It is the common opinion among practical farmers and others that a college farm is necessarily expensive; that its operations are necessarily done at a loss. That opinion prevailed at the Colorado Agricultural College and thruout the state at the time the work outlined in this bulletin was started. The Thirtieth Report (1908) of the Colorado State Board of Agriculture reported College Farm receipts and disbursements as follows:

| | Receipts | Disbursements |
|---|---|---|
| 1907 | $ 77.30 | $ 7,537.65 |
| 1908 | 438.12 | 8,901.09 |
| | $515.42 | $16,438.74 |

Apparently from the report of the State Board of Agriculture, the College Farm was an exceedingly expensive institution. When, however, it is considered that during this period the farm acted as a general service bureau to the institution, and that the only receipts credited to the farm were for grain and hay sold to outside parties in excess of what was required to feed the animals of the various likestock departments, it becomes apparent at once why the disbursements were so heavy in excess of the receipts. In other words,

* *Note*—ACKNOWLEDGMENT: The first farm manager was Prof. H. M. Bainer, to whom a great deal of credit is due in starting the farm cost system in March, 1910, when the work was first authorized by the State Board of Agriculture. Mr. Bainer remained in charge of the work until July, 1910, since which time the work has been in charge of the writer. Under the conditions of college service, it would have been impossible to have carried the work to as successful a conclusion as it has been carried without the services of an efficient farm superintendent to execute the policies decided upon by the Farm Manager. Great credit is due Mr. William O'Brien, Farm Superintendent, for constant and efficient service, a great deal of which has made possible the present state of completion. Mr. Carl Morse has rendered valuable assistance in the preparation of the tabular matter and in repeated checking of tabular results. All computations have either been done or checked on adding and other computing machines. It is hoped this has reduced the errors to a minimum. The original daily summaries have been prepared by the clerical force in the office of the Farm Manager. Credit is due Miss Edith Weldon for her services in the preparation of this part of the system.


COLLEGE FARM
1914
Durkee Field (Athletic)
Colorado Athletic Field (1)
ARTHUR DITCH
Garden
Orchard 22 a Set 1914
Sub Irrigation
Orchard
J. B. Fragee

the receipts represented excess produce marketed upon the city markets.

The Thirty-second Report of the State Board of Agriculture reported College Farm receipts and disbursements as follows:

| | Receipts | Disbursements |
|---|---|---|
| 1909 | $1,721.73 | $6,790.21 |
| 1910 | 7,640.61 | 9,955.73 |
| | $9,362.34 | $16,745.94 |

A careful study of the years 1909 and 1910 will show differences existing previous to and at the time of the inauguration of the present system of cost accounts. The present system was started in March, 1910. While these figures show only $9,362.34 receipts, a figure considerably less than the disbursements, they show a marked increase. Even these figures do not represent the true state of affairs, because they only record transactions which pass thru the Secretary's office and for which cash was actually paid. Transfers and produce used by the farm itself do not appear in the report of the Secretary to the Board.

A careful study of these figures will show that the disbursements of the farm for the biennial period, 1907 and 1908, are almost identical with the disbursements in the biennial period 1909 and 1910. The receipts in the second period have enormously increased. A careful business statement of all that transpired would make a more favorable showing for the College Farm, but it is not deemed as important as the data on the cost of producing crops and the cost of various farm operations. Accordingly such statement is not included at this time.

The conditions that existed in 1910, when the present system of keeping cost accounts on the College Farm was inaugurated, was essentially as follows: The College Farm raised produce which was fed to animals in the Animal Husbandry Department and to the horses in the co-operative Government-State Carriage Horse Breeding Experiments. Such produce was not credited as a farm receipt. But the sale of animals from the other departments was accounted as a receipt and the differences in the prices which were received for animals and the labor cost was put down for a profit in those cases where the animals were exclusively fed upon farm produce. If the College Farm force performed labor upon the campus, upon the roads and drives, or for other departments they received no compensation therefor and this labor service, which was in no way connected with the operations of the farm, became one of the items of expense publicly charged against the College Farm. Realizing that this system was unfair, a change was inaugurated. A Farm Manager was appointed and a system of cost accounting started in March, 1910.

One of the first things done was to divide the enterprises of the farm into two separate classes; those operations and costs directly chargeable to the growth and care of crops in the field; and second, a subdivision which covered all those classes of labor and other expenses classifiable under the heading of labor service. Thus the farm labor force performed two functions, farm work, and general institutional work.

The farm was divided up into fields and a corrected map constructed. Each of the fields was given a number or letter. Any expense of any kind put upon the field, whether in money, man or horse labor, or the application of water, was charged to the specific field. A record was kept of the crops growing on each field in order that it might be possible to compute the cost of growing each specific crop in different years. These records were started in March, 1910, and have been kept continuously to date. Records have been worked up in tabular form showing the cost of taking care of each field for each year of the period for which records have been kept. Practically all of the operations in the care of the different crops have been kept separately so that we are able to give the total cost of caring for the field and the total cost of each individual operation performed thereon, such as irrigating, seeding, plowing, harrowing, harvesting, etc. From these data there has been worked out a set of data showing the cost of producing crops. The cost of producing the different individual crops has been tabulated and is included in this publication. It was not thought advisable to print the cost of caring for the different individual fields because it was thought that there would be a greater amount of public interest in the cost of growing alfalfa, beets, pasture, oats and other crops than there would be in the cost of caring for particular fields on the College Farm. Since these fields produced the crops the cost of operating the land for a specific crop is included in the tabular cost of that crop. It is not considered that these data compare directly with the costs that might be obtained upon privately owned farms in the same district. In the first place, the labor of the College Farm is limited to a specific number of hours per day, which is seldom the case upon privately owned farms.

Then again, the College Farm must perform many field operations purely for appearances. These operations do not increase the receipts, but do cost money and man and horse labor. Most privately owned farms would avoid such expenses because they would give no return for capital and labor expended. Aside from these features it is thought that considerable comparison with privately

DAILY LABOR REPORT.

Name........................................ Day........................ Date.......................................19*...

| KIND OF WORK<br>Implements Used, Number of Loads. Give Exact Number of Hours at Each Kind of Work. | Department Worked For | Field | Man Hours | HORSE | |
|---|---|---|---|---|---|
| | | | | Number Used | Hours |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
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| | | | | | |
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REMARKS:

Daily Labor Report Blank used upon the Colorado Agricultural College Farm.

owned farms within the district can be directly made. The method followed can be used.

Owing to the fact that a large number of laborers were employed upon the College Farm, a system of checks was installed. Each man was required to make out a Daily Labor Report slip, showing exactly what he did and where he did it and the number of man and horse hours applied to the different things upon which he worked during the day.

These Daily Labor blanks were turned into the Farm Superintendent each day. The Farm Superintendent carefully checked each slip to see that the proper charges and places of work were recorded upon the slips. All of the slips were summarized upon a daily summary sheet. These summary sheets were then checked by the Farm Manager to insure correctness of charges. The daily summary sheets were used as a basis for the system of accounts kept by the college bookkeeper.

In making charges to the various departments of the college for work done, a uniform rate was agreed upon. The price per man hour was twenty cents and for a horse hour twelve and one-half cents. These figures were purely arbitrary and were agreed upon after a preliminary estimate.

## COST OF MAN LABOR.

In determining the cost of man labor on the College Farm, the total number of man hours for the year divided by the total cost of man labor for the year gave us the man labor cost per hour for the specific year. It will be noticed from a consultation of the table that the cost did not remain uniform in the different years. This may be partially explained from the fact that labor paid by the month will have a variable number of working days within the year. Some years there is more sickness. Some years weather conditions are such as to cut short the hours of labor at certain seasons of the year; then, each monthly employee who has been with the college a year has been permitted a vacation period. All of these factors change the total amount of time which the laborer will put in from year to year. Then in some years, for construction and other purposes, higher priced labor has been employed for short periods.

TABLE. No. 1.
COST OF MAN LABOR ON COLLEGE FARM.

| | 1910 | 1911 | 1912 | 1913 | June 1, '14 | Average for Period |
|---|---|---|---|---|---|---|
| Total No. of hours.. | 33,606½ | 40,244¾ | 55,664¾ | 47,618½ | 18,353 | |
| Total cost of labor... | $6,638.00 | $8,838.00 | $12,219.14 | $11,022.70 | $4,238.00 | |
| Cost per hour ....... | 0.198 | 0.219 | 0.219 | 0.231 | 0.231 | 0.22 |

## COST OF HORSE LABOR.

In determining the cost of horse labor, the entire cost of caring for the horses was included. These costs were subdivided, showing the interest and depreciation on harness and on the barn in which the horses are quartered; the man labor performed for or on the horses; the horse labor for horses; hay, grain, straw, grinding feed, chores, miscellaneous barn supplies, and interest and depreciation on the horses themselves. Where the progeny increased in value this increase in value was deducted from the total of the itemized costs. In other words, the increase in progeny value represents a credit which reduces the total cost of caring for the animals to the amount of the increase.

TABLE No. 2.
COST OF HORSE LABOR.

| ITEM. | 1910 Cost | 1911 Cost | 1912 Cost | 1913 Cost | Total cost for 4 years | 4-year average |
|---|---|---|---|---|---|---|
| Int. and dep. on harness.. | $ 79.02 | $ 51.78 | $ 69.04 | $ 58.76 | $ 258.60 | $ 64.65 |
| Int. and dep. on horse barn | 400.00 | 400.00 | 400.00 | 400.00 | 1,600.00 | 400.00 |
| Man labor .............. | 97.60 | 82.11 | 90.80 | 126.60 | 397.11 | 99.28 |
| Horse labor ............ | 23.40 | 17.60 | 30.28 | 38.11 | 109.39 | 27.35 |
| Hay .................. | 734.84 | 825.57 | 620.04 | 688.08 | 2.868.53 | 717.13 |
| Grain ................ | 808.90 | 1,108.70 | 803.87 | 916.59 | 3,638.06 | 909.51 |
| Straw ................. | 71.21 | 62.26 | 84.14 | 93.50 | 311.11 | 77.78 |
| Grinding ............... | .50 | 2.65 | 5.43 | ........ | 8.58 | 2.86 |
| Chores ................ | 106.85 | 127.94 | 150.50 | 75.10 | 460.39 | 115.10 |
| Supplies ............... | 326.55 | 108.55 | 202.90 | 300.45 | 938.45 | 234.61 |
| Int. and dep. on horses.... | 446.00 | 446.00 | 382.00 | 386.00 | 1,660.00 | 415.00 |
| Total cost per year..... | $3,094.87 | $3,233.16 | $2,839.00 | $3,083.19 | $12,250.22 | $3,063.27 |
| Less value of progeny increase ............... | | 722.00 | 50.00 | 700.00 | 1,472.00 | |
| Net cost per year........ | $3,094.87 | $2,511.16 | $2,789.00 | $2,383.19 | $10,778.22 | |
| Total number horse hours. | 25,876.00 | 30,400.00 | 34,028.00 | 30,730.00 | 121,034.00 | |
| Cost per horse hour....... | 0.120 | 0.083 | 0.082 | 0.078 | 0.09 | |

It will be seen from these figures that it has cost from a minimum of practically eight cents, to a maximum of twelve cents for every horse hour obtained for all kinds of work, or an average of practically nine cents (0.089 cents).

## CROP COSTS.

In determining the cost of growing specific crops for each year the total acreage of that crop upon the College Farm, no matter in what field that growth occurred, was considered. Some of the crops have not been grown the entire period, so that the cost for only a limited number of years in which records have been kept can be given for such crops. Every item of expense and every operation performed upon a specific crop has been taken into account in working up these costs; consequently from year to year the items in the tabulated statements will vary somewhat, because in some years a certain operation was performed which was not performed in all of the other years. In determining the amount to legitimately charge the fields on account of machinery used, the following method was pursued. We can illustrate this method by taking one or two specific instances. In the case of plowing, to determine the machinery cost of plowing in a specific year, the total value of the plows used was taken as a basis. This total value was charged interest and depreciation. The interest, depreciation and repairs were considered to be the total machinery cost for plowing for the particular year under consideration. To get the amount to charge to any specific crop, the total number of acres upon which plows were used was divided into the total machinery cost of plowing. This would give the cost per acre. A charge was then made for the machinery cost based upon the acres which a particular crop occupied for a given year.

These costs are summarized in Table No. 3. In this table are given the entire cost and number of acres upon which the machine was used in each of the four years. The total cost and the acre cost are shown for each of the different machines used. In making up the machinery cost for any particular crop a total is taken of the separate machines used in the production and harvesting of that crop. Those machines which do not enter into the production of the crop in any way are not considered in computing the machinery cost of the crop. Here again, it will be noticed that the overhead charge for machinery is much greater proportionately where the acreage upon which the machine is used is relatively small. The greater the acreage which the machine is made to cover in a given season, the lower the machinery cost per acre. As previously stated, it is considered that the annual cost of farm machines consists in the sum of its depreciation, interest and repairs.

The same method in principle was followed with the use of irrigation water. The total cost of water was divided by the number of acres upon which water was used which would give the acre charge. In this instance the method had to be varied slightly because some fields were only irrigated once, while others were irrigated three times. A unit charge per acre was worked out for a single irrigation. Where a crop received three irrigations, three times the unit charge was placed against the crop.

TABLE No. 3.
COST OF FARM MACHINERY.

Number acres on which machine was used.
Total cost of each machine.
Cost of each machine per acre.

| MACHINE. | 1910 Total acres | 1910 Total cost | 1910 Cost per acre | 1911 Total acres | 1911 Total cost | 1911 Cost per acre | 1912 Total acres | 1912 Total cost | 1912 Cost per acre | 1913 Total acres | 1913 Total cost | 1913 Cost per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total value all machinery | | $1,404.77 | | | $1,210.10 | | | $1,096.68 | | | $ 983.18 | |
| Plows and eveners | 116.49 | $ 53.82 | $ 0.462 | 125.23 | $ 45.73 | $0.366 | 102.38 | $ 38.88 | $ 0.380 | 78.73 | $ 32.93 | $ 0.418 |
| Drills | 188.44 | 24.84 | .132 | 128.97 | 20.61 | .160 | 87.68 | 17.83 | .203 | 74.54 | 15.16 | .203 |
| Harrows | 210.35 | 4.60 | .022 | 241.75 | 3.91 | .016 | 145.60 | 3.33 | .023 | 89.98 | 2.83 | .031 |
| Disks | 70.71 | 5.75 | .081 | 12.00 | 4.89 | .407 | 10.35 | 4.16 | .402 | 26.04 | 3.55 | .136 |
| Mowers | 127.94 | 32.20 | .251 | 166.88 | 27.37 | .164 | 163.08 | 23.26 | .143 | 162.50 | 19.78 | .122 |
| Wagons | 272.47 | 3.88 | .014 | 254.88 | 3.54 | .014 | 233.25 | 3.04 | .013 | 288.64 | 2.61 | .009 |
| Manure spreader | 9.25 | 63.25 | 6.838 | 124.89 | 53.77 | .431 | 86.05 | 45.59 | .530 | 38.29 | 38.87 | 1.015 |
| Binders | 128.6 | 66.70 | .519 | 102.35 | 55.55 | .543 | 65.79 | 75.96 | 1.156 | 41.69 | 67.86 | 1.628 |
| Rakes | 127.94 | 31.05 | .243 | 166.88 | 26.39 | .158 | 163.08 | 22.43 | .137 | 162.50 | 19.12 | .118 |
| Leveler and grader | 12.66 | 5.01 | .396 | 79.55 | 4.25 | .053 | 38.40 | 3.56 | .093 | 30.62 | 3.08 | .101 |
| Ditcher | 128.60 | 0.34 | .003 | 102.35 | 0.29 | .003 | 65.72 | .25 | .004 | 41.69 | 0.21 | .005 |
| Shovels—irrigating | 288.77 | 2.76 | .010 | 288.77 | 2.35 | .008 | 288.77 | 1.99 | .007 | 288.77 | 1.69 | .006 |
| Forks—hay | 272.47 | 1.38 | .005 | 254.88 | 1.17 | .005 | 233.25 | .99 | .004 | 228.64 | .86 | .004 |
| Rollers | 88.18 | 10.35 | .117 | 5.00 | 8.80 | 1.760 | | Not used. | | 17.00 | 6.33 | .372 |
| Scythes | 49.40 | 1.96 | .040 | 235.20 | 1.74 | .007 | 25.75 | 1.40 | .054 | 0.70 | 1.17 | 1.671 |
| Cultivators | .7 | 1.15 | 1.64 | 11.70 | 0.98 | .08 | 14.00 | .83 | .06 | 9.00 | 0.71 | .08 |
| Beet knives and forks | | | | 2.00 | 1.98 | .99 | 4.50 | 1.62 | .36 | ....... | ........ | ....... |
| TOTALS | 2,092.97 | $ 309.04 | $ 10.773 | 2,203.28 | $ 263.32 | $ 5.165 | 1,727.63 | $ 245.12 | $ 3.596 | 1,579.33 | $ 216.76 | $ 5.919 |
| Total average cost per acre of all machinery | | 0.15 | | | 0.12 | | | 0.14 | | | 0.14 | |

The same method was followed in obtaining the machinery cost of harrowing. Where the harrow was used only once, the charge would be only one-third as large as where the harrow was used three times for a particular crop. It is thought that this method has resulted in a fair distribution of the expense of the different specific crops, as each crop was made to share its proportion of the total cost for that particular charge.

### *Cost of Growing Alfalfa.*

With alfalfa, a perennial crop, it is recognized that two separate sets of conditions were to be met: first, the cost of caring for alfalfa already established, commonly called *old alfalfa;* and second, the cost of starting, establishing and caring for new or young alfalfa. Table No. 4 gives the separate and total cost of caring for established or old alfalfa.

Table No. 5 gives the cost of establishing new alfalfa. The cost of establishing alfalfa varies quite markedly, because of seasonal conditions. With the weather just right a stand can be established much easier and more cheaply than when difficult weather conditions are to be met. In the case of certain fields, due to the fact that at least two and sometimes three failures occurred before a stand was obtained, the cost was markedly increased.

These separate costs have been further computed to show a total cost and cost per ton of growing alfalfa in the different years. These figures are presented in Table No. 6. It will be noted by checking up the figures in the different tables that the cost per ton very greatly increased in years of poor yield, and fell off markedly in years of high yield. In other words, acreages considered, the total cost of producing alfalfa remained remarkedly uniform; the cost per ton, however, went up and down with the yield of crop produced.

TABLE No. 6.
TOTAL COST AND COST PER TON OF ALFALFA.

| Year | Tons | Total Cost | Cost per Ton |
|---|---|---|---|
| 1910 .......................... | 192.43 | $ 980.78 | $5.10 |
| 1911 .......................... | 361.59 | 1,623.24 | 4.49 |
| 1912 .......................... | 439.29 | 1,699.76 | 3.87 |
| 1913 .......................... | 444.85 | 1,608.37 | 3.62 |

Table No. 7 brings out this comparison very well, because it shows the total yield of alfalfa and the yield per acre for each year.

## TABLE No. 4.
### COST OF MAINTAINING OLD ALFALFA.

**1910—75.89 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | ...... | ...... | ...... | ...... | $100.16 |
| Manuring | ...... | ...... | ...... | ...... | ...... | ...... |
| Plowing | ...... | ...... | ...... | ...... | ...... | ...... |
| Harrowing | 27 | $ 5.40 | 63 | $ 7.87 | $ 1.02 | 14.29 |
| Leveling | ...... | ...... | ...... | ...... | ...... | ...... |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 2.5 | 0.50 | 5 | 0.62 | 1.44 | 2.56 |
| Seed | ...... | ...... | ...... | ...... | ...... | 4.75 |
| Weeding | 6 | 1.20 | 2 | 0.25 | 1.20 | 2.65 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 208 | 41.60 | 3 | 0.37 | 0.68 | 42.65 |
| Harvesting | 1,390 | 278.00 | 1,492 | 186.51 | 38.92 | 503.43 |
| TOTALS | 1,633.5 | $ 326.7 | 1,565 | $ 195.62 | $ 43.26 | $ 670.49 |
| COST PER ACRE | 21.52 | 4.3 | 20.62 | 2.58 | 0.57 | 8.84 |

**1911—119.78 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | ...... | ...... | ...... | ...... | $ 176.43 |
| Manuring | 71 | $ 14.20 | 112 | $ 14.00 | $ 4.18 | 32.38 |
| Plowing | ...... | ...... | ...... | ...... | ...... | ...... |
| Harrowing | 75.5 | 15.10 | 151 | 18.87 | 2.34 | 36.31 |
| Leveling | 2.5 | 0.50 | 5 | 0.62 | 0.22 | 1.34 |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 27.25 | 5.45 | 50.5 | 6.31 | 7.64 | 19.40 |
| Seed | ...... | ...... | ...... | ...... | ...... | 62.05 |
| Weeding | 60.5 | 12.10 | 47 | 5.87 | 0.64 | 18.61 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 772.5 | 154.50 | ...... | ...... | 1.00 | 155.50 |
| Harvesting | 2,244 | 448.80 | 2,054 | 256.77 | 40.63 | 746.20 |
| TOTALS | 3,253.25 | $ 650.65 | 2,419.5 | $ 302.44 | $ 56.65 | $1,248.22 |
| COST PER ACRE | 27.16 | 5.43 | 20.19 | 2.52 | 0.47 | 10.42 |

**1912—137.63 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | ...... | ...... | ...... | ...... | $ 91.29 |
| Manuring | 440 | $ 88.00 | $ 590 | $ 73.75 | $ 22.54 | $ 184.29 |
| Plowing | 61 | 12.20 | 169 | 21.13 | 10.32 | 43.65 |
| Harrowing | 24 | 4.80 | 49 | 6.12 | 1.18 | 12.10 |
| Leveling | 2 | 0.40 | 4 | 0.50 | 1.54 | 2.44 |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 10 | 2.00 | 20 | 2.50 | 6.67 | 11.17 |
| Seed | ...... | ...... | ...... | ...... | ...... | 6.17 |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 75.4 | 150.80 | 8 | 1.00 | 1.03 | 152.83 |
| Harvesting | 3,103 | 620.60 | 2,387.5 | 298.43 | 38.66 | 957.69 |
| TOTALS | 3,715.4 | $ 878.80 | 3,227.5 | $ 403.43 | $ 81.94 | $1,461.63 |
| COST PER ACRE | 27.0 | 6.38 | 23.45 | 2.93 | 0.60 | 10.62 |

**1913—112.24 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | ...... | ...... | ...... | ...... | $ 172.64 |
| Manuring | 30 | $ 6.00 | 40 | $ 5.00 | $ 19.71 | 30.71 |
| Plowing | ...... | ...... | ...... | ...... | ...... | ...... |
| Harrowing | ...... | ...... | ...... | ...... | ...... | ...... |
| Leveling | ...... | ...... | ...... | ...... | ...... | ...... |
| Rolling | 5 | 1.00 | 15 | 1.88 | 2.75 | 5.63 |
| Drilling | 5 | 1.00 | 10 | 1.25 | 1.50 | 3.75 |
| Seed | ...... | ...... | ...... | ...... | ...... | 9.00 |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 387 | 77.40 | ...... | ...... | 0.76 | 78.16 |
| Harvesting | 2,489 | 497.80 | 2,492 | 311.50 | 31.96 | 841.26 |
| TOTALS | 2,916 | $ 583.20 | 2,557 | $ 319.63 | $ 56.68 | $1,141.15 |
| COST PER ACRE | 25.98 | 5.19 | 22.78 | 2.85 | 0.50 | 10.16 |

## TABLE No. 5.
### COST OF ESTABLISHING NEW ALFALFA.

**1910—25.75 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 34.06 |
| Manuring | ...... | ...... | ...... | ...... | ...... | ...... |
| Manure | ...... | ...... | ...... | ...... | ...... | ...... |
| *Plowing | ...... | ...... | ...... | ...... | ...... | ...... |
| Harrowing | 2 | 0.40 | 4 | 0.50 | 0.36 | 1.26 |
| Leveling | ...... | ...... | ...... | ...... | ...... | ...... |
| Rolling | 3.5 | 0.70 | 7 | 0.88 | 1.90 | 3.48 |
| Disking | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 29.5 | 5.90 | 5.9 | 7.37 | 3.40 | 16.67 |
| Seed | ...... | ...... | ...... | ...... | ...... | 66.66 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 195 | 39.00 | 1 | 0.13 | 0.26 | 39.39 |
| Harvesting | 154.5 | 30.90 | 191 | 23.88 | 12.40 | 67.18 |
| TOTALS | 384.5 | $ 76.90 | 262 | $ 32.76 | $ 18.32 | $ 228.70 |
| COST PER ACRE | 11.83 | 2.99 | 10.17 | 1.27 | 0.71 | 8.88 |

**1911—21.6 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 32.40 |
| Manuring | ...... | ...... | ...... | ...... | ...... | ...... |
| Manure | ...... | ...... | ...... | ...... | ...... | ...... |
| *Plowing | 104.5 | 20.90 | 248.5 | 31.07 | 7.91 | 59.88 |
| Harrowing | 33 | 6.60 | 82.5 | 10.33 | 0.35 | 17.28 |
| Leveling | 13 | 2.60 | 39 | 4.87 | 1.15 | 8.62 |
| Rolling | 1 | 0.20 | 2 | 0.25 | 8.80 | 9.25 |
| Disking | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 90.5 | 18.10 | 58 | 7.25 | 346 | 28.81 |
| Seed | ...... | ...... | ...... | ...... | ...... | 57.57 |
| Ditching | 7 | 1.40 | 14 | 1.75 | 0.05 | 3.20 |
| Weeding | 70 | 14.00 | 59 | 7.37 | 0.16 | 21.53 |
| Irrigating | 78 | 15.60 | ...... | ...... | .17 | 15.77 |
| Harvesting | 104.5 | 20.90 | 68 | 8.50 | 7.37 | 36.77 |
| TOTALS | 501.5 | $ 100.30 | 571 | $71.39 | $29.42 | $ 291.08 |
| COST PER ACRE | $23.21 | $4.64 | $26.43 | $3.30 | $ 1.36 | $13.47 |

**1912—20.17 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 12.31 |
| Manuring | 185 | 37.00 | 306 | 38.25 | 5.66 | 80.91 |
| Manure | ...... | ...... | ...... | ...... | ...... | ...... |
| *Plowing | 106 | 21.20 | 272 | 34.00 | 7.66 | 62.86 |
| Harrowing | 16 | 3.20 | 41 | 5.13 | .47 | 8.80 |
| Leveling | 20 | 4.00 | 49 | 6.12 | 1.87 | 11.99 |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... |
| Disking | 9 | 1.80 | 36 | 4.50 | 3.82 | 10.12 |
| Drilling | 25 | 5.00 | 50 | 6.25 | 4.10 | 15.35 |
| Seed | ...... | ...... | ...... | ...... | ...... | 51.37 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 105 | 21.00 | ...... | ...... | 0.15 | 21.15 |
| Harvesting | 378 | 75.60 | 288 | 36.00 | 5.99 | 117.59 |
| TOTALS | 844 | $ 168.80 | 1,042 | $ 130.25 | $ 29.72 | $ 392.45 |
| COST PER ACRE | $42.15 | $8.43 | $52.05 | $6.51 | $1.48 | $19.60 |

**1913—18.19 ACRES.**

| ITEM. | Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 24.56 |
| Manuring | 1 | .20 | ...... | ...... | ...... | .20 |
| Manure | ...... | ...... | ...... | ...... | ...... | ...... |
| *Plowing | 116.5 | 23.30 | 338.5 | 42.32 | 7.60 | 73.22 |
| Harrowing | 34 | 6.80 | 92.5 | 11.55 | .56 | 18.91 |
| Leveling | 27.5 | 5.50 | 67 | 8.38 | 1.84 | 15.72 |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... |
| Disking | 14 | 2.80 | 56 | 7.00 | 1.18 | 10.98 |
| Drilling | 20.5 | 4.10 | 41 | 5.12 | 3.66 | 12.88 |
| Seed | ...... | ...... | ...... | ...... | ...... | 40.93 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 184 | 36.80 | ...... | ...... | .11 | 36.91 |
| Harvesting | 201 | 40.20 | 173 | 21.62 | 4.60 | 66.42 |
| TOTALS | 588.5 | $ 119.70 | 768 | $ 95.99 | $ 19.55 | $ 300.73 |
| COST PER ACRE | $32.62 | $6.52 | $42.57 | $5.32 | $1.84 | $ 16.56 |

*Fall Plowing—No record. This system started March, 1910.

It will be noticed that the cost per ton shown in Table No. 6 is highest in 1910; the yield is also lowest that year. The cost per ton is lowest in 1913; the average yield per acre is likewise highest in 1913.

TABLE No. 7.

TOTAL YIELD AND ACRES WITH YIELD PER ACRE OF ALFALFA.

| Year | Acres | Total Yield in Tons | Yield per Acre in Tons |
|---|---|---|---|
| 1910 .................... | 86.89 | 172.55 | 1.99 |
| 1911 .................... | 124.28 | 363.44 | 2.92 |
| 1912 .................... | 168.00 | 524.35 | 3.12 |
| 1913 .................... | 159.64 | 527.56 | 3.30 |
| Totals.............. | 538.81 | 1,587.90 | |
| Average............ | | | 2.95 |

In Table No. 8 are given the cost in man and horse hours of labor for manuring alfalfa. These costs are reported in man and horse hours on the assumption that the amount of man and horse labor can be directly compared on the College and privately owned farms, while the value of that labor may vary widely between the College and privately owned farms, and may vary widely between privately owned farms in the same and different sections.

TABLE No. 8.

MAN AND HORSE LABOR COST FOR MANURING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.69 | 71 | 7.33 | 112 | 11.56 | 2.92 | 2.51 | 3.96 |
| 1912 | 50.18 | 625 | 12.46 | 896 | 17.86 | 3.12 | 3.99 | 5.72 |
| 1913 | 28.92 | 31 | 1.10 | 40 | 1.5 | 3.30 | 0.33 | 0.46 |
| Totals .. | 88.79 | 727 | | 1,048 | | | | |
| Av. 3 yrs. | | | 8.19 | | 11.8 | 3.16 | 3.85 | 2.67 |

In Table No. 9 are recorded the man and horse hours of labor required to plow land in preparation for seeding alfalfa.

TABLE No. 9.

MAN AND HORSE LABOR COST FOR PLOWING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 5.0 | 45 | 9.00 | 101.5 | 20.3 | 2.92 | 3.08 | 7.17 |
| 1912 | 30.76 | 136 | 4.42 | 362 | 11.77 | 3.12 | 1.41 | 3.77 |
| 1913 | 28.04 | 187 | 6.67 | 546 | 19.47 | 3.30 | 2.05 | 5.90 |
| Totals.. | 63.80 | 368 | | 1,009.5 | | | | |
| Av. 3 yrs. | | | 5.77 | | 15.82 | 3.34 | 1.73 | 4.74 |

Table No. 10 gives the man and horse hour costs for harrowing in preparation for seeding. Table No. 10 also indicates the man and horse hours for harrowing required for the production of a ton of alfalfa hay. Most of the harrowing applied is applied in preparation of the seed bed, but occasionally the crop has been harrowed in fighting insects, killing out weeds or reducing the crust which may have formed on the surface of the alfalfa field.

TABLE No. 10.

MAN AND HORSE LABOR COST FOR HARROWING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 29.07 | 27.00 | 0.93 | 43 | 1.5 | 1.99 | 1.46 | 0.08 |
| 1911 | 95.40 | 86.50 | 0.91 | 177 | 1.86 | 2.92 | 0.31 | 0.62 |
| 1912 | 50.18 | 28.00 | 0.56 | 67 | 1.34 | 3.12 | 0.18 | 0.43 |
| 1913 | 28.04 | 49.50 | 1.77 | 133.5 | 4.76 | 3.30 | 0.54 | 1.44 |
| Totals .. | 202.69 | 191.00 | | 421.5 | | | | |
| Av. 4 yrs. | | | 0.94 | | 2.07 | | 0.32 | 0.72 |

Table No. 11 shows the cost of man and horse labor for leveling in preparation for alfalfa seeding.

TABLE No. 11.

MAN AND HORSE LABOR COST FOR LEVELING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1912 | 20.17 | 20 | 1.00 | 49 | 1.90 | 3.12 | 0.30 | 0.61 |
| 1913 | 28.04 | 40 | 1.40 | 104 | 3.80 | 3.30 | 0.42 | 1.15 |
| Totals ... | 48.21 | 60 | | 153 | | | | |
| Av. 2 yrs. | | | 1.24 | | 3.17 | | 0.31 | 0.98 |

Table No. 12 indicates the man and horse labor cost for disking the alfalfa. Only one year recorded a charge for this item.

TABLE No. 12.

MAN AND HORSE LABOR COST FOR DISKING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1913 | 18.54 | 27.0 | 1.4 | 108 | 5.8 | 3.30 | 0.42 | 1.76 |
| Av. 1 yr. | | | 1.4 | | 5.8 | | 0.42 | 1.76 |

Table No. 13 gives the man and horse labor costs for rolling. This item is only recorded against one year.

TABLE No. 13.

MAN AND HORSE LABOR COST FOR ROLLING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1913 | 5.0 | 5 | 1.00 | 15 | 3 | 3.30 | 0.30 | 0.91 |
| Av. 1 yr. | | | 1.00 | | 3.0 | | 0.30 | 0.91 |

Table No. 14 gives the man and horse labor costs for drilling the alfalfa. The method of seeding employed was drilling.

TABLE No. 14.

MAN AND HORSE LABOR COST FOR DRILLING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 26.59 | 14 | 0.53 | 28 | 1.05 | 1.99 | 0.03 | 0.05 |
| 1911 | 5.00 | 26 | 5.20 | 12 | 1.40 | 2.92 | 1.78 | 0.48 |
| 1912 | 20.17 | 25 | 1.24 | 50 | 2.48 | 3.12 | 0.40 | 0.79 |
| 1913 | 33.04 | 36 | 1.08 | 72 | 2.16 | 3.30 | 0.33 | 0.65 |
| Totals .. | 84.80 | 101 | | 162 | | | | |
| Av. 4 yrs. | | | 1.19 | | 1.91 | 2.95 | 0.42 | 0.68 |

Table No. 15 gives the miscellaneous man and horse labor applied which could not be charged to any of the regular cost items of which we were keeping track. These items include such things as burning weeds, putting out poison bran for grasshoppers and like items.

TABLE No. 15.

MAN AND HORSE LABOR COST FOR MISCELLANEOUS WORK ON ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 48.36 | 12 | 0.25 | 7 | 0.15 | 1.99 | 0.10 | 0.10 |
| 1911 | 95.14 | 128.5 | 1.33 | 137 | 1.50 | 2.92 | 0.48 | 0.51 |
| Totals .. | 143.50 | 140.5 | | 144 | | | | |
| Av. 2 yrs. | | | 0.98 | | 1.00 | | 0.38 | 0.38 |

Table No. 16 records the man and horse labor costs for irrigating alfalfa.

TABLE No. 16.
MAN AND HORSE LABOR COST FOR IRRIGATING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 73.5 | 267.5 | 3.64 | 4 | .05 | 1.99 | 1.83 | .03 |
| 1911 | 113.13 | 717 | 6.34 | | | 2.92 | 2.17 | |
| 1912 | 185.64 | 829 | 4.47 | | | 3.12 | 1.43 | |
| 1913 | 152.8 | 600 | 3.92 | | | 3.30 | 1.82 | |
| Totals .. | 387.55 | 2,172.75 | | 4 | | | | |
| Av. 4 yrs. | | | 4.62 | | | | 1.14 | |

Table No. 17 gives the total man and horse hours for harvesting. It was not attempted, in keeping the record of the harvesting cost, to separate the different items of harvesting, such as mowing, raking, cocking, stacking, etc. All of these items have been lumped together under the broad heading of harvesting.

TABLE No. 17.
MAN AND HORSE LABOR COST FOR HARVESTING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 86.89 | 1,513.5 | 17.42 | 1,658 | 12.18 | 1.99 | 8.75 | 6.12 |
| 1911 | 121.88 | 2,434.5 | 19.97 | 2,235 | 18.34 | 2.92 | 6.83 | 6.28 |
| 1912 | 157.80 | 3,452 | 21.87 | 2,661.5 | 16.87 | 3.12 | 6.91 | 5.41 |
| 1913 | 157.89 | 2,959 | 18.74 | 2,906 | 18.40 | 3.30 | 5.68 | 5.58 |
| Totals .. | 524.46 | 10,359 | | 9,460.5 | | | | |
| Av. 4 yrs. | | | 19.75 | | 18.04 | | 6.72 | 6.13 |

Table No. 18 summarizes these costs and indicates the cost in man and horse labor for the production of alfalfa, giving the values in total per acre and per ton of hay produced. In years of heavy

TABLE No. 18.
MAN AND HORSE LABOR COST FOR RAISING ALFALFA.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 95.09 | 1,885.5 | 19.82 | 1,779 | 18.71 | 1.99 | 9.96 | 9.40 |
| 1911 | 113.13 | 3,222.5 | 28.49 | 2,503 | 21.72 | 2.92 | 9.76 | 7.44 |
| 1912 | 141.8 | 4,664 | 32.89 | 3,958 | 27.91 | 3.12 | 10.54 | 8.95 |
| 1913 | 150.28 | 3,756 | 24.99 | 3,742 | 24.90 | 3.30 | 7.57 | 7.55 |
| Totals .. | 500.30 | 13,528.00 | | 11,982.00 | | | | |
| Av. 4 yrs. | | | 27.03 | | 23.95 | | 9.28 | 8.21 |

rainfall, where a considerable amount of hand turning is made necessary because hay gets caught in the rains, the man labor cost per ton rises. The lowest man labor cost recorded happened in the years where there was the least interference during haymaking from untoward weather conditions.

### *Cost of Growing Cabbage.*

Cabbage was grown two seasons to feed to livestock. During these two seasons costs were kept of the different items. These are recorded in detail in Table No. 19.

(See page 18.)

### *Cost of Growing Corn Silage.*

Corn silage has been grown for three years under irrigated conditions. The cost in man labor, horse labor and machinery charges, together with the value of man and horse labor at the standard charge prices is given in Table No. 20. In the succeeding detailed tables of specific items of cost are presented the acre and ton costs in money and labor.

Table No. 21 gives the total yields and costs, with yield per acre and cost per ton of silage. The yields recorded seem to be relatively low. They probably represent an average of local conditions. Experimentally, much higher yields have been obtained. These, however, have not been included in the general farm costs. The average cost per ton to place corn silage in the silo for the three-year period is $4.49, counting the man labor at twenty cents per hour, horse labor at twelve and a half cents an hour, and the machinery cost after the method and in the amounts indicated in Table No. 20.

TABLE No. 21.
TOTAL YIELD AND COST, WITH YIELD PER ACRE AND COST PER TON OF CORN SILAGE.*

| Year | Acres | Total Yield in Tons | Tons Per Acre | Total Cost | Cost per Ton |
|---|---|---|---|---|---|
| 1911 .................... | 9.0 | 68.626 | 7.65 | 188.84 | 2.75 |
| 1912 .................... | 9.0 | 67.313 | 7.48 | 235.71 | 3.50 |
| 1913 .................... | 9.0 | 68.490 | 7.61 | 269.55 | 3.93 |
| Totals .................. | 27.0 | 204.429 | | 694.10 | |
| Average, 3 years......... | | | 7.57 | | 3.39 |

*NOTE: Cost computed with man labor at rate of 20 cents per hour and horse labor at 12½ cents per hour, the standard charge.

TABLE No. 19.

COST OF GROWING CABBAGE.

| ITEMS. | 1910—0.7 ACRES. | | | | | | 1911—0.7 ACRES. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Man Labor | | Horse Labor | | Machinery | Total | Man Labor | | Horse Labor | | Machinery | Total |
| | Hours | Cost | Hours | Cost | Cost | Cost | Hours | Cost | Hours | Cost | Cost | Cost |
| Water | ........ | $...... | ........ | $...... | $...... | $ 0.92 | ........ | $...... | ........ | $...... | $...... | $ 1.05 |
| Hauling Manure | 28 | 5.60 | 55 | 6.88 | 4.79 | 17.27 | 11 | 2.20 | 22 | 2.75 | 0.30 | 5.25 |
| Manure | ........ | ...... | ........ | ...... | ...... | ........ | ........ | ...... | ........ | ...... | ...... | ........ |
| Plowing | 8 | 1.60 | 24 | 3.00 | 0.32 | 4.92 | 8.5 | 1.70 | 25.5 | 3.31 | 0.28 | 5.29 |
| Harrowing | 3 | 0.60 | 6 | 0.75 | 0.02 | 1.37 | 4 | 0.80 | 10 | 1.25 | 0.01 | 2.06 |
| Marking | ........ | ...... | ........ | ...... | ...... | ........ | 5.5 | 1.10 | 5.5 | 0.69 | ...... | 1.79 |
| Setting Plants | 34.5 | 6.90 | ........ | ...... | ...... | 6.90 | 46.5 | 9.30 | ........ | ...... | ...... | 9.30 |
| *Plants | ........ | ...... | ........ | ...... | ...... | ........ | ........ | ...... | ........ | ...... | ...... | ........ |
| Irrigating | 7.5 | 1.50 | ........ | ...... | 0.01 | 1.51 | 18 | 3.60 | 4 | 0.50 | 0.01 | 4.11 |
| Cultivating | ........ | ...... | ........ | ...... | ...... | ........ | 45.5 | 9.10 | 8 | 1.00 | 0.07 | 10.17 |
| Harvesting | 47 | 9.40 | 31 | 3.87 | 0.03 | 13.30 | 62 | 12.40 | 34 | 4.25 | 0.03 | 16.68 |
| Total | 128 | $25.60 | 116 | $ 14.50 | $ 5.17 | $ 46.19 | 201 | $ 40.20 | 109 | $ 13.75 | $ 0.70 | $ 55.70 |

*NOTE: Price paid for plants not included. Plants were purchased by another department and no record kept by them.

| ITEM. | 1913—9 ACRES. | | | | | |
|---|---|---|---|---|---|---|
| | ...abor | | Horse Labor | | Machinery Cost | Total Cost |
| | H | Cost | Hours | Cost | | |
| Water | .. | $...... | ....... | $...... | $...... | $ 12.15 |
| Hauling Manure | ... | 37.20 | 324 | 40.50 | 9.14 | 86.84 |
| Manure | .. | ...... | ....... | ....... | ....... | ........ |
| Plowing | | 10.80 | 147 | 18.37 | 3.76 | 32.93 |
| Harrowing | | 3.60 | 54 | 6.75 | 0.28 | 10.63 |
| Disking | | ...... | ....... | ....... | ....... | ........ |
| Leveling | | ...... | ....... | ....... | ....... | ........ |
| Drilling | | 2.70 | 7 | 0.87 | 1.83 | 5.40 |
| Seed | .. | ...... | ....... | ....... | ....... | 0.50 |
| Cultivating | | 16.80 | 64 | 8.00 | 0.71 | 25.51 |
| Irrigating | | 0.60 | 5 | 0.62 | 0.05 | 1.27 |
| Cutting | | 21.30 | ....... | ....... | ....... | 21.30 |
| Hauling | | 20.30 | 203 | 25.37 | 0.05 | 45.72 |
| Filling Silo | | 27.20 | 4 | 0.50 | ....... | 27.70 |
| Totals | | $ 140.50 | 808 | $ 100.98 | $ 15.82 | $ 269.95 |
| Average per acre | | 15.61 | 89.6 | $ 11.22 | $ 1.75 | $ 29.99 |

TABLE No. 20.
COST OF GROWING CORN SILAGE.

| ITEM. | 1911—9 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ... | $... | ... | $... | $... | $ 13.50 |
| Hauling Manure | ... | ... | ... | ... | ... | ... |
| Manure | ... | ... | ... | ... | ... | ... |
| Plowing | 28 | 5.60 | 84 | 10.50 | 3.29 | 19.39 |
| Harrowing | 19 | 3.80 | 47 | 5.88 | 0.14 | 9.82 |
| Disking | 10 | 2.00 | 40 | 5.00 | 3.66 | 10.66 |
| Leveling | 10 | 2.00 | 25 | 3.13 | 0.47 | 5.60 |
| Drilling | 13 | 2.60 | 26 | 3.25 | 1.44 | 7.29 |
| Seed | ... | ... | ... | ... | ... | 0.50 |
| Cultivating | 85 | 17.00 | 99 | 12.37 | 0.81 | 30.18 |
| Irrigating | 53 | 10.60 | ... | ... | 0.07 | 10.67 |
| Cutting | 135 | 27.00 | ... | ... | ... | 27.00 |
| Hauling | 88 | 17.60 | 176 | 22.00 | 0.13 | 39.73 |
| Filling Silo | 73 | 14.60 | ... | ... | ... | 14.60 |
| Totals | 514 | $ 102.80 | 497 | $ 62.13 | $ 10.01 | $ 188.94 |
| Average per acre | 5.71 | $ 11.42 | | $ 6.90 | $ 1.11 | $ 20.99 |

| ITEM. | 1912—9 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ... | $... | ... | $... | $... | $ 5.49 |
| Hauling Manure | ... | ... | ... | ... | ... | ... |
| Manure | ... | ... | ... | ... | ... | ... |
| Plowing | 60 | 12.00 | 218 | 24.75 | 3.42 | 40.17 |
| Harrowing | 18 | 3.60 | 45 | 5.62 | 0.21 | 9.43 |
| Disking | ... | ... | ... | ... | ... | ... |
| Leveling | ... | ... | ... | ... | ... | ... |
| Drilling | 10 | 2.00 | 20 | 2.50 | 1.83 | 6.33 |
| Seed | ... | ... | ... | ... | ... | 0.50 |
| Cultivating | 139 | 27.80 | 78 | 9.75 | 0.54 | 38.09 |
| Irrigating | 20 | 4.00 | ... | ... | .06 | 4.06 |
| Cutting | 203 | 40.60 | ... | ... | ... | 40.60 |
| Hauling | 113 | 22.60 | 226 | 28.25 | 0.12 | 50.97 |
| Filling Silo | 196 | 39.20 | 7 | .87 | ... | 40.07 |
| Totals | 759 | $ 151.80 | 594 | $ 71.74 | $ 6.18 | $ 253.71 |
| Average per acre | 84.3 | $ 16.86 | 66 | $ 7.87 | $ 0.69 | $ 26.19 |

| ITEM. | 1913—9 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|
| Water | ... | $... | ... | $... | $... | $ 12.15 |
| Hauling Manure | 186 | 37.20 | 324 | 40.50 | 9.14 | 86.84 |
| Manure | ... | ... | ... | ... | ... | ... |
| Plowing | 54 | 10.80 | 147 | 18.37 | 3.76 | 32.93 |
| Harrowing | 18 | 3.60 | 54 | 6.75 | 0.28 | 10.63 |
| Disking | ... | ... | ... | ... | ... | ... |
| Leveling | ... | ... | ... | ... | ... | ... |
| Drilling | 13.5 | 2.70 | 7 | 0.87 | 1.83 | 5.40 |
| Seed | ... | ... | ... | ... | ... | 0.50 |
| Cultivating | 84 | 16.80 | 64 | 8.00 | 0.71 | 25.51 |
| Irrigating | 3 | 0.60 | 5 | 0.62 | 0.05 | 1.27 |
| Cutting | 106.5 | 21.30 | ... | ... | ... | 21.30 |
| Hauling | 101.5 | 20.30 | 203 | 25.37 | 0.05 | 45.72 |
| Filling Silo | 136 | 27.20 | 4 | 0.50 | ... | 27.70 |
| Totals | 702.5 | $ 140.50 | 808 | $ 100.98 | $ 15.82 | $ 269.95 |
| Average per acre | 78.05 | $ 15.61 | 89.6 | $ 11.22 | $ 1.75 | $ 29.99 |

Table No. 22 gives in detail the man and horse labor cost for hauling corn to the silo. These costs seem to be remarkedly uniform throughout the period.

TABLE No. 22.
MAN AND HORSE LABOR COST FOR HAULING CORN TO SILO.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 88 | 9.78 | 176 | 19.56 | 7.65 | 1.28 | 2.56 |
| 1912 | 9.0 | 113 | 12.56 | 226 | 25.11 | 7.48 | 1.68 | 3.36 |
| 1913 | 9.0 | 101.5 | 11.25 | 203 | 22.56 | 7.61 | 1.48 | 2.97 |
| Totals .. | 27.0 | 302.5 | | 605 | | | | |
| Av. 3 yrs. | | | 11.20 | | 22.41 | | 1.47 | 2.96 |

Table No. 23 presents the man and horse labor cost for raising corn silage. These costs are given in total and also the cost per ton. It will be seen that the lowest labor cost for raising the silage was obtained in the first year. 1912 and 1913 required more cultivations because of moister weather conditions which accounts for the slightly higher labor cost.

TABLE No. 23.
MAN AND HORSE LABOR COST FOR RAISING CORN SILAGE.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 514 | 57.11 | 497 | 55.22 | 7.65 | 7.47 | 7.22 |
| 1912 | 9.0 | 739 | 82.11 | 594 | 66.00 | 7.48 | 10.98 | 8.82 |
| 1913 | 9.0 | 702.5 | 77.00 | 808 | 89.78 | 7.61 | 10.12 | 11.80 |
| Totals .. | 27.0 | 1,955.5 | | 1,899 | | | | |
| Av. 3 yrs. | | | 68.70 | | 70.33 | | 8.98 | 9.19 |

Table No. 24 gives in detail the man and horse labor cost for filling the silo.

TABLE No. 24.
MAN AND HORSE LABOR COST FOR FILLING SILO.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 73 | 8.11 | ........ | ........ | 7.65 | 1.06 | ........ |
| 1912 | 9.0 | 196 | 21.78 | 7 | 0.78 | 7.48 | 2.91 | 0.11 |
| 1913 | 9.0 | 136 | 16.22 | 4 | 0.45 | 7.61 | 2.13 | 0.06 |
| Totals .. | 27.0 | 405 | | 11 | | | | |
| Av. 3 yrs. | | | 15.00 | | 0.41 | | 1.98 | 0.05 |

Table No. 25 records the cost in man and horse labor for cutting the corn preparatory to silage making.

TABLE No. 25.

MAN AND HORSE LABOR COST FOR CUTTING CORN.*

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 135 | 11.75 | ........ | ........ | 7.65 | 1.54 | ........ |
| 1912 | 9.0 | 203 | 22.56 | ........ | ........ | 7.48 | 3.02 | ........ |
| 1913 | 9.0 | 106½ | 11.75 | ........ | ........ | 7.61 | 1.54 | ........ |
| Totals .. | 27.0 | 444.5 | | | | | | |
| Av. 3 yrs. | | | 16.46 | | | | 2.03 | |

*NOTE—Cut with corn knives by hand.

Table No. 26 gives the man and horse labor in detail for manuring the land which produced the crop. These data necessarily are limited to the seasons in which manuring was done.

TABLE No. 26.

MAN AND HORSE LABOR COST FOR MANURING SILAGE CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1913 | 9 | 186 | 20.67 | 324 | 36 | 7.61 | 2.72 | 4.73 |
| 1914 | 9 | 489 | 54.33 | 647 | 72 | ** | | |
| Totals .. | 18 | 675 | | 971 | | | | |
| Av. 1 and 2 yrs. | | | 37.5 | | 53.94 | | 2.72 | 4.73 |

**1914 data not complete when going to press.

Table No. 27 gives the cost in man and horse labor for disking the land in preparation for the silage corn. Since this preparation was performed only one year, but one season's result can be presented.

TABLE No. 27.

MAN AND HORSE LABOR COST FOR DISKING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9 | 10 | 1.11 | 40 | 4.45 | 7.65 | 0.15 | 0.58 |
| Av. 1 yr. | | | 1.11 | | 4.45 | | 0.15 | 0.58 |

Table No. 28 gives the man and horse labor cost for leveling, for the sole year in which leveling was done for the silage crop.

TABLE No. 28.

MAN AND HORSE LABOR COST FOR LEVELING LAND FOR CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9 | 10 | 1.11 | 25 | 2.78 | 7.65 | 0.15 | 0.36 |
| Av. 1 yr. | | | 1.11 | | 2.78 | | 0.15 | 0.36 |

Table No. 29 records the man and horse labor cost for the planting process.

TABLE No. 29.

MAN AND HORSE LABOR COST FOR PLANTING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 13 | 1.45 | 26 | 2.89 | 7.65 | 0.19 | 0.38 |
| 1912 | 9.0 | 10 | 1.11 | 20 | 2.22 | 7.48 | 0.15 | 0.30 |
| 1913 | 9.0 | 13.5 | 1.50 | 7 | 0.78 | 7.61 | 0.20 | 0.10 |
| 1914 | 9.87 | 28 | 2.90 | 29 | 2.94 | ** | | |
| Totals .. | 36.87 | 64.5 | | 82 | | | | |
| Av. 4 yrs. | | | 1.75 | | 2.22 | | 0.179 | 0.26 |

**1914 data not completed when going to press.

Table No. 30 gives the man and horse labor costs for plowing and preparation of the seed bed. These costs do not cover the tillage operations required after the corn was planted.

TABLE No. 30.

MAN AND HORSE LABOR REQUIRED FOR PLOWING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9 | 28 | 3.11 | 84 | 9.33 | 7.65 | 0.41 | 1.22 |
| 1912 | 9 | 60 | 6.67 | 218 | 24.22 | 7.48 | 0.89 | 3.24 |
| 1913 | 9 | 54 | 6.00 | 147 | 16.33 | 7.61 | 0.79 | 1.85 |
| 1914 | 9.87 | 64 | 6.48 | 192 | 19.45 | ** | | |
| Totals .. | 36.87 | 206 | | 641 | | | | |
| Av. 4 yrs. | | | 5.59 | | 17.39 | | 0.52 | 1.66 |

**1914 data not completed when going to press.

Table No. 31 gives the man and horse labor costs in harrowing, practically all of which was done previously to planting.

TABLE No. 31.

MAN AND HORSE LABOR COST FOR HARROWING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 76.5 | 8.50 | 129 | 14.33 | 7.65 | 1.11 | 1.87 |
| 1912 | 9.0 | 18 | 2.00 | 54 | 6.00 | 7.48 | 0.27 | 0.80 |
| 1913 | 9.0 | 18 | 2.00 | 45 | 5.00 | 7.61 | 0.26 | 0.66 |
| 1914 | 9.87 | 19 | 1.92 | 47 | 4.75 | ** | ........ | ........ |
| Totals .. | 36.87 | 131.5 | | 275 | | | | |
| Av. 4 yrs. | | | 3.57 | | 7.45 | | 0.41 | 0.84 |

**1914 data not completed when going to press.

The irrigating costs are recorded in Table No. 32.

TABLE No. 32.

MAN AND HORSE LABOR COST FOR IRRIGATING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 53 | 5.89 | ........ | ........ | 7.65 | 0.77 | ........ |
| 1912 | 9.0 | 20 | 2.22 | ........ | ........ | 7.48 | 0.30 | ........ |
| 1913 | 9.0 | 3 | 0.33 | 5 | 0.56 | 7.61 | 0.04 | 0.07 |
| Totals .. | 27.0 | 76 | | 5 | | | | |
| Av. 3 yrs. | | | 2.81 | | 0.19 | | 0.37 | 0.02 |

The labor of cultivation is recorded in Table No. 33.

TABLE No. 33.

MAN AND HORSE LABOR COST FOR CULTIVATING CORN.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Tons | HOURS PER TON | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 9.0 | 85 | 9.45 | 99 | 11.00 | 7.65 | 1.24 | 1.44 |
| 1912 | 9.0 | 139 | 15.45 | 78 | 9.67 | 7.48 | 2.07 | 1.29 |
| 1913 | 9.0 | 84 | 9.33 | 64 | 7.11 | 7.61 | 1.23 | 0.93 |
| Totals .. | 27.0 | 308 | | 241 | | | | |
| Av. 3 yrs. | | | 11.41 | | 8.93 | | 1.51 | 1.18 |

## *Cost of Producing Oats.*

Table No. 34 summarizes the various costs included in the production of the oat crop for the four years, 1910 to 1913, inclusive.

TABLE NO. 34.

COST OF GROWING OATS.

| ITEM. | 1910—101.07 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost | 1911—65.60 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 133.61 | ...... | $...... | ...... | $...... | $...... | $ 90.38 |
| Manuring | ...... | ...... | ...... | ...... | ...... | ...... | 180 | 36.00 | 240 | 30.00 | 4.47 | 70.47 |
| Plowing | 384.5 | 76.90 | 1,145.5 | 143.19 | 46.70 | 266.79 | 401.5 | 80.30 | 1,206.5 | 150.81 | 22.55 | 253.66 |
| Harrowing | 127 | 45.40 | 321 | 40.13 | 2.23 | 67.76 | 103 | 20.60 | 278.5 | 34.79 | 0.99 | 56.38 |
| Rolling | 44 | 8.80 | 161.5 | 20.17 | 7.90 | 36.87 | ...... | ...... | ...... | ...... | ...... | ...... |
| Leveling | 0.5 | 0.10 | 1 | 12 | 0.63 | .85 | 23.5 | 4.70 | 62 | 7.75 | 1.18 | 13.63 |
| Disking | 30 | 6.00 | 120 | 15.00 | 4.50 | 25.50 | ...... | ...... | ...... | ...... | ...... | ...... |
| Hauling Seed | 5 | 1.00 | 10 | 1.25 | ...... | 2.25 | ...... | ...... | ...... | ...... | ...... | ...... |
| Seed | ...... | ...... | ...... | ...... | ...... | 122.92 | ...... | ...... | ...... | ...... | ...... | 66.12 |
| Drilling | 101 | 20.20 | 330.5 | 41.32 | 13.30 | 74.82 | .46 | 9.20 | 181 | 22.62 | 9.85 | 41.67 |
| Ditching | 1 | 0.20 | 2 | 0.25 | 0.04 | .49 | 1 | 0.20 | 2 | 0.25 | 0.03 | 0.48 |
| Weeding | 4.25 | .85 | 1.5 | 0.19 | 0.39 | 1.43 | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 433.5 | 86.70 | 16 | 2.00 | 1.09 | 89.79 | 291.25 | 58.25 | 12 | 1.50 | 0.57 | 60.32 |
| Harvesting | 902 | 180.40 | 720 | 90.00 | 53.69 | 324.09 | 546.5 | 109.30 | 568 | 71.00 | 27.15 | 207.45 |
| Totals | 2,032.75 | $ 406.55 | 2,829 | $ 353.62 | $ 130.47 | $1,147.17 | 1,592.75 | $ 318.55 | 2,550 | $ 318.72 | $ 66.79 | $ 860.56 |
| Average per acre | 20.11 | 4.02 | 27.99 | 3.5 | 1.29 | 11.35 | 24.28 | 4.36 | 38.87 | 4.86 | 1.02 | 31.19 |

| ITEM. | 1912—51.54 ACRES Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost | 1913—26.5 ACRES. Man Labor Hours | Man Labor Cost | Horse Labor Hours | Horse Labor Cost | Machinery Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water | ...... | $...... | ...... | $...... | $...... | $ 127.60 | ...... | $...... | ...... | $...... | $...... | $ 35.78 |
| Manuring | 498 | 99.60 | 801 | 100.13 | 22.09 | 221.82 | 15 | 3.00 | 20 | 2.50 | 10.02 | 15.52 |
| Plowing | 261 | 52.20 | 728 | 91.00 | 20.58 | 163.78 | 185.5 | 37.10 | 523 | 65.38 | 11.08 | 113.56 |
| Harrowing | 87 | 17.40 | 197 | 24.63 | 1.18 | 43.21 | 45.5 | 9.10 | 135 | 16.87 | 0.83 | 26.80 |
| Rolling | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Leveling | 5 | 1.00 | 10 | 1.25 | 1.55 | 3.80 | 55 | 11.00 | 60 | 7.50 | 2.74 | 21.24 |
| Disking | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Hauling Seed | 1 | 0.20 | 2 | 0.25 | ...... | 0.45 | ...... | ...... | ...... | ...... | ...... | ...... |
| Seed | ...... | ...... | ...... | ...... | ...... | 61.74 | ...... | ...... | ...... | ...... | ...... | 31.80 |
| Drilling | 53 | 10.60 | 170 | 21.25 | 10.46 | 42.31 | 24 | 4.80 | 94 | 11.75 | 4.92 | 21.47 |
| Ditching | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Weeding | 2 | 0.40 | ...... | ...... | 0.53 | 0.93 | ...... | ...... | ...... | ...... | ...... | ...... |
| Irrigating | 192 | 38.40 | 2 | 0.25 | 0.41 | 39.06 | 91 | 18.20 | ...... | ...... | 0.16 | 18.36 |
| Harvesting | 310 | 62.00 | 306 | 38.25 | 51.82 | 152.07 | 232 | 46.40 | 169 | 21.13 | 44.86 | 112.39 |
| Totals | 1,409 | $ 281.80 | 2,216 | $ 277.01 | $ 108.62 | $ 856.77 | 648 | $ 129.60 | 1,001 | $ 125.13 | $ 74.61 | $ 396.92 |
| Average per acre | 27.34 | 5.47 | 42.99 | 5.37 | 2.11 | 16.62 | 24.45 | 4.87 | 37.77 | 4.72 | 2.82 | 14.98 |

The detailed distribution of these labor costs are supplied in succeeding tables. Table No. 35 records the man and horse labor costs for drilling oats.

TABLE No. 35.

MAN AND HORSE LABOR COST FOR DRILLING OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | in Bu. | Man | Horse |
| 1910 | 94.75 | 101 | 1.07 | 330.5 | 3.49 | 32⅛ | 0.03 | 0.11 |
| 1911 | 93.85 | 50.5 | 0.50 | 189 | 2.04 | 64 5-6 | 0.01 | 0.03 |
| 1912 | 48.00 | 52 | 1.08 | 152 | 3.17 | 75⅛ | 0.01 | 0.04 |
| 1913 | 41.69 | 44 | 1.06 | 143 | 3.43 | 63 1-6 | 0.02 | 0.05 |
| 1914 | 70.19 | 68 | 0.97 | 241 | 3.43 | ** | | |
| Totals .. | 348.48 | 315.5 | | 1,055.5 | | | | |
| Av. 5 yrs. | | | 0.90 | | 3.02 | | 0.02 | 0.05 |

** 1914 data not complete when going to press.

Table No. 36 records the man and horse labor costs applied to the land when the plowing was done with a tractor. This table is put in at this point to indicate something of the horse requirements even where tractors are used in preparation of the seedbed.

TABLE No. 36.

MAN AND HORSE LABOR COST FOR PLOWING WITH TRACTOR—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | in Bu. | Man | Horse |
| 1913 | 12 | 79 | 6.58 | 42 | 3.50 | 63 1-6 | 0.10 | 0.06 |

The disking and cost for man and horse labor is recorded in Table No. 37.

TABLE No. 37.

MAN AND HORSE LABOR COST FOR DISKING—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | in Bu. | Man | Horse |
| 1910 | 49.33 | 30 | 0.61 | 120 | 2.43 | 32⅛ | 0.02 | 0.07 |
| 1913 | 7.50 | 26 | 3.46 | 98 | 13.07 | 64 5-6 | 0.05 | 0.20 |
| 1914 | 18.67 | 26 | 1.39 | 95 | 5.09 | ** | | |
| Totals .. | 75.50 | 82 | | 313 | | | | |
| Av. 3 yrs. | | | 1.09 | | 4.14 | | 0.03 | 0.11 |

** 1914 data not complete at time of going to press.

Table No. 38 gives these costs for rolling. Rolling is a cost recorded for only two seasons, and those seasons in which the operation was necessary to prepare a desirable seedbed.

TABLE No. 38.

MAN AND HORSE LABOR COST FOR ROLLING FOR OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 61.25 | 44 | 0.72 | 161.5 | 2.64 | 32.5 | 0.02 | 0.08 |
| 1913 | 12 | 9 | 0.75 | 36 | 3.00 | 63 1-6 | 0.01 | 0.05 |
| Totals .. | 73.25 | 53 | | 197.5 | | | | |
| Av. 2 yrs. | | | 0.72 | | 2.69 | | 0.01 + | 0.07 |

The leveling costs are recorded in Table No. 39.

TABLE No. 39.

MAN AND HORSE LABOR FOR LEVELING—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 11.25 | 0.5 | 0.04 | 1 | 0.09 | 32⅛ | ........ | ........ |
| 1911 | 34.93 | 41.5 | 1.19 | 101 | 2.89 | 64 5-6 | 0.02 | 0.04 |
| 1912 | 16.61 | 5 | 0.30 | 19 | 0.60 | 75⅛ | 0.004 | 0.008 |
| 1913 | 26.69 | 55 | 2.06 | 60 | 2.25 | 63 1-6 | 0.03 | 0.03 |
| 1914 | 41.19 | 37 | 0.90 | 105 | ** | | | |
| Totals .. | 130.67 | 139.0 | | 277 | | | | |
| Av. 5 yrs. | | | 1.06 | | 2.12 | | 1.018 | 0.013 |

** 1914 data not complete at time of going to press.

The man and horse labor costs for harrowing, in preparation of the seedbed are given in Table No. 40.

TABLE No. 40.

MAN AND HORSE LABOR COST FOR HARROWING—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 94.75 | 127 | 1.34 | 321 | 3.38 | 32⅛ | 0.04 | 0.11 |
| 1911 | 63.85 | 120.5 | 1.89 | 324.5 | 5.80 | 64 5-6 | 0.02 | 0.08 |
| 1912 | 49.5 | 80 | 1.61 | 179 | 3.61 | 75⅛ | 0.02 | 0.05 |
| 1913 | 41.69 | 94 | 2.25 | 261 | 6.25 | 63 1-6 | 0.04 | 0.10 |
| 1914 | 79.69 | 150 | 1.88 | 376 | 4.72 | ** | | |
| Totals .. | 329.48 | 571.5 | | 1,461.5 | | | | |
| Av. 5 yrs. | | | 1.73 | | 4.44 | | 0.03 | 0.08 |

** 1914 data not complete at time of going to press.

The man and horse labor cost for plowing in preparation for oats is presented in Table No. 41.

TABLE No. 41.

MAN AND HORSE LABOR COST FOR PLOWING FOR OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 65.5 | 364.5 | 5.57 | 1,088 | 16.61 | 32⅛ | 0.17 | 0.52 |
| 1911 | 63.85 | 446 | 6.98 | 1,344 | 21.00 | 64 5-6 | 0.11 | 0.32 |
| 1912 | 49.52 | 261 | 5.27 | 745 | 15.10 | 75⅛ | 0.07 | 0.20 |
| 1913 | 29.69 | 206.5 | 6.90 | 567 | 19.10 | 63 1-6 | 0.11 | 0.30 |
| 1914 | 60.69 | 452 | 7.44 | 1,690 | 27.80 | ........ | ........ | ........ |
| Totals .. | 269.25 | 1,730.0 | | 5,434 | | | | |
| Av. 5 yrs. | | | 6.43 | | 20.82 | | 0.11 | 0.32 |

Table No. 42 records the man and horse labor costs for manuring land to be used for oats.

TABLE No. 42.

MAN AND HORSE LABOR COST MANURING—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1911 | 11.00 | 180 | 16.30 | 240 | 21.73 | 64 5-6 | 0.19 | 0.30 |
| 1912 | 35.15 | 495 | 14.10 | 796 | 26.46 | 75⅛ | 0.02 | 0.03 |
| 1913 | 9.87 | 15 | 1.80 | 20 | 2.02 | 63 1-6 | 0.26 | 0.52 |
| 1914 | 3.00 | 50 | 16.67 | 98 | 32.67 | ........ | ........ | ........ |
| Totals .. | 59.02 | 740 | | 1,154 | | | | |
| Av. 4 yrs. | | | 12.54 | | 19.55 | | 0.17 | 0.27 |

Table No. 43 summarizes the man and horse labor costs for the production of the oat crop, and gives these costs per bushel of oats produced in addition to acre charges.

TABLE No. 43.

SUMMARY OF MAN AND HORSE LABOR COST—OATS (TOTAL TIME).

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 99.75 | 2,033.5 | 20.39 | 2,829 | 28.36 | 32⅛ | 0.63 | 0.88 |
| 1911 | 60.10 | 1,442.25 | 24.00 | 2,276.5 | 37.88 | 64 5-6 | 0.37 | 0.58 |
| 1912 | 45.02 | 1,275 | 28.32 | 2,012 | 44.69 | 75⅛ | 0.38 | 0.59 |
| 1913 | 26.69 | 648 | 24.28 | 1,001 | 37.50 | 63 1-6 | 0.38 | 0.59 |
| Totals .. | 231.56 | 5,398.75 | | 8,118.5 | | | | |
| Av. 4 yrs. | | | 23.31 | | 35.06 | 52.5 | 0.44 | 0.67 |

In the production of any crop there are always some miscellaneous items of labor expense which cannot be conveniently classified under the usual operations. These miscellaneous labor items are given for three years in which they occurred in Table No. 44.

TABLE No. 44.
MISCELLANEOUS MAN AND HORSE LABOR COST FOR OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 80.5 | 30.5 | 0.38 | 71 | 0.88 | 32⅛ | 0.01 | 0.03 |
| 1911 | 49.1 | 129 | 2.63 | 54 | 1.10 | 64 5-6 | 0.04 | 0.02 |
| 1912 | 9.87 | 2 | 0.2 | ........ | ........ | 75⅛ | 0.01— | ........ |
| Totals .. | 147.47 | 161.5 | | 125 | | | | |
| Av. 3 yrs. | | | 1.16 | | 0.90 | | 0.02 | 0.02 |

Table No. 45 records the harvesting costs per acre and per bushel, in man and horse labor.

TABLE No. 45.
MAN AND HORSE LABOR COST FOR HARVESTING OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 94.75 | 902 | 9.52 | 720 | 7.6 | 32⅛ | 0.3 | 0.24 |
| 1911 | 62.35 | 627.5 | 10.07 | 629 | 10.09 | 64 5-6 | 0.16 | 0.16 |
| 1912 | 48.0 | 292 | 6.10 | 279 | 5.81 | 75⅛ | 0.08 | 0.08 |
| 1913 | 41.69 | 358 | 8.59 | 292 | 7.00 | 63 1-6 | 0.13 | 0.11 |
| Totals .. | 246.79 | 2,179.5 | | 1,920 | | | | |
| Av. 4 yrs. | | | 8.83 | | 7.78 | 53.5 | 0.16 | 0.14 |

Table No. 46 presents the man and horse labor costs for irrigation of the oat crop.

TABLE No. 46.
MAN AND HORSE LABOR COST FOR IRRIGATING—OATS.

| Year | Acres | MAN HOURS | | HORSE HOURS | | Average Yield in Bu. | HOURS PER BU. | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per Acre | Total | Per Acre | | Man | Horse |
| 1910 | 94.75 | 434 | 4.58 | 16 | 0.17 | 32⅛ | 0.14 | 0.005 |
| 1911 | 52.1 | 248.75 | 4.77 | 12 | 0.23 | 64 5-6 | 0.07 | 0.004 |
| 1912 | 48.0 | 176 | 3.66 | 2 | 0.4 | 75⅛ | 0.005 | 0.0006 |
| 1913 | 41.69 | 195 | 4.67 | ........ | ........ | 63 1-6 | 0.07 | ........ |
| Totals .. | 236.54 | 1,053.75 | | 30 | | | | |
| Av. 4 yrs. | | | 4.45 | | 0.13 | 53.5 | 0.08 | 0.0027 |

Table No. 47 gives the total yield and total cost, and cost per bushel to produce oats, charging labor at the regular college and

TABLE NO. 49.

COST OF GROWING PASTURE.

| ITEM. | 1910—26.68 ACRES. | | | | | | 1911—44.33 ACRES. | | | | | | 1912—44.33 ACRES. | | | | | | 1913—44.33 ACRES. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Man Labor | | Horse Labor | | Machinery Cost | Total Cost | Man Labor | | Horse Labor | | Machinery Cost | Total Cost | Man Labor | | Horse Labor | | Machinery Cost | Total Cost | Man Labor | | Horse Labor | | Machinery Cost | Total Cost |
| | Hours | Cost | Hours | Cost | | | Hours | Cost | Hours | Cost | | | Hours | Cost | Hours | Cost | | | Hours | Cost | Hours | Cost | | |
| Water | ....... | $..... | ....... | $..... | $..... | $ 37.05 | ....... | $..... | ....... | $..... | $..... | $ 66.58 | ....... | $..... | ....... | $..... | $..... | $ 21.02 | ....... | $..... | ....... | $..... | $..... | $ 52.08 |
| Manuring | 4 | 0.80 | ....... | ....... | ....... | 0.80 | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Plowing | ....... | ....... | ....... | ....... | ....... | ....... | 16 | 3.20 | 32 | 4.00 | .32 | 7.52 | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Harrowing | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | 10 | 2.00 | 40 | 5.00 | 0.54 | 7.54 | ....... | ....... | ....... | ....... | ....... | ....... |
| Disking | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Leveling | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | 8 | 1.60 | ....... | ....... | ....... | 1.60 | ....... | ....... | ....... | ....... | ....... | ....... |
| Drilling | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | 4.00 | ....... | ....... | ....... | ....... | ....... | ....... |
| Seed | ....... | ....... | ....... | ....... | ....... | ....... | 28 | 5.60 | ....... | ....... | 0.40 | 6.00 | 7 | 1.40 | 4 | 0.50 | 0.81 | 2.71 | ....... | ....... | ....... | ....... | ....... | ....... |
| Weeding | 12 | 2.40 | ....... | ....... | 0.80 | 3.20 | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | 20 | 4.00 | 1 | 0.13 | 0.05 | 4.18 |
| Ditches | ....... | ....... | ....... | ....... | ....... | ....... | 98 | 19.60 | ....... | ....... | 0.33 | 19.93 | 55 | 11.00 | ....... | ....... | 0.09 | 11.09 | 81 | 16.20 | ....... | ....... | 0.19 | 16.39 |
| Irrigating | 61.5 | 12.30 | 5 | 0.62 | 0.30 | 13.22 | 13 | 2.60 | 16 | 2.00 | 2.16 | 6.76 | 10 | 2.00 | 13 | 1.62 | 1.53 | 5.15 | 2 | 0.40 | 4 | 0.50 | 1.33 | 2.23 |
| Haying | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Total | 77.5 | $15.50 | 5 | $0.62 | $1.10 | $54.27 | 155 | $ 31.00 | 48 | $ 6.00 | $ 3.21 | $ 106.79 | 90 | $ 18.00 | 57 | $ 7.12 | $ 2.97 | $ 53.11 | 103 | $ 20.60 | 5 | $ 0.63 | $ 1.57 | $ 74.88 |
| Average per acre | 2.9 | 0.58 | 0.2 | 0.03 | 0.04 | 2.03 | 3.5 | 0.67 | 1.1 | 0.14 | 0.07 | 2.41 | 2 | 0.40 | 1.3 | 0.16 | 0.07 | 1.20 | 2.3 | 0.46 | 0.1 | 0.014 | 0.04 | 1.70 |

farm labor charge of 20 cents an hour for man and 12½ cents an hour per horse.

TABLE No. 47.

TOTAL COST AND COST PER BUSHEL OF OATS.

| Year | Total Yield Per Bu. | Total Labor Cost | Threshing Cost at 6c Per Bu. | Total Cost | Cost Per Bu. |
|---|---|---|---|---|---|
| 1910 | 3,044.6 | $1,031.94 | $ 182.68 | $1,214.62 | 0.40 |
| 1911 | 3,118.0 | 860.07 | 187.08 | 1,048.15 | 0.34 |
| 1912 | 4,211.1 | 775.68 | 252.67 | 1,028.35 | 0.24 |
| 1913 | 1,725.0 | 437.60 | 103.50 | 541.10 | 0.31 |
| Totals | 12,098.7 | | | 3,832.22 | |
| Average 4 years | | | | | 0.32 |

Table No. 48 gives the total and average yield per acre of oats for the four-year period included within this publication. The average bushels per acre for the four-year period is 53½, the lowest yield 32½ and the highest 75⅛ bushels. These yields are averages of all the oats grown on the general College Farm.

TABLE No. 48.

TOTAL AND AVERAGE YIELD PER ACRE OF OATS.

| Year. | Acres | Total Yield Bushels | Bushels Per Acre |
|---|---|---|---|
| 1910 | 94.75 | 3,044.60 | 32⅛ |
| 1911 | 51.35 | 3,330.00 | 64 5-6 |
| 1912 | 48.04 | 3,610.00 | 75⅛ |
| 1913 | 41.69 | 2,633.75 | 63 1-6 |
| Totals | 235.83 | 12,618.35 | |
| Average | | | 53.5 |

## *Cost of Growing Pasture.*

In growing pasture the cost of caring for the pasture crops could be accounted by the College Farm. Since most of the animals kept upon the pastures belong to another department who kept a record of their own, no attempt was made in this publication to record returns or carrying capacities of such pastures. Thus the costs given in Table No. 49 are only those labor and machinery costs which involve the College Farm Department. Labor of caring for the animals pastured thereon is not herein recorded because of this departmental arrangement. This is probably a fair representation of the amount of labor required to maintain a pasture, but has no reference whatever to the labor required to look after the stock carried by such a pasture.

## *Cost of Growing Sugar Beets.*

Sugar beets were produced for feed upon the College Farm two years of the period. Table No. 50 summarizes the man, horse and machinery costs, together with miscellaneous other items of cost.

(See page 29.)

## *Cost of Growing Wheat.*

Wheat has only been produced upon the College Farm two years of the period . In 1911 the wheat harvested came from shattered seed. It was thus volunteer wheat and was allowed to remain upon the land because alfalfa was seeded thereon. The crop recorded, therefore, is a volunteer crop for 1911. Table No. 51 summarizes the various items of cost for growing wheat for the two years, 1910 and 1911.

(See page 30.)

It would seem to be of sufficient interest at this point to summarize some of the labor costs for particular farm operations. These summary costs are the averages obtained for each of the operations for all of the years in which they were performed in the four-year period, 1910-1913, inclusive. In obtaining the average number of man hours and the average number of horse hours, the total hours work for the particular operation for the entire period and the total acres upon which that operation was performed for the entire period are taken as the basis of computation. Thus we have in the case of plowing, Table No. 52, an average man labor acre cost of 6.23 hours and an average horse labor cost of 19.15 hours Charging at the rate of 20 cents an hour for man labor and 12½ cents an hour for horse labor, the average cost per acre was $3.64 for plowing for the four-year period. A careful examination of these figures with scattered data obtained from other farms and localities would indicate that this is very near to average farm requirements where plowing of similar character is done.

TABLE No. 52.

AVERAGE LABOR COST PER ACRE—PLOWING.

Average 1910-1913, Inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 6.23 | 19.15 | $3.64 |

TABLE No. 50.
COST OF GROWING SUGAR BEETS.

| ITEM. | 1910—2 ACRES. | | | | | | 1911—*1¾ ACRES. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Man Labor | | Horse Labor | | Machinery | | Man Labor | | Horse Labor | | Machinery | |
| | Hours | Cost | Hours | Cost | Cost | Total Cost | Hours | Cost | Hours | Cost | Cost | Total Cost |
| Water | ........ | $...... | ....... | $...... | $...... | $ 3.00 | ........ | $...... | ....... | $...... | $...... | $ 1.22 |
| Plowing | 15 | 3.00 | 40 | 5.00 | 0.92 | 8.92 | 18 | 3.60 | 54 | 6.75 | 1.61 | 11.96 |
| Harrowing | 4.5 | 0.90 | 13.5 | 1.69 | 0.04 | 2.63 | 6 | 1.20 | 13 | 1.62 | 0.10 | 2.92 |
| Leveling | ........ | ....... | ....... | ....... | ....... | ........ | 7 | 1.40 | 21 | 2.62 | 0.41 | 4.43 |
| Drilling | 4.5 | 0.90 | 9 | 1.13 | 0.26 | 2.29 | 3 | 0.60 | 6 | 0.75 | 0.36 | 1.71 |
| Seed | ........ | ....... | ....... | ....... | ....... | 2.00 | ........ | ....... | ....... | ....... | ....... | 1.80 |
| Thinning and Cultivating | 123 | 24.60 | 25.5 | 3.19 | 0.18 | 27.97 | 84 | 16.80 | 19 | 2.37 | 0.11 | 19.28 |
| Irrigating | ........ | ....... | ....... | ....... | ....... | ........ | 12.5 | 2.50 | ....... | ....... | 0.01 | 2.51 |
| Harvesting | 116 | 23.20 | 21 | 2.62 | 1.88 | 27.70 | 302 | 60.40 | 214 | 26.75 | 0.63 | 87.78 |
| Storing | 9 | 1.80 | 9 | 1.13 | ....... | 2.93 | ........ | ....... | ....... | ....... | ....... | ........ |
| Total | 272 | $ 54.46 | 118 | $ 14.76 | $ 3.28 | $ 77.44 | 432.5 | $ 86.50 | 327 | $ 40.86 | $ 3.23 | $ 133.61 |
| Average per acre | 136 | 27.23 | 59 | 7.38 | 1.64 | 38.72 | 216.25 | 43.25 | 163.5 | 20.43 | 1.61 | 66.805 |

* Two acres planted, 1¾ acres harvested.

TABLE No. 51.
COST OF GROWING WHEAT.

| ITEM. | 125 BU.—1910—16.63 ACRES. Man Labor | | Horse Labor | | Machinery | | 620 BU.—1911—16.63 ACRES. Man Labor | | Horse Labor | | Machinery | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | Cost | Hours | Cost | Cost | Total Cost | Hours | Cost | Hours | Cost | Cost | Total Cost |
| Water | ...... | $...... | ...... | $...... | $...... | $ 21.95 | ...... | $...... | ...... | $...... | $...... | $ 24.95 |
| Plowing | 18.5 | 3.70 | 48 | 6.00 | 7.68 | 17.38 | 47.5 | 9.50 | 146.5 | 18.31 | 6.09 | 33.90 |
| Harrowing | 15.25 | 3.05 | 33.5 | 4.19 | 0.37 | 7.61 | 18.5 | 3.70 | 50.5 | 6.31 | 0.27 | 10.28 |
| Disking | 3 | 0.60 | 6 | 0.75 | 1.35 | 2.70 | ...... | ...... | ...... | ...... | ...... | ...... |
| Rolling | 3.5 | 0.70 | 14 | 1.75 | 1.95 | 4.40 | ...... | ...... | ...... | ...... | ...... | ...... |
| Drilling | 17 | 3.40 | 34 | 4.25 | 2.20 | 9.85 | 5.5 | 1.10 | 5 | 0.62 | 2.66 | 3.38 |
| Seed | ...... | ...... | ...... | ...... | ...... | 29.93 | ...... | ...... | ...... | ...... | ...... | ** |
| Hauling Seed | ...... | ...... | ...... | ...... | ...... | ...... | 2 | 0.40 | 3 | 0.38 | ...... | 0.78 |
| Weeding | ...... | ...... | ...... | ...... | ...... | ...... | 2 | 0.40 | ...... | ...... | 0.67 | 1.07 |
| Destroying Insect Eggs | ...... | ...... | ...... | ...... | ...... | ...... | 5 | 1.00 | 10 | 1.25 | ...... | 2.25 |
| Irrigating | 28 | 5.60 | ...... | ...... | 0.17 | 5.77 | 76 | 15.20 | 2 | 0.25 | 0.18 | 15.63 |
| Harvesting | 95.5 | 19.10 | 103 | 12.86 | 8.95 | 40.91 | 146 | 29.20 | 151 | 18.88 | 9.35 | 57.43 |
| Total | 180.75 | $ 36.15 | 238.5 | $ 29.80 | $ 22.67 | $ 140.50 | 302.5 | $ 60.50 | 368 | $ 46.00 | $ 19.22 | $ 149.67 |
| Average per acre | 10.87 | 2.17 | 14.34 | 1.79 | 1.36 | 8.45 | 18.19 | 3.64 | 22.13 | 2.76 | 1.16 | 9.00 |

** Volunteer Seed.

Harrowing cost, on an average, 1.57 hours of man labor and 3.79 hours of horse labor; at the standard charge, a money cost of 79 cents per acre.

TABLE No. 53.
LABOR COST PER ACRE—HARROWING.
Average 1910-1913, inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 1.57 | 3.79 | $0.79 |

Leveling for irrigation, which consists almost entirely of running a long plank leveler, gave the costs tabulated in Table No. 54. At the standard charge, these would have a money value of 51 cents per acre.

TABLE No. 54.
LABOR COST PER ACRE—LEVELING.
Average 1910-1913, inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 1.11 | 2.40 | $0.51 |

Rolling was not performed every year. Table No. 55 shows that when rolling was performed that it was done at an average money cost of 49 cents per acre.

TABLE No. 55.
AVERAGE LABOR COST PER ACRE——ROLLING.
Two years only.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 0.74 | 2.72 | $0.49 |

Disking cost on an average, 79 cents per acre.

TABLE No. 56.
LABOR COST PER ACRE—DISKING.
Average of three years.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 1.15 | 4.47 | $0.79 |

Drilling, which was performed every year of the period, gave an average money cost of 56 cents per acre.

TABLE No. 57.
LABOR COST PER ACRE——DRILLING.
Average 1910-1913, inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 1.04 | 2.82 | $0.56 |

Irrigating, which is almost exclusively a man labor job, horse labor appearing only in the ditching work in field head ditches and laterals, gave a total labor cost of $1.08.

TABLE No. 57.
AVERAGE LABOR COST PER ACRE—IRRIGATING.
Average 1910-1913, inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 5.36 | 0.06 | $1.08 |

The average cost of miscellaneous labor applied per acre was 33 cents. This heading covers those work items not readily classifiable in the regular field operations, such as repairing flood damage, cleaning out patches of undesirable weeds, and other similar unusual operations.

TABLE No. 58.
AVERAGE MISCELLANEOUS LABOR COST PER ACRE.
Average 1910-1913, inclusive.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 1.07 | 0.95 | $0.33 |

The average harvesting labor cost amounted to $5.31 for the four-year period.

TABLE No. 59.
AVERAGE COST PER ACRE—HARVESTING.
Average 1910-1913.

| Average Man Hours | Average Horse Hours | Average Cost Horse and Man Labor |
|---|---|---|
| 17.16 | 15.03 | $5.31 |

In Table No. 61 are summarized the average amount of man hours, horse hours, and the average cost of the labor required to produce a bushel of oats, a bushel of wheat, a ton of alfalfa, and a ton of silage. The labor cost to produce oats or wheat is seen to be not far different when reduced to bushel units with the yields prevailing under our conditions. A similar statement may be made in regard to the production of ton units of alfalfa or silage. The total amount of labor for each unit of production is almost the same in each case.

TABLE No. 61.

AVERAGE TOTAL MAN AND HORSE LABOR COST.

| | For One Bushel Oats | For One Bushel Wheat | For One Ton Alfalfa | For One Ton Silage |
|---|---|---|---|---|
| Man hours ................ | 0.44 | 0.51 | 9.16 | 8.98 |
| Horse hours ................ | 0.66 | 0.81 | 8.12 | 9.19 |
| Total average labor cost per bu. | $0.17 | $0.20 | $2.85 | $2.94 |

The actual cost in dollars and cents to different individual farmers may vary considerably from the figures given here, because the price paid to labor may be considerably different than that paid upon the College Farm. It may be higher, and it may be lower, but a direct means of comparison is possible if the number of man hours and the number of horse hours are considered.

While space forbids a detailed statement of the cost of production on individual fields, a summary of the man labor, horse labor, total machinery, and total costs may be of interest as showing what the College land actually produced in returns. In Table No. 62 are given these figures on the thirty-seven fields under consideration. Some of these fields continually return a loss because they are worked by the College Farm for other departments. This is true of those fields used for pasture purposes, and in those years in which alfalfa is seeded fields almost without exception show a loss. Sometimes fields show a loss because of the character of the crop put in. Usually this is expected by the Farm Manager, but in order to best serve the institution, it is sometimes necessary to put crops upon the fields which will return a loss. This may be good institutional policy because of the inter-relation of departments, tho it is poor business from the standpoint of economical land management. Some crops are required in instructional work which can only be obtained by growing them ourselves. By an examination of

Table No. 62, which gives the total returns and net profits annually, it will be seen that while some fields return a loss each year, that the returns from all the fields uniformly show a net profit for the period under investigation. This net profit is in excess of all expenses properly chargeable to the fields, including the items of cost summarized and many others. In 1910, the net profit was $636.54; in 1911, the net profit was $2,325.61; in 1912, the net profit from all fields was $1,778.40; in 1913 the net profit amounted to $2,263.84. Thus it will be seen that the College land has been operated at a net profit, but the College Farm Department which operates the land and in addition acts as a general institutional service bureau has sometimes had its balance on the wrong side of the ledger.

TABLE No. 62.
SUMMARY FIELDS.*
For four years—1910-1913.

**1910.**

| | Man Hours | Horse Hours | Machinery Cost | Total Cost | Returns | Profit | Loss |
|---|---|---|---|---|---|---|---|
| Field 1 | 292 | 338.5 | $ 14.97 | $ 144.54 | $ 165.65 | $ 21.11 | |
| Field 2 | 141 | 112 | 3.90 | 55.55 | 144.00 | 88.45 | |
| Field 3 | 118 | 87 | 4.03 | 50.78 | 100.25 | 49.47 | |
| Field 4 | 206.5 | 298 | 24.82 | 117.14 | 121.29 | 4.15 | |
| Field 5 | 314.5 | 344 | 16.88 | 162.06 | 175.59 | 13.53 | |
| Field 6 | | | | | | | |
| Field 7 | | | | | | | |
| Field 8 | | | | | | | |
| Field 9 | 28.5 | 5 | 0.50 | 20.55 | | | 20.55 |
| Field 10 | 10 | | 0.50 | 15.70 | | | 15.70 |
| Field 11 | 133 | 148 | 5.68 | 63.56 | 92.66 | 29.10 | |
| Field 12 | 111 | 87 | 5.13 | 52.95 | | | 52.95 |
| Field 13 | 197 | 183 | 5.68 | 80.75 | 178.22 | 97.47 | |
| Field 14 | 227.5 | 241 | 5.02 | 93.57 | 243.24 | 149.67 | |
| Field 15 | 208 | 183 | 6.96 | 86.47 | 168.83 | 82.36 | |
| Field 16 | 248.5 | 236.5 | 5.09 | 97.19 | 287.31 | 190.12 | |
| Field 17 | | | | 5.28 | | | 5.28 |
| Field 18 | 117.5 | 187 | 5.70 | 64.71 | 60.32 | | 4.39 |
| Field 19 | 267.5 | 470.5 | 23.22 | 180.56 | 176.32 | | 4.24 |
| Field 20 | 76.5 | 73.0 | 1.10 | 28.37 | 81.90 | 53.53 | |
| Field 21 | 128 | 116 | 5.17 | 46.19 | | | 46.19 |
| Field 22 | 147.75 | 174 | 11.84 | 85.79 | 176.78 | 90.99 | |
| Field 23 | 19.0 | | 0.06 | 12.51 | | | 12.51 |
| Field 24 | 132.75 | 172 | 13.42 | 85.23 | 176.78 | 91.55 | |
| Field 25 | 244 | 342.5 | 14.31 | 135.10 | 165.65 | 30.55 | |
| Field 26 | 180.75 | 238.5 | 22.67 | 140.50 | 90.00 | | 50.50 |
| Field 27 | 284 | 301.5 | 6.80 | 114.26 | | | 114.26 |
| Field 28 | | | | | 18.00 | 18.00 | |
| Field 29 | 232.75 | 314.5 | 13.83 | 126.93 | 147.55 | 20.62 | |
| Field 30 | | | | | | | |
| Field A | 141 | 137 | 5.42 | 103.91 | 33.68 | | 70.23 |
| Field B | 195.5 | 253.5 | 11.06 | 104.26 | 114.24 | 9.98 | |
| Field C | 207.5 | 291.5 | 11.06 | 111.50 | 114.24 | 2.74 | |
| Field D | 196 | 285 | 11.60 | 108.28 | 114.24 | 5.96 | |
| Field E | 186 | 288 | 11.07 | 116.11 | 115.54 | | 0.57 |
| Field F | 191.5 | 291 | 11.02 | 111.81 | 119.42 | 7.61 | |
| Field X | 244.5 | 135 | 12.90 | 150.64 | 127.59 | | 23.05 |
| TOTALS | 5,428 | 6,333.5 | $ 291.41 | $2,872.75 | $3,509.29 | $1,056.96 | $ 420.42 |
| Net Profits on all Fields for 1910, 1911, 1912 and 1913 | | | | | | $ 636.54 | |

**1911.**

| | Man Hours | Horse Hours | Machinery Cost | Total Cost | Returns | Profit | Loss |
|---|---|---|---|---|---|---|---|
| Field 1 | 280.75 | 436.00 | $ 11.43 | $ 151.42 | $ 302.88 | $ 151.46 | |
| Field 2 | 250 | 125 | 2.66 | 79.03 | 196.95 | 117.92 | |
| Field 3 | 155.5 | 93 | 3.76 | 57.58 | 141.69 | 84.11 | |
| Field 4 | 298.5 | 282.5 | 8.96 | 123.99 | 113.39 | | 10.60 |
| Field 5 | 332 | 192 | 7.62 | 118.52 | 246.46 | 127.94 | |
| Field 6 | 7 | 8 | .27 | 4.69 | | | 4.69 |
| Field 7 | 28 | 10 | 1.87 | 16.59 | | | 16.59 |
| Field 8 | 1 | | 0.06 | 2.28 | | | 2.28 |
| Field 9 | 23.5 | | 0.23 | 20.53 | | | 20.53 |
| Field 10 | 35 | 20 | 0.31 | 24.81 | | | 24.81 |
| Field 11 | 317 | 288 | 7.79 | 120.73 | 249.98 | 129.25 | |
| Field 12 | 38.5 | 12 | 0.38 | 23.28 | | | 23.28 |
| Field 13 | 273.5 | 227 | 3.61 | 101.22 | 295.25 | 194.03 | |
| Field 14 | 321.5 | 222 | 3.65 | 108.92 | 405.02 | 296.10 | |
| Field 15 | 327 | 245 | 3.61 | 114.18 | 138.80 | 24.62 | |
| Field 16 | 274.5 | 238 | 4.53 | 102.57 | 309.10 | 206.53 | |
| Field 17 | 29 | 39 | 1.58 | 18.46 | | | 18.46 |
| Field 18 | 211 | 219 | 13.57 | 103.41 | 34.43 | | 68.98 |
| Field 19 | 290.5 | 352 | 15.85 | 187.67 | | | 187.67 |
| Field 20 | 51.5 | 44 | 0.73 | 19.75 | 60.39 | 40.64 | |
| Field 21 | 201 | 109 | 0.70 | 55.70 | | | 55.70 |
| Field 22 | 239 | 349 | 10.18 | 126.46 | 294.00 | 167.54 | |
| Field 23 | 22 | | 0.09 | 13.86 | | | 13.86 |
| Field 24 | 266 | 451 | 8.94 | 102.22 | 294.00 | 191.78 | |
| Field 25 | 229.5 | 337 | 10.02 | 125.07 | 168.00 | 42.93 | |
| Field 26 | 302.5 | 368 | 19.22 | 149.67 | 454.69 | 305.02 | |
| Field 27 | 248 | 193 | 3.73 | 93.35 | 209.90 | 116.55 | |
| Field 28 | | | | | | | |
| Field 29 | 283.5 | 438.5 | 9.33 | 145.16 | 422.40 | 277.24 | |
| Field 30 | 27.5 | 31 | 2.36 | 21.15 | 16.92 | | 4.23 |
| Field A | 196.75 | 138.5 | 4.84 | 100.91 | | | 100.91 |
| Field B | 272.5 | 431.5 | 8.48 | 136.91 | 120.48 | | 16.43 |
| Field C | 227 | 417 | 8.48 | 121.10 | 120.48 | | 0.62 |
| Field D | 185 | 285.5 | 10.57 | 107.33 | 196.80 | 89.47 | |
| Field E | 256.5 | 298 | 6.99 | 120.13 | 184.45 | 64.32 | |
| Field F | 304 | 272.5 | 6.15 | 117.87 | 229.75 | 111.88 | |
| Field X | 478.5 | 430 | 10.18 | 216.40 | 372.32 | 155.92 | |
| TOTALS | 7,284.5 | 7,602.00 | $ 212.73 | $3,252.92 | $5,578.53 | $2,895.25 | $ 569.64 |
| Net Profits on all Fields for 1910, 1911, 1912 and 1913 | | | | | | 2,325.61 | |

**1912.**

| | Man Hours | Horse Hours | Machinery Cost | Total Cost | Returns | Profit | Loss |
|---|---|---|---|---|---|---|---|
| Field 1 | | | $ | $ | $ | $ | $ |
| Field 2 | 223 | 104 | 2.17 | 64.14 | 182.27 | 118.13 | |
| Field 3 | 160 | 80 | 2.25 | 48.76 | 133.61 | 84.85 | |
| Field 4 | 166 | 197 | 5.83 | 70.01 | 214.89 | 144.88 | |
| Field 5 | 384 | 205 | 3.15 | 112.28 | 298.19 | 185.91 | |
| Field 6 | 16 | 40 | 0.55 | 9.58 | | | 9.58 |
| Field 7 | 43 | 13 | 1.83 | 15.25 | | | 15.25 |
| Field 8 | 1 | | 0.01 | 1.04 | | | 1.04 |
| Field 9 | | | | 6.34 | | | 6.34 |
| Field 10 | 28 | 4 | 0.61 | 16.81 | | | 16.81 |
| Field 11 | 271 | 165 | 2.37 | 83.10 | 224.24 | 141.14 | |
| Field 12 | | | | | | | |
| Field 13 | 295 | 178 | 2.37 | 89.53 | 265.68 | 176.15 | |
| Field 14 | 247 | 214 | 2.98 | 85.10 | 272.64 | 187.54 | |
| Field 15 | 503 | 506 | 7.73 | 192.64 | 223.23 | 30.59 | |
| Field 16 | 525 | 502 | 8.41 | 182.10 | 247.94 | 65.84 | |
| Field 17 | 2 | 4 | .09 | 3.43 | | | 3.43 |
| Field 18 | 149 | 75 | 1.65 | 43.87 | 111.65 | 67.78 | |
| Field 19 | 502 | 323.5 | 18.11 | 171.00 | 198.72 | 27.72 | |
| Field 20 | | | | 1.31 | | | 1.31 |
| Field 21 | 22 | 35 | 1.96 | 12.66 | | | 12.66 |
| Field 22 | 219 | 391 | 20.16 | 129.06 | 282.80 | 153.74 | |
| Field 23 | 20 | | 0.04 | 7.85 | | | 7.85 |
| Field 24 | 193.5 | 306 | 35.73 | 150.36 | 282.80 | 132.44 | |
| Field 25 | 566 | 739 | 16.37 | 255.67 | 20.04 | | 235.63 |
| Field 26 | 581 | 852 | 40.06 | 292.88 | 282.80 | | 10.08 |
| Field 27 | 292 | 306 | 19.72 | 122.83 | 209.90 | 87.07 | |
| Field 28 | | | | | 12.85 | 12.85 | |
| Field 29 | 209 | 318 | 18.16 | 117.57 | 260.40 | 142.83 | |
| Field 30 | 201 | 128 | 2.18 | 69.09 | 167.11 | 98.02 | |
| Field A | 168 | 146 | 2.89 | 60.54 | 74.16 | 13.62 | |
| Field B | 278 | 303 | 13.35 | 136.77 | 65.94 | | 70.83 |
| Field C | 150 | 228 | 16.06 | 85.91 | 238.40 | 152.49 | |
| Field D | 64 | 161 | 11.00 | 59.41 | | | 59.41 |
| Field E | 16 | 24 | 4.31 | 18.41 | | | 18.41 |
| Field F | | | | | | | |
| Field X | 456 | 307 | 8.24 | 151.98 | 375.42 | 223.44 | |
| TOTALS | 6,950.50 | 6,854.50 | $ 270.34 | $2,867.28 | $4,645.68 | $2,247.03 | $ 468.63 |
| Net Profits on all Fields for 1910, 1911, 1912 and 1913 | | | | | | 1,778.40 | |

**1913.**

| | Man Hours | Horse Hours | Machinery Cost | Total Cost | Returns | Profit | Loss |
|---|---|---|---|---|---|---|---|
| Field 1 | | | $ | $ | $ | $ | $ |
| Field 2 | 209 | 191 | 12.93 | 92.42 | 251.75 | 159.33 | |
| Field 3 | 123 | 96 | 6.16 | 61.75 | 122.92 | 61.17 | |
| Field 4 | 157 | 160 | 8.12 | 72.51 | 201.75 | 129.24 | |
| Field 5 | 364.5 | 350 | 17.12 | 155.22 | 273.09 | 117.87 | |
| Field 6 | | | | 1.40 | | | 1.40 |
| Field 7 | 29 | 4 | 1.36 | 14.75 | | | 14.75 |
| Field 8 | | | | 1.40 | | | 1.40 |
| Field 9 | 30 | 1 | 0.11 | 20.28 | | | 20.28 |
| Field 10 | 28 | 1 | 0.11 | 19.34 | | | 19.34 |
| Field 11 | 250 | 174 | 12.35 | 97.19 | 229.36 | 132.17 | |
| Field 12 | | | | | | | |
| Field 13 | 242 | 186 | 2.51 | 87.25 | 242.56 | 155.31 | |
| Field 14 | 171 | 165 | 2.97 | 70.99 | 229.10 | 158.11 | |
| Field 15 | 280 | 212 | 2.51 | 98.08 | 296.00 | 197.92 | |
| Field 16 | 260 | 242 | 12.39 | 107.78 | 229.18 | 121.40 | |
| Field 17 | | | | 5.40 | | | 5.40 |
| Field 18 | 120 | 67 | 1.30 | 40.43 | 147.39 | 106.96 | |
| Field 19 | 93 | 41 | 2.16 | 63.29 | | | 63.29 |
| Field 20 | 2 | 4 | 0.29 | 4.09 | | | 4.09 |
| Field 21 | 20 | 25 | 0.18 | 8.26 | | | 8.26 |
| Field 22 | 254.5 | 403 | 9.94 | 142.48 | 66.50 | | 75.98 |
| Field 23 | 23 | | 0.04 | 13.08 | | | 13.08 |
| Field 24 | 241.5 | 417 | 10.84 | 146.71 | 79.94 | | 66.77 |
| Field 25 | 244 | 227 | 2.77 | 94.35 | 316.96 | 222.61 | |
| Field 26 | 380 | 577 | 40.78 | 231.31 | 407.50 | 176.19 | |
| Field 27 | 201 | 205 | 2.74 | 82.86 | 270.13 | 187.27 | |
| Field 28 | | | | | | | |
| Field 29 | 268 | 424 | 33.77 | 165.61 | 282.50 | 116.89 | |
| Field 30 | 252 | 142 | 1.85 | 74.36 | 159.99 | 85.63 | |
| Field A | 181 | 215 | 2.46 | 78.32 | 207.55 | 129.23 | |
| Field B | 174 | 211 | 2.46 | 76.46 | 251.44 | 174.98 | |
| Field C | 344 | 365 | 9.61 | 158.25 | 63.42 | | 94.83 |
| Field D | | | | | | | |
| Field E | | | | | | | |
| Field F | | | | | | | |
| Field X | 418 | 415 | 5.21 | 161.63 | 382.06 | 220.43 | |
| TOTALS | 5,359.5 | 5,520 | $ 205.04 | $2,447.25 | $4,711.09 | $2,652.71 | $ 388.87 |
| Net Profits on all Fields for 1910, 1911, 1912 and 1913 | | | | | | $2,263.84 | |

* NOTE—In this summary water, seed and some other costs are not listed, although their sum is included in the total cost.

# THE COLLEGE FARM AS A SERVICE BUREAU.

To operate the lands of the College Farm, which consist of 480 acres of irrigated land at the home plant and approximately 1,300 acres of foothill pasture land four miles from the home plant, requires a considerable force of farm labor. Since a force must be maintained, it was thot that the farm force could be so organized as to do a large proportion of the miscellaneous jobs which must always be done about an Agricultural College and Experiment Station. Accordingly, the existing force of the College Farm was slightly increased and so organized as to constitute an institutional service bureau. The type of service which the farm, acting as a service bureau, was called upon to do was highly varied.

The Agricultural College does not have a central heating plant. Because of this fact, it is necessary to haul coal to the individual plants of the several buildings. This was done by the College Farm. The labor of keeping the roads and drives, and general up-keep appearance of the institution was performed by the same farm service bureau—in fact, if any department of the institution, or the institution as a whole wanted work done, it called upon the farm and if the farm was able to do the work it was taken care of at once and bills rendered to the proper department. In addition to the work already mentioned, the farm did such things as the construction of experimental roads upon the campus and roads adjoining. A concrete mixer was purchased by the Farm Manager and since that time a large amount of concrete curbing about the campus, concrete sidewalks, irrigation flumes, concrete weirs, concrete floors and building foundations have been constructed. None of this work is properly farm work, as it has no connection, outside of the building of irrigation flumes and weirs, with the operation of the College Farm. By this organization of a service bureau within the force of the college farm the institution was able to have at hand at all times a force well trained in the performance of general institutional service and repair. This force could do most pieces of work cheaper than it could be contracted for on the outside, thus effecting a direct saving and the "readiness to serve" feature was often of more value to the institution than the cost of the work, because frequently this service would have the work done in less time than it would be possible to get bids from outside contractors.

A detailed tabulation of this work by departments follows. In many cases the departmental work is simply the furnishing of labor; in some cases, it consists in furnishing mechanical help; and in many cases in actual construction. During the past four years the College Farm force has constructed over 400 feet of concrete ditch flume, part of it submerged with drops and approaches; it has built twenty-two concrete weirs on the various college farms; it has built some 700 feet of concrete curbing; built a half mile of experimental road upon the College campus; has laid some 600 linear feet of concrete sidewalk; has built and completely installed an elevator in the college granaries; has built three complete concrete silos; and has done all the construction work upon a number of sheds, yards and buildings of the Animal Husbandry Department; has done the grading and campus improvement work for three new buildings constructed; has put in new concrete floors in five different localities used for classroom purposes; has built complete concrete foundations for the new Soils Laboratory. The general upkeep of the grounds, campus, roads and drives has all been done by this same labor force. This will give an indication of the type and variety of service rendered aside from the strict operations of the College Farm.

In tabular form this work is outlined below for each of the departments. The number of man hours, the receipts which represent what the department paid the farm service, and the actual cost to the farm are indicated in separate columns in each case. The character of the work is not given in this tabulation, since, if given in detail, it would represent a mass of material of little interest, yet so voluminous that its publication is scarcely warranted.

The total number of hours for each department, in man labor, and the total number of hours in horse labor are separately given in Tables Nos. 63 to 105. The data are so arranged as to show for each year the total number of man hours, the farm receipts and the actual cost to the farm. The same information is given in regard to the horse hours. The purpose in separating the man and horse hours is to show which has given the profit to the farm service, and which a loss during each season.

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## AGRONOMY DEPARTMENT.

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The services performed for the Agronomy Department consisted in drayage, hauling and preparation of soils and grains for the respective laboratories, preparation of land for crops used in the crops laboratory, and some of the necessary labor in growing and harvesting these crops.

TABLE No. 63.
WORK DONE FOR THE AGRONOMY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 583 | $116.60 | $115.43 | 978.5 | $122.32 | $117.42 |
| 1911 ......... | 107 | 21.40 | 23.43 | 77 | 9.63 | 6.39 |
| 1912 ......... | 72 | 14.40 | 15.77 | 113 | 14.14 | 9.27 |
| 1913 ......... | 14 | 2.80 | 3.23 | 13 | 1.62 | 1.01 |
| 1914 ......... | 3 | 0.60 | * | 3 | 0.37 | * |

* Not complete.

## ANIMAL HUSBANDRY DEPARTMENT.

The nature of the work performed for this department consisted in hauling hay and grain to the various types of livestock, repairing and building fences, sheds and yards for livestock, cleaning up yards, preparation of land for pastures, preparation of land for silage corn, irrigating pastures, harvesting hay on the pastures where new pastures were being established and on old pastures where the growth exceeded the grazing enough to make it advisable, cleaning up and burning weeds, hauling manure, furnishing extra help to take care of stock, and furnishing the labor on such miscellaneous extra crops as cabbage, turnips and other stock feeds.

TABLE No. 64.
WORK DONE FOR THE ANIMAL HUSBANDRY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 5,572 | $1,114.40 | $1,103.26 | 1,676 | $ 209.59 | $ 201.12 |
| 1911 ......... | 5,377 | 1,075.40 | 1,177.56 | 3,380 | 422.37 | 280.54 |
| 1912 ......... | 4,277.75 | 855.55 | 936.83 | 3.064 | 382.95 | 251.25 |
| 1913 ......... | 5,158.5 | 1,031.70 | 1,191.61 | 3,897 | 487.08 | 303.97 |
| 1914 ......... | 3,186 | 637.20 | * | 2,569 | 321.11 | * |

* Not complete.

## ANIMAL INVESTIGATION DEPARTMENT.

The work for Animal Investigation consisted in hauling grain and hay to the experimental animals being fed, cleaning pens, fence, shed and yard improvements.

TABLE No. 65.

WORK DONE FOR ANIMAL INVESTIGATION DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 1,686.5 | $ 337.30 | $ 333.93 | 669.5 | $ 83.71 | $ 80.34 |
| 1911 ......... | 1,883 | 376.60 | 412.38 | 1,724 | 214.26 | 143.09 |
| 1912 ......... | 130 | 26.00 | 28.47 | 101 | 12.62 | 8.28 |
| 1913 ......... | 21 | 4.20 | 4.85 | 10 | 1.25 | 0.78 |

## ATHLETIC DEPARTMENT.

The character of service performed for the Athletic Department consisted in grading the athletic fields, both the new Colorado Field (men's field) and the old Durkee Field (women's field); building boys' club house and grandstand; putting in concrete curbing around cinder track; laying water pipe and tile for irrigation of grass on athletic field; seeding down oval with grass inclosed in cinder track; setting out shrubbery, trees, etc., on the athletic field; care of shrubbery and lawn on athletic field; grading cinder track; hauling, placing and rolling cinders on same; police work at intercollegiate games.

TABLE No. 66.

WORK DONE FOR ATHLETIC DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 110 | $ 22.00 | $ 21.78 | 130 | $ 16.23 | $ 15.60 |
| 1911 ......... | 85.5 | 17.10 | 18.72 | 25 | 3.12 | 2.08 |
| 1912 ......... | 5,964.5 | 1,192.90 | 1,306.23 | 2,658 | 332.21 | 217.96 |
| 1913 ......... | 4,296 | 859.20 | 992.38 | 1,854 | 231.81 | 144.61 |
| 1914 ......... | 1,222 | 244.40 | * | 983 | 122.90 | * |

* Not complete.

## BOTANY AND FORESTRY DEPARTMENT.

The work furnished this department was largely drayage, altho labor was furnished for treatment of fence posts with preservative in the experimental post preservation plant; building post treating plant; building shed and sawmill and installing same,

TABLE No. 67.

WORK DONE FOR BOTANY AND FORESTRY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 157 | $ 31.40 | $ 34.38 | 79 | $ 9.87 | $ 6.56 |
| 1912 ......... | 1,409.5 | 281.90 | 308.68 | 222 | 27.72 | 18.20 |
| 1913 ......... | 139 | 27.80 | 32.11 | 25 | 3.12 | 1.95 |
| 1914 ......... | 19 | 3.65 | * | 29 | 3.62 | * |

* Not complete.

## BACTERIOLOGICAL INVESTIGATIONS.

The work done for this department consisted in carpenter work in the laboratory

TABLE No. 68.

WORK DONE FOR BACTERIOLOGICAL INVESTIGATION DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1913 ......... | 42 | $8.40 | $9.70 | | | |

## BUILDING AND REPAIRS.

The work done under this charge consisted largely in repair work on buildings, and hauling the necessary tools and materials for such repair work.

TABLE No. 69.

WORK DONE FOR BUILDING AND REPAIRS.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 377.5 | $ 75.50 | $ 74.75 | 65 | $ 8.13 | $ 7.80 |
| 1911 ......... | 166 | 33.20 | 36.35 | .......... | .......... | .......... |
| 1912 ......... | 235.5 | 47.10 | 51.57 | .......... | .......... | .......... |
| 1913 ......... | 1,010 | 202.00 | 233.31 | 128 | 16.00 | 9.98 |
| 1914 ......... | 182 | 36.40 | * | 46 | 5.75 | * |

* Not complete.

## BUILDING SUPERINTENDENT.

The work furnished this department consisted of drayage, concrete work about the buildings, and concrete construction work, and building repairs.

TABLE No. 70.

WORK DONE FOR BUILDING SUPERINTENDENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 479 | $ 95.80 | $ 104.90 | 58 | $ 7.25 | $ 4.76 |
| 1913 ......... | 878 | 175.60 | 202.82 | 393 | 49.15 | 30.65 |
| 1914 ......... | 1,407 | 281.40 | * | 647 | 80.86 | * |

* Not complete.

## CAMPUS.

The character of the work done upon the campus consisted in care of the lawns, cultivating the shrubbery, irrigating lawns and shrubbery; seeding new and reseeding old lawns; trimming and spraying trees; killing dandelions; grading and establishing new levels on lawns; removing snow from sidewalks; cleaning up and removing rubbish after building improvements and after storms.

TABLE No. 71.

WORK DONE FOR CAMPUS.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 4,224 | $ 844.80 | $ 836.35 | 3,490.5 | $ 436.30 | $ 418.86 |
| 1911 ......... | 2,601 | 520.20 | 569.62 | 2,628 | 328.52 | 218.12 |
| 1912 ......... | 5,029.25 | 1,005.85 | 1,101.41 | 2,427 | 303.33 | 199.01 |
| 1913 ......... | 6,267 | 1,253.40 | 1,447.68 | 2,231 | 278.86 | 174.02 |
| 1914 ......... | 1,418 | 273.60 | * | 484 | 60.54 | * |

* Not complete.

## CAMPUS IMPROVEMENT.

The work done and charged to Campus Improvement was authorized by a special appropriation of the legislature. This appropriation was largely expended in doing such work as curbing the campus along the principal city streets; grading and seeding down the parking thereon; putting in sidewalks; establishing roads, sidewalks and other decorative features upon the campus.

TABLE No. 72.
WORK DONE FOR CAMPUS IMPROVEMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 4,794 | $ 958.80 | $1,049.89 | 2,602 | $ 325.23 | $ 213.36 |

## CHEMICAL DEPARTMENT.

This department received drayage and farm help in the operation of experimental lands.

TABLE No. 73.
WORK DONE FOR CHEMICAL DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 1 | $ 0.20 | $ 0.22 | 4 | $ 0.50 | $ 0.33 |
| 1912 ......... | 9 | 1.80 | 1.97 | 4 | 0.50 | 0.33 |
| 1913 ......... | 384 | 76.80 | 88.70 | 775 | 96.85 | 60.45 |
| 1914 ......... | 37 | 7.40 | * | 68 | 8.50 | * |

* Not complete.

## CIVIL AND IRRIGATION ENGINEERING.

The work furnished this department consisted in drayage, installation of an underground tile subirrigation system, and the care of land and crop used in experiments on this land.

TABLE No. 74.
WORK DONE FOR CIVIL AND IRRIGATION ENGINEERING DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 92.5 | $ 18.50 | $ 18.31 | 89 | $ 11.13 | $ 10.68 |
| 1911 ......... | 57 | 11.40 | 12.48 | 14 | 1.75 | 1.16 |
| 1912 ......... | 66 | 13.20 | 14.45 | 44 | 5.50 | 3.61 |
| 1913 ......... | 300 | 60.00 | 69.30 | 329 | 41.13 | 25.66 |
| 1914 ......... | 29 | 5.80 | * | 69 | 8.63 | * |

* Not complete.

## COLLEGE EXPENSE.

The charges on College Expense were almost exclusively for drayage.

TABLE No. 75.
WORK DONE FOR COLLEGE EXPENSE.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 388.5 | $ 77.70 | $ 76.92 | 132.5 | $ 16.56 | $ 15.90 |
| 1911 ......... | 511.5 | 102.30 | 112.02 | 137.5 | 17.18 | 11.41 |
| 1912 ......... | 220 | 44.00 | 48.18 | 109 | 13.61 | 8.94 |
| 1913 ......... | 312 | 62.40 | 72.07 | 156 | 19.46 | 12.17 |
| 1914 ......... | 98 | 19.60 | * | 90 | 11.25 | * |

*Not complete.

## ELECTRICAL ENGINEERING AND PHYSICS.

The work for this department was mostly drayage, altho some work was performed in setting up power line poles.

TABLE No. 76.
WORK DONE FOR ELECTRICAL ENGINEERING AND PHYSICS DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 13.5 | $ 2.70 | $ 2.67 | 11 | $ 1.38 | $ 1.32 |
| 1912 ......... | 29.5 | 5.90 | 6.46 | 14 | 1.74 | 1.15 |
| 1913 ......... | 88 | 17.60 | 20.33 | 24 | 3.00 | 1.87 |
| 1914 ......... | 9 | 1.80 | * | 4 | 0.51 | * |

* Not complete.

## ENTOMOLOGY.

The work for this department consisted largely of drayage and the preparation of land for experimental plats used in insect investigations.

TABLE No. 77.

WORK DONE FOR ENTOMOLOGY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 19.5 | $ 3.90 | $ 3.86 | 39 | $ 4.88 | $ 4.68 |
| 1911 ......... | 65 | 13.00 | 14.24 | 37 | 4.63 | 3.07 |
| 1912 ......... | 54 | 10.80 | 11.83 | 88 | 11.00 | 7.22 |
| 1913 ......... | 14 | 2.80 | 3.23 | 28 | 3.45 | 2.18 |
| 1914 ......... | 3 | .60 | * | 9 | 1.13 | * |

* Not complete.

## FARM.

All labor which could properly be charged to the maintenance of the farm was charged to this account whether it consisted in preparation of feed, repairing buildings, erecting new buildings, fencing, grading in yards, preparing land, or otherwise. In other words, this account was kept for those charges which pertain to the operation of the College Farm as distinguished from the operation of the farm force as a College Service Bureau.

TABLE No. 78.

WORK DONE FOR FARM DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 5,559.5 | $1,111.90 | $1,100.78 | 2,373 | $ 296.72 | $ 284.76 |
| 1911 ......... | 6,432 | 1,286.40 | 1,408.61 | 2,400.5 | 300.10 | 199.24 |
| 1912 ......... | 10,650.5 | 2,130.10 | 2,332.46 | 5.686 | 710.70 | 466.25 |
| 1913 ......... | 9,552 | 1,910.40 | 2,206.51 | 6,029 | 753.69 | 470.26 |
| 1914 ......... | 3,829 | 765.80 | * | 2,353 | 296.83 | * |

*Not complete.

## FARMERS' INSTITUTES.

The work for this department consisted in drayage, preparation of exhibits for special trains, and preparing interiors of cars for special trains.

TABLE No. 79.
WORK DONE FOR FARMERS' INSTITUTES.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 70 | 14.00 | 15.33 | 51 | 6.38 | 4.23 |
| 1912 ......... | 14 | 2.80 | 3.07 | 7 | .88 | .57 |
| 1913 ......... | 596 | 119.18 | 137.68 | 97 | 12.13 | 7.57 |
| 1914 ......... | 154 | 30.80 | * | 71 | 8.87 | * |

*Not complete.

## FARM MECHANICS.

This department gives instruction in Farm Machinery and Farm Motors. The work performed as a consequence is largely drayage in delivering machines loaned by the large machinery companies, returning the same when the loan expires, assisting in moving heavy machinery and repairing of the same when used in classroom work; carpenter and iron work in connection with machinery.

TABLE No. 80.
WORK DONE FOR FARM MECHANICS DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 133 | $ 26.60 | $ 26.33 | 36.5 | $ 4.56 | $ 4.38 |
| 1911 ......... | 392.5 | 78.50 | 85.96 | 142 | 17.75 | 11.79 |
| 1912 ......... | 480 | 96.00 | 105.12 | 136 | 17.01 | 11.15 |
| 1913 ......... | 593.5 | 118.70 | 137.10 | 220 | 27.50 | 17.16 |
| 1914 ......... | 189 | 37.80 | * | 55 | 6.88 | * |

* Not complete.

## FARM MECHANICS AND ROADS.

The work done for this department was authorized by a state appropriation and consisted in the construction of an experimental road and in experimental concrete post making and tests of the posts made.

TABLE No. 81.
WORK DONE FOR FARM MECHANICS AND ROADS.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 1,632.5 | $ 326.50 | $ 323.24 | 1,362 | $ 170.27 | $ 163.44 |

## FUEL.

All work arising in unloading coal from cars, hauling coal to the various buildings and removing ashes is charged to this account.

TABLE No. 82.
WORK DONE FOR FUEL DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 1,016 | $ 203.20 | $ 201.17 | 1,058 | $ 132.27 | $ 126.96 |
| 1911 ......... | 1,787 | 357.40 | 391.35 | 1,895 | 236.88 | 157.29 |
| 1912 ......... | 2,136.5 | 427.30 | 467.89 | 2,395.5 | 299.40 | 196.43 |
| 1913 ......... | 2,333 | 466.60 | 538.92 | 2,379 | 297.45 | 185.56 |
| 1914 ......... | 1,303 | 260.60 | * | 1,314 | 164.22 | * |

* Not complete.

## GUGGENHEIM HALL.

Guggenheim Hall was erected by the late Senator Simon Guggenheim. Labor performed by the College Farm force consisted in cleaning up around the building, establishing the grades, installing drains and fixing the lawns.

TABLE No. 83.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 353 | $ 70.60 | $ 69.89 | 175 | $ 21.88 | $ 21.00 |
| 1911 ......... | 8 | 1.60 | 1.75 | .......... | .......... | .......... |

## HOME ECONOMICS.

Service given this department was largely in the shape of livery and drayage.

TABLE No. 84.
WORK DONE FOR THE HOME ECONOMICS DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 95 | $19.00 | $18.81 | 54 | $ 6.75 | $ 6.48 |
| 1911 ......... | 38.5 | 7.70 | 8.43 | 68 | 8.49 | 5.64 |
| 1912 ......... | 24 | 4.80 | 5.26 | 32 | 3.99 | 2.62 |
| 1913 ......... | 37 | 7.40 | 8.55 | 15 | 1.88 | 1.17 |
| 1914 ......... | 15 | 3.00 | * | .......... | .......... | .......... |

* Not complete.

## HORSE INVESTIGATION.

To this account was charged all work done by the College Farm force for the co-operative carriage horse breeding experiment conducted jointly by the United States Government and the Colorado Experiment Station. The work consisted of delivery of hay, grain and other feeds, repairing and building fences, repairing buildings, seeding down pastures, cleaning up and cutting weeds.

TABLE No. 85.

WORK DONE FOR HORSE INVESTIGATION.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 572.5 | $ 174.50 | $ 113.36 | 505 | $ 63.13 | $60.60 |
| 1911 ......... | 2,101 | 420.20 | 460.12 | 1,183.5 | 147.78 | 98.23 |
| 1912 ......... | 1,219 | 243.80 | 266.96 | 677 | 84.64 | 55.51 |
| 1913 ......... | 1,775 | 355.00 | 410.03 | 1,358 | 169.80 | 105.92 |
| 1914 ......... | 1,240 | 248.00 | * | 685 | 85.62 | * |

* Not complete.

## HORTICULTURE.

The work done for this department consisted of plowing, harrowing and rolling and other field work; hauling manure; irrigation; tree pruning; care of shrubbery; general greenhouse work; picking and marketing berries and other fruit; harvesting vegettables; cider making and other miscellaneous labor.

TABLE No. 86.

WORK DONE FOR HORTICULTURAL DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 2,649.5 | $ 529.90 | $ 524.60 | 2,875.5 | $ 358.52 | $ 345.06 |
| 1911 ......... | 4,951.5 | 990.30 | 1,084.38 | 3,755.5 | 469.52 | 311.71 |
| 1912 ......... | 2,255 | 451.00 | 493.85 | 1,094.5 | 136.83 | 89.75 |
| 1913 ......... | 3,468.5 | 693.70 | 801.22 | 1,156 | 144.54 | 90.17 |
| 1914 ......... | 1,612 | 322.40 | * | 509 | 63.64 | * |

* Not complete.

## IRRIGATION INVESTIGATION.

All work for experimental irrigation is charged to this account. The farm furnished labor in the building of a reservoir in the new

Experimental Hydraulic plant; built concrete flumes for open channel experiments; installed connecting pipe; did the concrete work of the laboratory foundations and the flumes and approaches to the laboratory in addition to a large amount of drayage and miscellaneous labor.

TABLE No. 87.

WORK DONE FOR IRRIGATION INVESTIGATION.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 1,228 | $ 245.60 | $ 268.93 | 648 | $ 81.01 | $ 53.78 |
| 1912 ......... | 5,770 | 1,154.00 | 1,263.63 | 3,078 | 384.79 | 252.40 |
| 1913 ......... | 1,083 | 216.60 | 250.17 | 599 | 74.93 | 46.72 |
| 1914 ......... | 207 | 41.40 | * | 62 | 7.76 | * |

* Not complete.

## LIBRARY.

The work done for the library was almost exclusively hauling books.

TABLE No. 88.

WORK DONE FOR THE LIBRARY.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 3 | $0.60 | $0.66 | 6 | $0.75 | $0.50 |
| 1913 ......... | 12 | 2.40 | 2.77 | 8 | 1.00 | 0.62 |
| 1914 ......... | 6 | 1.20 | * | 12 | 1.50 | * |

* Not complete.

## MATHEMATICS.

The work done for this department was exclusively drayage.

TABLE No. 89.

WORK DONE FOR THE MATHEMATICS DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 3 | $0.60 | $0.66 | 6 | $0.75 | $0.49 |
| 1914 ......... | 2 | 0.40 | * | 3 | 0.37 | * |

*Not complete.

## MECHANICAL DEPARTMENT.

The work done for this department consisted of drayage, assistance in building construction and the mechanical work necessary to install steam pumps, a part of the vacuum heating system, and occasional help furnished for placing heavy machinery.

TABLE No. 90.

WORK DONE FOR MECHANICAL DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 55 | $ 11.00 | $ 10.89 | 20 | $ 2.50 | $ 2.40 |
| 1911 ......... | 597 | 119.40 | 130.74 | 29 | 3.62 | 2.41 |
| 1912 ......... | 64 | 12.80 | 14.02 | 9 | 1.13 | 0.74 |
| 1913 ......... | 141 | 28.20 | 32.57 | 147 | 18.38 | 11.47 |

## MILITARY DEPARTMENT.

The work for this department consisted wholly of drayage.

TABLE No. 91.

WORK DONE FOR MILITARY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 138 | $27.60 | $30.22 | 68 | $8.50 | $5.64 |
| 1913 ......... | 12 | 2.40 | 2.77 | 12 | 1.50 | 0.94 |
| 1914 ......... | 14 | 2.80 | * | 5 | 0.62 | * |

* Not complete.

## MUSIC DEPARTMENT.

The Music Department received service in the shape of drayage, moving of pianos and similar services.

TABLE No. 92.

WORK DONE FOR MUSIC DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 37 | $ 7.40 | $ 7.33 | 32 | $ 4.00 | $ 3.84 |
| 1911 ......... | 63 | 12.60 | 13.80 | 26 | 3.24 | 2.16 |

## PERMANENT IMPROVEMENTS.

The work done for this department consisted of new work in the way of buildings and fences upon the land plant of the Agricultural College. In other words, it was considered that this department should be charged with those betterments of a permanent nature, whether they were new buildings or permanent repairs.

TABLE No. 93.

WORK DONE FOR PERMANENT IMPROVEMENT DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 734 | $ 146.80 | $ 145.33 | 394 | $49.27 | $47.28 |
| 1911 ......... | 248.5 | 49.70 | 54.42 | 69 | 8.63 | 5.73 |

## PLANT INDUSTRY.

For convenience all experimental work in Agronomy is charged to Plant Industry on the college books. The labor furnished for this work consisted of plowing, harrowing and leveling in preparing experimental plats for their respective crops; irrigation; assisting in harvesting; furnishing drayage and other miscellaneous services.

TABLE No. 94.

WORK DONE FOR PLANT INDUSTRY.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 900 | $ 180.00 | $ 178.20 | 1,075 | $ 134.38 | $ 129.00 |
| 1911 ......... | 1,798 | 359.60 | 393.76 | 2,334.5 | 291.80 | 193.76 |
| 1912 ......... | 437 | 87.40 | 95.70 | 346 | 43.26 | 28.37 |
| 1913 ......... | 182 | 36.40 | 42.04 | 285 | 35.64 | 22.23 |
| 1914 ......... | 16 | 3.20 | * | 28 | 3.50 | * |

* Not complete.

## POTATO INVESTIGATIONS.

In those years when the Station was receiving special appropriations for potato investigations, the College Farm force performed considerable labor in drayage, preparation of land for experimental potatoes; labor furnished in regulation of temperatures in experimental potato cellar; grading, and help furnished in the erection of experimental potato cellar and other miscellaneous items connected with the handling of potatoes connected with the investigation.

TABLE No. 95.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 396.75 | $ 79.35 | $ 86.89 | 11 | $1.37 | $ .90 |

## POULTRY DEPARTMENT.

For a number of years the College had a special appropriation for poultry investigations. While this arrangement prevailed all work done for the Poultry Department was charged under this heading. The work consisted in grading for poultry buildings and pens, building pens and erecting buildings, hauling feed, preparation and seeding land put into crops for green feed.

TABLE No. 96.
WORK DONE FOR POULTRY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 334.5 | $ 66.90 | $ 66.23 | 435.5 | $ 54.43 | $ 52.26 |
| 1911 ......... | 259 | 51.80 | 56.72 | 371.5 | 46.42 | 30.83 |
| 1912 ......... | 252 | 50.40 | 55.19 | 38 | 4.74 | 3.12 |
| 1913 ......... | 193 | 38.60 | 44.58 | 51 | 6.37 | 3.98 |

## POWER PLANT.

During the preliminary work for the new power plant, the building superintendent found it necessary to dig some test wells upon the proposed site of the plant in order to determine the underground conditions and their feasibility for sustaining the foundations for such a plant. Digging these test wells was the work performed under the charge "Power Plant."

TABLE No. 97.

WORK DONE FOR POWER PLANT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 59 | $ 11.80 | $ 12.92 | 6 | $0.75 | $0.49 |

## PRESIDENT'S OFFICE.

The work done under this heading and herein tabulated was exclusively drayage. All other work furnished the President's Office is charged under the heading of "College Livery," as other work performed for this office consisted largely in livery service.

TABLE No. 98.

WORK DONE FOR PRESIDENT'S OFFICE.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1913 ......... | 3 | $0.60 | $0.69 | 5 | $0.63 | $0.39 |

## PURCHASING AGENT.

The labor furnished the Purchasing Agent was almost exclusively drayage.

TABLE No. 99.

WORK DONE FOR PURCHASING AGENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1912 ......... | 181 | $36.20 | $39.64 | 326 | $40.74 | $26.73 |
| 1913 ......... | 257.5 | 51.50 | 59.48 | 451 | 56.38 | 35.18 |
| 1914 ......... | 89 | 17.80 | * | 168 | 21.00 | * |

* Not complete.

## ROADS AND DRIVES.

The upkeep of the roads and drives about the college campus and farms was charged to this account. The work consisted of repairing roads, building new roads, building culverts, removing snow from roads, cutting weeds and removing rubbish from the roads and drives, dragging and gravelling roads.

TABLE No. 100.

WORK DONE FOR THE ROADS AND DRIVES.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 504.5 | $ 100.90 | $ 99.89 | 564 | $ 70.50 | $ 67.68 |
| 1911 ......... | 1,682 | 336.40 | 368.36 | 1,078 | 134.79 | 89.47 |
| 1912 ......... | 1,453.5 | 290.70 | 318.32 | 990 | 123.75 | 81.18 |
| 1913 ......... | 2,420 | 484.00 | 559.02 | 1,662 | 207.71 | 129.64 |
| 1914 ......... | 280 | 56.00 | * | 346 | 43.24 | * |

* Not complete.

## RURAL EDUCATION.

The rural education department received carpenter work used to prepare exhibit cases.

TABLE No. 101.

WORK DONE FOR RURAL EDUCATION DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 3.5 | $0.70 | $0.77 | .......... | .......... | .......... |

## SCHOOL OF AGRICULTURE.

The labor furnished the School of Agriculture was largely drayage and the work necessary to level and prepare the athletic field.

TABLE No. 102.

WORK DONE FOR THE SCHOOL OF AGRICULTURE.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1911 ......... | 8 | $1.60 | $1.75 | 16 | $2.00 | $1.33 |
| 1913 ......... | 11 | 2.20 | 2.54 | 11 | 1.38 | 0.86 |

## STUDENT LIFE—BOYS.

To Boys' Student Life was charged the labor furnished class proctors in assisting them in looking after the welfare of the male students.

TABLE No. 103.
WORK FURNISHED FOR STUDENT LIFE—BOYS.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1913 ......... | 13 | $ 2.60 | $3.00 | 18 | $2.25 | $1.40 |

## STUDENT LIFE—GIRLS.

Under this heading was charged the livery furnished the dean of women in her work in looking after the girls, in seeing that they were provided with proper rooming houses and rooming house surroundings.

TABLE No. 104.
WORK DONE FOR STUDENT LIFE—GIRLS.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1914 ......... | 6 | $1.20 | * | 6 | $0.75 | * |

* Not complete.

## VETERINARY DEPARTMENT.

The Veterinary Department received labor in the shape of drayage, repair of buildings, fences, general cleaning up, seeding pastures and removal of clinical material from the anatomy laboratories.

TABLE No. 105.
WORK DONE FOR VETERINARY DEPARTMENT.

| | Man Hours | Receipts | Actual Cost | Horse Hrs. | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| 1910 ......... | 287.5 | $57.50 | $56.93 | 307 | $38.38 | $36.84 |
| 1911 ......... | 465 | 93.00 | 101.84 | 231 | 28.88 | 19.17 |
| 1912 ......... | 279.5 | 55.90 | 61.21 | 289 | 36.13 | 23.70 |
| 1913 ......... | 436.5 | 87.30 | 100.83 | 338 | 42.24 | 26.36 |
| 1914 ......... | 140 | 28.00 | * | 127 | 15.89 | * |

* Not complete.

TABLE No. 106.

WORK DONE FOR ALL DEPARTMENTS FOR YEARS 1910 TO 1913, INCLUSIVE.

| Department. | Man Hours | Receipts | Actual Cost | Horse Hours | Receipts | Actual Cost |
|---|---|---|---|---|---|---|
| Agronomy | 776 | $ 155.20 | $ 157.86 | 1,181.5 | $ 147.71 | $ 134.09 |
| Animal Husbandry | 20,385.25 | 4,077.05 | 4,409.26 | 12,017 | 1,501.99 | 1,036.88 |
| Animal Investigation | 3,720.50 | 744.10 | 779.63 | 2,504.5 | 311.84 | 232.49 |
| Athletic | 10,456 | 2,091.20 | 2,339.11 | 4,667 | 583.37 | 380.25 |
| Bacteriological Investigations. | 42 | 8.40 | 9.70 | ........ | ........ | ........ |
| Botany and Forestry | 1,705.50 | 341.10 | 375.17 | 326 | 40.71 | 26.71 |
| Building and Repairs | 1,789 | 357.80 | 395.98 | 193 | 24.13 | 17.78 |
| Building Superintendent | 1,357 | 271.40 | 307.72 | 451 | 56.40 | 35.41 |
| Campus | 18,121.25 | 3,624.25 | 3,955.06 | 10,776.5 | 1,347.01 | 1,010.01 |
| Campus Improvement | 4,794 | 958.80 | 1,049.89 | 2,602 | 325.23 | 213.36 |
| Chemistry | 394 | 78.80 | 90.89 | 783 | 97.85 | 61.11 |
| Civil and Irr. Engineering | 515.50 | 103.10 | 114.54 | 476 | 59.51 | 41.11 |
| College Expense | 1,432 | 286.40 | 309.19 | 535 | 66.81 | 48.42 |
| Elec. Engineering and Physics | 131 | 26.20 | 29.46 | 49 | 6.12 | 4.34 |
| Entomology | 152.50 | 30.50 | 33.16 | 192 | 23.96 | 17.15 |
| Farm | 32,194 | 6,438.80 | 7,048.36 | 16,488.5 | 2,061.21 | 1,420.51 |
| Farmers' Institutes | 680 | 135.98 | 156.08 | 155 | 19.39 | 12.37 |
| Farm Mechanics | 1,599 | 319.80 | 354.51 | 534.5 | 66.82 | 44.48 |
| Farm Mechanics and Roads. | 1,632.50 | 326.50 | 323.24 | 1,362 | 170.27 | 163.44 |
| Fuel | 7,272.50 | 1,454.50 | 1,599.33 | 7,727.5 | 966.00 | 666.24 |
| Guggenheim Building | 361 | 72.20 | 71.64 | 175 | 21.88 | 21.00 |
| Home Economics | 194.50 | 38.90 | 41.05 | 169 | 21.11 | 15.91 |
| Horse Investigation | 5,667.50 | 1,133.50 | 1,250.47 | 3,723.5 | 465.35 | 320.26 |
| Horticulture | 13,324.50 | 2,664.90 | 2,904.05 | 8,881.5 | 1,109.41 | 836.69 |
| Irrigation Investigation | 8,081 | 1,616.20 | 1,782.73 | 4,325 | 540.73 | 352.90 |
| Library | 15 | 3.00 | 3.43 | 14 | 1.75 | 1.12 |
| Mathematics | 3 | .60 | .66 | 6 | .75 | .49 |
| Mechanical Engineering | 857 | 171.40 | 188.22 | 205 | 25.63 | 17.02 |
| Military | 150 | 30.00 | 32.99 | 80 | 10.00 | 6.58 |
| Music | 100 | 20.00 | 21.13 | 58 | 7.24 | 6.00 |
| Permanent Improvements | 982.50 | 196.50 | 199.75 | 463 | 57.90 | 53.01 |
| Plant Industry | 3,317 | 663.40 | 709.70 | 4,040.5 | 505.08 | 373.36 |
| Potato Investigations | 396.75 | 79.35 | 86.89 | 11 | 1.37 | .90 |
| Poultry | 1,038.50 | 207.70 | 222.72 | 896 | 111.96 | 90.19 |
| Power Plant | 59 | 11.80 | 12.92 | 6 | .75 | .49 |
| President's Office | 3 | .60 | .69 | 5 | .63 | .39 |
| Purchasing Agent | 438.50 | 87.70 | 99.12 | 777 | 97.12 | 61.91 |
| Roads and Drives | 6,060 | 1,212.00 | 1,345.59 | 4,294 | 536.75 | 367.97 |
| Rural Education | 3.50 | .70 | .77 | ........ | ........ | ........ |
| School of Agriculture | 19.00 | 3.80 | 4.29 | 27 | 3.38 | 2.19 |
| Student Life—Boys | 13 | 2.60 | 3.00 | 18 | 2.25 | 1.40 |
| Veterinary | 1,468.50 | 293.70 | 320.81 | 1,165 | 145.63 | 106.07 |

## THE COLLEGE LIVERY.

For convenience in supplying the institution with horses and carriages for the performance of college business, entertainment of state, government and other officials, and for the entertainment of state and institutional visitors, a charge account was started which we called "College Livery." The department or office receiving livery services was charged at the following rates:

Single horse and two-seated surrey:

| | With Driver | Without Driver |
|---|---|---|
| Per day | $5.00 | $3.00 |
| Half day | 3.00 | 2.00 |

Team and two-seated surrey:

| | With Driver | Without Driver |
|---|---|---|
| Per day | $5.00 | $3.00 |
| Half day | 3.00 | 2.00 |

For five hours or less, half-day rates were charged, and for more than five hours, day rates were charged.

In order to determine what this service cost the Farm Department, careful record was kept of the different items of cost which are summarized in Table No. 107. In 1910 and 1911, when the number of hours of livery service was the largest, the standard charge returned a small profit, as indicated. In 1912 and 1913, there was less demand for the College Livery service and during these years the maintenance of this service resulted in a loss to the College Farm.

TABLE No. 107.
COST OF COLLEGE DELIVERY.

| Year. | Man Hours | Actual Cost of Man Labor | Horse Hours | Actual Cost of Horse Labor | Int. and Depreciat'n on Equipm't | Total Cost | Receipts | Profits | Loss |
|---|---|---|---|---|---|---|---|---|---|
| 1910 | 149.5 | $29.60 | 541.5 | $64.98 | $90.85 | $185.43 | $220.20 | $34.77 | $.......... |
| 1911 | 85 | 18.62 | 468.5 | 38.89 | 80.98 | 138.49 | 189.00 | 50.51 | .......... |
| 1912 | 108 | 23.65 | 200.5 | 16.44 | 68.31 | 108.40 | 73.90 | .......... | 34.50 |
| 1913 | 125 | 28.88 | 260 | 20.28 | 55.85 | 105.01 | 90.00 | .......... | 15.01 |
| Totals | 467.5 | $100.75 | 1,470.5 | $140.59 | $295.99 | $537.33 | $573.10 | $85.28 | $49.51 |
| Total Profit 4-year period | | | | | | 35.77 | | | 35.77 |
| | | | | | | $573.10 | $573.10 | $85.28 | $85.28 |

Bulletin 204 January, 1915

# The Agricultural Experiment Station

OF THE

Colorado Agricultural College

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# BRISKET DISEASE

(Dropsy of High Altitudes)

By

Geo. H. Glover and I. E. Newsom

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# The Agricultural Experiment Station

FORT COLLINS, COLORADO

# BRISKET DISEASE

(Dropsy of High Altitudes.)

Preliminary Report.

## INTRODUCTION.

For a number of years the Station has received letters from stockmen, living in the mountainous region of Colorado, giving accounts of a disease in cattle in which the most prominent symptom seemed to be a swelling of the brisket. Outside of a few visits made by the Veterinarian of the Experiment Station and the State Veterinarian, nothing of importance was done to determine the nature of the malady. In April, 1913, two South Park stockmen, Lew W. Robbins and David Collard, advanced one hundred dollars each, to be placed at the disposal of the Station for a study of the disease. Upon explanation of their action, the Park County Stockgrowers Association, which is composed of members who live at elevations of from eight to ten thousand feet, agreed to take over the expense and the two men were reimbursed. This money has been used only for work done in South Park and to meet incidental and traveling expenses. The Station has at all times paid the salaries of the men engaged in the work and furnished practically all of the necessary equipment. Since that time the State of Colorado has by special appropriation added materially to the fund thus broadening the scope of the work.

The work is still in progress and much of the detail is purposely left out of this report to be embodied in a later and more technical treatise on the subject, the idea being to give in a later report a rather complete and exhaustive description since to our knowledge the disease, as such, has not been described.

The plan of procedure mapped out was, first, to determine whether the disease could be transmitted from one animal to another; second, to find the cause; third, to make a complete study of its various manifestations; and fourth, to find a remedy.

We are indebted to the two gentleman named above, to Messrs. George Clark, W. H. Lilley, Howard Wright and Archibald Head of Jefferson; to Mr. T. W. Forman of Divide; to H. L. Guiraud of Garo, and to Erhardt and Felding of Nathrop, for furnishing animals and rendering great assistance in the work. We are also under obligations to the Cox-Jones Commission Company of Den-

ver for assistance in caring for the animals that were shipped there, and to Dr. J. C. Exline, U. S. Inspector in charge at Denver, for making observations.

This report is based upon personal observations made on thirty-two cases and autopsies held on six. In addition to this, several cases have been seen on which no special observations were made and no records kept.

## HISTORY AND DISTRIBUTION.

This disease has been known in South Park, which is a high mountain park, varying in altitude from nine to ten thousand feet, since 1889 and in all probability existed before that time. It has been reported from North Park, which is approximately eight thousand feet, on numerous occasions. The people around Divide (about nine thousand feet) have reported many cases. It does not seem to exist to any extent in the San Luis Valley, which runs in altitude from seven to eight thousand feet, but is frequently reported from the high ranges surrounding it, when the cattle pasture on the forest reserves during the summer. It seems then to exist in the mountains of Colorado from the Wyoming line on the north to the New Mexico line on the south. We have not personally seen cases at altitudes below seven thousand feet, although we have talked with men who believe they have, and it would seem that an occasional case of a similar nature might occur at any altitude.

Thinking that other mountain states must suffer to some extent, we addressed letters to either the State Veterinarian, the Station Veterinarian, or both, of the States of Utah, Wyoming, Montana, Idaho, Nevada and California. We received replies from all except Idaho, stating that such a disease had not been brought to their notice. In spite of these negative replies, we have good reason to believe that the disease exists in the high altitudes of some of these states, although it has never seemed to assume such proportions as to be called to the attention of the veterinary officials.

In a conversation with Dr. John R. Mohler, Assistant Chief of the U. S. Bureau of Animal Industry, he expressed himself as having read something in Swiss literature of a similar disease. He has so far, unfortunately, been unable to find the article. We have addressed a letter to the Veterinary College at Berne, Switzerland, with the hope of gaining information from that source and if successful will include it in a later report.

## ECONOMIC IMPORTANCE.

It is very difficult to estimate the cost of this disease to the State. During the winter of 1913-1914 one South Park stockman estimates that out of between four and five hundred cattle, he lost thirty calves and ten or twelve older animals. Another man lost twelve during the winter of 1912-1913. Still another says, after several years' experience, he has lost practically all bulls that he shipped in from a low altitude and he figures his loss at about five per cent. It seems conservative to estimate the annual loss at one or two per cent of all cattle above eight thousand feet. While this may seem small, yet in the aggregate it means many thousands of dollars.

## TRANSMISSION.

We have tried only twice to transmit the disease, as the nature of the malady and the further investigation did not seem to warrant more work along this line. One cubic centimeter of blood was drawn from the jugular vein of case one, a seven-year-old cow, and injected into the jugular vein of a two-year-old steer. The steer was under observation for more than a year following and showed no symptoms of the disease. Ten cubic centimeters of serum were taken from the pleural cavity of case two (a calf that was slaughtered for the purpose of making the autopsy) and injected subcutaneously into the brisket of a healthy calf. This calf was under observation for more than a year and developed no symptoms of the disease.

Several cases have been known where an affected animal ran with numbers of healthy ones for weeks with no spread of the disease. No attempt has ever been made to isolate diseased animals and yet it does not appear that this practice has had any effect in spreading the disease. Later in this article we will have something to say as to the cause and it will then appear why we do not regard the disease as transmissible or even as infectious.

## ANIMALS AFFECTED.

The disease has been investigated in cattle only, and seems to be much more prevalent in these animals. Man and the horse probably suffer similarly under the same conditions in occasional cases. Animals of all ages are affected, although it is not commonly recognized in young calves since these animals often die without showing the swelling of the brisket. Case number nine showed the typical lesions on post mortem examination, although at the time it was only six weeks old. Many calves die from this disease when the owners believe it to be diphtheria or some other malady.

## EFFECT OF CLIMATE.

At the lower altitudes, eight thousand to nine thousand feet, the disease is more prevalent in the winter, in fact seldom appears in the summer, while at the higher levels up to thirteen thousand, it is a summer disease, largely, however, because cattle do not remain at these elevations in the winter. A wet cold summer is associated with a marked increase in the disease, and an especially hard winter may make a difference in the number of cases. This is rather easily explained by saying that more work is put upon the heart during cold weather and this would break down an already weakened organ all the more quickly.

## SYMPTOMS.

The first evidence of the disease is a dull, listless appearance, the hair stands on end and the ears droop. The animal appears gaunt owing to failure to take the usual amount of food. There may be a slight moist cough. A diarrhoea usually appears soon after the other symptoms, or it may even be the first symptom noted. The respiration is increased and the pulse is rapid and weak. Many calves die in this stage without showing any swelling of the brisket. In some instances the appetite remains good up to within a few days of death.

Later, there appears a swelling of the loose tissue under the jaw and a swelling of the loose tissues of the brisket. Either swelling may appear first, but gradually the two merge into each other as the whole under part of the neck becomes dropsical. In male animals, the sheath may swell considerably and the hind limbs become puffy. The fore limbs may stock in extreme cases. The swelling of the brisket may become enormous in size, extending out in front of the fore limbs as a rather firm doughy mass. There is no pain on pressure and the part is not increased in temperature. The abdomen may swell markedly in its lower portion due to accumulation of fluid.

The respiration becomes increased but labored only on exercise. A moist cough is very commonly noticed. A clear mucous discharge comes from the eyes and nostrils. There is no fever. The heart-beats are increased, especially on slight excitement or exercise when they may run one hundred to one hundred and twenty per minute. Under these circumstances the beat is tumultous but lacks force as evidenced by a very weak pulse. A pronounced jugular pulse is common in the later stages.

Forced exercise in this later stage will cause labored breathing, coughing, hemorrhage from the nose, and if continued, rapid death. Consequently it is difficult to drive them to a point where they can be shipped.

The animals become very weak, so that the slightest exertion or excitement causes them to fall. This has been noticed repeatedly when attempting to restrain them for close observation.

The blood in all cases observed has shown an increase in hemoglobin and a rather decided increase in the number of red blood corpuscles, counts averaging near twelve million per cubic millimeter for adult cattle and somewhat more for calves.* Counts made at an altitude of 9,000 feet on four normal cows, running in age from four to ten years, varied from 6,880,000 to 11,320,000. Those made on six calves from three to six months old at the same altitude ran from 11,960,000 to 21,200,000.**

The urine has never in our observation shown the presence of either albumen or sugar, although we rather expected to find the former. We have developed no suitable method for determining whether there is a greater or lesser quantity excreted in a given time.

The usual course of the disease is from two weeks to three months, although a few animals have been known to apparently recover in the spring, only to be taken down again the following fall. We may say that most animals die within a month after symptoms are first noticed, the older cattle living longer than the younger.

Death seems to be due either to suffocation, or exhaustion and paralysis of the heart.

## LESIONS.

The carcass is usually emaciated. The subcutaneous tissues in the region of the brisket, lower side of the neck, and under the jaw are infiltrated with a clear serum. It does not flow freely when incised, but can be squeezed out. Sometimes the subcutaneous tissue of the limbs is similarly affected.

When the abdomen is opened, a considerable quantity of straw colored fluid escapes, sometimes as much as six or eight gallons. The peritoneum may show a few hemorrhages and occasionally one is large enough to form a considerable mass of clotted blood (case 2.) The membrane itself in all of its folds is much thickened with the fluid above mentioned which can be squeezed out.

The walls of the stomach and intestines are thickened from the same cause. The mucous membrane of the fourth stomach and of the intestines may show small hemorrhages.

The liver is always much enlarged and is tough, firm and leathery. On section it has a grayish mottled appearance, the cut veins being very large. The condition of the liver is very noticeable and seems to be constant. On microscopic examination the grayish appearance is seen to be due to new fibrous tissue that entirely surrounds the lobules and has compressed the secreting cells until many

* In nearly all cases the blood for counting was taken from the capillaries of the ear.
** Counts made in November.

have undergone fatty degeneration and others have entirely disappeared. The central veins are engorged with blood.

The spleen appears normal both on autopsy and under the microscope. The kidneys show passive congestion and under the microscope there is considerable dilatation of the vessels with the cells of the tubules undergoing degeneration and loosening. The pancreas and bladder are normal.

In the thorax a large amount of fluid is to be found as in the abdomen. The lungs are edematous and therefore near the lower borders a few reddened solidified and slightly depressed areas. When the animal has died of the disease the lungs may be reddened and the bronchial tubes show hemorrhages. The heart is enlarged, dilated and usually flabby. It is pale in color and may or may not be thicker than normal in its walls. It has been our experience in the limited number of cases that the hearts of the young animals are dilated and flabby with thin walls, while in the older ones there is hypertrophy with dilatation. No vegetations have been found on the valves nor any lesion that would lead to the belief that a valvular disturbance existed.

Under the microscope in three cases there has been noted excess fibrous tissue with more or less round cell infiltration. Some degeneration exists, the degenerated fibres being replaced by new fibrous tissue. Numerous *sarcosporidia* are found in every section, but no special importance is attributed to these, as they are rather common in normal animals.

The pericardium and epicardium are edematous and thickened.

## DIFFERENTIAL DIAGNOSIS.

It simulates traumatic pericarditis, but can be differentiated by the fever which usually accompanies the latter disease. On post mortem examination the finding of pus in the pericardium would eliminate "brisket disease" and point to traumatism.

It could easily be mistaken for pneumonia, especially if complicated with pleurisy, in which case the brisket might be swollen. The diagnosis here would be based on the presence of fever in the live animal and on autopsy, signs of inflammation in the lungs and pleura.

We see no reason for confusing the disease with diphtheria, but since it has been done, will say that diphtheria can only be diagnosed when there are ulcers and an extremely foul odor in the mouth.

## TREATMENT.

From our experience in six cases and from the experience of several stockmen, shipping to a lower altitude seems to be sufficient to effect a cure and where feasible is always to be recommended. The difficulty arises, first, in getting the animals to the railroad, and then in the expense of shipping after they are taken there. However, since the animals may be considered worthless, all that is received for them over and above expenses should be looked upon as clear profit. Animals can usually be hauled to the railroad and it is perfectly feasible to pay for a car for two or more of them. In some localities the affected animals can be slowly driven to a lower altitude, thus effecting a recovery. This is frequently done in the San Luis Valley, where the belief prevails that practically all recover when driven from the mountains to the valley, where the elevation is between seven and eight thousand feet. Just how much lower it is necessary for them to go cannot be said at this time, but certainly a change from nine thousand to five thousand two hundred and eighty feet has proven effective. Men in South Park believe some calves have been saved by driving them from eleven thousand to nine thousand feet elevation. In the San Luis Valley a difference of two or three thousand feet has proven sufficient. With our present knowledge, shipping or driving to a lower altitude should be first considered. If this is not possible, then medicinal treatment can be tried.

Much digitalis has been used in the form of a drench, with some quite favorable reports. It was given in the form of the fluid extract in doses of one-half to one teaspoonful once to three times daily. It appears to have been of more value in older animals, as little if any relief was noticed in calves. On the whole, it is doubtful if digitalis in this form is dependable. The fluid extract was used because of its easy administration in the hands of stockmen, although we were cognizant of the reports that have been made concerning its being rendered inert in the stomachs of ruminants. Two cases, Nos. 30 and 31, were given digitalin without favorable results. This drug is quite irritating when used hypodermically.

Certainly the animals should be kept as quiet as possible and under the minimum amount of exertion and excitement. The question arises as to whether they can be successfully treated at the altitude where they contract the disease and this we cannot answer at this time. At least it is hoped that the disease can be held in abeyance until a convenient time for taking them to a lower altitude. Strychnine given hypodermically has given no good results.

Lancing the swollen brisket and placing various medicaments within can do no good and is to be considered barbarous. It is in line with slitting the tail and putting in salt and pepper, and like the latter practice it should be eliminated as soon as possible. The swollen brisket is merely a symptom of a general dropsy, and a weakened heart and surgical manipulation of it can be of no value. We must either strengthen the heart or lessen its work.

## PREVENTION.

Since the disease is far more prevalent in cattle shipped in from low altitudes than in natives, it would seem only wise that importations be somewhat curtailed or, if practiced, that the animals be brought more gradually to the extreme altitudes. For instance, hold them for a few months or seasons, at a moderate elevation, say seven or eight thousand feet. This practice is not likely to prevent all cases as is evidenced by reading the history of case eight, but would probably be worth while.

Since extreme exertion on first arrival at the higher level seems to play a part, more care should be taken in the handling of the animals during the first weeks to see that they are not subjected to long hard drives. Realizing that these animals are usually wild, we are aware of the difficulty in complying with this suggestion.

The practice of buying pure bred bulls from low altitudes, while praiseworthy in its intent, seems to be responsible for some of the difficulty. Not only do the bulls themselves in many instances die of the disease after some months' residence under the new conditions, but their calves appear to be much more susceptible than calves sired by native bulls. In order to reduce this source of trouble it is recommended that bulls be purchased from altitudes more nearly approaching that at which they are to be used. We believe that this practice, if followed, would do much toward eliminating the disease. Finally, it may become necessary to abandon some of the higher ranges, especially during cold and wet summers. Since the disease has not been seen in sheep it may be possible to range these animals at the higher levels where the cattle do not thrive.

## CAUSE.

Whatever may be the real cause of the malady, it would seem from our work thus far, that the matter of barometric pressure as influenced by the altitude is the deciding factor in the disease. About November 10, 1913, two two-year-old steers (cases 5 and 6), affected with the disease, as evidenced by a profuse diarrhoea and marked swelling of the brisket, were shipped from Jefferson, the altitude of which is nine thousand five hundred feet, to Denver (altitude five thousand two hundred and eighty feet). They were kept in the stockyards at the latter place for a little over two weeks when the diarrhoea was checked and the swelling of the brisket had entirely disappeared. On November 28th, they arrived at the

Station at Fort Collins (altitude five thousand feet), having been driven the same afternoon about six miles. Outside of a rapidity of respiration which might have been due to the drive, they appeared perfectly normal. They were under observation until December 17th, when, having been apparently normal since their first arrival, they were sold to a local feeder. The feeder reported that these steers fattened as well as any others in the lot and that they were sold for slaughter about April 10, 1914. No medicinal treatment of any kind was given them.

Case number seven, a yearling calf was shipped by express from Jefferson on February 11, 1914. It arrived in Fort Collins on the 12th, where, on examination, it appeared dull and had little appetite. The calf was thin, the coat staring, but the feces were of normal consistency. It was reported that the calf had had a marked diarrhoea on leaving Jefferson. After the second day the calf appeared entirely normal and remained so until March 9th, when it was returned to Jefferson, where it has since remained. On October 25, 1914, it was reported that the calf was in perfect health and had shown no return of the trouble.

On August 5, 1914, case twenty, a bull seven years old, was shipped from Jefferson to Denver (Cut No. I.). This bull had

Cut No. I. Case XX. Taken at Jefferson, Colorado, August 4, 1914, the day before shipping.

been on a range between 11,000 and 12,000 feet above sea level. He was driven to an altitude of about ten thousand feet two weeks previous and on the day before shipping was hauled eight miles in a wagon. He arrived in Denver on August 6th, where he was unloaded in the yards and allowed to remain there under observation until August 31st. Improvement was noticed, beginning about two days after arrival, until when seen on the 19th, all swelling had disappeared, and except for being thin, he appeared normal and re-

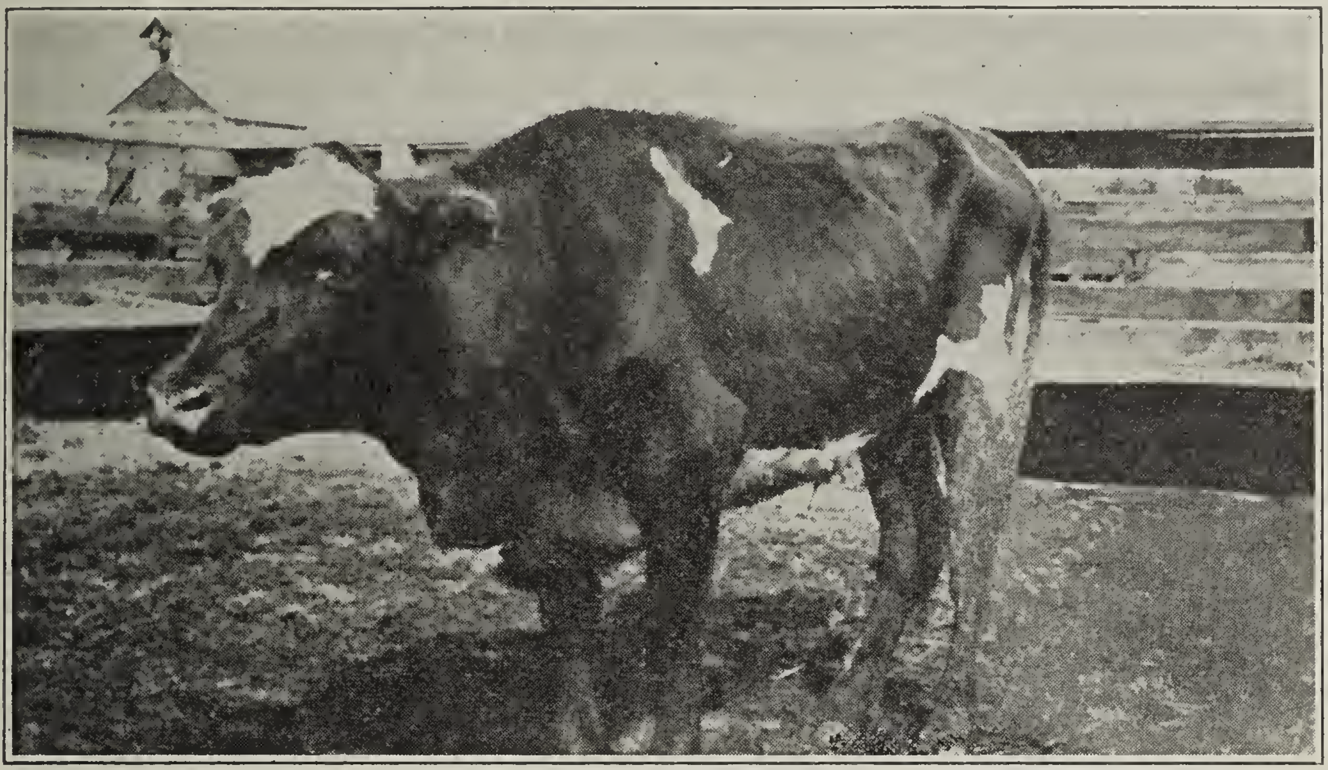
Cut No. II. Case XX. Taken at Denver, Colorado, August 19, 1914, just thirteen days after arrival. Animal normal except for being thin.

mained so until the 31st, since which time he has not been seen. The photograph for Cut No. II. was taken on August 19th.

Case twenty-one (Cut No. III.), a steer three years old, was shipped with case number twenty, and was given the same treatment. On the 19th he appeared much improved (Cut No. IV.), and on the 23rd he had entirely recovered.

On September 14, 1914, case number twenty-three, a yearling steer, was shipped by express from Jefferson to Fort Collins. On arrival the animal was weak, the respiration and pulse were rapid, the tail and hind limbs were soiled with dried feces, showing a previous diarrhoea; the feces at the time were of normal consistency. The steer continued to improve in general appearance until this writing, October 14th, when he seems to be normal. It has been a rather common practice among the stockmen of the San Luis Valley, when their animals became affected on the high ranges, to drive them down to their ranches, altitude about seven thousand five hundred feet, where they usually recovered.

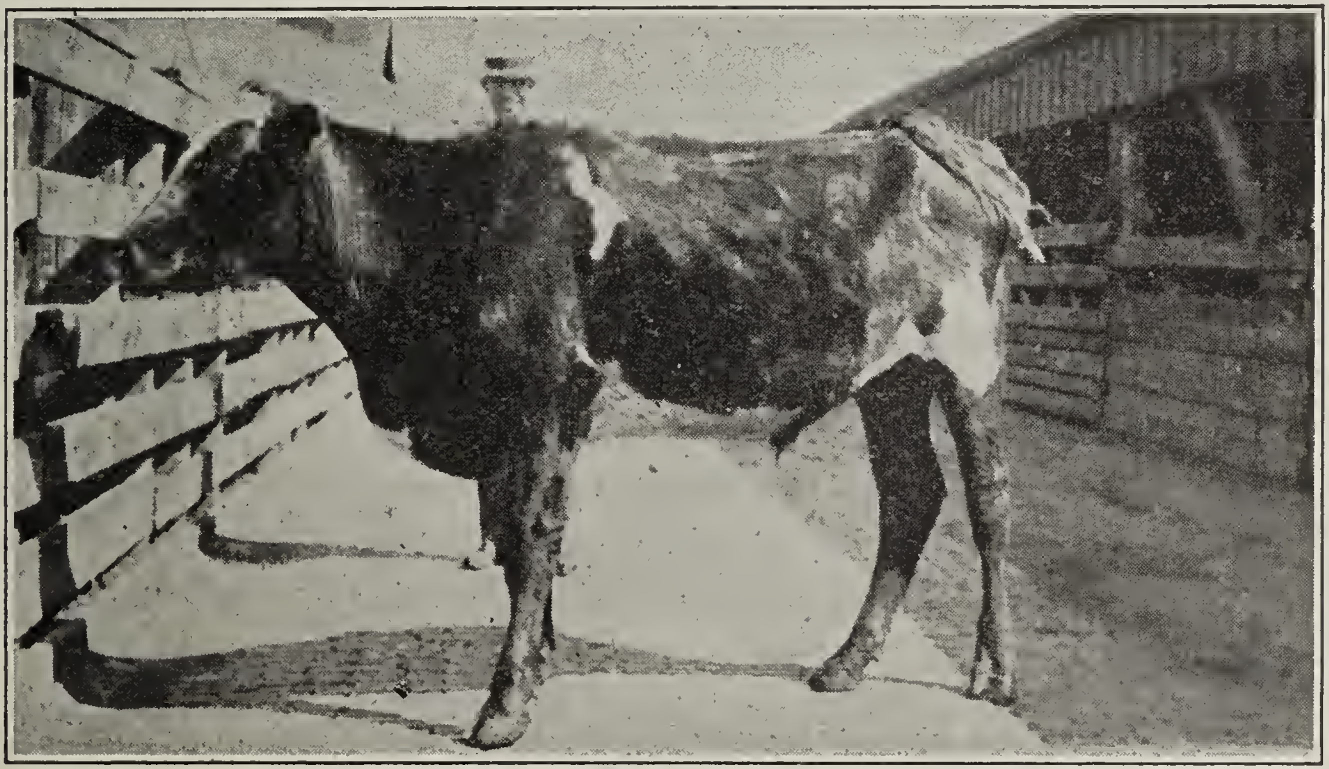
Altogether then there have been six cases shipped from a high altitude (9,500 to 11,000 feet) to a lower one (5,000 to 5,280) and



Cut No. III. Case XXI. Taken at Denver, Colorado, August 6, 1914, on the day of arrival, from Jefferson.

in each case prompt recovery followed. In no case was any medicinal treatment given.

One might suspect that a change of diet has something to do with it, but animals become affected both in the summer when at



Cut. No. IV. Case XXI. Taken on August 19th, thirteen days after arrival at Denver. Brisket still slightly swollen. All swelling had disappeared by the 23d.

pasture on the mountain grasses and in the winter when the food is entirely of hay cut in the parks. Furthermore, the hay in North Park is quite different from that of South Park. Hay from both places is shipped out in large quantities to lower altitudes but there is no evidence that it has caused any such disease.

Most investigators of the effects of high altitude, agree that unacclimated people passing from a low to a high altitude notice that the respiration and heart-beat markedly increase, that there is extreme weakness on slight exertion and even fainting and hemorrhage.* Is it not conceivable that at this time extra exertion or excitement would seriously dilate the heart, which dilatation might become so extreme as to cause degeneration of the muscle walls with chronic insufficiency, resulting finally in generalized dropsy? Several cases of dilatation of the heart in man have been attributed to ordinary exertion in high altitudes before becoming accustomed to the changed conditions.

Babcock in his book entitled "Disease of the Heart" details a case where a gentleman of fifty-seven, who was accustomed to a low altitude brought on an acute dilatation by carrying a traveling bag for several blocks in Denver (altitude 5,280). He died some two years later, with typical symptoms of chronic cardiac dilatation the inference being that the injury to the heart had taken place at the time of the extra exertion in Denver.

The same author attributes another case to an exhausting journey through a snow storm at an altitude of eighteen thousand feet.

Let us consider the experience of a trainload of wild Texas steers brought from sea level to an altitude of, say ninety-five hundred feet, unloaded amid considerable excitement and driven to a distant ranch. Already the altitude with its rarefied atmosphere has made it necessary for the heart to beat much faster. Add to this the excitement and exertion incident to the animals being wild, and it is not surprising that some of them would permanently injure the heart muscle so that in some weeks or months it would fail to perform its work. Presuming that a little later the animals were driven up rocky trails and through thick forests to an altitude of from eleven thousand to thirteen thousand feet, and with this excessive exertion the wonder is that so few of them are permanently injured.

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* The Anglo-American expedition to the top of Pike's Peak as given by the editor of the Journal of the American Medical Association reported as follows: "The more immediate effects after arrival were blueness of the face and lips, nausea, intestinal disturbance, headache, fainting in some persons, and periodic breathing, besides great hyperpnea on exertion or holding the breath a few seconds."

The horses that follow these cattle are practically all raised in districts where they do their work. When asked if low altitude horses were ridden, one man answered, "They are of no use." This expresses it well. Most stockmen know that a low altitude horse is of little value for work in high altitudes until he has become acclimated. We ourselves saw a very valuable Percheron stallion that had been shipped from a low altitude to an altitude of nine thousand five hundred feet. In less than a year he suffered from heart insufficiency to such an extent that the excitement of a man passing into the corral would cause him to fall. Just previous to falling no pulse could be detected at the jaw.

A physician who practiced at Fairplay, Colorado, altitude ten thousand feet, says that most old people at that altitude die with generalized dropsy. The same man reports two cases of generalized dropsy associated with other conditions as being much improved on going to Denver. It is rather a common practice for physicians to send heart patients to a lower altitude. In a spirit of fairness, however, we should add an extract from a letter written by a physician of several years' experience in practice at Leadville, Colorado, altitude ten thousand feet. "We have acute cardiac dilatation which will cause edema, but I believe with proper treatment they will recover as well at this altitude as lower down. It is my experience as well as the experience of other physicians here that the injurious effects of high altitudes have been much exaggerated, especially so in those born at this elevation."

In support of this contention, that the altitude is the important factor, we submit the following additional facts. There are four stockmen in South Park who seem to have more trouble than any others. These men range their cattle in the summer above timber line at an altitude above eleven thousand feet, which is one of the highest ranges in the United States.

The range near Buena Vista that runs from eleven thousand to thirteen thousand feet had not been used by cattle previous to the summer of 1914 when, as detailed under case twenty-four, twelve animals were lost out of one hundred and sixteen. The owners had ranged cattle at altitudes approximating eight thousand feet for several years, with no bad results. Cattle shipped from a low altitude are always more affected than those native to the country. There are several instances where a number of low altitude cattle have been shipped to South Park with markedly disastrous results. One man says that in several years' experience he has never yet shipped in a bull from a low altitude that did not sooner or later die of this disease. Is it not probable that some of the calves from these bulls would show a similar weakness in this respect, thus explaining the high mortality in calves? That is, as we look upon the problem, it requires a stronger heart to carry an animal through the vicissitudes incident to an existence at a high altitude than it does at a low one. Some hearts, in fact most of them, have sufficient reserve force to meet the new conditions, as is evidenced by the rather common observation that hearts of cattle at high altitudes are heavier and thicker (hypertrophy) than those lower down. Some animals, however, do not have this reserve force and exhaustion of the heart with dilatation results. Such animals would undoubtedly give rise to a certain number of offspring whose hearts would be insufficient to meet the vigorous conditions.

## CASE REPORTS.

**CASE No. 1.**—Black and white cow, age seven or eight; weight nine hundred and fifty. **History**—Noticed to be ailing the previous summer; swelling appeared under jaw about three weeks before; later, swelling of the brisket. About the 27th of March she refused food for a couple of days. On March 30 the swollen brisket was lanced, after which she seemed to improve, and drank more water than usual. Seen on April 5, 1913, near Jefferson, Colorado; altitude nine thousand feet; in fair flesh; rather wild, so that restraint was resisted and only accomplished after much excitement on the part of the animal. Following this, the temperature was 103° F.; respiration rapid with whistling sounds in trachea. An attempt was made to tap the swelling under the jaw without results. There was no weakness, feces very thin, and watery discharge from the nostrils, owner thinks animal better. One cubic centimeter of blood was removed from the jugular vein and injected into the jugular vein of a healthy steer. Cow remained in poor condition throughout the summer and was shipped out in the fall, passing from observation.

**CASE No. 2.**—Hereford steer, short, yearling, South Park, altitude nine thousand feet, raised there. **History**—Noticed to be sick about a week previous; seen on April 6, 1913, in fair state of flesh; respiration not labored but slightly increased, moist cough; temperature 102.6; appetite good; feces quite thin and dark in color; no mucous or blood; brisket swollen and flabby; April 7th, temperature 101.9. Calf eating, appears strong. Brisket swollen more than on day previous and rather more firm on pressure. Diarrhoea marked, feces dark in color. Abdomen enlarged. April 8th, increase in swelling of brisket with thickening of lower part of neck. Diarrhoea continues. Temperature 102.5. Jugular pulse well marked. April 9th, symptoms same as on previous days. Temperature 101.8. Slaughtered for examination. Post mortem examination.—Large edematous area at the brisket estimated to be ten inches long by eight inches wide. About three gallons of straw-colored fluid in the thoracic cavity. Considerable in the pericardium. Large blood clot the size of one's fist in the right lung near the dorsal part and just above the point where the bronchus enters. Collapsed red areas in the apical and cardiac lobes near the lower margin. By far the larger part of the lungs appear normal.

Estimated three gallons of fluid in the abdominal cavity. Mesentery very much thickened throughout its whole extent. Fluid can be easily squeezed out. Large blood clot near anterior mesenteric artery. Several small hemorrhages under the serous membrane. Liver enlarged and hard, on section is mottled gray. Spleen normal. Interior of rumen and reticulum black. Folds in the fourth stomach very edematous.

Many ulcers in the mucous membrane most of which are healed. Several reddened areas, some sand present. Mucous lining of intestine loosened and easily torn off. Intestinal contents thin, watery, no bad odor. Kidneys petechial. Bladder normal.

**CASE No. 3.**—Grade Hereford, black with white face, age one year, weight three hundred pounds. Found sick four days before. Altitude nine thousand five hundred feet. Seen on September 29, 1913. Grunting with every breath, dull, listless, mucous discharge from eyes; mucous membrane pale; jugular pulse very marked; jugular veins so full that they stand out and are plainly visible some yards away; no appetite; drinks freely; thin fetid diarrhoea; temperature 101.6; respiration 30 and audible; pulse 90; heart tumultous; brisket enormously enlarged and rather firm on pressure; some regurgitation of gas; coughs frequently; animal died during the night of September 30. **Post Mortem**—Subcutaneous tissue markedly edematous over brisket and under surface of the neck, extending as far back as umbilicus and forward to the symphysis of the lower jaw; enormous quantities of fluid in the thoracic cavity; heart enlarged and dilated; lungs congested in spots; bronchitis, due to a considerable number of lung worms; hemorrhagic spots in tissues about the pharynx and trachea; hemorrhages under the peritoneum at several places, an especially large one under the spleen; spleen normal; liver hard, enlarged and mottled on section; kidney passively congested; mucous membrane of the fourth stomach and intestines reddened throughout; a large quantity of fluid in the abdominal cavity; the serous membrane of the intestinal walls is much thickened by edema.

**CASE 4.**—Yearling calf, weight three hundred and fifty pounds; seen on September 29, 1913; altitude nine thousand feet. The previous day he had been driven in off the range, but owing to his failure to travel well has been left behind. **Symptoms**—Profuse diarrhoea, not dark in color; very weak and grunting; brisket greatly swollen as well as the loose tissues under the jaw; mucous and watery discharge from the eyes; dull; listless; temperature 101.1; respiration 18; pulse 100. Slaughtered on the morning of the 30th for examination; a few hemorrhagic areas on the rumen; estimated a couple of gallons of fluid in the abdominal cavity and as much in the thoracic; mesentery edematous; four rather large ulcers in the fourth stomach; no reddening in either the stomach or intestines; liver enlarged and quite hard, being mottled on section; lungs normal except a few small areas in dependent portions of the cephalic and cardiac lobes, which are solidified and depressed; heart not large but quite flabby; no lung worms and no bronchitis.

**CASES No. 5 AND 6.**—Two two-year-old steers with badly swollen briskets and showing profuse diarrhoea, shipped from Jefferson, Colorado, altitude nine thousand feet, to Denver, where they remained in the stockyards for three weeks, during which time they completely recovered. They arrived at the Station at Fort Collins on November 28, 1913, in a normal condition, were kept under observation until December 17th, when they were sold as feeders. The purchaser reported that they fed out as well as any others in the lot and were sold for slaughter about April 10, 1914. One of these steers came originally from either New Mexico or Arizona and the other from Marysville, Utah.

**CASE 7**—A calf raised at Jefferson, Colorado, altitude nine thousand feet, shipped to Fort Collins by express on February 11, 1914, because of a marked diarrhoea, dullness, swelling of the abdomen and droopy ears, denoting brisket disease. On arrival the following day the feces were normal, the animal was weak and dull with little appetite. No swelling of the brisket; temperature 102. It became brighter in a few days and continued to improve until within a week it was normal. The calf was returned to Jefferson on March 9, 1914, since which time there has been no recurrence of the disease.

**CASE 8.**—July 1, 1914. Three-year-old steer, grade Shorthorn, altitude nine thousand two hundred feet, Divide, Colorado. **History**—One of a bunch of yearlings brought from Nebraska to an alaiaude of about eight thousand feet, near Manitou. Present owner bought them the spring previous and had lost one other steer similarly affected; been sick for four weeks. **Symptoms**—Brisket moderately swollen, no appetite, dull, thin, staring coat, swollen under the jaw; scouring badly but feces not black; respiration hurried. He was given a teaspoonful of fluid extract of digitalis by the mouth on July 2 and 3. On the 4th he was given two doses of a teaspoonful each, one in the morning and one in the evening. On the 5th three doses were given. He grew steadily worse until some time during the night of the 5th, when he died. **Post Mortem Examination**—Subcutaneous tissue markedly edematous throughout the region of the brisket, neck, intermaxillary space and over all four limbs;

Cut No. V. Case VIII. Taken on July 2, 1914, at Divide, Colorado, three days before death.

lungs collapsed in a few small areas, the left one showing a few hemorrhages; tracheal and bronchial mucous membranes hemorrhagic; no parasites; a large quantity of fluid in the thorax; heart enlarged with thick walls; epicardium edematous; several gallons in the abdomen with all of the serous membrane and walls of the hollow viscera decidedly thickened with fluid; mucous membrane of fourth stomach and intestines reddened over entire area. Liver very dark, hard and enlarged, mottled on section; spleen normal and kidneys showing congestion. An abscess estimated as holding a pint of pus was found in the wall between the reticulum and the omasum; there was a blackened wire nail in it; it did not, however, extend through the diaphragm into the thorax.

**Case 9.**—Female, calf, aged six weeks, Shorthorn. **History**—Been on the range at an altitude between eleven thousand and twelve thousand feet along with cases ten to twenty-one, inclusive. This case is given especially because it represents a typical one picked out from a number of others that were supposed to have diphtheria. It was also stated that one man had lost thirty calves during the previous year similarly affected and that this year many were dying from the same affection. An examination of the mouth of a considerable number revealed no ulcers nor any diseased condition, consequently this one was picked out for autopsy. It had been sick for two weeks, brought to ranch nine thousand feet, a week before. **Symptoms**—In good flesh, but the flanks are sunken, due to failure to suck; hair is standing on end and ears droop; seems to have considerable strength; no noticeable swelling of the brisket or submaxillary space; coughs occasionally; some diarrhoea. **Autopsy**—Edema of the loose tissues surrounding pharynx and larynx; estimated that there was a gallon of fluid in the thorax, as much in the abdomen and a pint in the percardium; lungs normal except for a few collapsed and red areas near ventral border; heart flabby and dilated; peritoneum and walls of the hollow abdominal organs markedly edematous; liver enlarged and hard, being mottled with gray on section. The interior of the intestines and stomach are pale, being due probably to the fact that the animal was bled before examination.

**CASE 19.**—August 3, 1914. A calf that was presumed to be sick like the others, but had been in pasture at about nine thousand five hundred feet. It had developed a swelling of the brisket during the night previous to our visit and was very dull and grunting when seen; diarrhoea marked; died on the night of August 4.

**CASE 20.**—Shorthorn bull, pure bred, age 4 years; raised at Golden, Colorado, altitude about five thousand five hundred feet; was purchased and shipped to South Park (nine thousand feet) in June, 1913. During the following winter he developed a considerable swelling of the brisket. Digitalis was given at the rate of one-half teaspoonful of the fluid extract daily. He recovered in about a month and in the spring was sent with the other cattle to the range between eleven thousand and twelve thousand feet. He was noticed to be ailing about the middle of July and a week later his brisket was swollen and he was driven down to an altitude of about ten thousand feet; seen on August 1. **Symptoms**—Stands in shade, seldom moves, dull, no appetite; brisket swollen enormously; sheath swollen; legs thickened and edematous, the hocks being especially puffy; ears drooped; no diarrhoea. On August 4th he was hauled eight miles in a wagon to Jefferson, where he was loaded with Case 21 and shipped to Denver. On the 6th of August he was apparently gasping for breath, his mouth was open and he was very dull. (It was a very hot day and the animal was in the sun.) However, his appetite seemed good. On August 10th the swelling of the brisket had decreased fully one-half; appetite good; on the 19th all trace of swelling had disappeared and he was normal except that he was thin. He was sold on the 31st as a feeder and passed out of our observation.

**CASE 21.**—Grade Shorthorn steer, three years old. **History**—Raised in Texas and purchased in Denver a year previous; found ailing the latter part of July on the range at altitude above eleven thousand feet; driven to ranch (nine thousand feet) where he had for two weeks received digitalis daily without avail. Shipped to Denver on August 5, 1914, where he showed the following symptoms on arrival. **Symptoms**—Dull, little appetite, ears drooped; respiration labored, panting; brisket swollen enormously, rather firm and hard on pressure; feces normal. On August 10th he was eating well and appeared brighter, but the swelling was about the same as on the 6th. On the 19th much brighter, swelling of brisket nearly all gone, that which was left being flabby. On the 23d he appeared entirely normal and was sold as a feeder on the 31st.

During the time cases twenty and twenty-one were in the stockyards at Denver, they were under close observation by the inspectors of the U. S. Bureau of Animal Industry.

The following data is appended as kindly submitted by Dr. J. C. Exline, Inspector in Charge.

Denver, Colorado, September 25, 1914.

Dr. J. C. Exline,
Inspector in Charge,
Denver, Colorado.

Sir: August 5, 1914, there was received at the Denver Union Stockyards from Jefferson, Colo., one red bull, weight about 1,200 pounds, and one red and white steer, weight about 1,000 pounds, held for observation, account so-called "Brisket Disease." Animals found to be emaciated, an edematous condition noted, extending posteriorly from sub-sternal to scrotal region; between forelegs it was from 12 to 15 inches wide, pit on pressure, apparently filled with an exudate which involved the inferior thoracic-abdominal region, and legs. The following temperatures have been recorded:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aug. 6. | Bull— | 3:00 p.m. | 101.8 | Aug. 6. | Steer— | 3:00 p.m. | 101.4 |
| Aug. 7. | Bull— | 9:00 a.m. | 101.4 | Aug. 7. | Steer— | 9:00 a.m. | 101.2 |
| Aug. 8. | Bull— | 8:30 a.m. | 100.3 | Aug. 8. | Steer— | 8:30 a.m. | 101.2 |
| Aug. 8. | Bull— | 3.00 p.m. | 101.2 | Aug. 8. | Steer— | 3:00 p.m. | 102.4 |
| Aug. 9. | Bull— | 11:00 a.m. | 101.2 | Aug. 9. | Steer— | 11:00 a.m. | 102 |
| Aug. 10. | Bull— | 8:30 a.m. | 100.8 | Aug. 10. | Steer— | 8:30 a.m. | 101 |
| Aug. 10. | Bull— | 3:00 p.m. | 104.4 | Aug. 10. | Steer— | 3:00 p.m. | 103.2 |
| Aug. 11. | Bull— | 11:00 a.m. | 101.6 | Aug. 11. | Steer— | 11:00 a.m. | 103 |
| Aug. 11. | Bull— | 4:00 p.m. | 104 | Aug. 11. | Steer— | 4:00 p.m. | 104 |
| Aug. 12. | Bull— | 9:00 a.m. | 101.8 | Aug. 12. | Steer— | 9:00 a.m. | 102.6 |
| Aug. 13. | Bull— | 9:00 a.m. | 101.8 | Aug. 13. | Steer— | 9:00 a.m. | 102.2 |
| Aug. 14. | Bull— | 9.00 a.m. | 101.2 | Aug. 14. | Steer— | 9:00 a.m. | 100.6 |
| Aug. 27. | Bull— | 10:00 a.m. | 101.8 | Aug. 27. | Steer— | 10:00 a.m. | 102 |
| Aug. 28. | Bull— | 9:00 a.m. | 101 | Aug. 28. | Steer— | 9:00 a.m. | 101.2 |
| Aug. 28. | Bull— | 3:00 p.m. | 102.6 | Aug. 28. | Steer— | 3:00 p.m. | 101.8 |
| Aug. 29. | Bull— | 9:00 a.m. | 101.6 | Aug. 29. | Steer— | 9:00 a.m. | 101.2 |
| Aug. 29. | Bull— | 3:00 p.m. | 102 | Aug. 29. | Steer— | 3:00 p.m. | 101.8 |

Pulse found soft and weak first few days. Urination frequent, normal in color—the high temperatures probably due to being in open pens several days. Animals apparently regained normal condition and were shipped as feeders to Omaha, Neb., August 31, 1914.

Very respectfully,
A. W. SWEDBERG,
V. I., Yards.

Denver, Colo., October 6, 1914.

Dr. J. C. Exline,
Inspector in Charge.

Sir: The following observations were made and temperatures taken for a period of eleven days, on two cases of brisket disease—bull and steer—at the Denver Union Stockyards:

Subject: Shorthorn bull, about five years old, in poor condition, with considerable swelling of brisket.

TEMPERATURE.

| | 10 a.m. | 3 p.m. |
|---|---|---|
| Aug. 15. | 101.6 | |
| Aug. 16. | No temperature taken. | |
| Aug. 17. | 100.8 | 102 |
| Aug. 18. | 101 | 101.6 |
| Aug. 19. | 101.4 | 102 |
| Aug. 20. | 100.6 | 100.8 |
| Aug. 21. | 100.6 | 101.8 |
| Aug. 22. | 101.4 | 100.2 |
| Aug. 23. | 100.4 | |
| Aug. 24. | 101.4 | 101 |
| Aug. 25. | 101 | 103.8 |

The swelling of brisket generally lessened from day to day until on the day of the last observation it had almost entirely disappeared.

Subject: Steer, grade, about four years old, in poor condition, brisket very much swollen.

TEMPERATURE.

| | 10 a.m. | 3 p.m. |
|---|---|---|
| Aug. 15. | 102 | |
| Aug. 16. | No temperature taken. | |
| Aug. 17. | 102.6 | 102.4 |
| Aug. 18. | 101.6 | 102.4 |

Diarrhoea was present up to this date when the evacuations became normal.

TEMPERATURE.

| | 10 a.m. | 3 p. m. |
|---|---|---|
| Aug. 19. | 101.8 | 101.8 |
| Aug. 20. | 101.4 | 102 |
| Aug. 21. | 100.8 | 101.4 |
| Aug. 22. | 101 | 101.4 |
| Aug. 23. | 100.6 | |
| Aug. 24. | 100.6 | 101.2 |
| Aug. 25. | 100 | 103 |

There was still considerable swelling of brisket on this date, but it had lessened from day to day during the period of observation.

The high temperature of both bull and steer, at 3 p. m., on August 25, were probably due to the animals being removed from a covered shed to an open corral.

During the period of observation, both animals ate well and drank freely.

Very respectfully,

H. B. CHANEY, V. I.

**CASE 23.**—Yearling steer, grade Hereford; raised at an altitude of about nine thousand feet; was noticed to be ailing some two weeks before shipping out. Two days after shipping the brisket was markedly swollen and diarrhoea was profuse. On the day of shipping, however, the brisket was not swollen. Arrived at Fort Collins September 15, 1914. He was extremely weak and rather dull, appetite good, hind limbs covered with feces showing a previous diarrhoea; respiration 120; heart-beat could not be obtained under normal circumstances; no swelling of the brisket. Animal became brighter and added flesh until this writing, when he is perfectly normal.

**CASE 24.**—Two-year-old Hereford steer, one of a bunch of one hun-hundred and sixteen steers shipped from Panhandle, Texas, in March, 1914, to Nathrop, Colorado, altitude seven thousand six hundred and ninety-six. On May 1st they were driven to a range between ten thousand and thirteen thousand feet, where they remained until September 27th. During this time seven had died with what appeared to be brisket disease and on September 27th six were sick and four were missing. Case 24 had been driven the previous day to an altitude of a little less than eight thousand feet, where, owing to exhaustion he and one other had been left, the other sick ones being taken to an altitude of a little less than eight thousand feet. On September 28th, the brisket and loose tissue of the jaw were badly swollen; there was profuse diarrhoea; the animal was very weak and grunting; respiration 36; pulse 120 and very weak; heart bating tumultously; moist cough; did the following day while being transported in a wagon to a lower altitude. Two others of this group died within the next two weeks in spjite of the fact that they were removed to an altitude of eight thousand feet.

**CASE 28.**—Seen August 16, 1913, ten miles above Morrison, on Bear Creek, altitude seven thousand feet. **History**—Jersey cow, seven years old; taken from Littleton, January 10, 1913, driven to Canfield's ranch, stood the journey well. Canfield thinks the brisket might have been slightly swollen at that time. A month later the cow was constipated, had desire for salt and drank much water. A nasal discharge was noticeable. The brisket enlargement partially disappeared for a time; heart beating violently. July 15th diarrhoea was present and feces had offensive odor; weakness, anorexia, malaise, indisposed to move. **Symptoms**—Temperature 102.5; respirations labored; fore feet wide apart; offensive diarrhoea; temperature of body evenly distributed; heart beating fast and labored; pulse full and hard; jugular on right side was corded, the size of a man's wrist, extending from the bifurcation near angle of jaw downward for ten inches; an old scar was found in the region of the throat and over the jugular, looked as though it might have been surgical. **Post Mortem**—Cow was destroyed by bullet in head and bleeding; test with hemoglobin scale indicated one hundred per cent; edema of brisket extreme and not extended to the lower pectoral region; edema not present in extremities; great quantities of sera found in thorax and abdomen; edema of mesentery and areolar tissue in region of brisket; heart muscles flabby and showing some degeneration; right side of heart dilated and no excessive accumulation of fluid around the heart; lungs normal save a wash-out appearance; spleen normal; liver much enlarged, hard and nutmeg appearance; blood seemed to coagulate normally; bowel contents fluid and nearly empty; a thrombus fully six inches long in jugular vein; kidneys appeared slightly congested but otherwise normal. The cow was in good flesh when symptoms first appeared and did not show debility, fever and disturbances of reflexes, volition, etc., that would be expected in case of infection.

**CASE 30.**—Yearling, Hereford heifer; weight 500 pounds; altitude nine thousand feet; near Hartsel, Colorado. **History**—One of a bunch of southern heifers shipped into South Park on May 13, 1914, and pastured at an altitude of about nine thousand feet during the summer. She was noticed to be sick about the middle of October when the roundup took place. Seen on November 6, 1914, at which time there was a moderate swelling of the brisket, a puffiness under the jaw and a very much distended abdomen. She was thin, weak, had little appetite and a rather profuse diarrhoea.

November 7.—Pulse 120 and weak; temperature 103.2. The thorax was tapped with trocar and cannula, but not to exceed a pint of fluid was obtained. Four gallons of fluid were drawn from the abdomen, which noticeably reduced its size. At 8 a. m. ¼ gr. digitalin was given hypodermically; at 1.30 p. m. ¼ gr. digitalin and ¼ gr. strychnine; 5 p. m. ¼ gr. digitalin.

November 8.—Brisket swollen more than on previous day, abdomen slightly fuller than after tapping. One-fourth gr. digitalin and ¼ gr. strychnine given morning and evening.

November 9.—Brisket and abdomen same as on previous day. Same medicament as on previous day. Red blood corpuscles 14,120,000.

November 10.—Weak; temperature 102.3. One-fourth grain digitalin and ¼ gr. strychnine morning and evening.

November 11.—One-eighth grain digitalin and ¼ gr. strychnine given in the morning. Animal very weak. Died within thirty minutes after the last dose of medicine.

**Post Mortem.**—Carcass emaciated. Subcutaneous tissue edematous on under surface of jaw, neck, chest and part of abdomen; probably a gallon of fluid in the thoracic cavity and a small amount in the pericardium; lungs normal except lower portion of cephalic and cardiac lobes which appear reddened and collapsed; heart much dilated and flabby even the left ventricle collapsing as does the right in some cases; no macroscopic valvular lesions. Abdominal cavity contained a small amount of fluid, the mesentery and subserous tissues throughout being markedly edematous. Liver enlarged and hard. mottled on section. Spleen normal, other organs normal except for generalized edema. Areas of necrosis on the side of the neck evidently resulting from the digitalin.

**CASE No. 31.**—Hereford heifer, yearling, shipped to South Park from the South previous spring in same bunch as No. 30. Noticed to be sick on week previous to date of our first visit by exhibition of diarrhoea followed later by a distended abdomen. Seen on November 6, 1914. Animal in fair state of flesh, rather strong, appetite good, diarrhoea, slight swelling under jaw, none of the brisket, abdomen distended moderately. Was treated approximately as No. 30 until November 11, when she, being very weak and the swelling of the brisket being quite marked, treatment was discontinued. The swelling of the neck due to the digitalin was very noticeable. Her pulse ran between 100 and 120 during the time of observation with a temperature varying from 102 to 105.5, the high temperatures being charged to the abscesses produced by the digitalin. The red count on November 9th was 16,200,000.

## SUMMARY.

A disease occurs in cattle in the high altitudes of Colorado, the principle symptoms of which are swelling of the brisket and of the loose tissues under the jaw, usually diarrhoea and a moist cough with gradual emaciation and death.

It is chronic in character but is fatal in practically all cases.

On autopsy the most marked features are general dropsy, enlarged and hard liver and dilated heart.

In six cases shipped to a lower altitude (about five thousand

feet) all recovered without other treatment, although it seems reasonable to believe that they would have died had they not been shipped.

It appears to be caused by an exhaustion of the heart muscle associated with a varying degree of dilatation and hypertrophy and this being brought about by exertion before acclimatization at high altitudes, or in the case of calves, inherited cardiac weakness.

Medical treatment has so far proven of little avail, but where possible shipping the affected animals to a lower altitude is recommended.

Preventive measures include the use of bulls that have been raised at altitudes of eight thousand feet or more, with a view to building up a hardier strain of cattle, also the curtailment of indiscriminate shipping of low altitude cattle to high altitudes.

Bulletin 205 February, 1915

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

# *Yellow-berry in Wheat*

## ITS CAUSE AND PREVENTION

*By* WM. P. HEADDEN

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# The Agricultural Experiment Station

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# YELLOW-BERRY IN WHEAT—ITS CAUSE AND PREVENTION

By Wm. P. Headden

In the prosecution of the study of Colorado wheats which we now have been carrying on for two years, we find that the condition designated as yellow-berry constitutes one phase of it which we think is of sufficient interest to justify us in presenting it at this time.

The question is in no way a new one, still there seems to be considerable confusion regarding it, while its cause has been assigned to very different agencies and no positive claim made to any direct means for its prevention.

The term "yellow-berry" is used to designate a condition of the wheat kernel which gives it a mottled appearance, due to internal white spots. In bad cases, the whole berry may be affected, when its color will vary from white to a light yellow according to the color of the outer layers or covering of the kernel. Such kernels are more or less opaque when viewed in transmitted light. Normal kernels are uniformly flinty or glassy in appearance and are translucent when viewed in transmitted light.

I do not know when the first mention of it was made, but it evidently existed in Hungary in 1900, for Kosutany in his work on "Der Ungarische Weizen und das Ungarishe Mehl" makes definite mention of flinty, mealy and half mealy kernels. I take it further that his expression "degree of mealiness," as applied to wheat, is probably nothing else than the extent to which the grain was affected by what we call yellow-berry. I suppose that it was well known before this, for it is spoken of in such matter of fact way, without further description or definition, that one assumes it to have been considered by the author as a familiar subject. This, however, is the first mention of it that I know of in such a way as to indicate a general condition of a crop. As just stated, there is no further comment on its characteristics. The grain is specified as flinty, mealy and half-mealy. There is no question but that these different kinds of kernels occur in the same variety and lot of wheat for the percentage of each kind of kernel is given. Schinder in Der Getreidebau, 1907, also mentions mealy and half-mealy kernels.

The next definite mention that I find of it was by H. L. Bolley, South Dakota Station Report 1904, pp. 35-36. Next by Lyon and Keyser, Nebraska Bulletin 89, 1905. These authors seem to have had their attention directed to the subject by the complaints of farmers, grain dealers, and millers. Their statement is that the investigation of this subject was begun in 1902. Following this in 1908, Bulletin 156 of the Kansas Experiment Station on "The Yellow-berry Problem in Kansas Hard Wheats" appeared. It would appear that others, among them Prof. H. Snyder of Minnesota Experiment Station, had discussed the same question without designating it by any special name.

The first and most important question regards its effects upon the quality of the grain. I find no definite data given upon this subject. Lyon and Keyser give a measure of the injury to the Nebraska crop in terms of loss to the farmer. This is put down at from one-half to one million dollars annually. This was the estimated loss on a market where the wheat was not sharply graded, many of the millers making no difference at all in the price. I have been informed that Kansas and Oklahoma at times have suffered to a much greater extent in the matter of market values than Nebraska, because their wheat sought a market where the grading was much stricter. I have found an instance in Colorado in which a mill would not buy yellow-berry wheat, at any price. The reason given me was that one could not be sure of the quality of the flour turned out. This particular mill was blending winter and spring wheats. The sample in question was a winter wheat, Turkey Red, and was very badly affected by yellow-berry. That the generally accepted effect of this affection on the value of the wheat is a detrimental one, is indicated by the use of the term "deteriorated wheat." We find this term used quite frequently when it is difficult to know just what is meant by it.

Lyon and Keyser established the fact that the yellow-berry kernels contained less nitrogen than the flinty or horny ones, so that there is more in the problem than a prejudice on the part of the wheat-buyers. If we are correct in using the percentage of nitrogen present in wheat as a measure of its value, these yellow-berries are really inferior to the flinty ones, and this is a good reason why they should command a lower price.

If there is any sharp and satisfactory distinction between the use of the terms yellow-berry and soft wheats, I have failed to notice it. I am strongly inclined to think that such a distinction should be made, but it does not seem to have been made and there is certainly some confusion. The California and Oregon wheats are spoken of as soft, starchy wheats. The yellow-berry wheats are spoken of in the same way, but that the same thing is meant in the two cases is not clear. It is, however, true, I think, that they are low in protein, high in starch, and light in color. Wheats affected by yellow-berry are, especially when the whole berry is involved, white, or, if the outer covering is highly colored, yellowish. They are always opaque. This is an extreme condition. The whole of the berry may not be involved, and then the portion not involved is translucent. The Defiance, a spring wheat, is normally a medium amber colored, translucent wheat, but when affected by the yellow-berry may be wholly of a dull white color and opaque. I really do not know the proper classification of our Defiance wheat. It certainly belongs to the light colored spring wheats, but it cannot be said to be low in nitrogen as it ranges from 1.8 to 2.4 per cent, for samples taken over two consecutive years. If we express this in terms of protein we have, using 6.25 as our factor, from 11.25 to 15.0 percent protein, or using 5.7 as a factor, we have from 10.26 to 13.08 percent protein, so that there seems to be a satisfactory amount of protein present and the starch cannot be excessively high. Still a normal kernel of this wheat is a very different thing from one wholly affected with the yellow-berry which is white, opaque, and has a certain roughness, the appearance of a loose structure. All such kernels when crushed between the teeth are soft and mealy.

The affection may occur in one or in both halves of the kernel as a sharply defined spot, either large or small, so that we find the kernels designated as "spotted." One-half of the kernel may be involved throughout or there may be a strip along the back of the kernel. When viewed in transmitted light, we often observe the affection as small, opaque spots, or one-half of the berry is either opaque or more or less strongly clouded. It follows that when viewed in transmitted light, we have kernels wholly translucent, translucent with dark spots, one-half translucent, or cloudy and wholly opaque.

Writers on this subject are agreed that it is a more or less serious affection. They also agree in regard to its appearance, but when they come to consider the cause of it they are not agreed at all. So far as I can find, only three of the works mentioned assign any cause. Prof. H. L. Bolley in the North Dakota Station report, 1904, part I, pp. 35-36, seems to have been the first to assign a definite cause for it. It seems, however, to have been referred to before this, but in such a general way that subsequent explanation is required to definitely relate the statements to this affection. Prof. Bolley says:

"Considerable attention has been given to the cause of starchy, spotted grains in hard winter wheats, the trouble being known locally as 'White belly.' Grains of this character are generally graded as soft wheats and are believed to be inferior to the hard wheats of the Northwest. A number of experiments were carried on in which germination trials, microscopical tests, and cross-fertilization trials were made and also the effect studied of exposure of harvested bundles to the ordinary weather conditions."

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

It must be borne in mind that Prof. Bolley's conclusions are based upon the results of experiments and observations made for the purpose of discovering the cause of this affection and these conclusions exclude crossing and heredity as causes of it, but predicate the action of moisture, air and sun as its cause and care on the part of the owner as its cure or rather that it can thereby be avoided.

Lyon and Keyser arrived at a similar conclusion based upon very similar experiments. Lyon and Keyser, Nebraska Bul. 89, (1900), p. 27, say:

"To see if the Yellow-berries were due to bleaching by sun and weather after harvest, sheaves were taken from the same portion of the same plot, one-half being left exposed and the other half cured in a dry room which was only moderately lighted. The sheaves were cut July 10, 1903. The exposed bundle was left out until Aug. 21, 1903, the only protection given being a frame of wire netting having a mesh small enough to keep out sparrows. In September the bundles were carefully thrashed and the grain separated into two portions, 'Yellow Berry' and 'Horny Red,' keeping each bundle by itself. The bundle kept in a dry dark room had twenty-five per cent of yellow-berries, while the exposed bundle had ninety-seven and two-tenths per cent yellow-berries."

"Other noticeable changes took place. The grain from the protected bundle was bright and of good, clear color. The grain from the exposed bundle was very much discolored and so badly bleached as not to be marketable."

This experiment was repeated in 1904 with practically the same result. These authors also investigated the effect of the degree of maturity or the time of cutting upon the amount of yellow-berry. The result was that grain cut 7 July, 1904, contained seven and six-tenths percent, and that cut when over-ripe nineteen percent, an increase of eleven percent. The relation of the weather, character of the season, was also considered. On investigating this subject they arrived at the following conclusions:

"In the crop of 1901 there was 10.5 per cent; in the 1902 crop 4.3 per cent; in the 1903 crop 25 per cent of yellow-berries, and in the crop of 1904, 20 per cent of yellow-berries. There is quite a definite relation between the per cent of yellow-berries in the crop and the character of the season in so far as the latter affects the date of ripening, the composition and the yield of wheat."

The authors base a suggestion for the lessening of the percentage of yellow-berries upon these observed facts, recommending early cutting and prompt stacking. They further discuss the composition of the 'Horny Red' and the 'Yellow Berries,' showing that there is a decided difference in this respect, the horny kernels being the richer in nitrogen and also the heavier; further, that the yellow-berries had larger starch grains and more air spaces, vacuoles, and cite Nowachi[1] as suggesting "as early as 1870 that the difference in appearance between mealy and horny wheat kernels is due to the presence in the former of a larger volume of air spaces than in the latter." Again they say: "It appears that large starch granules and large and numerous vacuoles are associated in yellow kernels, the white appearance of the endosperm being due doubtless to the latter."

They also quote Hackel[2] as follows:

"If the albumenoids so fill up the intervals between the starch grains that the latter seem to be imbedded in cement, the albumen appears translucent and the fruit is called corneous; but if the union is less intimate, there remain numerous small air cavities and the albumen is opaque and the fruit is mealy. Both conditions may occur in the same variety (wheat) and they seem to be occasioned by differences in climate and soil."

In their summary, p. 50, they again formulate these conclusions admirably as follows:

" 'Yellow-berry' in hard winter wheat causes an annual loss to the wheat raisers of Nebraska of from one-half to one million of dollars. The chief cause of this condition is allowing wheat to become over-ripe and failure to stack the sheaves.

" 'Yellow-berries' as compared with hard, red ones have a lower gluten content, and are lighter in weight."

In 1908, Professors Roberts and Freeman, Kansas Bul. 156, discussed the subject under the title, "The Yellow-berry Problem in Kansas Hard Winter Wheat." This yellow-berry is considered the most serious problem confronting the wheat growers of Kansas and the characteristics of the affection are described in detail. The yellow-berry is sharply distinguished from berries bleached by exposure, which seems to me a fair distinction and one not heretofore made. The authors say:

"It should further be emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect which ap-

1. Untersuchungen uber das Reifen des Getreides, Halle, 1870, pp. 76-77.
2. The True Grasses, E. Hackel (Trans. Scribner & Southworth), p. 26.

pearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such frequently is the result of exposure to the weather."

While this statement stands in opposition to the conclusions of the preceding investigators, it seems to me to be worthy of consideration. If I understand Lyon and Keyser aright, they claim that there was a decided increase of yellow-berry after the grain was cut, but do not claim that all of the weathering effects are to be classed as yellow-berry. On the contrary, the statements that they make tend to convey the idea that they attribute the increase in the amount of yellow-berry after cutting to the continued absorption of carbohydrates from the plant after cutting, still their statement of the chief cause includes weathering after cutting. The view presented in the Kansas bulletin is that the yellow-berry is caused by some physiological condition and is a heritable quality as the following statements show:

"The yellow-berry, then, appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained. The essential thing, from the practical standpoint is to discover whether pure stocks of wheat can be found which produce constantly a minimum amount of yellow-berry in the hard wheat region and in localities in which the yellow-berry ordinarily occurs."

These writers consider the subject an important one for Kansas and refer to it as a factor in the deterioration of their wheat.

"Any factor that brings about deterioration in the grade of this wheat (Kansas winter wheat, H.) calls for serious investigation. The yellow-berry is such a factor. The presence of the yellow-berry in any quantity in our hard wheat affects unfavorably its commercial grading and its market price."

As to the cause of it, or to what they believe to be the cause of it, they are not as definite as could be desired. I have already stated that they consider it a "physiological growth product" and that it is an heritable character, still, as is readily understood, climate and growing conditions in general, are not without influence. These authors evidently consider them of great importance for they approvingly quote Schindler, Der Weizen, Berlin, 1895, as follows:

"With the length of the vegetative period, especially with the extent of the interval between blossoming and ripening, not only the dimensions of the kernel increase but also the quantity of carbohydrates stored therein, while the protein content diminishes." * * *

"It is not justifiable to speak of the size of the kernel and the protein content of the berry as 'race characters.' They may be such to a certain limited extent, but the influence of the race will in this connection be far exceeded by the influence of the climate and partly also by the soil and cultivation."

The quotation continues to set forth the dependence of the character of the grain, i. e., whether it is starchy or rich in protein upon conditions of growth, especially upon weather conditions. It also discusses the effects of transferring a wheat, "endemic" to a given climate, to a different one, especially to a hotter and drier one. The application of this quotation seems to depend upon its bearing upon the relative quantities of protein and starch produced in the berry. The fundamental distinction between the flinty and yellow-berries is plainly considered to be their relative richness in protein or in starch. I do not understand from the quotation that the author, Schindler, had the yellow-berry condition specifically in mind but the relation of the protein content to that of the starch. This may be a part of the yellow-berry problem. It evidently is, but we may have high or low protein without our special affection of yellow-berry. Two different samples of the same variety of wheat, each equally free from yellow-berry, may vary quite as much in their protein content as two samples, one of which is affected with the yellow-berry and the other not. Still, it must be acknowledged, that the chief difference effected in the composition of the wheat is, so far as we know, precisely this, i. e., a lower protein and a higher starch content, but the physical characters of the kernels are very different from normal berries. There can be no doubt about Schindler's attaching great importance to the weather conditions, for he is quoted as saying:

"From these considerations it undisputably follows that even in one and the same locality and with the same variety, the relation between protein and starch must be a variable one according to the weather conditions, even though it is to be admitted that individual sorts or races, as the case may be, may possess for themselves an especially different energy of assimilation. It is certain, however, that this latter in its final effect stands far behind that of climate and of the weather."

There can be no doubt that the author intends to attribute a determinative influence upon the composition of wheat to the climatic factors whether he had the yellow-berry in mind or not. The authors, Roberts and Freeman, evidently consider the yellow-berry something more than an abnormal ratio between the protein and starch content of wheat, for they say that:

"The yellow-berry is a case of not merely a failure to form the normal amount of gluten **but probably also of a corresponding failure on the part of the plant to compensate by a relative increase in the starch content.**"

It is not evident upon what they base this opinion, at least, I have found no definite data given except the nitrogen determinations made and given in the Nebraska Bulletin 89. I suppose that this judgment is based upon their knowledge of the physical properties of the berries. These would appeal to most persons familiar with them as quite sufficient to justify the opinion expressed. But, whatever the composition and properties of these berries may have been, they (Roberts and Freeman) assume that climatic factors are, above all others, important in determining these and set themselves the task of finding out the critical period in the development of the grain, or that period when it is most susceptible to the action of those factors determining the yellow-berry. They experimented with winter wheat and consequently have two periods of growth, the autumn and spring periods. They find that the longer the autumnal period, especially with favorable conditions in the early part of the period, the higher the percentage of yellow-berry. In the season 1905-06, they found for wheat planted 28 September in moist soil 53.80 percent yellow-berry; for wheat planted 16 October in rather dry soil 19.58 percent yellow-berry. They find in these results, the two quoted are the extremes of a series, a relation between the length of the autumn growing period and the amount of yellow-berry produced. In 1906-07 they obtain results of the same significance; a difference of thirteen days in planting is followed by a difference of 12 percent in the yellow-berries. This difference was, as in the preceding year, in favor of the late planting, this giving the lower percentage of yellow-berry. They divided the spring into practically three periods, and studied the effect of the mean temperature and rainfall and also considered the whole of the spring growing period; so that they treated of the whole period from first heading to maturity, for three weeks before maturity, and for two weeks before maturity. I can do no better than to give their own words to state their results.

"If we attempt to interpret the effect of these combined influences in terms of the rapidity of growth of the plants and of the ripening of the grain, and to correlate them with the percentage production of yellow-berry, we shall find, as previously stated, that the prevalent idea that slow ripening is correlated with high percentages of yellow-berry is apparently justified by the data collected from our wheat cultures for 1906-07 when the total averages for the two years are compared. When, however, the data for the different varieties within a given season are considered, this rule does not hold. Now, since it is improbable that influences that would operate as between different seasons to bring about such a result would fail to operate in a given season, there must, therefore, be other factors which complicate the results, and which are not analyzable without taking into consideration data with reference not alone to climatological conditions but also to the hereditary tendencies of the varieties concerned."

These sentences state as clearly as can be stated the conclusion at which Roberts and Freeman arrived, though they subsequently, and perhaps concurrently, with the experiments on which this conclusion is based, made quite a series of experiments upon, "Individual and varietal inheritance of yellow-berry," the conclusion of which does not seem to be altogether satisfactory or decisive. Not being, perhaps, a competent judge, I will not venture to formulate a conclusion, but will again give the authors' own language.

"In view of the fact that but one head from each plant of the pedigree stocks had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others, **and is heritable.**

"In so far as this is the case, the yellow-berry problem is one which is capable of being handled by the breeder with a view to the propagation of pure strains of wheat which may be found free from the yellow-berry under all conditions. It, therefore seems reasonable to hope that from a group of pure strains of pedigree wheats producing no yellow-berry for two successive years—which we have—a race of wheat may be derived which will go entirely wide of this tendency to deterioration in the product."

I believe that this quotation presents the conclusion which the authors would have us draw from their results as clearly and fairly as they have anywhere stated it. One thing seems clear, that is, that while they admit that the weather influences the development of yellow-berry they sought throughout their work some specific cause for it and think that it is to be found in some inherent quality in the strain or race of wheat which may be strengthened by climatic conditions and the length of the growing season.

In 1913 Prof. H. L. Bolley of North Dakota returns to the subject in Bulletin 107 of that station entitled "Wheat; Soil Troubles and Seed Deterioration; Causes of Soil Sickness in Wheat Lands; Possible Methods of Control; Cropping Methods in Wheat." We are concerned only with what he says regarding the subject of yellow-berry. Prof. Bolley throughout this bulletin speaks of deteriorated wheat and seems to include under this term a variety of things which evidently may have different causes, for, as Prof. Bolley himself states, the problem is a complex one, but he gives us no clear analysis of the deterioration had in mind and appeals to diseases of the plant to account for deterioration in general. There is no doubt but that Prof. Bolley is entirely correct in maintaining that disease may cause the death of plants or curtail their productiveness, but he seems to attribute practically all deterioration to disease, or infestation of some kind, and to minimize the current teaching relative to the importance of those questions of food supply in the soil, generally had in mind when we speak of fertility. He seems to take exception to the stress laid, by chemists in particular, upon these questions, with which I have no quarrel, and it is not my intention, in this place at least, to take any exceptions to his views. This is in no way my purpose, but simply to give such quotations as may faithfully present his views upon the question forming the subject of this bulletin. Under the caption "Symptoms of Deterioration as noted in Soil and Seed," he uses the following language:

"The history of wheat cropping shows that at first new lands yield bounteously in quantity and quality, but in a comparatively few years an evident deterioration of the seed produced sets in. The fall in bushelage per acre is not more marked or more rapid than the deterioration in quality as to plumpness of grain, flour content, hardness, color and other characteristics. By almost common consent, many agriculturists, chemists, biologists, millers and farmers have assumed, when such conditions of the crop arise after more or less continuous cropping to wheat and other cereals, that the **lands have 'deteriorated.'** The symptoms as observed in the slow growth of the crop, the dying out of young plants, the blighting, 'tip-burning,' 'sun-scalding' and discoloration of the young plants, the weakness of the straw, the shrivelled seed, the common deficiency in proteid content of the grain have all been taken as indicating improper food relations."

"I think I am safe in saying that **it has been quite commonly assumed** that lost nitrogen, phosphate, lime **or other plant food** deficiencies are to be expected under such cropping conditions. Furthermore, chemists, as they measure availability of plant food, have found that such old soils often show more or less change in the available plant food. The writer, knowing as he does that a wheat plant can extract essentially all of the available material of a particular food element from the soil before showing noticeable change in its growth relations has always doubted that the general conclusions of soil deterioration under such cropping conditions is justifiable; for there are many fertile soils which fail to produce normal wheat, and there are some very poor, weak soils which produce nice, properly colored milling wheat. These, so-called, deteriorated wheat soils produce high yields and quality in other crops."

It is evident that the deterioration here had in mind includes plumpness of the grains, the flour that they will yield, their color and hardness. In the quotation given, and also in other portions of the bulletin, he plainly questions the correctness of the general assumption that there is a relation between the food supply in the soil and these conditions, especially that there has been a soil deterioration in this respect, or, as it is commonly expressed, in soil fertility. The author even goes further and asserts that the application of farmyard manure may even produce "disastrous results" in the nature of soft, overgrown straw and shrivelled, off-grade grain. His interpretation of this is that it shows that the land has not deteriorated. The author further strengthens his position by discussing new and virgin lands, still to be found in their wheat-growing sections, but I will quote his own words.

"New and virgin lands remaining in the wheat belt unplowed, even though they represent select areas of land, when plowed and sowed to wheat, under present conditions, cannot now as in early days be relied upon to produce the quality of wheat then produced on immediately adjacent lands. As often as otherwise the crop is apt to produce light weight, off-colored, 'spotted,' 'white-bellied,' 'black-pointed,' 'pie-bald,' shrivelled grain upon a rag-like, light weight straw. Because of these facts, many of our most able, old-time wheat growers have been inclined to contend that there must have occurred changes in climatic conditions. No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years. These lands certainly are as fertile as the adjacent areas which were broken in the early days of wheat culture. It can be seen at a glance that these present new lands are now subject to wheat diseases coming through poor seed and by dust and dirt from the adjacent old worked wheat lands."

The cause of deterioration, as the author sees it, is here distinctly attributed to diseases coming through poor seed and by dust and dirt from the adjacent, old-worked, infected wheat lands. The deterioration consists in the kernels being of light weight, off-colored "black-pointed," "spotted," "pie-bald," "white-bellied," and shrivelled. This is on new or virgin land after one or two years. At least I so understand it, for he says that:

"No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years."

In summarizing the symptoms on a subsequent page, he is quite as explicit and his statements are more general. He says:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary; for this immature shrivelled grain is apt to have a comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown, and other colorations of the berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of the fungi or to changes caused by them."

Later the author explains the cause of young plants dying, ascribing this cause to genera of Fusarium and Colletotrichum. In so doing, he says:

"Each of the various types of injured grains as pink-colored, black-pointed, white-bellied, etc., breed true, reproduce themselves. Certain conditions of soil, weather and variety, however, seem to largely affect the development of these features."

It is certainly difficult to reconcile the conclusion of the former publication of this station, North Dakota, with the statement just made, for in the conclusion drawn from previous work the same author says:

"From the results (of experiments made.—H.) the author believes that the white spots are not due to crossing nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff."

It is possible that the author had reason for changing his opinion before writing Bulletin 107, North Dakota Experiment Station. If so, he failed to state the reason or even to take any cognizance of the statements of the earlier bulletin. In a lecture delivered before the agricultural students of the University of Wisconsin, which appeared in Science, July, 1913, he maintains, or rather asserts, the findings of the later bulletin. The author may have an object, worthy and well advised in North Dakota, but it is not effective in shedding light upon the question that I have in hand, though he evidently includes the condition of yellow-berry as constituting a symptom of deterioration.

The four bulletins from which these statements have been given constitute about all of the literature to be found in our station publications touching upon yellow-berry.

I am not at all sure that the California bulletins on the wheats of California have this question in view at all. A white wheat is by no means a diseased wheat or an abnormal one, though at times it would seem almost as though they were really describing wheats which were so badly affected that every kernel was mealy or starchy. These wheats are spoken of by some as white, soft, starchy wheats. Dr. G. W. Shaw and A. J. Gaumnitz describe White Australian as follows:

"Grain large, long, plump, white, soft, opaque, starchy interior: Little Club, grain medium large, short, white, irregular in shape, very soft and starchy interior; Sonora, short, round, plump, white starchy interior."

It would be difficult to give a better description of kernels of our wheats wholly affected by yellow-berry. I may be mistaken, but I do not understand the California bulletins to deal with their wheat as diseased or deteriorated wheats, but that they consider these wheats as normally white, soft wheats. If they consider them abnormal wheats, diseased wheats, they assign no cause, and suggest no remedy and so far as the yellow-berry question is concerned, or better so far as our present discussion of the yellow-berry question is concerned, the Californian wheats may be neglected simply because the study of these wheats as presented in their bulletins is not parallel to the phase of our work presented in this bulletin. As stated, no better description of wheat kernels, wholly affected with yellow-berry, could be given than the descriptions of the various California wheats furnish,—large, white, plump, soft, opaque, starchy, —these are the only adjectives one could properly use in describing some samples of our Defiance, whereas for the description of other varieties, we could not use them truthfully at all. The Defiance kernel in its normal condition is a short, plump, light-amber colored, translucent, flinty kernel. Even the term soft, if used to express the ease with which the kernel may be crushed between the teeth, would apply to the abnormal, but not to the normal kernels of Defiance wheat. I think there is no reservation to be made in stating that a kernel wholly affected with yellow-berry is much softer than a normal, flinty berry of the same variety, and it is certainly very different in appearance.

There is a perfect agreement in the descriptions of yellow-berry given by the different authors so that there is no question but that they have written about the same condition. The best description is, perhaps, given by Roberts and Freeman. "By the term 'yellow-berry' is meant the appearance" (in wheat of a hard flinty grain), "of grains of a light yellow color, opaque, soft and starchy. These opaque yellow grains constituting what are called 'yellow-berries,' may have this character throughout, but sometimes from a small fraction to half of a grain will be yellow and starchy, while the remainder of the kernel will be hard, flinty and translucent."

It very often happens that the only imperfection in a kernel will be a sharply defined spot in one or the other half, or in both halves of the kernel; again the affection is more diffused and may involve one-half of the kernel or a streak along the back of the kernel. Owing to the fact that these spots and areas are less translucent than the surrounding flinty portion, often being quite opaque, the best manner of observing the kernels is by transmitted light. In this way it will be discovered that many kernels which by reflected light one would consider free from the affection, are in reality quite badly affected. When the berry is wholly affected its general color will be affected by the color of the bran or outer coating and will vary from dull white with a tinge of yellow, to yellow. Such kernels are usually, if not always, plump and when cut transversely, exhibit a white, starchy interior without any horny portion whatever. Such kernels are soft and starchy. If such kernels as show small yellow spots be cut through transversely, these spots will show in the section as white, mealy, or starchy circles imbedded in a horny, translucent matrix. (See inserted Plate).

The plate needs but little explanation. It represents six varieties of wheat, three spring and three winter. The top row in each case represents normal flinty berries, the second row mildly affected berries and the bottom row badly affected berries.

While authors are agreed, so far as they attempt to describe the appearance of yellow-berry, they are not agreed as to its cause. Two different causes are assigned for it in North Dakota bulletins. In the one first published, the cause was stated definitely to be the action of moisture, air and sun upon the berries while still in the chaff. Prof. Bolley, the author, said:

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued, the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

This statement is definite in regard to both cause and remedy.

In Nebraska Bul. 89, we have essentially the same conclusion:

"The chief cause of this condition is allowing wheat to become over-ripe and failure to stack the sheaves. 'Yellow-berries' as compared with hard, red ones have a lower gluten content and are lighter in weight."

The authors of the Kansas bulletin 156, do not agree with these views for they state definitely:

"It should be further emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect, which appearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such is frequently the result of exposure to the weather."

This statement is not in accord with the statements of the two bulletins previously quoted. The Nebraska bulletin gives the actual increase in yellow-berry produced by exposure. I assume, as there is no statement to the contrary, that Lyon and Keyser sorted their kernels in reflected and not transmitted light and in this way failed to count many affected kernels in the protected wheat which would have become easily recognized on bleaching the grain. In other words, I think that the yellow-berry was rendered more easily recognized, more evident, by the bleaching, but not caused by it. There is, however, a fact which would appear to support the assumption of an increase after cutting, i. e., that the deposition of starch may continue for a time after cutting at the expense of material accumulated in the plant, but this would seem to apply to the protected as well as to the exposed wheat.

After having written the above, I received a note from Prof. Keyser, a portion of which pertains to this subject and reads as follows:

"It is stated in Bulletin 89 of the Nebraska Experiment Station that exposure to weather conditions, increases the amount of yellow-berry present in the grain. I think, perhaps, in view of a fuller experience with yellow-berry, that a slightly different statement of the facts observed would come more nearly to stating what actually took place. The bulletin states that exposure increased the yellow-berry. What actually occurred seems to be, that exposure increased the readiness with which yellow-berry present was detected. In other words, exposure enabled us to see yellow-berry in cases where it was not visible in the bright, freshly thrashed, or freshly harvested grain. In other words, exposure enabled us to detect yellow-berry in those cases which were on or near the boundary line of yellow-berry and clear, corneous grain."

This leaves no doubt in my mind but that the apparent increase of the yellow-berry on exposure to the weather, was due not to the formation of the yellow spots in the grain, but that the effect of the bleaching was simply to reveal yellow-berry in many kernels in which it was not readily detected in their fresh, unbleached condition. The continued deposition of starch after cutting, especially of grain not fully ripe, remains a possibility.

The Kansas bulletin goes further and states:

"The yellow-berry then appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained."

After having studied the problem, in apparently all of its physiological phases, the conclusion of these investigators, Roberts and Freeman, is succinctly given in these words:

"In view of the fact that but one head from each plant of the pedigree stock had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others **and is heritable.**"

This statement is the nearest approach to a formulated conclusion, embodying the results of their extended experiments that I have found. This conclusion is positively opposed to that arrived at by Prof. Bolley in the Annual Report of the North Dakota Station for 1904, in which he states:

"That the white spots are not due to crossing, nor are they matters of heredity, but this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is still in the chaff."

Prof. Bolley himself practically repudiates the conclusion here stated, especially in regard to the direct cause of the affection, in North Dakota Bulletin 107, and again in a lecture given before the agricultural students of the University of Wisconsin and published in Science, July, 1913. Prof. Bolley in discussing the deterioration of wheat makes the following statements bearing upon the causes of it:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off **whether it is well harvested or not.** This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary, for this immature shrivelled grain is apt to have comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown and other colorations of berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of fungi or to changes caused by them."

Again he says:

"Each of the various types of injured grains as pink colored, 'black-pointed,' 'white-bellied,' etc., breed true, reproduce themselves."

It is evident from these passages and others given, that Prof. Bolley now holds the "pie-bald", "yellow or white bellied", condition to be due to the action of fungi. He puts these yellow-berries in the same class with black-pointed berries, with pink or brown colored berries, and assumes that they all have the same cause, namely fungi. Concerning the black-pointed berries he is certainly correct and also in regard to the pink and brown berries alluded to, but he includes the spotted and yellow-berries with these, which is wrong. This presents the subject as treated of in our American literature so far as the stations are concerned. The United States Department of Agriculture has given a full statement, a fair reproduction, of Kansas Bulletin 156 in one of its accounts of station work. This is a matter of the distribution of the results of station work, so I have not mentioned it.

As I have before intimated, I am not sure but that all of the work of the California Station on the white wheats do not deal with yellow-berry, but Dr. Shaw and his collaborators have confined themselves to a study of the wheats as they grow and not to the question of why they are mealy or starchy.

I have some samples of Idaho wheats which are very white and starchy, in fact, I can see no distinction between the physical properties of these samples and some samples of Colorado wheats which I fear must be acknowledged to present samples of wheat badly affected by yellow-berry. As I think many of our wheat growers will be interested, I will state these cases a little more fully. Our Colorado Defiance, a spring wheat, is normally a medium-amber colored wheat with a rather short, plump, flinty kernel. I have a number of samples of this wheat every kernel of which is almost white, wholly opaque, and has a dead, porous appearance, and when broken between the teeth simply crushes down and does not break with any life, and creates a sensation of mealiness on the tongue. When such kernels are cut they appear to be a mass of starch. Such samples scarcely bear any resemblance at all to normal Defiance wheat. I have samples of Red Chaff of which this is true in a very high degree. I have also seen just as extreme cases in kernels of Turkey Red and Kubanka. While I have samples of Turkey Red in which it is difficult to find a single kernel that is not affected, I have no samples of either Turkey Red or of Kubanka as bad as the Defiance and Red Chaff samples described. I have samples of Dicklow Spring wheat from Idaho which, if possible, are even worse than our Colorado samples of Defiance and Red Chaff. The kernels of these samples are plump, white, opaque, soft and starchy. I also have samples of Marquis grown in Idaho and also elsewhere in which it is very difficult, if not quite impossible, to find any kernels entirely free from the affection. It is for such reasons that I am convinced that if we find the cause of yellow-berry we will find at the same time the cause for the whiteness, opaqueness, starchiness and softness of all of the western wheats whether they grow in Colorado or in California.

In this place it should be emphasized that under yellow-berry is understood a condition indicated by yellow or white spots which may involve the whole kernel, with a greater or less degree of opacity, starchiness and softness. *There may be soft wheats which do not show this condition at all, but this softness is another thing which is distinct from the softness of these kernels.* Our Colorado Defiance is a softer wheat than the Red Fife, whether it should be classed as a soft wheat or not, is not my purpose to decide, but even in its best condition, it is a softer wheat than some others. It is not in this sense that we use the term soft as applied to these yellow-berry wheats. When we speak of softness due to yellow-berry, we mean that they are yellow or white, opaque, starchy and easily crushed; more easily crushed than flinty berries of the same variety of wheat grown under the same conditions.

I am strengthened in my surmise that the Californian wheats belong to this class of yellow-berry wheats by the description of Californian wheats given by Mr. Henry F. Blanchard in Bulletin 178 of the Bureau of Plant Industry, U. S. Department of Agriculture, in which he describes thirty-six varieties, all of which are characterized as spotted or starchy. In this description as well as in that given by Dr. Shaw and Mr. Gaumnitz, we are strongly reminded of our yellow-berry.

I have mentioned this for no other reason than to suggest that the condition of yellow-berry is not a local phenomenon to be explained by some local condition of climate, coastal or continental.

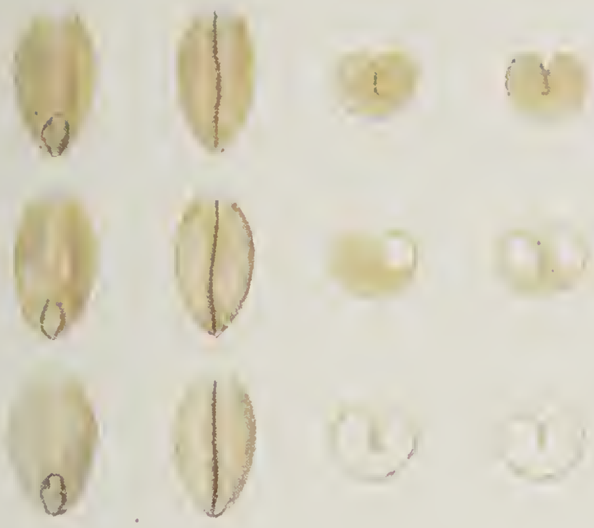
There is ample evidence in the literature of wheat that this condition is neither new nor confined to this country. This is true even after we make allowance for possible misapprehensions due to accidental coincidences in description. Reference has already been made to mention of starchy berries as early as 1870. In 1904 we find starchy berries mentioned by H. von Feilitzen in Jour. Landw., also by F. Moertlbauer., Ills. Landw. It is further mentioned by Dr. Thomas Kosutany in his work on Hungarian wheats and flour, Der Ungarische Weizen und das Ungarishe Mehl, printed in 1907. In discussing the quality of wheat produced on large estates, and that produced on small estates, and by the peasant farmer, he says:

"I take the weight per hectolitre, the weight per 1,000 kernels and the degree of mealiness, together with the protein and gluten content into consideration in making the comparison."

Dr. Kosutany again refers to this subject in discussing the effects of the weather. After stating that very significant variations in the gluten content of grains were to be attributed to the weather conditions, he explains that the weight of 1,000 kernels of the weaker wheats is greater than that of 1,000 kernels of the strongest wheats, which he also considers as an effect of the weather conditions. He adds:

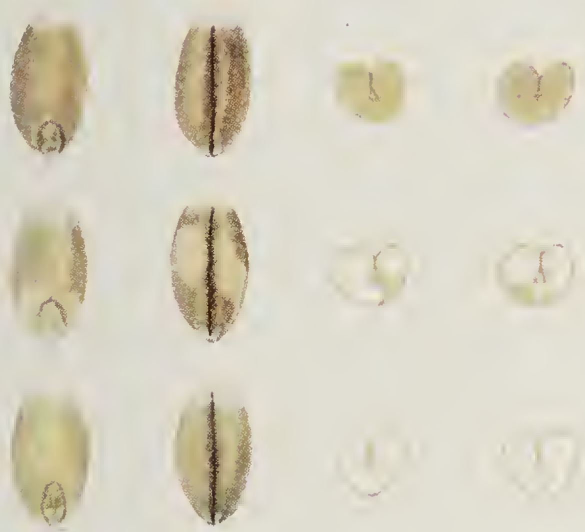
"The mealiness in the weaker wheats is 36.78 per cent; in the better wheats 23.25 per cent, from which it follows that the protein-rich wheats are altogether the glassier which is intimately connected with that which I have already discussed and considered necessary to mention in connection with the weight per 1,000 kernels."

The occurrence of starchy and spotted kernels is evidently very common in the Hungarian wheats. Dr. Kosutany gives the record of mealy kernels in the harvests of seven years, for 1890, and from 1899 to 1905. Out of eighty-three samples given in the harvest of 1890 there is only one sample entirely free from mealy or half-mealy, starchy or spotted kernels, and only 24 out of the



Kubanka

Turkey Red



Red Fife

Kharkov

Defiance

Prize Taker

remaining 82 samples that contain less than 15 percent of affected kernels. In the harvest of 1899, 38 samples, the average number of glassy, flinty kernels was 51.4 percent (Max. 78, Min. 9), of mealy kernels 16.3 percent (Max. 64, Min. 2), of half mealy, 32.5 percent (Max. 45, Min. 19); harvest of 1900, 53 samples, average mealiness 41.86 percent; 1901, 53 samples, 24.56 percent; 1902, average mealiness 44.85 percent; 1903, average mealiness 33.71 percent; 1904, average mealiness 24.09 percent, and in 1905, 26.08 percent mealiness. There were some samples in each year entirely free from this affection; in 1904 nine of the fifty-three samples, or 17 percent, were entirely free from affected berries. This affection is also mentioned as occurring in Roumanian wheat. Thirty samples are given for each of the three years, 1900, 1901 and 1902. The average of affected kernels for the three years is slightly over 91 percent.

These data will certainly suffice to indicate that "yellow-berry" has a very wide distribution whether this condition is identical with the starchiness of the Pacific coast wheat and all due to the same cause, which I think is the case, or not. That the same cause is operative in all cases seems probable, whether it is in Roumania, California or Colorado.

It seems to be customary to consider this mealiness as necessarily a sign of deterioration. I am not prepared to accept this view unreservedly. The term deteriorated wheat may at times be used advisedly, but it is very often used in a very loose, and in so general a signification as to mean nothing to the reader. The Pacific coast wheats are considered soft, weak wheats, this may be true and still it may be a question whether the starchy character of the wheat is indicative of deterioration. The Hungarian wheats are certainly considered among the very strongest wheats to be obtained and yet starchy and spotted berries make up a very considerable percentage of the average crop, in some few cases constituting the whole of some of the individual crops. Dr. Kosutany stoutly maintains that the Hungarian wheats have not deteriorated, though such claim has been made. It seems to me very probable that they may always have had starchy and spotted kernels in their wheat, but this does not necessarily follow from anything that is stated. Whether starchy kernels are necessarily kernels of inferior quality or not, I do not know. It is evident that millers object to them and, at least, the more advanced of these millers base their judgment upon the result of baking tests so it seems that the quality of the gluten must be inferior. Its quantity in slightly affected kernels is not necessarily low; on the contrary, it may be nearly or quite as high as in wheats of high quality.

In badly affected kernels I do not think that there can be any question but that the total nitrogen and the washed gluten are lower than in flinty kernels grown under apparently identical conditions of soil and weather. This question, however, is entirely beyond the purpose of the present bulletin.

Concerning the cause of mealiness in the Hungarian wheats, Dr. Kosutany makes no explicit statements, incidentally, however, he does, but considers it with other qualities of the wheat. In discussing the qualities of wheat produced upon larger estates compared with such as is produced by small growers, he says:

"Judged by the determination of the degree of mealiness, the balance swings likewise in favor of the large land-owner and more thorough soil culture, which at first sight is surprising, for if the small owner's wheat is smaller grained, then according to the theory which we have proposed it should not only be protein-richer but also more glassy, because the wheat plant with shallow culture ends its assimilative activity earlier and therefore should contain less starch and more gluten in its kernels, which must be characterized by a greater glassiness. That this is not so can only be explained by this, that the fields in the smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by the soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible that a less advantageous rotation plays a part in it, in that the small owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring, must be relatively low in its nitrogen content."

The conclusion here stated in reference to the cause of mealiness is at variance with the opinions previously given. The previous views have disregarded the soil as a possible cause of starchiness or have dragged it in in the most incidental manner, apparently for the purpose of conceding that the soil has some influence, but the manner of statement always carries with it the intimation that the soil is at best a minor factor.

One of the tasks that Dr. Kosutany has set himself is to show that the Hungarian wheats have not deteriorated. I understand him to adopt the evidently correct view that mealy kernels are apt to be lower in proteins than flinty kernels and that a wheat rich in protein is probably better than one poorer in protein. With these views in mind his statements in the following quotations are readily understood. These statements are made near the close of his discussion of the relative desirability of wheat grown on large, well cultivated and fertilized estates and on smaller ones:

"I can, therefore, emphatically assert that the statement of those who claim to find the reason for the decreasing gluten content of (our) wheat in the intensive cultivation is erroneous and on the contrary it can be declared as a principle that through more careful soil-culture, heavier manuring, etc., not only more wheat can be grown upon the respective wheat-soils but (wheat) richer in gluten and for this reason better and more valuable. The statement that the quality, that is, protein-gluten content, of the wheat diminished with increased harvests has ceased to be valid as a rule. Cases may occur, as follows from the above (reference is here made to the results of experiments.—H.) that we can, by means of manures, especially slowly acting nitrogenous manures, and cultivation, within certain limits, not only increase the yield of wheat, but also increase its value which is closely related to its protein—respectively, gluten content.

"A proof of this is furnished by mills with an extended experience which place a higher value upon the wheat from the larger estates, provided the seed has not come from foreign lands, than upon the peasant's wheat; further, (by the fact) that in certain sections of the country, particularly in Banat, the quality of the wheat has actually deteriorated in consequence of the exhaustion of the soil, of ill-advised rotation of crops, of poor cultivation, etc., whereas the quality in other sections * * * according to the mills has increased in consequence of more careful cultivation and manuring."

Our own observations of the occurrence and cause of the yellow-berry are, so far as they are parallel, in harmony with those of Dr. Kosutany. Our observations now extend over two years and involve seventy-two experiments with field observations in other sections of the state, together with twenty-four samples from another state.

I do not think that there can be any question of the identity of the affection of our wheat with that of Kansas, Nebraska or North Dakota, and *almost no question but that the starchy, opaque wheats of California, and the Pacific coast states, in general, are identical in their character with extreme cases of yellow-berry in Colorado and have the same cause.*

In 1913 we had twelve plots of one-tenth acre each, i. e., four plots of each of three varieties. These plots were not planted for the purpose of studying yellow-berry, but yellow-berry developed very plentifully in some plots and not in others. In 1914 the experiments were repeated, no change whatever being made in the experiments, the same variety being planted on each set of plots and the individual plots received the same treatment. Owing to force of circumstances which no one could change, the ground was plowed in the Spring of 1913 instead of in the Fall of 1912. The land was turned to a depth of 12 inches and sub-soiled to a depth of 16 inches. These statements will suffice to indicate our purpose to give the ground a thorough cultivating. It is scarcely necessary to give further details of the cultivation in this connection.

The varieties used in our experiments were all spring wheats, Defiance, a variety originated at this station thirty-odd years ago; Red Fife, seed obtained from South Dakota Experiment Station; Kubanka, seed also obtained from South Dakota Experiment Station.

In 1913 the plots were all sowed on 25 and 26 of April. The Fife was harvested on 6 August, 103 days from planting. The Kubanka was harvested 13 August and the Defiance on 14 August, or 110 and 111 days respectively, from the date of planting. The period of vegetation was short and the ripening took place in clear warm weather. The soil was quite dry, ten of the twelve plots which we shall discuss had received but little, so good as no water, since 12 June. All of the wheat was threshed on 21 and 22 August without having so much moisture as a heavy dew fall upon it after cutting.

In 1914 all plots were sowed on the afternoon of 6 and morning of 7 April, and harvested 6, 7 and 8 August. Fife was rather over-ripe. All of the plots were cut 122 or 123 days from planting. The irrigating water applied was one foot on all except plots 4 and 8, which received two irrigations, amounting to one and one-half acre-feet. In these statements I am making no note of a few hundredths of a foot either way. For our present purposes we omit the rainfall during the vegetative period. It may, however, be taken as six inches per year for the two years. This is very nearly correct. The time and manner of rainfall is of much more consequence to us than the amount that we usually have. We threshed all of the lots on 21 and 22 August. So far as the harvesting and threshing of these wheats are concerned the weather conditions were perfect. The Fife was unfortunately ripe enough to shatter a little but had stood not more than two days longer than was desirable. While the Defiance and Kubanka are normally about eight to ten days later in maturing than the Fife, they were not more than one or two days later than this variety in 1914. This abnormally early ripening was due to a shower that fell, 28 July, accompanied by some wind. The shower was of short duration but violent. It beat these varieties down rather badly, the leaves and stems, especially on some of the plots of Defiance, rusted and the crop was very materially injured. The same was true of the Kubanka but not to the same extent as of the Defiance. The Fife was scarcely injured at all by this shower because it was somewhat nearer maturity.

In order to facilitate the understanding of the experiments I add a plan of the experiments and the results obtained in 1913 on the plots considered in this bulletin.

## EXPERIMENTAL WHEAT PLOTS, 1913.

1. DEFIANCE
   Nitrogen, 80 lbs. per acre in two applications.
   Yellow-berry, none.

2. DEFIANCE
   Soluble phosphorus, 40 lbs. per acre. One application.
   Yellow-berry, 10 percent.

3. DEFIANCE
   Potassium, 150 lbs. per acre, one application.
   Yellow-berry, 30 percent.

4. DEFIANCE
   Check. Yellow-berry, 24 percent.

5. RED FIFE
   Nitrogen, 80 lbs. per acre in two applications.
   Yellow-berry, none.

6. RED FIFE
   Soluble phosphorus, 40 lbs. per acre, one application.
   Yellow-berry, 24 percent.

7. RED FIFE
   Potassium, 150 lbs. per acre, one application.
   Yellow-berry, 42 percent.

8. RED FIFE
   Check. Yellow-berry, 31 per cent.

9. KUBANKA
   Nitrogen, 80 lbs. per acre.
   Yellow-berry, none.

| |
|---|
| 10. KUBANKA<br>Soluble phosphorus, 40 lbs. per acre.<br>Yellow-berry, 35 percent. |

| |
|---|
| 11. KUBANKA<br>Potassium, 150 lbs. per acre.<br>Yellow-berry, 37 percent. |

| |
|---|
| 12. KUBANKA<br>Check. Yellow-berry, 31 percent. |

The above diagram is self explanatory. The grains used were Defiance, Red Fife and Kubanka; the fertilizers were nitrogen, phosphorus, and potassium.

The percentages of yellow-berry obtained are indicated on each plot. Note the variations in each variety, depending upon the kinds and proportions of fertilizers used.

While we made thirty-six experiments in each of the years we will consider only twelve plots for three reasons: First, it will shorten the statement of our data; Second, the other twenty-four sets of data would simply confirm the twelve sets which we give, and, Third, I do not wish to anticipate, any further than is necessary for my present purpose, the data bearing upon the principal object of the real project in hand, which is not to discover the cause and prevention of yellow-berry in wheat, *though this may be the most far-reaching and practical result which I shall obtain.*

The land used in these experiments has been cropped continuously for six years without fertilization. It is now seven years since it was in alfalfa. The soil proper varies from eight to twelve inches in depth. While the subsoil is a little richer in lime salts, it differs less from the soil above it than is usually the case. This subsoil is capable of forming a very desirable soil when brought to the surface, aerated and permitted to become enriched in nitrogen. Only the principal features of the composition of this soil and subsoil is given, but these are sufficient for our purpose, namely, to give as correct an account of our conditions as is possible; for this purpose the amounts of phosphoric acid, potash and nitrogen are all that we deem necessary.

Main Features in Composition of Soil and Subsoil.

| | Soil Agricultural Analysis Percent. | Soil Mass Analysis Percent. | Subsoil Agricultural Analysis Percent. | Subsoil Mass Analysis Percent. |
|---|---|---|---|---|
| Phosphoric Acid | 0.175 | 0.217 | 0.160 | 0.185 |
| Potash (Potassic oxid) | 0.715 | 2.475 | 0.573 | 2.607 |
| Total Nitrogen | 0.143 | .... | 0.060 | .... |
| Citric acid soluble. | | | | |
| Phosphoric acid | 0.021 | | 0.015 | |
| Potash (Potassic oxid) | 0.036 | | 0.018 | |
| One-fifth normal nitric acid soluble. | | | | |
| Phosphoric acid | 0.066 | | 0.073 | |
| Potash (Potassic oxid) | 0.057 | | 0.020 | |
| Portion of soil soluble in water | 0.388 | | 0.345 | |

The last determination, the portion of the soil soluble in water, is given because I believe that this is an important factor in the agriculture of the semiarid regions. To some, the figures 0.388 and 0.345 may convey only a slight notion of the mass of salts involved. The samples of soil and subsoil together were taken to a depth of a little more than one and three-quarters feet, but the wheat plant under favorable conditions sends its roots down to a distance of more than twice this depth. The amount of water soluble material in the soil represented by our samples amounts to 3,670 pounds as the average for each million pounds of soil, which gives us from 12 to 13 tons of soluble salts per acre taken to this depth of one and three-quarters feet. While the salts actually dissolved out of this soil by the water may not be capable of acting as plant foods, it seems improbable that they are indifferent or take no part in the changes which are constantly going on in the soil. Our theory for instance of the action of lime includes its ability to liberate potassium salts, likewise it is believed that soda salts may in some cases also act to make the potassium which may be too firmly held to be readily taken up by the plants, more available and in this way exercise a beneficial action on the growing crop. If these views be correct it would seem probable that this large amount of soluble salts may constitute an important factor in the question of the fertility of the soil.

The supply of the plant foods which it is usually considered necessary to take into account is ample in this soil to produce abundant crops. This is not a matter of theory, but of fact. It would be very bad for the theory if it indicated a contrary conclusion, for this soil will yield from 30 to 40 bushels of wheat without the application of manures of any kind, chemical or farmyard.

The experiments mentioned were made in sets of three and a check. Inasmuch as we used three varieties we have a series of twelve experiments on each of three sections of land. In this place I will give the results from one section only, but I will give the results for two years, in which we have wheat after wheat. The varieties used were, as stated, Defiance, Red Fife and Kubanka. I applied liberally each of the desirable elements, nitrogen, phosphorus and potassium, singly but not in combination. My reason for doing this has nothing to do with the object of this bulletin. I have stated the quantities applied but I wish to divorce the subject of yellow-berry from all questions of yield and quality in so far as I possibly can. I will give the yield and weight per bushel for the two years to remove any impression of exhausted soil or unfavorable cultural conditions.

YIELD AND WEIGHT PER BUSHEL, CROPS OF 1913 AND 1914.

| | | | 1913 | | 1914 | |
|---|---|---|---|---|---|---|
| Variety | Designation of plot | Area of plot | Bushels per acre | Wt. lbs. per bu. | Bu. per acre | Wt. lbs. per bushel |
| Defiance | Nitrogen Plot........ | 1-10 acre | 42 | 60 | 29 | 56 |
| | Phosphorus Plot..... | 1-10 acre | 40 | 62 | 39 | 58½ |
| | Potassium Plot...... | 1-10 acre | 43 | 62 | 37 | 59½ |
| | Check Plot.......... | 1-10 acre | 38 | 62½ | 33 | 56 |
| Red Fife | Nitrogen Plot....... | 1-10 acre | 39 | 63 | 52 | 64¼ |
| | Phosphorus Plot..... | 1-10 acre | 33 | 63½ | 45 | 63½ |
| | Potassium Plot...... | 1-10 acre | 33 | 63½ | 44 | 64¼ |
| | Check Plot.......... | 1-10 acre | 31 | 63½ | 43 | 63¾ |
| Kubanka | Nitrogen Plot....... | 1-10 acre | 39 | 63 | 49 | 64½ |
| | Phosphorus Plot..... | 1-10 acre | 38 | 64½ | 47 | 65 |
| | Potassium Plot...... | 1-10 acre | 37 | 64¾ | 45 | 65 |
| | Check Plot.......... | 1-10 acre | 36 | 63½ | 43 | 65 |

These yields including the Fife check 1913, and all of the Defiance plots for 1914, give no hint of exhausted soil and only by comparison with the yields of the other plots do they hint of any unfavorable conditions.

Some of these wheats are badly affected with yellow-berry and the most of them, almost all of them in fact, are affected in some degree. The only other affections at all noticeable in these samples are now and then a berry discolored brown and a few black-ended berries. The black-ended and brown berries are due to infection by fungi. The number of such berries was not greater in 1914 than in 1913, though I used the crop of 1913 for seed in 1914 and used the same plots for the respective varieties. Neither the seed nor the soil was treated in any manner. This is simply a statement of fact. It is not intended to commend this procedure, but we had little or no reason to treat our seeds. The only reason that we would have had for treating it would have been to combat the Altenaria which is the principal cause of our black-pointed berries, and the ordinary treatment usually given seed grain is of little or no value in this case. There is no question but that the soil may become seriously infected with fungi injurious to crops and all reasonable means should be used to prevent or correct such a condition, but our grain is not injured by fungi.

As already stated, the weather conditions during the growing period of these crops were favorable, only one unfortunate feature appearing in the two seasons. This was a violent shower on 28 July 1914; this shower was of short duration but did considerable injury to my crop. The only question which concerns us in regard to this injury is, did it play any part in the production of the yellow-berry? This question can be answered in the negative, especially if we consider the question to refer to the cause of this affection. The reason is conclusive, because the yellow-berry had already appeared in the wheat, that is in some of it, before this, besides in 1913 we had perfect weather conditions and we had yellow-berry, not so badly as in 1914, but badly enough to give a definite, negative answer to the question suggested in this connection.

The only causes, heretofore, assigned for the appearance of this affection in wheat are over-ripeness of the wheat, standing too long in shock, exposure to the action of moisture, air and sunshine, a heritable "tendency", the action of fungi, and climatic and weather conditions,—no one of which can be considered as the cause in our case. In 1913 the wheat was cut just as soon as we considered it safe to do so, and likewise in 1914, except that the Fife was a day or two earlier than the Kubanka and Defiance, and they were cut on the same day. The wheat was allowed to stand in shock not more than twelve days either year and no rain beyond a trace, less than four-hundredths of an inch during the twelve days, fell upon it, so we considered over-ripeness or late cutting and exposure after cutting as sufficiently answered by the elimination of both, besides the yellow-berry appeared in the most pronounced fashion while the berries were still green. That adverse climatic conditions had nothing to do with it, is evident from the record, for we had clear, warm, dry weather conditions for the whole growing periods of the two years, with the slight exception already mentioned.

We have no proof at all of any fungous trouble with either the wheat or the plants other than that already mentioned which is not significant and has no relation at all to the yellow-berry.

The two things are entirely distinct. We have flinty berries, wholly unobjectionable in any respect except that of having a blackened end, we also have spotted or yellow-berries both with and without such ends. The blackened ends are due to fungi; this fact is quite easily established by placing the black-ended berries in a culture dish under proper conditions when an abundant growth of the fungus affecting the berry will be obtained. Simple cases of yellow-berry do not afford this proof of fungous affection.

The question of a "tendency" which is heritable is fully set aside by the fact that we can, from the same lot of seed, under identical conditions of climate, grow crops affected with or free from yellow-berry.

Furthermore, the question is not one of the total supply of plant food. I have given the yields per acre for two succeeding years for the same varieties of wheat planted on the same sections of ground, every fourth one of which is a check plot. The minimum crop on any check plot for the two years is 31 bushels per acre, with the wheat weighing 63½ pounds per bushel. The same plot the succeeding year, without the application of any fertilizer and planted to the lowest yielding variety experimented with, yielded 43 bushels, weighing 63¾ pounds per bushel. This yield and weight per bushel does not indicate any deficiency of fertility and yet this wheat is badly affected with yellow-berry. I deem it altogether justifiable to conclude that yellow-berry is not a matter of total available plant food in the soil. It is no more a matter of starvation than of fungous trouble, which has nothing whatever to do with it, nor of a total excessive supply, but evidently a question of the ratio in which these food elements are present. In our case it is evidently the ratio between the potassium and nitrogen which determines the absence or presence of yellow-berry. I am satisfied that this is the cause of our yellow-berry and believe that the explanation is applicable to all cases. We have red wheats from some sections of Colorado which are white and mealy or starchy. These samples are as white and as mealy as any white wheat that I have seen. We have all degrees of this affection from a single, minute, yellow spot set in a flinty mass to the degree just designated in which the whole kernel is mealy. The cause of this is the one just stated, the ratio of the available potassium to the available nitrogen.

While it is possible that mealy wheat grown in Idaho or California might owe its mealiness or starchiness to some other cause, I hold it as quite certain that this is not the case, but that it is due to the fact that in these soils the ratio of available potassium to the available nitrogen is too high. There may be, as in our case there is, as shown by the yield of the check plots, an ample supply of nitrogen to grow bountiful crops, 38 and 33, 31 and 43, and 36 and 43 bushels for the checks with different varieties for the respective years, but the degree of mealiness or starchiness, the yellow-berry, in the wheat depends upon the relative available supply of these two elements.

The object of this bulletin is to show this cause and to offer some suggestions regarding the prevention of yellow-berry, and not to discuss the quality of the wheat. This feature is reserved for presentation with further results of our study which may not appear for some time. This much may, however, be stated at this time. The composition of the wheat, whether it involves quality or not, is profoundly affected. This result is independent of "climatic conditions." What modifying influence "climatic conditions" may exercise I will not at this time attempt to discuss, but it is subordinate, so far as yellow-berry and its effects are concerned, to the influence of the soil,—in this case, specifically to the potassium-nitrogen ratio.

The record of yellow-berry for the two years 1913 and 1914 on the twelve plots taken into consideration in this bulletin is given below, together with the record of "black-pointed" berries for 1913.

PERCENTAGE OF YELLOW-BERRY IN CROPS OF 1913 AND 1914.

| Variety | Fertilizer | 1913 Black-pointed berries percent | 1913 Yellow-berries percent | 1914 Yellow-berries percent |
|---|---|---|---|---|
| Defiance | Nitrogen | 6.7 | none | none |
| | Phosphorus | 12.9 | 10.0 | 50.0 |
| | Potassium | 15.3 | 30.0 | 63.0 |
| | Check | 13.0 | 24.0 | 36.0 |
| Red Fife | Nitrogen | 2.0 | none | 24.0 |
| | Phosphorus | 5.0 | 24.0 | 97.0 |
| | Potassium | 5.0 | 42.0 | 98.0 |
| | Check | 5.0 | 31.0 | 98.0 |
| Kubanka | Nitrogen | 5.0 | none | 23.0 |
| | Phosphorus | 12.6 | 35.0 | 94.0 |
| | Potassium | 9.5 | 37.0 | 96.0 |
| | Check | 16.0 | 31 | 97.0 |
| Results observed in field culture | | | | |
| Turkey Red | Land affected by nitre | | | 25.0 |
| | Land not affected by nitre | | | 100.0 |

The statement of these results in percentages of spotted and yellow-berries conveys no adequate notion of the differences noticeable between these samples. The potassium not only increased the number of yellow-berries, but imparted to the grains grown with its application a fullness of form and a paleness or deadness of color that are very marked, together with the appearance of mealiness or opacity.

We see that, in every case, the application of nitrogen which was in the form of sodic nitrate, greatly reduced the amount of yellow-berry, in some cases even preventing it altogether.

To my mind the two samples representing actual field conditions in another portion of the state are more interesting than any of my experiments, for in the one we have the natural, if I may use the term, development of nitrates in the soil, and in the other we have the ordinary cultural conditions obtaining on a farm well kept by a thrifty owner. In the one we have seventy-five percent of the berries translucent or entirely free from yellow-berry, in the other we have none entirely free, but nearly all badly affected. These grains are so different that the manager of the local mill stated that they spoke of such samples as constituting different varieties. In fact, this manager himself spoke of them as distinct varieties, and this too, in spite of the fact that he knew that the same lot of seed, Turkey Red, had been distributed to these parties.

These facts pertaining to the effects of the nitrate are entirely consonant with observations already on record. H. von Feilitzen, (Abs. Expt. Sta. Record, Vol. XVII, p. 24) says:

"Two years' experiments on four different kinds of soils show that glassy, hard kernels of spring wheat or barley are richer in protein than those of a mealy consistency.

"Glassiness or mealiness in the seed produced no effect upon the yield and size of the kernel, but apparently exerted a slight effect upon the glassiness or mealiness of the grain. The proportion of glassy kernels was found to be greater and the protein of the grain was higher, as a rule, on moor soil than on soil of mineral origin. The climatic conditions are considered as producing a marked effect on the quality of the grain. Nitrogenous fertilizers in general, increased the percentage of glassy kernels."

Also F. Moertlbauer (Abs. Exp. Sta. Record, Vol. XXV. p. 334) says:

"Very early applications (of sodic nitrate) on winter wheat decreased the flintiness of the kernels, late applications increased it. In every case where a part was applied late the hardness was improved. A top dressing when the heads began to form invariably produced a marked increase in the flintiness. * * * The protein content varied with the flintiness. The correlation was not a close one. Flintiness is not the only condition which determines the protein content."

These are the most direct and definite statements that I have found bearing upon the effect of the available plant food upon the prevalence of yellow-berry, the observation of Feilitzen that moor soils which are usually low in potassium produce a larger proportion of flinty berries than mineral soils, is suggestive of the views presented in this bulletin. The quotations from Dr. Kosutany have a similar significance but are not so explicit.

I have carefully avoided any discussion of the differences in the composition and quality of flinty and yellow-berries in this bulletin as being beyond its purpose. These subjects will be dealt with in a subsequent bulletin.

A question will naturally arise in regard to the part played by water and the condition of the plant at the time this may be applied. While I hold this to be the first and most important question in irrigation, I do not know that anyone has actually studied it. I have made some observations in regard to its effect upon the production of yellow-berry. The observations are not wholly consistent in details, but are concordant in showing that neither the time of application nor the total amount applied stands in any casual relation to the development of the yellow-berry. I have samples of "dry land" wheat raised without irrigation in which it is difficult to find a single kernel entirely free from this affection and I have also samples of wheat grown with the application of three acre-feet of water plus some rainfall and this, too, is very badly affected. Some of my own samples were grown with the application of two acre-feet, some with one and one-half acre-feet, and some with one acre-foot, and I can discover no relation whatsoever between the amount of water applied and the prevalence or absence of yellow-berry. I have stated very plainly and the plainness was intentional, that the giving of the percentage of affected berries does not adequately express the differences between samples grown with the application of nitrates and those grown with the application of potassium. The appearance of the kernels is different, the one is translucent and the other is opaque. This holds too in the case of irrigation, i. e., while the yellow-berry may be very bad heavy irrigation seems to slightly improve the appearance of the berries. I have two sets of three samples each which received one, two and three acre-feet of water respectively, and those samples receiving the three feet of water are the better appearing samples, while they are practically all affected with yellow-berry, I feel perfectly justified in stating that the application of irrigating water up to three acre-feet, does not produce the yellow-berry and also that the withholding of all water will not prevent it; for the yellow-berry is independent of this factor.

The remedy is plain, increase the ratio of nitrogen to that of potassium in the soil. This does not mean that it is necessary to add nitrogen because there is a deficiency of it to grow a crop. Our check plots grew good crops, from 31 to 43 bushels per acre, but the wheat from the check plots was badly affected with yellow-berry, while the wheat from our nitrogen plots was all practically free from it.

I have my doubts whether it will ever be feasible for our farmers, and probably it will not be feasible for many farmers anywhere to use sodic nitrate to prevent the formation of yellow-berry. There are other considerations to be weighed besides the cost, but this alone is probably prohibitive. This, however, will depend upon the amount which may be found necessary to apply.

The minimum amount necessary to apply will be found to vary greatly depending upon the soil and the time of application.

The observation of Moertlbauer that an early application of nitrates to winter wheat increased the mealy or yellow-berries does not apply, according to our observations, to spring wheat for we have had very favorable results in suppressing the yellow-berry by making but one application at the time of sowing the seed. I do not know but that better results would have been attained, in fact, I think that we would have attained much better results, had this same application been made after the grain had set, but this would have required us to apply water enough to carry the nitrate into the soil. Our plots received two applications of nitrate. There are other phases to the question which would take us too far afield to attempt to discuss in this place, but it may be stated, that it is an easy matter to add too much nitrate. I am not prepared at this time to suggest the minimum quantity likely to be effective, the best time to apply it, or the maximum which may be used without disadvantageous results. The quantity to be added will vary with the soil, and it may be that but few farmers could wisely follow any definite rule with the same results.

A point which demands mention in this place is, that as soon as the ratio of the nitrogen is too high, we obtain shrunken wheat irrespective of other conditions, and also abnormal ripening. The top and bottom portions of the straw will turn yellow while the middle portion and the leaves are too green to cut without danger of the sheaves rotting. This is a condition which I understand is frequently complained of by our farmers. The appearance of shrunken kernels without any apparent, adequate cause has also been noted very often.

Wheat seems to be very sensitive to these conditions, though almost all of our writers on this subject have attributed only a minor importance to them, claiming that climatic conditions almost wholly determine the character of the grain. While we cannot make ourselves independent of climatic conditions, however much or little we may mean by the term, it is evident that our data given do not fit into this view. I have omitted any detailed discussion of the composition of the yellow-berry wheat on purpose to avoid a premature discussion of these points. It seems wise, however, to make the above statements lest some one should be led to expect too much from the adoption of our suggestions for the prevention of yellow-berry.

Wheat affected with yellow-berry is considered inferior in quality and is graded low on the market. The removal of this affection will certainly cause the wheat to be graded higher and probably also actually improve the quality, but this seems to be an open question, for the Hungarian wheat is of the best quality though, as we have seen, the wheat is very far from being free from this affection.

There is another way of combating the trouble, the one suggested by Dr. Kosutany, i. e., through thorough cultivation and manuring, also by a proper rotation of crops. In offering an explanation for the smallness of the kernels and the inferior quality of wheat grown on small farms, as compared with wheat grown on large estates in Hungary, he uses the following language:

"The balance swings in favor of the large landowner and intensive, thorough culture, according to the determination of the degree of mealiness which at first sight is rather surprising, for if the wheat grown by the small landowner is smaller-grained, then it should, according to the theory which we have proposed, not only be richer in protein but also flintier, because the wheat planted with shallower culture ends its assimilative activity earlier and should contain less starch and more gluten and, therefore, should be characterized by a higher degree of flintiness. That this is not so can be explained only by this, that the fields on smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by these soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible, that a less advantageous rotation plays a part in it, in that the smaller owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring must be low in its nitrogen content. Accordingly we can draw the conclusion that the wheat grown upon small farms, is of lower value, because it has a lower weight per hectolitre, is smaller grained and less flinty, contains less gluten and less protein. Here a wide province opens up to intensive, thorough cultivation, since with the deepening of the soil the vegetative period of the wheat is lengthened, the kernels do not shrink, the plant is more richly supplied with nitrogen, its roots penetrate deeper into the soil and can take up a richer supply of nourishment. The heavier manuring provides the wheat with richer nitrogenous food and contributes to the formation of a wheat richer in gluten, flintier, with great absolute weight and a higher weight per hectolitre."

The effect of crop rotation is well illustrated by a case observed by Prof. Keyser while he was connected with the U. S. Department of Agriculture and stationed in Nebraska. Prof. Keyser has fully stated this case in a letter addressed to me on the subject and with his permission I state it in his own words:

"A certain field in York county, Nebraska, had grown corn for a number of years. A portion of the field had been seeded down to clover. The year the clover was broken up the corn land was seeded to oats. The clover and oat stubble were broken up and the entire field seeded to Turkey Red winter wheat. The year was favorable to good production and a good yield was returned on both parts of the field. The wheat from the land which had been in corn a number of years, however, contained a very high percentage of yellow-berry, although it was otherwise of good quality. The wheat on the clover sod, however, had very little yellow-berry, although there was an occasional kernel in evidence. Aside from this difference there was very little difference to be detected in the wheat from both parts of the field.

"The owner sent the wheat to the Nebraska State Fair, sending samples from each portion of the field. There was no appreciable inferiority of the yellow-berry wheat except the presence of the yellow-berry, both samples being unusually good. As I remember it, this wheat was seeded in the fall of 1902, harvested in 1903 and exhibited that fall."

It is altogether in keeping with what we believe about the effects of various crops to assume that the corn and oats had exhausted the available nitrogen in that portion of the field which had been planted successively to these crops, while the clover had actually added nitrogen to the soil increasing the ratio of the nitrogen supply to that of the potassium with the results above given. Prof. Keyser states that the yield was a good one and that the samples of wheat exhibited were unusually good, therefore, we are free to infer that the land had not been exhausted so far as crop production was concerned nor was the wheat affected with any other trouble than yellow-berry.

There is still another way to reduce or prevent the trouble, it is to cultivate the land fallow for one season during which some of our lands will acquire nitrates enough to produce a crop of wheat but little affected with yellow-berry. The department of agronomy under Prof. Keyser is conducting experiments with wheat on land sixteen feet to the west of that on which I am conducting my experiments. I am cropping continuously and he is cropping and cultivating fallow alternate years. The grain on my check plots comparable to his land produced wheat in 1914 having 97 and 98 percent yellow-berry, his wheat showed 14 percent yellow-berry.

The wheats received essentially the same treatment throughout the season, irrigation and care, except that his was harvested by hand and mine with a reaper. This comparison is of Red Fife with Marquis. In comparing Kubanka grown from my own seed on fallowed ground and grown on my check plot, I find that grown on fallowed ground to contain 13 per cent of affected berries and that grown on my cropped ground is practically all affected, by actual count 97 percent. It may be argued that my land was deficient in nitrogen because I had grown a crop of wheat on it the preceding year and had added no nitrogen to compensate for what I had taken off; this is true, but I had not affected the producing capacity of the soil, as the crop harvested was 43 bushels of wheat weighing 65 pounds per bushel. On the other hand we know that this land rapidly enriches itself in nitric nitrogen, so much so, that in October 1914, fallowed land, now planted to wheat contained nitric nitrogen equivalent to 518 pounds of sodic nitrate taken to a depth of seven inches. Such land will not produce yellow-berry.

It is evident that different pieces of land will require different treatment and no rule can take the place of intelligent observation and some experimentation on the part of the grower himself. The difference in composition and quality of flinty and yellow-berry kernels have been reserved for later discussion.

## SUMMARY.

The appearance of yellow or white, mealy or half-mealy, or spotted kernels in wheat, otherwise without apparent blemish and known as Yellow-berry, is not due to over-ripeness, nor to exposure after cutting, nor to the action of fungi, nor is it a "tendency" heritable in the wheat, as has been claimed by different authors.

We have no substantiation of the claim sometimes made that climatic conditions favorably influence, the development of, or cause yellow-berry.

Yellow-berry can be very much lessened or entirely prevented by the application of a sufficient quantity of available nitrogen.

Yellow-berry can be greatly intensified or increased by the application of available potassium.

The application of available phosphorus has no appreciable effect upon its prevalence.

Yellow-berry is not indicative of an exhausted soil, that is, one which will not produce abundant yields.

Yellow-berry indicates that potassium is present in excess of what is necessary to form a ratio to the available nitrogen present, advantageous to the formation of a hard, flinty kernel.

Yellow-berry should not be mistaken for or confused with black-ended berries or with brown or other discolorations in the berries. These affections are not general affections as the yellow-berry is and are not produced by the same cause.

Yellow-berry is under the control of the grower. If there be sufficient difference in the price of grain produced he can control it with a margin of profit.

The means at his disposal for its control are:

First: The judicious use of sodic nitrate.

Second: The thorough cultivation of his soil with the application of nitrogenous manures.

Third: A rotation of crops in which a clover and possibly other legumes precede the wheat.

Fourth: Fallow cultivation.

These observations apply to all of our western soils, rich in potassium and relatively, not absolutely, poor in available nitrogen.

Bulletin 206 May, 1915

# The Agricultural Experiment Station

OF THE

## Colorado Agricultural College

# SPUR BLIGHT OF THE RED RASPBERRY CAUSED BY SPHAERELLA RUBINA

*By* WALTER G. SACKETT

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# SPUR BLIGHT OF THE RED RASPBERRY CAUSED BY SPHAERELLA RUBINA

*By Walter G. Sackett.*

For more than twenty years, the growing of red raspberries in northern Colorado has been one of the chief occupations of those engaged in horticultural pursuits. There is probably no one district in the United States which produces more red raspberries for a given territory than Loveland, Colorado.

In the year 1914, the Loveland Fruit Growers' Association handled 10,120 crates,* which represents approximately 80 per cent. of the crop; the Boulder Association shipped 1,550 crates, less than one-half of the crop, and the Longmont Association 5,000, making a total of 16,670 crates handled in a wholesale way, to say nothing of those marketed through other channels and consumed locally. The average price paid to the Loveland growers for the season 1914 amounted to $1.27 per crate, and estimating the cost of production and packing at 75 cents per crate, we have a net return of approximately 50 cents on every crate. The demand for these berries is always far in excess of the supply, which makes it possible to control the price and secure a reasonable return for the grower. The present acreage in the Loveland district is in the neighborhood of seventy acres; Longmont follows with forty, and Boulder with thirty. In addition to this, there are a number of plantations around Fort Collins which a little more than supply the local trade. Nowhere in the state do we obtain the yields that are secured in the Loveland, Longmont and Boulder districts; 375 crates per acre is a fair average, while 600 have been obtained under optimum conditions.

The Marlboro is the most popular variety, although the Cuthbert is grown to some extent. In flavor, quality, size and color, the Northern Colorado berries are second to none in the United States, but because of inadequate facilities for pre-cooling, a prerequisite to refrigeration in transit, the fruit has not found its way to the eastern and Mississippi Valley markets. Our berries ripen from two to three weeks later than those in the lower altitudes, and while this question of a market has never given us any concern thus far, it is very clear that if such an emergency should

*One crate contains twenty-four pint boxes.

Figure 1.

arise, we would have little difficulty in disposing of the crop to the eastern trade. At present, we are shipping in the open express car as far east as central Kansas and Lincoln and Omaha, Nebraska; north to Billings, Montana, and south to northern Texas and Oklahoma.

From this brief statement of the raspberry industry in Northern Colorado, it will be seen that any factor or factors which materially affect the production of berries may mean much to the prosperity of the section. An examination of the yields for the years 1910-1913, inclusive, as shown by the shipments made by one of the largest Fruit Growers' Asosciations, indicates clearly that certain agents were operating to bring about a marked decrease in production for that period. In 1909, the association mentioned handled 13,150 crates, while in 1910, only 1,655. Quite naturally, those engaged in the berry business felt considerably alarmed over this state of affairs, and at the request of the most extensive growers, we have undertaken to study the prevalent conditions and to ascertain some of the causes which are contributing to these failures.

Figure 2.

As a result of six years of observation, we believe that no one factor alone is responsible for this state of affairs, but rather that it has come about through the combination of several, among which we may mention the following: Late frosts, method of covering and time of taking up canes, poor cultivation, age of plantations, and injury caused by *Sphaerella rubina*.

## LATE FROSTS.

One of the most disastrous things that can befall a raspberry plantation is to have a killing frost late in the spring after the new canes have begun their growth, and are from 12 to 15 inches high. Frequently, we have a warm, sunny April with moisture conditions just right to produce a rapid, vigorous development of the young canes, and then the first or second week in May we will have a freeze that may damage the new canes very considerably. This is exactly what happened in the springs of 1909 and 1910. In the latter year, the spring promised to be an early one; the berry bushes had been uncovered and taken up, and many of the young canes were 12 to 15 inches high. About the middle of May there

Figure 3.

occurred a severe freeze, and practically every new cane was seriously injured, if not killed outright. The growing tips were blackened and the canes were shriveled for a distance of one-half to three inches below this. When they were split lengthwise, the pith was found to be blackened at the tip, browned further down to within two or three inches of the ground, below which it was white and normal to all appearances.

As soon as favorable weather conditions return, one of two things usually happens: The frozen canes either make no further growth and the roots send up a new crop of suckers, or they sprout out from below the frozen tips and develop a forked cane consisting of two or more spindling shoots in place of one good, substantial cane. Such branched canes are usually undesirable, and if single ones can be obtained, even though of a later origin, their growth should be encouraged. Large, thrifty canes mean handsome returns in berries, while the inferior ones yield nothing but disappointment.

Many growers make the serious mistake of allowing too many canes to develop in the spring. Dr. Sandsten, our horticulturist, recommends that, "each plant or hill should not be allowed to grow

Figure 4.

more than twelve new canes each year. These should be reduced to eight or ten in the spring. The extra canes are to replace those that happen to break in covering and uncovering. All others should be removed as soon as they appear. By keeping these young canes or suckers down, the strength is thrown into the main canes, thus promoting strong growth and greater fruiting capacity."

## METHOD OF COVERING CANES.

Because of the frequent cold winds during the winter months which have a decided drying action on the canes, to say nothing of their freezing effect, it has been found necessary to protect them in some manner.

Different materials have been employed for this, such as straw, strawy manure, and gunny sacks, but nothing has been found quite so satisfactory as soil. Some four years ago, the writer tried a combination of straw and soil, using just enough of the latter to hold the straw in place, the object in this being to keep the soil away from the canes so that in case the following spring should be wet and there should be some delay in taking up the berries, the injury from ground scald and rot would be reduced. It happened,

Figure 5.

however, that the spring was very favorable to getting the canes up early, so we were not privileged to see the benefit, if any, from the use of the straw. The experiment was not without its lesson, however, for it demonstrated very clearly that straw, even though covered with soil, is not an adequate protection. Although not all of the canes were killed, a very large proportion never came out into leaf.

As checks on this method of covering, part of the same row was left entirely uncovered, and an adjacent row was covered with soil. Every cane that was left unprotected was killed, while every one that was covered with soil grew. The results of these experiments are shown in Figs. 1 and 2.

The right-hand row of Fig. 1 was left uncovered and all the canes were dead. The left-hand row was covered with soil, and abundant leaves are to be seen coming out; in Fig 2, the row on the right was covered with straw and soil, that on the left with soil; the former shows numerous bare, dead canes, and a few live ones with scattering leaves, the latter, vigorous canes with many leaves.

That the air had a much freer access to the canes which were covered with straw is evident from two facts: First, a large proportion of the canes were killed, and second, the young shoots or suckers were six to eight inches high, while those that were covered with soil were just coming through the ground, a fact which would seem to indicate that the former had gotten an early start, due to a freer circulation of warm air. The former were more numerous and more stalky than the latter; the same was true of the new growth from the bushes which were left entirely uncovered, but to a less extent.

Fig. 3 shows the vigorous young shoots coming from the straw covered bushes, and Fig. 4 those arising from the roots of the soil-covered canes. The old canes in Fig. 3, straw-covered, but naked and dead, stand out in sharp contrast to the leafy, thrifty ones in Fig. 4 which were covered with soil. The experience of the most successful growers, together with the results of our experiments, point clearly to soil alone as the most satisfactory method of protection during the winter months. A light covering, just enough to exclude the air, possibly two inches over the root ends, is adequate.

## TIME TO TAKE UP CANES.

Just when to take the berries up in the spring is always a problem, not because we do not know what practice is best to follow, but because we do not know what weather conditions to expect. On the one hand, if the spring is going to be late, cold and dry, little harm will result if the canes are left buried until after the first of May; on the other hand, if it is warm and wet, nothing could be more disastrous than to allow them to remain covered until this late date. The danger from uncovering and taking them up too early results from subsequent late freezes during the first part of May. The fruit spurs are usually well advanced by this time, and the new canes are six to eight inches in height. If the bushes are left covered until late and the weather is warm, with considerable moisture, the canes throw out long, spindling white shoots which wilt and shrivel as soon as they come into contact with the air and sunshine, particularly if there is a little wind blowing; this, of course, means that the canes must grow a second set of fruit spores, which, at their best, are inferior to the first. While there is some difference

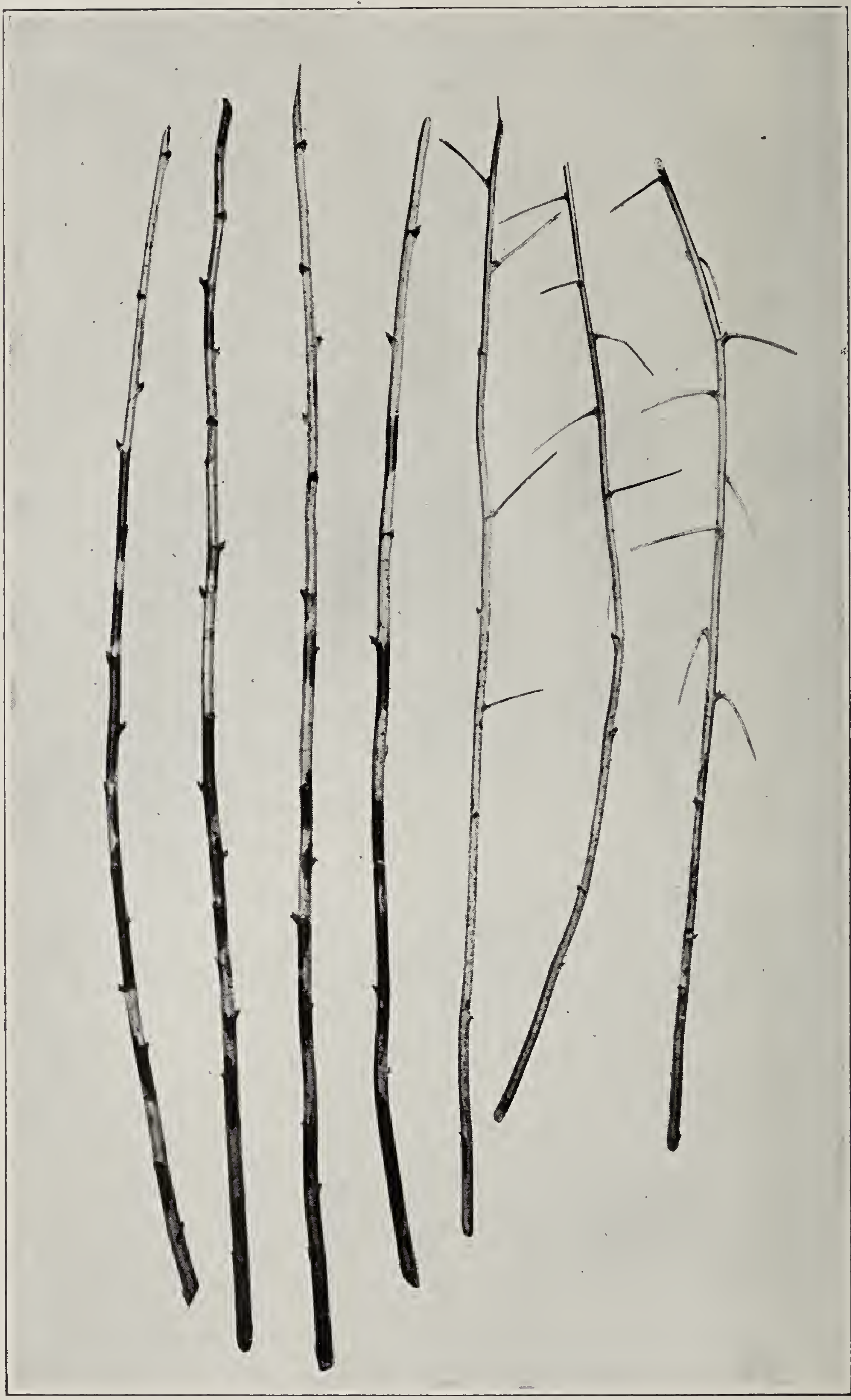

Figure 6.

of opinion concerning the wisdom of early or late uncovering, the most successful growers are agreed that the former procedure is the safer practice.

The method adopted consists in plowing away the soil from the sides of the row early in April, and in gradually removing the soil from the top so as to admit air and sunshine. In this way, the young growth becomes accustomed to the new conditions gradually, and is hardened off before it is completely exposed; at the same time, the canes have an opportunity to dry off, and if severe cold weather does follow, they will be in a more resistant condition than if saturated with water. The canes may be left in this semi-covered condition for eight to ten days, or even longer, if cold weather prevails, without doing them any injury. With this preliminary hardening, they should be ready to take up by the middle of April, and should be able to withstand rather wide ranges of temperature.

## POOR CULTIVATION.

Another factor which has undoubtedly played a part in the reduced yield of many plantations is insufficient and improper cultivation. We have depended too much upon irrigation, and not enough upon cultivation to maintain the proper moisture content of the soil. The result has been that the soil in the raspberry row has become puddled, hard, and so tightly compacted that it is practically impossible for the irrigating water to penetrate and reach the roots. Without sufficient moisture, the plants are unable to obtain the necessary mineral food from the soil, and starvation is the result. Furthermore, the roots must have air for the growth and development of the bushes, and with the soil packed so firmly around them, proper aeration of the root system is impossible.

In place of planting in drills or rows, a hill system would be more desirable since cross-cultivation would then be possible, and it would be a relatively simple matter to break up the hard ridges between the hills. Where planting has been carried out in rows, much good can be accomplished by tearing up the hard soil between the bushes with a grubbing-axe or mattock several times during the season.

## AGE OF PLANTATIONS.

Experience has shown that although given the best of care, raspberry bushes begin to deteriorate quite rapidly after the plantation has reached the age of twelve to fifteen years. Even where thorough cultivation and systematic manuring have been practiced faithfully, we find that the old roots lack the vitality necessary to produce vigorous fruiting canes. There is no question but that some of the plantations in Northern Colorado are suffering from old age and should be plowed up and consigned to the brush pile. This factor alone, in many cases, will account for decreased yields.

In place of re-setting the land to berries at once, it would be much better to plant it to some hoed crop for a year or two, in order to get the old raspberry rows thoroughly broken up. At the end of this period, the land may be seeded to alfalfa or sweet clover, in which case the alfalfa should be plowed under in the fall of the second or third year, and the sweet clover at the end of the second year. In place of cutting the last crop for hay, this should be turned under and used as a green manure, in which capacity it will yield a much greater return than if harvested for hay. This done, the land may be again set to raspberries.

## INJURY CAUSED BY *SPHAERELLA RUBINA*.

### *Description of the Disease.*

The first indications of the injury here referred to make their appearance about the middle of July. If the young, green canes are examined carefully, chocolate brown discolorations of the epidermis will be found occurring on the lower portion of the cane in the region of the point of attachment of the leaves, the node; again, small spots may occur between the nodes, the internode, and on the petioles of the leaves. The petiole infection is shown at 1, and the node infection at 2 in the colored plate which was prepared from material collected August 9, 1913. The whole area surrounding the growing buds at the base of the leaves soon becomes involved and turns brown; the buds appear to stop their development, shrivel and drp up. If the developing bud is not killed outright during the fall and winter, it is so weakened that the following spring it is able to send forth only a small, weakly spur which may come into leaf, but rarely reaches the blossom stage. The leaves on such spurs are usually small, yellow, and apparently poorly nourished. They struggle along for a few weeks, and usually die of starvation. The result of this condition is a cane with practically no fruit-spurs for a distance of 20 to 24 inches above the ground, and with only the upper half producing berries. (See Fig. 10.) There certainly is little ground for argument that a patch in this condition is producing all that it might and is a paying investment.

In the case of the petiole infection, the nourishment seems to be interfered with so seriously that the stem soon collapses and the whole leaf droops and ultimately dies, leaving nothing but the dry stem remaining. (See Fig. 3 colored plate.)

Figure 7.

The infection at the node can be traced, in nearly every case, to a lesion on the petiole which has spread toward its base and involved the bud region. From the nodes, the discoloration spreads rather rapidly into the inter-nodes, the discoloration from one coalescing with that from another, sometimes entirely encircling the cane, so that in six weeks time the whole bottom third may be dark, purplish brown in color. Fig. 5 shows a portion of two such canes on the left, and a healthy one on the right. In Fig. 6, four diseased (left) and three normal (right) canes are given to illustrate the distribution and extent of the discolored areas late in the season. (Sept. 13, 1913.)

The bark or cortex frequently cracks and splits for a distance longitudinally, where it has become brown and exposes the moist, green tissue beneath. (Fig. 4 colored plate.) As a result of this, the canes dry out prematurely, become brittle and break very easily, when they are put down in the fall and taken up in the spring. This fact coincides with the statement of the growers that the canes have become more brittle in recent years than formerly. Whereas less than 5 per cent. should be lost in this way, some growers estimate the number as large as 30 to 50 per cent.; some report only 2 per cent. broken, while the average is between 10 and 20 per cent.

From the middle of September to the first of October, grayish white patches may be seen developing in the center of the brown blotches (Fig. 7), and if these light areas are examined very carefully a few weeks later, they will be found to be thickly studded with minute black specks or pustules. (Fig. 8.)

### *Pathological Changes.*

A microscopic examination of a cross-section of a raspberry cane discloses three rather well defined cortical regions beneath the epidermal layer. The outer one consists of relatively large thick-walled cells along the outer edge, the middle one of large thin-walled cells, and the inside one of smaller thick-walled cells. By exercising special care, it is possible to separate the outside structure from the inside with a sharp scalpel, owing to the fragile character of the large thin-walled cells of the middle region. If the outside portion is removed from a healthy, green cane free from all discoloration, the aspect of the remaining inside region is almost white with a faint suggestion of green. If a similar dissection is made of a brown diseased cane thru the brown spot, both the outside and inside portions of the cortex will be found to be brown in color. Such a dissection is shown in Fig. 9. Here the outside part was peeled from adjoining normal and diseases areas and


COLORADO AGRL. EXPT. STA.

shows the change in the color of the deep layers, in passing from healthy to diseased tissue. From A to C the cane was normal and green in color; the outside cortex was removed from B to D; from B to C the inside cortex was white; from C to D it was brown; from D to E the cane was brown. This discoloration appears to the naked eye to extend no deeper than the cortex, but a microscopic examination of a section shows that this is not altogether correct.

The cells of the entire cortical layer, from the epidermis to the phloem, are badly shrunken and present a brown shriveled aspect characteristic of dead, collapsed tissue. Many of the phloem elements, as well as the cells of the medullary rays show an accumulation of food material greater than that of corresponding cells of normal tissue. While these cells appear amber brown in color, they are perfect in outline and in general structure, and do not suggest a fungous invasion. The brown color which they exhibit is traceable, in all probability, to the excessive food material which has been deflected to these regions as a result of the enzymotic influence, exerted by the fungus which has invaded and destroyed the adjoining cortical layer. The strengthening tissue (stereome), wood (xylem), and pith (medulla) exhibit no pathological condition.

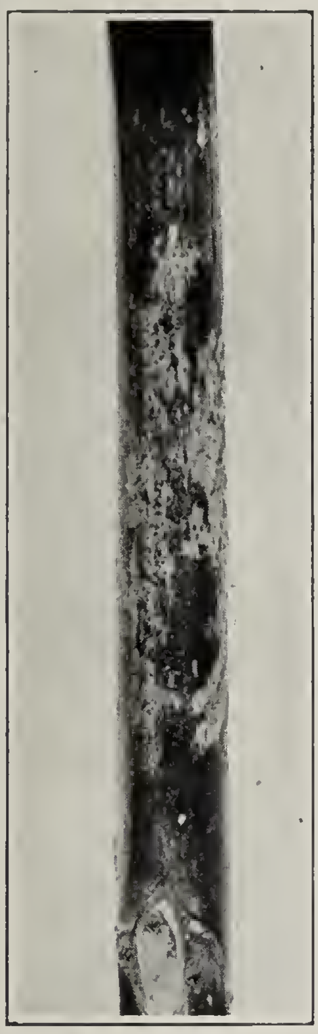

Figure 8.

*The Causal Organism.*

A microscopic examination of the brown cortical tissue shows it to be permeated with the mycelium of a fungus. This fungus has been isolated repeatedly with little difficulty from such material and has been grown for more than three years upon standard

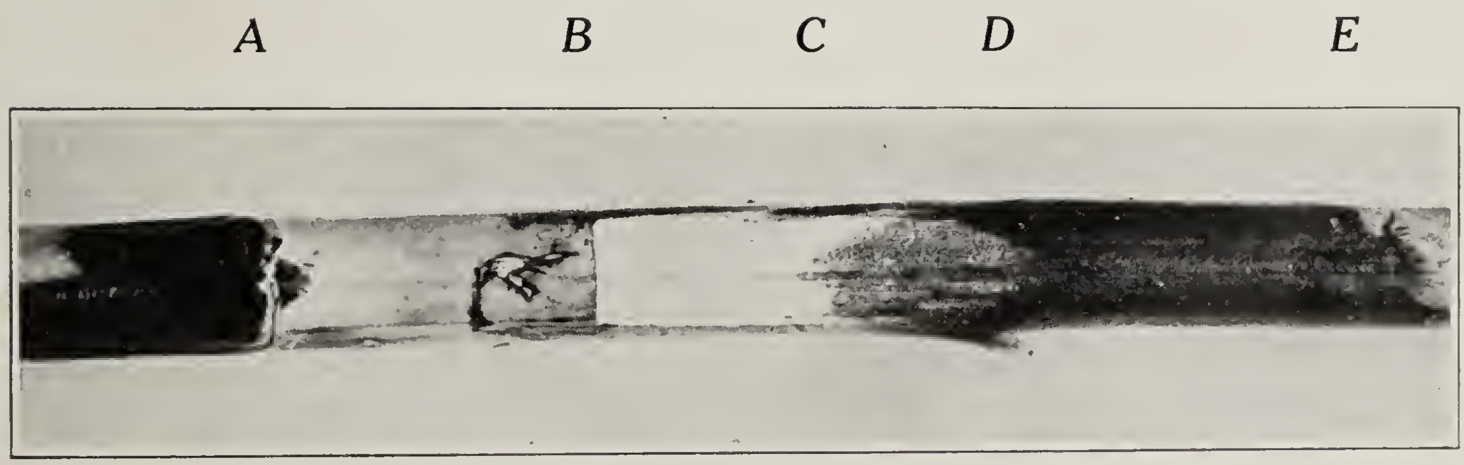


Figure 9.

nutrient agar, plus 15. It has been re-inoculated into healthy canes from pure cultures by means of needle punctures, and typical brown splotches characteristic of the injury have been produced inside of two weeks; from the lesions thus produced, the original fungus has been re-isolated. Both the brown septate mycelium and the fruiting bodies (perithecia) present on the canes, as well as the changes produced in the plant, correspond to the description of the pyrenomycete, *Sphaerella rubina*, and its attendant injuries given by Peck in the 48th Annual Report of the New York State Museum, Part I, page 114. The description follows:

"*Sphaerella rubina* n. sp. Perithecia minute, .007 to .009 in. broad, commonly gregarious, sometimes forming extended patches, submembraneous, obscurely papillate, pertuse, subglobose or depressed, at first covered by the epidermis, becoming superficial when the epidermis falls away, black; asci cylindrical, subsessile, .003 to .0035 in. long, .00045 to .0005 broad; spores uniseriate or subbiseriate, oblong, obtuse, uniseptate, generally constricted in the middle, hyaline, .0006 in. long, .00024 to .0003 broad, the upper cell often a little larger than the lower.

"Stems of cultivated raspberries. Menands. April and May.

"This species is injurious to the plants it attacks. The affected plants either die from the disease or are so weakened by it that they are winter-killed wholly or in part. Generally the epidermis is whitened over the patches of the fungus, but some times brown spots indicate the presence and location of the fungus. The mycelium consists of brown septate filaments. From *Didymella applanata*, which this fungus resembles in some respects, it is separated by the absence of paraphyses."

Stewart and Eustace*, while investigating the cause of raspberry cane blight, which they believe to be due to a species of Coniothyrium (C. fuckelii?) have found *Sphaerella rubina* associated with Coniothyrium. However, they are of the opinion that this organism is not injurious to the canes on which it occurs, and plays no part as a casual agent in cane blight in which the wood itself is attacked. Our trouble is manifestly distinct from cane blight, for in no case is the wood involved.

Concerning the injury to red raspberries by *Sphaerella rubina* in New York State, Peck** gives the following:

"Having been informed that the raspberry patches of the fruit growers in the vicinity of Marlboro, Ulster County, were suffering from disease, and wishing to know the cause of it, a visit

*Bulletin 226, N. Y. Exp. Station, Geneva, N. Y., p. 357, Dec., 1902.

**Sixty-fourth Annual Report (1910) N. Y. State Museum—State Botanist, p. 7, 1911.

Figure 10. Unsprayed Canes.

was made to that place in July. An examination of the diseased canes showed that they were suffering from an attack of a parasitic fungus, whose technical name is *Sphaerella rubina* P. The fruiting canes develop their leaves and flowers as usual, but before the fruit ripens it withers and dies in the branches. The dryness of the season and an attack of 'red spider' were apparently contributing causes of the failure of the crop, and the loss was severe. The diseased canes bear patches of the fungus. It matures its spores early in the season. In the type specimens, they were found in May. The young canes showed brown or blackish patches one or two inches on the lower part. In some cases they were near the ground, thereby indicating a probable infection when they were but a few inches tall. These spots had not yet developed their

Figure 11.

perithecia or spore cases, but doubtless would toward the end of the season and the next spring be ready to shed their spores and renew the species in the succeeding crop of young canes. Theoretically, the disease should be prevented by spraying the young canes with a good fungicide like Bordeaux mixture or lime-sulphur mixture, but it would be necessary to give the first spraying when the young shoots are only three or four inches high. This should be repeated once a week until the canes of the previous year begin to blossom."

As mentioned above, during the latter part of September or the first of October, there appear on the gray discolorations of the brown splotches numerous tiny black pustules under the epidermis of the new canes. These resemble little pimples pushing up under the skin and are the developing perithecia or spore cases of the fungus (See Fig. 8.) They mature early in the spring, producing a large number of spores or seed which are destined to spread the disease. The pustules break through the epidermis, burst and liberate millions of spores to be carried by the wind to new tender canes just coming through the ground, or at best but a few inches

Figure 12. Sprayed Canes.

high. Once located on the new succulent growth, the spores germinate, begin active invasion of the cortex, and in due time the characteristic brown splotches appear.

It is clear from this description of the time and method of infection that if any remedial measures are to be resorted to, such measures must be directed toward protecting the young developing canes against the attack of the fungous spores, as early in the spring as possible. This is best accomplished by covering them with some poison or fungicide before the spores begin to scatter, which will not permit their growth and development when they alight.

Too much stress cannot be laid upon the importance of the early application of the fungicide or spray material, since it is of no value whatever after the fungus has once invaded the deeper tissues. Prevention is our only hope of combatting the trouble, for we have no remedy, save a plow, when it has become once established. Spraying will prevent the disease.

### *Control Measures.*

For the past two years we have been carrying on spraying experiments at Loveland, Colorado, in an effort to control the Sphaerella injury. In this work we have used an adhesive bordeaux mixture composed of 3 pounds of copper sulphate (bluestone), 2 pounds of stone lime, and 50 gallons of water (3-2-50), to which 2 pounds of rosin fish oil soap were added as a sticker.

Figure 13. Sprayed Cane.

In 1913, the first application was made May 29th, at which time the new canes were from 8 to 12 inches high; the second spraying was made on June 12th, and it was our purpose to give a third application about June 26th, making the three treatments approximately two weeks apart, but because of continued rainy weather, it was impossible to get into the patch with a spraying outfit, so this had to be abandoned. The berries were beginning to ripen by the time the ground had dried off, and nothing more was done until the picking season was over and the old canes were all removed. On August 18th, a final application was given, to carry the bushes into fall and winter in a protected condition. At this time, scattered here and there through the patch were a few canes with one or two brown splotches, but nowhere nearly as numerous as in unsprayed plantations. In 1914, sprayings were made as follows, on the same patch: June 4, June 22, and August 18th. This time, the late June spraying was prevented by the very early ripening of the berries, it being deemed inadvisable to use the Bordeaux mixture, because of the danger of discoloring the fruit.

It is understood, of course, that the Bordeaux mixture is applied to the young canes only, and not to the fruiting canes, since it is the former that we wish to protect from possible infection from the old diseased canes. In spraying raspberries, as well as other things, it must be remembered that thoroughness is what counts; great care should be exercised to see that every part of the cane, particularly the portion next to the ground, is entirely covered with the spray material each time the operation is carried on. In place of attempting to spray both sides of the row and between the bushes at the same time, requiring the operator to reach around them, we have found it more practical and more expeditious to drive between the rows, to treat the inside of the rows next to us and part way between the bushes, and then to drive down the next middle and finish the other side of the former row and one side of a new row.

The old fruiting canes should be removed and burned as soon as the berries have been gathered in order to prevent any possible infection of the new canes.

*Preparation of Bordeaux Mixture.*

We have found a barrel spraying outfit adequate for this work and entirely satisfactory. The pump employed should be capable of giving at least 50 pounds pressure, and can be purchased for from ten to twelve dollars, exclusive of the barrel.

For preparing the Bordeaux mixture, it will be found convenient to have two half barrels with a capacity of about 30 gallons each, made by sawing in two a 60 gallon barrel. Three or four wooden candy pails should also be provided.

For every 50 gallons of Bordeaux mixture, dissolve 3 pounds of copper sulphate in two or three gallons of boiling water in one of the wooden pails, and slake the corresponding amount of lime, 2 pounds, in another, using just enought water to keep the lime from burning, and to give a thick, smooth paste, of about the consistency of white-coat. Two pounds of rosin fish oil soap are dissolved in about 2 gallons of water. The solution of copper sulphate is next poured into one of the half barrels, and enough water added to make 25 gallons; the slaked lime is washed into the other half barrel, with enough water added to make 23 gallons; the 2 gallons of water on the soap will make the 50 gallons of water shown in the formula 3-2-50. The diluted solution of copper sulphate and lime are now ready to be mixed. No better method has been devised for doing this on a small scale than that shown in

Figure 14. Sprayed Canes.

Fig. 11. The two operators, each provided with a bucket, dip up equal amounts of the copper sulphate and lime solutions, respectively, and pour them together at the same rate at a height of two or three feet above a mixing-barrel. (See Fig. 11.) This permits of thorough mixing in falling, and in view of the fact that the value of Bordeaux mixture as a fungicide depends largely upon its method of preparation, the procedure here described should be adhered to rather closely. After the lime and bluestone have been brought together in the mixing barrel, the whole should be stirred thoroughly with a long paddle, at which time the soap solution may be added. It is now ready for use.

*Cost of Materials.*

The commercial copper sulphate can be obtained in 100 pound

Figure 15. Unsprayed Canes.

quantities from the Mine & Smelter Supply Company, Denver, Colorado, at 7 cents per pound, f. o. b. Denver. Stone lime can be purchased locally for $1.75 per barrel of 200 pounds. Rosin fish oil soap can be obtained from James Good, Number 939 North Front Street, Philadelphia, Pa., at the following prices, f. o. b. Philadelphia:

25 lb. buckets at 5c per lb.
50 lb. buckets at 4½c per lb.
100 lb. buckets at 4¼c per lb.
170 lb. buckets at 4c per lb.
Half barrel (275 lb.) at 3¾c per lb.
Barrel (about 425 lb.) at 3½c per lb.

At the above prices, 50 gallons of Bordeaux mixture cost approximately thirty-two cents, and 400 gallons, the quantity required for one acre, would amount to $2.56. If four treatments are given during the season, three before picking at intervals of two weeks, and one immediately afterwards, the cost per acre for the season would be $10.24, an amount offset by eight or ten crates of berries; if the yield cannot be increased more than ten crates per acre by spraying, one would certainly be justified in the position that "the game is not worth the candle."

By giving three applications of Bordeaux mixture as mentioned above, we have reduced the number of diseased canes and the extent of the infections on these canes to less than seven per cent., and had we been able to carry out four sprayings as was our purpose, we have reason to believe that the injury could have been reduced to practically zero.

### *Results of Spraying.*

A comparison of Figures 12 and 13 with Fig. 10 suggests a very plausible and satisfactory explanation of the increased yield on the part of the sprayed canes. All of the canes shown in these illustrations are cut close to the ground; those in Figs. 12 and 13 threw out strong, vigorous fruit spurs 16 to 18 inches long, all the way to the ground; those in Fig. 10 have practically no spurs within 18 to 24 inches of the ground; the former were sprayed, the latter were not, and it is obvious that the canes with the larger number of spurs will produce more fruit than the naked ones. By an actual count of the fruit spurs on the lower 24 inches of 100 sprayed canes, the average number was found to be 9.82, while on a like number of unsprayed canes, there was but 3.55 to the first 24 inches. Again, 65 per cent. of the sprayed canes had their lowest fruit spur within 6 inches of the ground, 32 per cent. from 6 to 12 inches, and 3 per cent. above 12 inches; with the unsprayed canes 37 per cent. had the first spur within 6 inches of the ground, 41 per cent. from 6 to 12 inches, and 22 per cent. above 12 inches.

In Figs. 14 and 15 are shown sprayed and unsprayed canes, respectively, in the spring condition just as they are leafing out. The sprayed canes with their numerous leaves present an entirely different picture from the naked, spindling ones which were unsprayed.

Below are given the actual returns from an experimental patch which was sprayed three times:

Mr. A. H. Gifford, Loveland, Colo.—1½ acres.

| | |
|---|---|
| Crop of 1912—Unsprayed canes | 200 crates |
| 1913—Unsprayed canes | 200 crates |
| 1914—Sprayed canes | 735 crates |
| Increase in yield for 1914 over 1913 | 535 crates |
| Gain per cent. for 1914 | 267.5% |

*Unsprayed Patches.*

| | | |
|---|---|---|
| Mr. A. 1¼ acre | 1912 | 300 crates |
| | 1913 | 400 crates |
| | 1914 | 275 crates |
| Mr. B. 4 acres | 1912 | 1,000 crates |
| | 1913 | 1,135 crates |
| | 1914 | 1,216 crates |
| Mr. M. ⅞ acres | 1912 | 330 crates |
| | 1913 | 350 crates |
| | 1914 | 570 crates |
| Mr. S. 1/3 acres | 1912 | 100 crates |
| | 1913 | 125 crates |
| | 1914 | 115 crates |
| Mr. A. 1⅛ acre | 1912 | 93 crates |
| | 1913 | 273 crates |
| | 1914 | 310 crates |
| Mr. K. ½ acre | 1912 | 175 crates |
| | 1913 | 240 crates |
| | 1914 | 324 crates |
| Mr. S. 1¾ acres | 1912 | 285 crates |
| | 1913 | 421 crates |
| | 1914 | 453 crates |
| Mr. S. 1/3 acre | 1912 | 75 crates |
| | 1913 | 106 crates |
| | 1914 | 70 crates |
| Mr. M. 1 acre | 1912 | 200 crates |
| | 1913 | 250 crates |
| | 1914 | 330 crates |
| Mr. S. 1 acre | 1912 | 175 crates |
| | 1913 | 278 crates |
| | 1914 | 532 crates |
| Mr. S. ¾ acre | 1913 | 487 crates |
| | 1914 | 365 crates |
| Mr. C. 1¾ acres | 1913 | 373 crates |
| | 1914 | 373 crates |
| Mr. L. 1 acre | 1912 | 325 crates |
| | 1913 | 250 crates |
| | 1914 | 300 crates |

The increase in yield for the year 1914 over that for 1913 due to more favorable climatic conditions amounts to 22.1 per cent. This figure represents an average from the returns of 21 unsprayed plantations around Loveland, Longmont, and Boulder.

It has been shown that where the bushes were sprayed, the increase of 1914 over 1913 was 267.5 per cent. Deducting from this the per cent. of increase assumed to be due to the favorable season, we still have 245.4 per cent. more berries from the sprayed than from the unsprayed canes, or 91.75 per cent. of the season's increase was the result of spraying. This represents an increase of 375 crates per acre, which, at a net profit of 50 cents per crate, would amount to $178.50, and deducting from this the cost of spray material for one acre, $10.24, for the season, there would remain for the grower a net gain of $167.26 per acre.

Whereas, under the present condition, the Fruit Growers' Associations in northern Colorado in 1914 handled 16,670 crates of red raspberries, there is little reason why this could not be increased to 50,000 crates, if systematic spraying were to be adopted generally.

## ACKNOWLEDGMENT.

I am indebted to Mr. W. O. Fletcher, manager of the Loveland Fruit Growers' Association, to Mr. G. V. Booth of the Longmont Association, and to Mr. L. H. Stanton of the Boulder Association, for the data relative to their respective associations.

To Mr. A. H. Gifford of Loveland, I am indebted for the numerous courtesies extended in connection with our spraying experiments which were carried out on his plantation.

Bulletin 207 May, 1915

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

# THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

*By* V. M. CONE

This bulletin is based upon work done in the hydraulic laboratory, at Fort Collins, Colorado, under a co-operative agreement between the Colorado Experiment Station and the Office of Experiment Stations, U. S. Department of Agriculture.

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# The Colorado Agricultural College

FORT COLLINS, COLORADO

## THE STATE BOARD OF AGRICULTURE

# THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

*By* V. M. CONE

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The question is often asked, "What is a Miner's Inch," or an "inch of water?"

The "Inch" is a unit of measure of flowing water which has been handed down to the irrigators of the West by the early day miners. There are several different Miner's Inches, and they are sometimes called "Customary Inches," which means the "Inch" principally used in any certain locality. When the value of the "Inch" or the conditions under which the "Inch" shall be measured is fixed by law, it is called a "Statute Inch."

An "Inch" of water is an indefinite quantity. It is the flow through an inch square orifice, but the flow varies with the size of the orifice, the distance from the top of the orifice to the surface of the water, and the method of placing the orifice. These conditions are not uniform in the different localities and it is not uncommon to see different standards on a single irrigation ditch. The depth of the orifice varies from 1 to 12 inches and the water pressure varies from zero to 6 inches above the top of the orifice. The orifice may be thin edged or a square cut leaving the edge the full thickness of the plank, and the issuing stream of water may flow free into the air or it may be partly covered by "back-water" on the down-stream side. The orifice may be placed in a large box where the water is practically at rest, or it may be placed in a small box where the water approaches the orifice with considerable velocity. Sometimes the orifice is the open end of a long box or tube placed in a nearly horizontal position through the ditch bank. Each of these conditions affect the quantity of water which will flow through a square inch of the orifice and it will therefore be seen that the "Inch" of water may be a variable quantity when measured in accordance with the following Colorado law:

"————; and water sold by the inch by an individual or corporation shall be measured as follows, to-wit: Every inch shall be considered as equal to an inch square orifice under a five-inch pressure and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch, to the surface of the water; said boxes, or any slot or aperture through which such water may be measured, shall in all cases be six inches perpendicular, inside measurement, except boxes delivering less than twelve inches, which may be square, with or without slides; all slides for the same shall move horizontally and not otherwise; and said box put into the banks of the ditch shall have a descending grade from the water in ditch of not less than one-eighth of an inch to the foot." (L. '74, p. 308.)

According to ex-State Engineer, John E. Field, the above law, which was passed in 1874, was drafted to meet the conditions under which irrigation water was being measured at that time in the vicinity of Denver. A box made of boards 16 feet long was placed through the ditch bank, and it was given a grade of at least one-eighth of an inch to the foot. If the irrigator had a water-right of 36 inches, the box would be made 6 inches square, inside measurement, and for 60 inches, it would be made 6 inches deep by 10 inches wide. It is interesting to note that although the law was intended to apply to the flow through such tube-boxes, it is so worded that it applies to practically all types of inch devices. Very few tube-boxes are used in Colorado now, nearly all inch measurements being made through thin edged orifices placed in the vertical side of a box so the issuing stream of water flows free into the air.

Former State Engineer, Nettleton, computed the flow through an orifice to correspond to the Colorado law, and stated the quantity to be 1/38.4 of a cubic foot per second. This value has been assumed to be the value of the Colorado "Statute Inch."

In order to secure definite information concerning the Colorado statute inch a series of experiments were made in the hydraulic laboratory, at Fort Collins, Colorado, during the fall of 1914 and the spring of 1915. The results of these experiments are given in the tables in this bulletin for the use of engineers and others who may have need of the actual data. Experiments were also made with one type of measuring device used in the Uncompahgre Valley, and with one of the Miner's Inch devices used in Southern California known as the Azusa hydrant.

## COLORADO STATUTE INCH.

**Box-Tubes.**—Many of the water rights in Colorado are stated in inches, though there are but few irrigation systems in the state under which the water is actually measured in inches. The water is usually measured in second feet, but it is necessary to know the quantity of water that will flow through orifices under the terms of the Colorado law in order that the irrigator may receive the amount he is entitled to.

In reply to an inquiry concerning the method of installing the outlet or tube-box, Mr. John E. Field gave the following description of the practice of 30 or 40 years ago. "In the earlier practice it was seldom that an effort was made to regulate the head over the outlet boxes. Where this effort was made, it was by means of a box or long-crested weir which would discharge back into the ditch the surplus water entering the box. This box or flume was placed parallel to the bank of the ditch and the outlet box was placed at the lower end. This did not regulate the head absolutely, but only approximately. Where this method was not used, the boxes were placed so that when the ditch was at normal stage there would be a 5-inch pressure. When there was a greater amount of water in the ditch, then the discharge through the box was greater, and when it was less it was in the nature of cutting down the amount purchased and a rough pro-rating of the available amount. When the ditch was very low this pro-rating was done by shutting down the boxes partially, even below the amount which had been purchased. Sometimes the head was maintained by having a check in the ditch, but when the amount of water in the ditch was small, this was generally prohibited, as those at the upper end of the ditch would receive their full amount and those at the lower end would get practically nothing."

The results of the experiments with tube-boxes are given in table 1. The boxes were 16 feet long and were given a descending grade of ⅛-inch to the foot. The discharge end was therefore 2 inches lower than the intake end. Metal strips ⅛ inch thick were placed around the intake end of each box so the inside dimensions of the orifice could be accurately determined. The inside depth of the box was practically 6 inches in every case and the water surface was 5 inches above the top of the orifice. So far as the law is concerned, the width of the box need not be the same as the width of the orifice, and experiments were therefore made with different widths of boxes for each width of orifice. A thin metal slide was made to fit between the metal strips on the end of the box, and this was adjusted to give any width of opening from 2 to 16 inches.

TABLE 1.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

| No. of Experiment | Orifice: D Depth in Inches | Orifice: B Breadth in Inches | Orifice: Nominal Area in Sq. Inches | Width of Box Inches | Discharge in Cubic Feet per Sec.: Observed By Experiment | Discharge: Cor-rect'd for Nominal Area | Discharge: Curve Value | Discharge: Statute Inches to One Sec. Ft. |
|---|---|---|---|---|---|---|---|---|
| 2738 | 6.025 | 2.002 | 12 | 2 | .348 | .346 | .345 | 34.8 |
| 2739 | 6.028 | 2.004 | 12 | 2 | .347 | .345 | .345 | |
| 2740 | 6.053 | 2.005 | 12 | 4 | .347 | .343 | .343 | 35.0 |
| 2741 | 6.053 | 2.005 | 12 | 4 | .346 | .342 | .343 | |
| 2745 | 6.059 | 2.002 | 12 | 6 | .344 | .340 | .341 | 35.2 |
| 2746 | 6.059 | 2.002 | 12 | 6 | .343 | .339 | .341 | |
| 2751 | 6.068 | 2.000 | 12 | 8 | .352 | .348 | .346 | 34.7 |
| 2752 | 6.068 | 2.000 | 12 | 8 | .351 | .347 | .346 | |
| 2777 | 6.058 | 2.005 | 12 | 14 | .343 | .339 | .338 | 35.5 |
| 2778 | 6.058 | 2.005 | 12 | 14 | .341 | .337 | .338 | |
| 2791 | 6.052 | 2.000 | 12 | 16 | .359 | .356 | .356 | 33.7 |
| 2792 | 6.052 | 2.000 | 12 | 16 | .360 | .357 | .356 | |
| 2807 | 6.034 | 2.004 | 12 | 16 | .358 | .355 | .354 | 33.9 |
| 2809 | 6.034 | 2.004 | 12 | 16 | .357 | .354 | .354 | |
| 2743 | 6.040 | 3.995 | 24 | 4 | .647 | .643 | .643 | 37.3 |
| 2744 | 6.040 | 3.995 | 24 | 4 | .646 | .643 | .643 | |
| 2747 | 6.042 | 3.997 | 24 | 6 | .658 | .654 | .653 | 36.8 |
| 2748 | 6.041 | 3.999 | 24 | 6 | .656 | .652 | .653 | |
| 2753 | 6.057 | 4.002 | 24 | 8 | .664 | .657 | .658 | 36.5 |
| 2754 | 6.057 | 4.002 | 24 | 8 | .664 | .657 | .658 | |
| 2759 | 6.062 | 3.998 | 24 | 10 | .666 | .659 | .661 | 36.3 |
| 2760 | 6.062 | 3.998 | 24 | 10 | .667 | .660 | .661 | |
| 2767 | 6.072 | 4.001 | 24 | 12 | .672 | .664 | .664 | 36.1 |
| 2768 | 6.072 | 4.001 | 24 | 12 | .673 | .665 | .664 | |
| 2779 | 6.058 | 3.999 | 24 | 14 | .665 | .659 | .658 | 36.5 |
| 2780 | 6.058 | 3.999 | 24 | 14 | .663 | .657 | .658 | |
| 2793 | 6.054 | 4.004 | 24 | 16 | .671 | .664 | .663 | 36.2 |
| 2794 | 6.054 | 4.004 | 24 | 16 | .670 | .663 | .663 | |

TABLE 1.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

| No. of Experiment | Orifice: D Depth in Inches | Orifice: B Breadth in Inches | Orifice: Nominal Area in Sq. Inches | Width of Box Inches | Discharge in Cubic Feet per Sec.: Observed By Experiment | Cor-rect'd for Nominal Area | Curve Value | Statute Inches to One Sec. Ft. |
|---|---|---|---|---|---|---|---|---|
| 2749 | 6.036 | 6.002 | 36 | 6 | .953 | .947 | .945 | 38.1 |
| 2750 | 6.036 | 6.002 | 36 | 6 | .950 | .944 | .945 | |
| 2755 | 6.051 | 6.000 | 36 | 8 | .969 | .961 | .963 | 37.4 |
| 2756 | 6.051 | 6.000 | 36 | 8 | .970 | .962 | .963 | |
| 2761 | 6.061 | 6.002 | 36 | 10 | .985 | .975 | .970 | 37.1 |
| 2762 | 6.061 | 6.002 | 36 | 10 | .984 | .974 | .970 | |
| 2769 | 6.068 | 6.000 | 36 | 12 | .986 | .975 | .976 | 36.9 |
| 2770 | 6.068 | 6.000 | 36 | 12 | .986 | .975 | .976 | |
| 2781 | 6.061 | 6.001 | 36 | 14 | .991 | .981 | .991 | 36.3 |
| 2782 | 6.061 | 6.001 | 36 | 14 | .989 | .979 | .991 | |
| 2795 | 6.046 | 6.001 | 36 | 16 | .986 | .978 | .978 | 36.8 |
| 2796 | 6.046 | 6.001 | 36 | 16 | .987 | .979 | .978 | |
| 2757 | 6.039 | 8.003 | 48 | 8 | 1.265 | 1.256 | 1.252 | 38.3 |
| 2758 | 6.039 | 8.003 | 48 | 8 | 1.258 | 1.249 | 1.252 | |
| 2763 | 6.054 | 7.999 | 48 | 10 | 1.285 | 1.274 | 1.275 | 37.6 |
| 2764 | 6.054 | 7.999 | 48 | 10 | 1.287 | 1.276 | 1.275 | |
| 2771 | 6.068 | 7.998 | 48 | 12 | 1.299 | 1.285 | 1.283 | 37.4 |
| 2772 | 6.068 | 7.998 | 48 | 12 | 1.296 | 1.282 | 1.283 | |
| 2783 | 6.063 | 8.001 | 48 | 14 | 1.309 | 1.295 | 1.291 | 37.2 |
| 2784 | 6.063 | 8.001 | 48 | 14 | 1.306 | 1.292 | 1.291 | |
| 2797 | 6.050 | 8.008 | 48 | 16 | 1.301 | 1.289 | 1.286 | 37.3 |
| 2798 | 6.050 | 8.008 | 48 | 16 | 1.298 | 1.286 | 1.286 | |
| 2765 | 6.054 | 10.004 | 60 | 10 | 1.576 | 1.561 | 1.565 | 38.3 |
| 2766 | 6.054 | 10.004 | 60 | 10 | 1.586 | 1.571 | 1.565 | |
| 2773 | 6.064 | 10.003 | 60 | 12 | 1.602 | 1.585 | 1.586 | 37.8 |
| 2774 | 6.064 | 10.003 | 60 | 12 | 1.601 | 1.584 | 1.586 | |
| 2785 | 6.068 | 9.998 | 60 | 14 | 1.603 | 1.585 | 1.594 | 37.6 |
| 2786 | 6.068 | 9.998 | 60 | 14 | 1.606 | 1.588 | 1.594 | |
| 2799 | 6.054 | 10.004 | 60 | 16 | 1.612 | 1.597 | 1.596 | 37.6 |
| 2800 | 6.054 | 10.004 | 60 | 16 | 1.607 | 1.592 | 1.596 | |
| 2775 | 6.063 | 12.004 | 72 | 12 | 1.892 | 1.872 | 1.873 | 38.4 |
| 2776 | 6.063 | 12.004 | 72 | 12 | 1.894 | 1.874 | 1.873 | |
| 2787 | 6.073 | 12.007 | 72 | 14 | 1.931 | 1.907 | 1.896 | 38.0 |
| 2788 | 6.073 | 12.007 | 72 | 14 | 1.929 | 1.905 | 1.896 | |
| 2801 | 6.054 | 12.000 | 72 | 16 | 1.915 | 1.898 | 1.898 | 37.9 |
| 2802 | 6.054 | 12.000 | 72 | 16 | 1.916 | 1.899 | 1.898 | |
| 2789 | 6.077 | 14.002 | 84 | 14 | 2.218 | 2.190 | 2.190 | 38.4 |
| 2790 | 6.077 | 14.002 | 84 | 14 | 2.219 | 2.191 | 2.190 | |
| 2803 | 6.058 | 14.004 | 84 | 16 | 2.234 | 2.212 | 2.206 | 38.1 |
| 2804 | 6.058 | 14.004 | 84 | 16 | 2.222 | 2.200 | 2.206 | |
| 2805 | 6.060 | 15.996 | 96 | 16 | 2.543 | 2.518 | 2.520 | 38.1 |
| 2806 | 6.060 | 15.996 | 96 | 16 | 2.547 | 2.522 | 2.520 | |

The discharge for each size of orifice and box is given in second feet in the next to the last column in table 1, and the number of statute inches equal to one second foot is given in the last column. It will be seen that, in general, the discharge for any certain size of orifice increases as the width of the box is increased, except for a slight reduction when the orifice is nearly the same size as the box. The number of statute inches to one second foot therefore decreases with a decrease in the size of the box, and it will also be noticed that the number of statute inches to one second foot increases as the size of the orifice is increased, which means that the discharge of each square inch of orifice decreases as the size of the orifice is increased. This is the opposite to the results obtained with thin-edged orifices having free flow, as given in tables 2 and 3. Box-tubes with orifices from 12 to 96 square inches gave discharges with the number of statute inches to one second foot varying from 33.7 to 38.4, and a greater number would no doubt be obtained for still larger orifices.

**Thin-Edged Orifices With Free Flow.**—A large majority of the present day Miner's Inch devices have a thin-edged orifice placed in the vertical side of a box, so the water passes into the air as it flows through the orifice. Experiments were made with this type of orifice in sizes ranging from 1 inch square to 6 inches deep by 16 inches wide. The depth of water above the top of the orifice was five inches in every case. The brass orifice taples were placed in the end of a concrete box having a cross-section of 10 feet by 6 feet deep. The experimental results are given in tables 2 and 3.

TABLE 2.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.

(Thin edged orifices.)

| No. of Experiment | Orifice: D Depth in Inches | Orifice: B Breadth in Inches | Nominal area in Sq. Inches | Discharge in Cubic Feet Per Sec.: Observed by experiment | Discharge in Cubic Feet Per Sec.: Corrected for Nominal area | Discharge in Cubic Feet Per Sec.: Curve Values |
|---|---|---|---|---|---|---|
| 1395 | 1.005 | 1.004 | 1 | .024 | .024 | .024 |
| 1396 | 1.005 | 1.004 | 1 | .024 | .024 | .024 |
| 1393 | 1.000 | 2.003 | 2 | .047 | .047 | .047 |
| 1394 | 1.000 | 2.003 | 2 | .047 | .047 | .047 |
| 1387 | 1.005 | 3.011 | 3 | .072 | .071 | .071 |
| 1388 | 1.005 | 3.011 | 3 | .072 | .071 | .071 |
| 1385 | 1.000 | 4.003 | 4 | .095 | .095 | .095 |
| 1386 | 1.000 | 4.003 | 4 | .095 | .095 | 095 |
| 1379 | 1.005 | 5.000 | 5 | .119 | .118 | .118 |
| 1380 | 1.005 | 5.000 | 5 | .119 | .118 | 118 |
| 1391 | 2.003 | 1.000 | 2 | .049 | .049 | .049 |
| 1392 | 2.003 | 1.000 | 2 | .049 | .049 | .049 |
| 1377 | 2.006 | 2.001 | 4 | .096 | .096 | .097 |
| 1378 | 2.006 | 2.001 | 4 | .097 | .097 | .097 |
| 1373 | 2.001 | 2.998 | 6 | .145 | .145 | .145 |
| 1374 | 2.001 | 2.998 | 6 | .145 | .145 | .145 |
| 1369 | 2.005 | 4.004 | 8 | .194 | .193 | .193 |
| 1370 | 2.005 | 4.004 | 8 | .194 | .193 | .193 |
| 1365 | 2.009 | 5.007 | 10 | .243 | .242 | .242 |
| 1366 | 2.009 | 5.007 | 10 | .243 | .242 | .242 |

TABLE 2.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.

(Thin edged orifices.)

| No. of Experiment | Orifice D Depth in Inches | Orifice B Breadth in Inches | Nominal area in Sq. Inches | Discharge in Cubic Feet Per Sec. Observed by experiment | Corrected for Nominal area | Curve Values |
|---|---|---|---|---|---|---|
| 1389 | 3.011 | 1.005 | 3 | .077 | .076 | .076 |
| 1390 | 3.011 | 1.005 | 3 | .077 | .076 | .076 |
| 1375 | 2.998 | 2.001 | 6 | .150 | .150 | .150 |
| 1376 | 2.998 | 2.001 | 6 | .149 | .149 | .150 |
| 1363 | 3.018 | 3.005 | 9 | .227 | .225 | .223 |
| 1364 | 3.018 | 3.005 | 9 | .227 | .225 | .223 |
| 1359 | 3.002 | 4.008 | 12 | .299 | .298 | .298 |
| 1360 | 3.002 | 4.008 | 12 | .299 | .298 | .298 |
| 1355 | 3.007 | 5.033 | 15 | .378 | .375 | .375 |
| 1356 | 3.007 | 5.033 | 15 | .378 | .375 | .375 |
| | | | | | | |
| 1383 | 4.003 | 1.000 | 4 | .106 | .106 | .105 |
| 1384 | 4.003 | 1.000 | 4 | .105 | .105 | .105 |
| 1371 | 4.004 | 2.005 | 8 | .208 | .207 | .207 |
| 1372 | 4.004 | 2.005 | 8 | .208 | .207 | .207 |
| 1361 | 4.008 | 3.002 | 12 | .313 | .312 | .309 |
| 1362 | 4.008 | 3.002 | 12 | .310 | .309 | .309 |
| 1353 | 3.999 | 4.007 | 16 | .411 | .410 | .410 |
| 1354 | 3.999 | 4.007 | 16 | .411 | .410 | .410 |
| 1349 | 4.005 | 5.020 | 20 | .515 | .512 | .513 |
| 1350 | 4.005 | 5.020 | 20 | .515 | .512 | .513 |
| | | | | | | |
| 1381 | 5.000 | 1.005 | 5 | .137 | .136 | .137 |
| 1382 | 5.000 | 1.005 | 5 | .138 | .137 | .137 |
| 1367 | 5.007 | 2.009 | 10 | .271 | .269 | .268 |
| 1368 | 5.007 | 2.009 | 10 | .271 | .269 | .268 |
| 1357 | 5.033 | 3.007 | 15 | .403 | .399 | .398 |
| 1358 | 5.033 | 3.007 | 15 | .401 | .397 | .398 |
| 1351 | 5.020 | 4.005 | 20 | .533 | .530 | .530 |
| 1352 | 5.020 | 4.005 | 20 | .529 | .526 | .530 |
| 1347 | 5.014 | 5.006 | 25 | .663 | .660 | .662 |
| 1348 | 5.014 | 5.006 | 25 | .665 | .662 | .662 |
| | | | | | | |
| 1345 | 6.006 | 2.005 | 12 | .331 | .330 | .332 |
| 1346 | 6.006 | 2.005 | 12 | .333 | .332 | .332 |
| 1343 | 6.006 | 3.998 | 24 | .652 | .652 | .650 |
| 1344 | 6.006 | 3.998 | 24 | .651 | .651 | .650 |
| 1341 | 6.006 | 6.002 | 36 | .975 | .974 | .972 |
| 1342 | 6.006 | 6.006 | 36 | .982 | .981 | .972 |
| 1339 | 6.006 | 7.997 | 48 | 1.306 | 1.305 | 1.302 |
| 1340 | 6.006 | 7.997 | 48 | 1.308 | 1.307 | 1.302 |
| 1337 | 6.006 | 9.995 | 60 | 1.636 | 1.635 | 1.634 |
| 1338 | 6.006 | 9.995 | 60 | 1.637 | 1.636 | 1.634 |
| 1335 | 6.006 | 11.997 | 72 | 1.968 | 1.967 | 1.970 |
| 1336 | 6.006 | 11.997 | 72 | 1.972 | 1.971 | 1.970 |
| 1333 | 6.006 | 13.997 | 84 | 2.303 | 2.301 | 2.304 |
| 1334 | 6.006 | 13.997 | 84 | 2.301 | 2.299 | 2.304 |
| 1331 | 6.006 | 15.998 | 96 | 2.645 | 2.643 | 2.641 |
| 1332 | 6.006 | 15.998 | 96 | 2.640 | 2.638 | 2.641 |
| | | | | | | |
| 2335 | 12.069 | 12.066 | 144 | 4.588 | 4.537 | |
| 2336 | 12.069 | 12.066 | 144 | 4.577 | 4.526 | |

TABLE 3.

DISCHARGE THROUGH MINER'S INCH ORIFICES OF VARIOUS SIZES*

| | ‡D—1 Inch | | | D—2 Inches | | | D—3 Inches | | | D—4 Inches | | | D—5 Inches | | | D—6 Inches | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| †B | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. | Discharge—Cu. ft. per sec. | Discharge—Cu. ft. per sec. per sq. in. of opening. | Number of Miners' Inches to one sec. ft. |
| 1.... | .024 | .0240 | 41.7 | .049 | .0245 | 40.8 | .076 | .0253 | 39.5 | .105 | .0263 | 38.1 | .137 | .0273 | 36.6 | .169 | .0282 | 35.5 |
| 2.... | .047 | .0235 | 42.6 | .097 | .0243 | 41.2 | .150 | .0250 | 40.0 | .207 | .0259 | 38.7 | .268 | .0268 | 37.3 | .331 | .0276 | 36.3 |
| 3.... | .070 | .0233 | 42.9 | .145 | .0242 | 41.4 | .223 | .0248 | 40.4 | .309 | .0257 | 38.8 | .398 | .0265 | 37.7 | .491 | .0273 | 36.7 |
| 4.... | .094 | .0235 | 42.6 | .193 | .0241 | 41.5 | .298 | .0248 | 40.3 | .410 | .0256 | 39.0 | .530 | .0265 | 37.7 | .650 | .0271 | 36.9 |
| 5.... | .118 | .0236 | 42.4 | .242 | .0242 | 41.3 | .375 | .0250 | 40.0 | .513 | .0257 | 39.0 | .662 | .0265 | 37.8 | .810 | .0270 | 37.0 |
| 6.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | .973 | .0270 | 37.0 |
| 7.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.14 | .0271 | 36.9 |
| 8.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.30 | .0271 | 36.9 |
| 9.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.47 | .0272 | 36.8 |
| 10.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.64 | .0273 | 36.7 |
| 11.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.80 | .0273 | 36.6 |
| 12.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 1.97 | .0274 | 36.6 |
| 13.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.14 | .0274 | 36.5 |
| 14.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.30 | .0274 | 36.5 |
| 15.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.47 | .0275 | 36.4 |
| 16.... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.64 | .0275 | 36.3 |

*Shapes of orifices conform to Colorado Statute. Head was 5 inches above top of orifice opening in all cases.

†B—Breadth or horizontal dimension of orifice in inches.

‡D—Depth or vertical dimension of orifice in inches.

Table 3 shows some interesting points. The discharge for each square inch of opening increases as the size of the opening is increased. For a constant depth of orifice the discharge per square inch of opening is the greatest for a width of 1 inch, decreases as the width is increased for a few inches, or approximately until the orifice is square for the larger sizes of orifices, and then increases as the width is increased. The number of Statute Inches to one second-foot varies from 42.9 to 35.5, but for the sizes of orifices commonly used, for measuring water to the individual irrigator, it is probable the value would be from 36 to 37, and as low as 35 might be obtained for wider orifices. The discharges given in table 3 are probably the least quantities that can be obtained for orifices of that type, because they were thin-edged, the velocity of approach was negligible, and the contractions were complete.

The discharge through full contraction, thin-edged, free-flow orifices having a depth or vertical dimension of 6 inches and a head of 5 inches above the top of the orifice, is represented by the formula,

$$Q = 0.169b - 0.06 + \frac{0.06}{1 + 0.015\ b^{2.6}}$$

in which Q is in second-feet, and b is the breadth or horizontal dimension of the orifice in inches.

**Uncompahgre Orifice.**—The type of orifice shown in figures 1 and 2 has been used for years on some of the canal systems now included in the Uncompahgre project of the U. S. Reclamation Service, and they conform to the Colorado Inch law in all respects as long as a 5-inch depth of water is maintained over the top of the orifice. The side of the box in which the orfice is placed is made 5 inches higher than the top of the orifice for a length of 5 feet, which acts as a spillway to regulate the head, but it is occasionally necessary to run a greater or less amount of water for short periods. When necessary to deliver 90 or 75 per cent of the full head temporarily the depth of water in the box will decrease as the depth decreases in the ditch, which saves changing the size of all of the orifices and they act somewhat as proportional dividers of the flow because all of the boxes on a ditch are set under almost identical conditions. When the supply of water in the ditch is greater than normal, the boxes act as spill-boxes. Mr. F. D. Pyle, manager of the Uncompahgre Project, has added a heavy galvanized iron orifice plate to the original device. The orifice is 6 inches deep and is provided with a slide which moves horizontally. Holes punched through the orifice plate and slide allow the slide to be set for each 0.05 second-foot up to 2 second feet and a padlock placed through the hole prevents the size of the orifice being tampered with after it is set by the ditch rider. Graduations on the side of the orifice indicate its discharge when operating as a weir.

The discharges through the Uncompahgre orifice under various conditions are given in table 4. Although the original water-rights are expressed in inches, the water is delivered in second-feet. By comparing tables 3 and 4 it will be seen that the discharge is greater through the

TABLE 4.

DISCHARGE FROM UNCOMPAHGRE ORIFICE IN CUBIC FEET PER SECOND

| Width of Opening in Inches. | Depth of Water Surface to Bottom of Orifice Opening in Inches. | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 2½ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 6 | 6½ | 7 | 7½ | 8 | 8½ | 9 | 9½ | 10 | 10½ | 11 | 11½ | 12 |
| 2 | .04 | .05 | .07 | .09 | .11 | .13 | .15 | .17 | .20 | .22 | .24 | .25 | .27 | .29 | .30 | .31 | .32 | .34 | .35 | .36 | .37 |
| 2½ | .05 | .06 | .08 | .10 | .13 | .16 | .19 | .21 | .24 | .27 | .30 | .32 | .34 | .36 | .38 | .40 | .41 | .42 | .43 | .44 | .45 |
| 3 | .06 | .08 | .10 | .13 | .16 | .19 | .22 | .26 | .29 | .33 | .36 | .38 | .40 | .43 | .45 | .47 | .49 | .51 | .52 | .53 | .54 |
| 3½ | .06 | .09 | .12 | .15 | .18 | .22 | .26 | .30 | .34 | .38 | .42 | .45 | .47 | .50 | .53 | .55 | .57 | .59 | .61 | .62 | .63 |
| 4 | .07 | .10 | .13 | .17 | .21 | .25 | .29 | .34 | .39 | .43 | .47 | .51 | .54 | .57 | .60 | .63 | .65 | .67 | .69 | .71 | .72 |
| 4½ | .08 | .11 | .15 | .19 | .23 | .28 | .33 | .38 | .43 | .48 | .53 | .57 | .60 | .64 | .67 | .70 | .73 | .76 | .78 | .80 | .82 |
| 5 | .08 | .11 | .15 | .19 | .23 | .31 | .33 | .38 | .43 | .48 | .59 | .63 | .67 | .71 | .74 | .78 | .81 | .84 | .86 | .89 | .91 |
| 5½ | .10 | .14 | .18 | .23 | .28 | .34 | .40 | .46 | .52 | .59 | .65 | .69 | .73 | .78 | .82 | .86 | .89 | .92 | .95 | .98 | 1.00 |
| 6 | .11 | .15 | .20 | .25 | .30 | .36 | .43 | .50 | .56 | .64 | .70 | .75 | .80 | .85 | .89 | .93 | .97 | 1.00 | 1.03 | 1.06 | 1.09 |
| 6½ | .12 | .16 | .21 | .27 | .33 | .39 | .46 | .54 | .61 | .69 | .76 | .81 | .86 | .91 | .96 | 1.00 | 1.04 | 1.08 | 1.12 | 1.15 | 1.18 |
| 7 | .13 | .18 | .23 | .29 | .35 | .42 | .50 | .57 | .65 | .74 | .81 | .87 | .92 | .98 | 1.03 | 1.08 | 1.12 | 1.16 | 1.20 | 1.24 | 1.28 |
| 7½ | .14 | .19 | .25 | .31 | .38 | .45 | .53 | .61 | .69 | .79 | .87 | .93 | .98 | 1.04 | 1.10 | 1.15 | 1.20 | 1.25 | 1.29 | 1.33 | 1.37 |
| 8 | .14 | .20 | .26 | .33 | .40 | .48 | .56 | .64 | .73 | .83 | .92 | .99 | 1.05 | 1.11 | 1.17 | 1.23 | 1.28 | 1.33 | 1.37 | 1.42 | 1.46 |
| 8½ | .15 | .21 | .28 | .35 | .42 | .50 | .59 | .68 | .78 | .88 | .97 | 1.05 | 1.11 | 1.18 | 1.24 | 1.30 | 1.36 | 1.41 | 1.46 | 1.51 | 1.56 |
| 9 | .16 | .22 | .29 | .37 | .44 | .53 | .63 | .72 | .82 | .93 | 1.02 | 1.10 | 1.17 | 1.24 | 1.31 | 1.37 | 1.43 | 1.49 | 1.54 | 1.60 | 1.65 |
| 9½ | .17 | .24 | .31 | .39 | .47 | .56 | .66 | .76 | .86 | .97 | 1.07 | 1.16 | 1.23 | 1.31 | 1.38 | 1.45 | 1.51 | 1.57 | 1.63 | 1.69 | 1.74 |
| 10 | .18 | .25 | .33 | .41 | .49 | .59 | .69 | .79 | .90 | 1.02 | 1.13 | 1.22 | 1.30 | 1.38 | 1.45 | 1.52 | 1.59 | 1.65 | 1.71 | 1.77 | 1.83 |
| 10½ | .19 | .27 | .34 | .43 | .51 | .61 | .72 | .83 | .94 | 1.07 | 1.18 | 1.28 | 1.36 | 1.44 | 1.51 | 1.59 | 1.66 | 1.73 | 1.79 | 1.85 | 1.91 |
| 11 | .20 | .28 | .36 | .45 | .54 | .64 | .75 | .87 | .99 | 1.12 | 1.23 | 1.33 | 1.42 | 1.50 | 1.58 | 1.66 | 1.73 | 1.80 | 1.87 | 1.94 | 2.00 |
| 11½ | .21 | .29 | .38 | .46 | .56 | .67 | .78 | .90 | 1.03 | 1.16 | 1.28 | 1.38 | 1.48 | 1.57 | 1.65 | 1.73 | 1.81 | 1.88 | 1.95 | 2.02 | 2.09 |
| 12 | .22 | .30 | .39 | .48 | .58 | .69 | .81 | .94 | 1.07 | 1.21 | 1.33 | 1.44 | 1.54 | 1.63 | 1.72 | 1.80 | 1.88 | 1.96 | 2.03 | 2.10 | 2.17 |

Uncompahgre orifice, because of the comparatively high velocity of approach in the orifice box. Orifices are used for delivering only a part of the water under this project, rectangular weirs being also used.

Figure 1. (a) Showing the usual method of placing an Uncompahgre orifice box in a ditch.

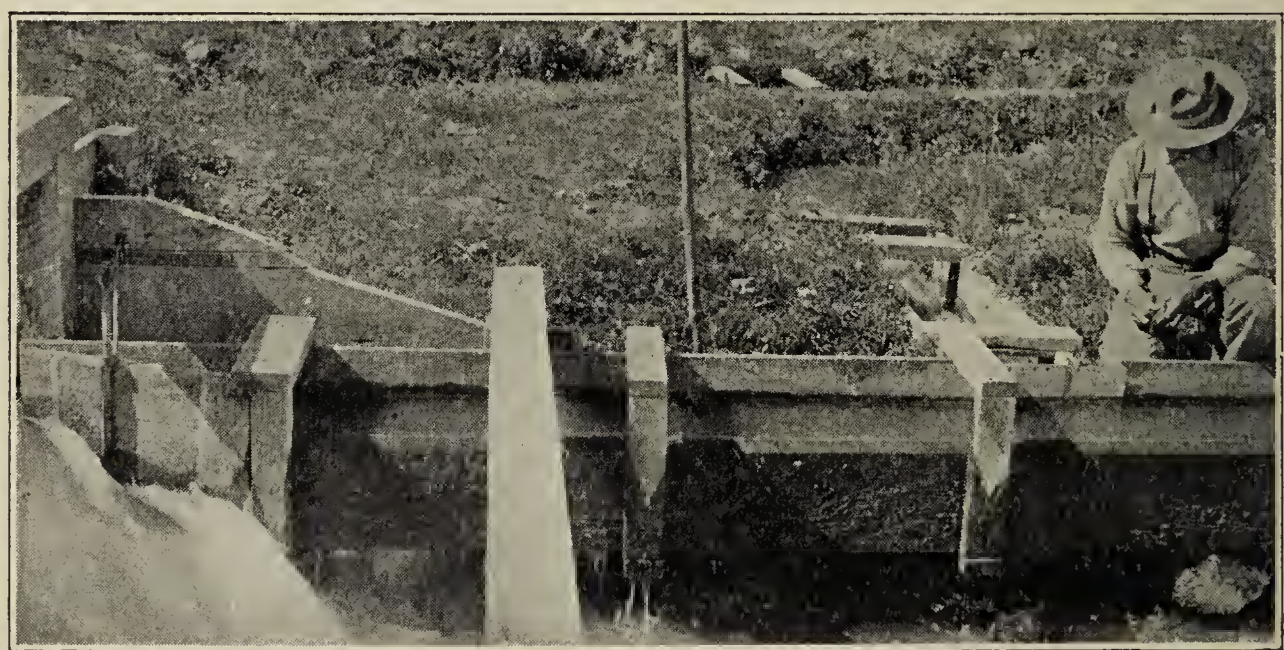

Figure 1. (b) Side view of Uncompahgre orifice spill-box.

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## AZUSA HYDRANT.

Where the price of irrigation water is high, as in Southern California, it is often desirable to do away with surface ditches and conduct the water to the land through underground pipes. This decreases the loss of water by seepage and evaporation, permits all of the land to be cultivated, and is especially desirable for orchard irrigation. The water is brought to the surface of the ground by standpipes which are arranged to deliver the water to several furrows. There are several different kinds of measuring devices used in connection with underground pipe systems, but only one was experimented with.

The Azusa hydrant is used in the vicinity of Azusa, California. The essential features are shown in figure 3, and the details of the orifices are shown in figure 4. It consists of a concrete box about 6 feet high placed in the supply pipe line, with the orifice plate set in the side of the box so the tops of the orifices are 12 inches below the top of the box. An overflow crest placed on the top of a dividing wall in the box is 2 inches above the top of the orifices. The flow through the orifices is regulated by a gate in the dividing wall near the floor. There are 4 orifices each 4 inches deep and of different widths which are supposed to deliver 10, 15, 25 and 50 miner's inches upon the basis of 50 miner's inches to 1 second foot and they may be used singly or in a combination. The orifice plate is made of cast iron carefully machined.

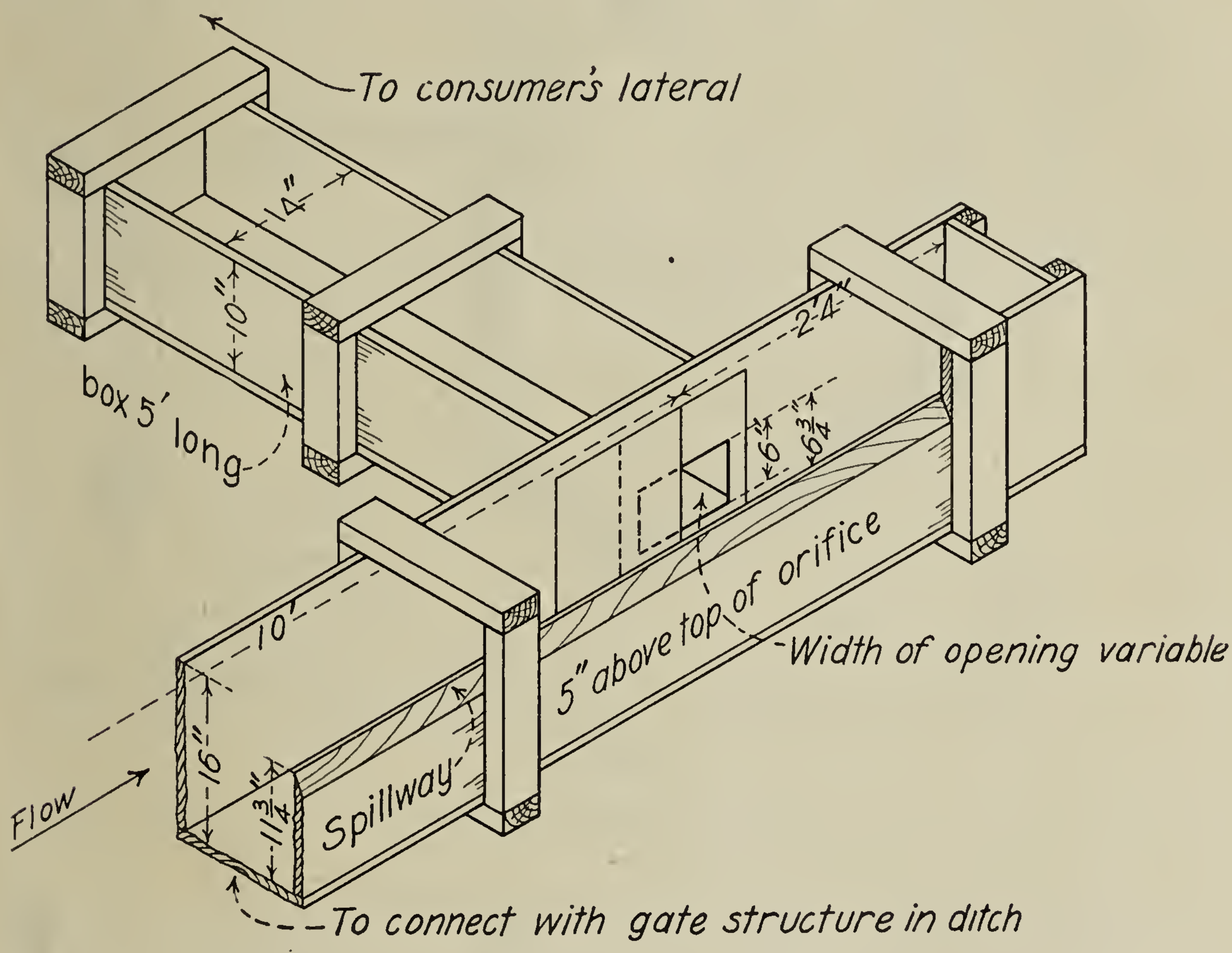


Figure 2. Some details of the Uncompahgre orifice.

The results of the experiments with the Azusa hydrant given in table 5, indicate the actual discharges to be from 2.0 to 6.4 percent less than the intended discharges. Table 6 gives the dimensions of orifices which will discharge the intended number of miner's inches. However, in actual practice the orifices become larger, due to the edges rusting, and the head of water is usually greater than 2 inches because a small amount is allowed to pass over the spillway or overflow.

In Bulletin 247 of the California Expkeriment Station, Mr. Frank Adams states the cost of the Azusa hydrant to be from $18 to $20 under a large contract, and about $30 when built singly. The orifice plate costs an additional $12.

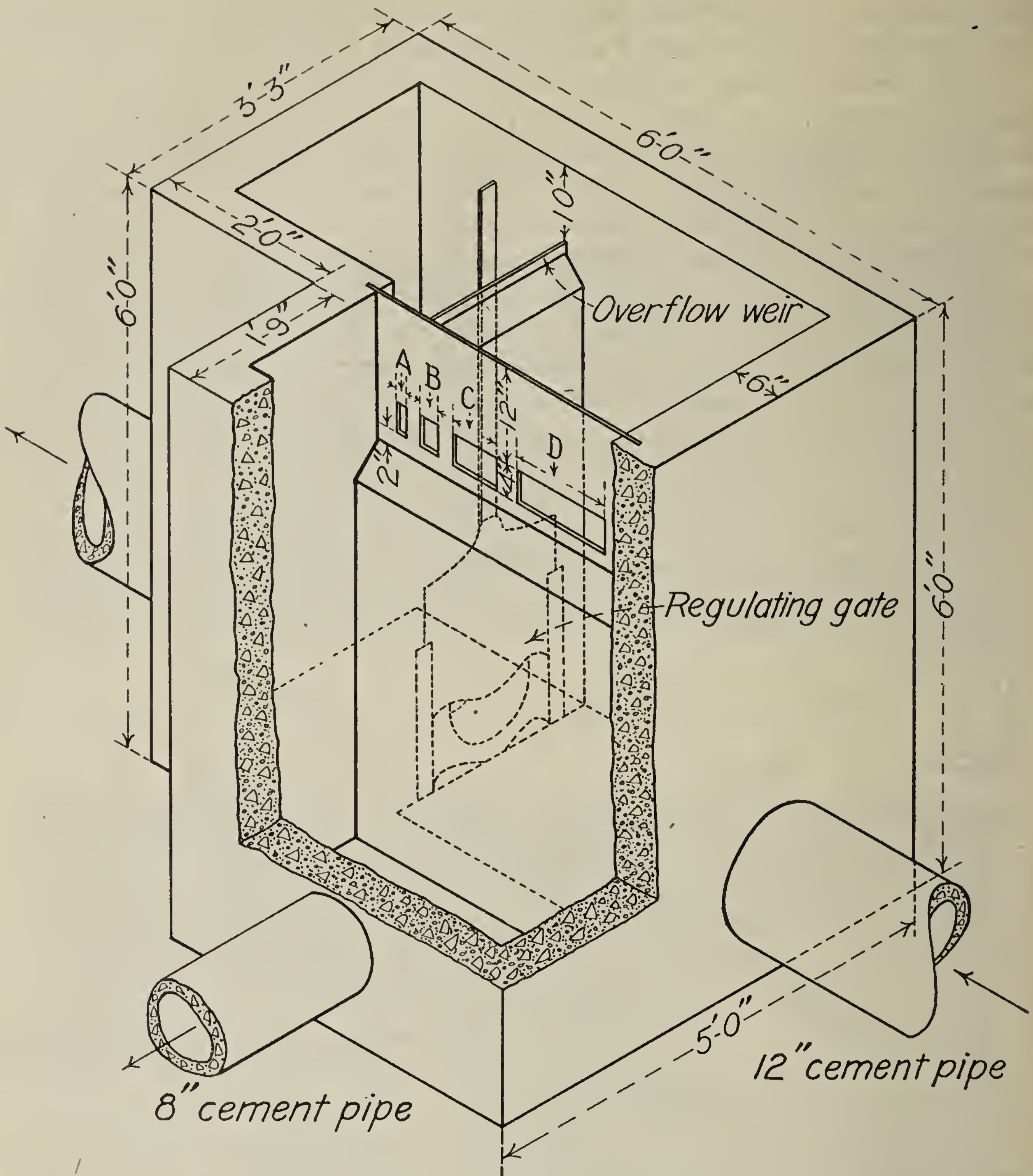


Figure 3. Azusa hydrant.

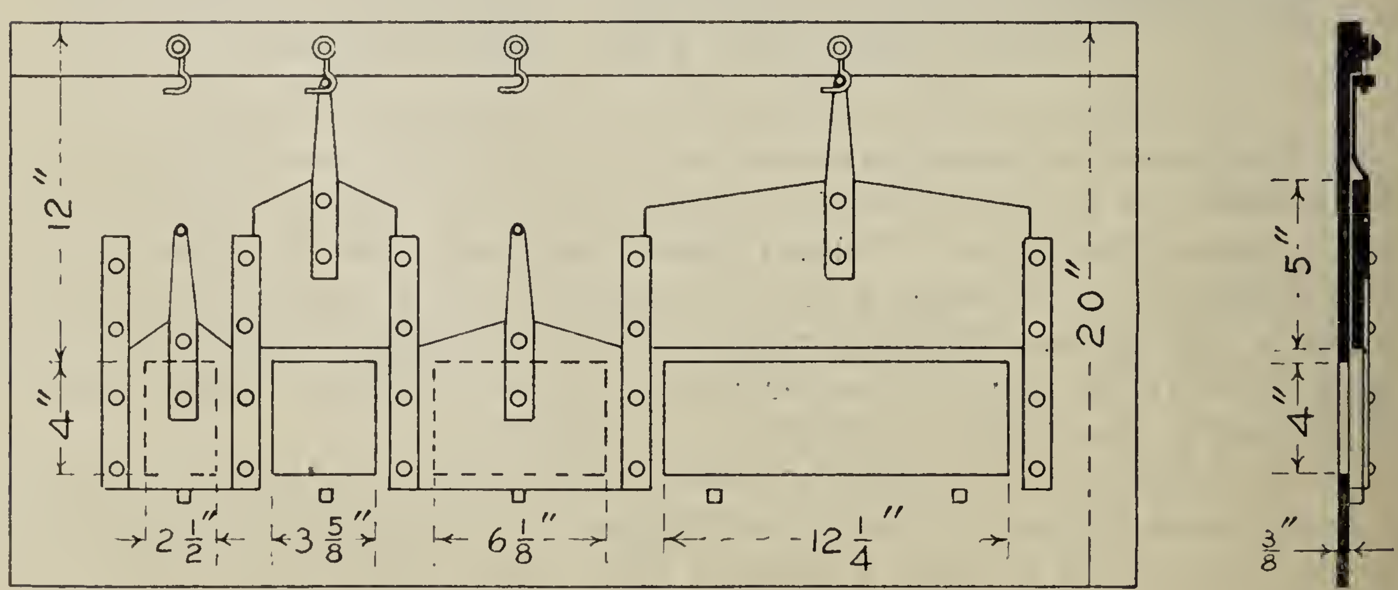


Figure 4. Details of Azusa hydrant orifice plate.

TABLE 5.
RESULTS OF EXPERIMENTS WITH AZUSA HYDRANT.

| Opening | Actual Area of Opening in Square Inches | Actual Discharge in Cubic Feet per Second | Discharge in Miner's Inches Corrected for Nominal Area | Intended Discharge in Miner's Inches | Percent* of Error |
|---|---|---|---|---|---|
| A | 9.991 | .195 | 9.8 | 10 | 2.0 |
| B | 14.488 | .281 | 14.1 | 15 | 6.4 |
| C | 24.494 | .474 | 23.7 | 25 | 5.5 |
| D | 49.008 | .967 | 48.4 | 50 | 3.3 |
| A+B | 24.479 | .478 | 23.9 | 25 | 4.6 |
| A+B+C | 48.973 | .959 | 48.0 | 50 | 4.2 |
| A+B+C+D | 97.981 | 1.925 | 96.3 | 100 | 3.8 |
| A+B+D | 73.487 | 1.439 | 72.0 | 75 | 4.2 |
| A+C | 34.485 | .668 | 33.4 | 35 | 4.8 |
| A+C+D | 83.493 | 1.641 | 82.1 | 85 | 3.5 |
| A+D | 58.999 | 1.157 | 57.9 | 60 | 3.6 |
| B+C | 38.982 | .762 | 38.1 | 40 | 5.0 |
| B+C+D | 87.990 | 1.729 | 86.5 | 90 | 4.1 |
| B+D | 63.496 | 1.248 | 62.4 | 65 | 4.2 |
| C+D | 73.502 | 1.451 | 72.6 | 75 | 3.3 |

* Percent of Error between intended discharge and correct discharge in Miners' inches, using the correct discharge as the basis. The Miners' Inch was taken as 1-50 cubic foot per second, which is Southern California practice.

TABLE 6.
WIDTH OF OPENINGS TO GIVE THE INTENDED DISCHARGE WITH AZUSA HYDRANT.

| Opening | Depth in Inches | Width in Inches | Discharge in Miner's Inches* |
|---|---|---|---|
| A | 4 | 2 9-16 | 10 |
| B | 4 | 3 ⅞ | 15 |
| C | 4 | 6 15-32 | 25 |
| D | 4 | 12 ⅝ | 50 |

* Southern California inch, which is 1-50 cu. ft. per sec.

## SUMMARY.

The value of the Colorado Statute Inch has been assumed to be 1/38.4 part of a cubic foot per second, and this figure has been commonly used for years. It is not a legal definition of the Statute Inch and may be in error as shown in tables 1, 2 and 3. The number of Statute Inches to the second foot may vary from at least 33.7 to 42.9 and still conform to the law in every particular. Although the use of the Statute Inch is somewhat limited at the present time, it is used in connection with interpreting water rights, and it would be well to have its value fixed by law as a definite part of a second foot.

The discharges obtained in these experiments are probably less than would be obtained in actual practice where one or more of the following conditions are usually found, and they all tend to increase the flow through an orifice: thick edges, such as an opening cut in a plank without outward bevel to the edges; rounding edges; velocity of approach which would be caused by an orifice placed in a small box, or an accumulation of sand which would reduce the distance from the bottom of the orifice to bottom of the box; an appreciably greater head due to the depth of water pouring over the spill-crest.

Some of the Miner's Inch measuring devices are well adapted to the conditions under which they are used. They are especially applicable to the measurement of small flows of water and when used in connection with a spill-box they act somewhat as a proportional divider. They are not well suited to the rotation method of delivery of water where large quantities are delivered for short periods, and they will not deliver a flow much in excess of their normal capacity. These measuring devices are often unjustly condemned, for the fault is not with the orifice structures as much as with the unit of measurement used, the Inch, whether it be called Miner's, Statute, Customary, or Farmer's Inch. These orifices are reasonably accurate in their measurement of water, but they should be calibrated or built according to plans which will give a known discharge, and this discharge should be expressed in cubic feet per second or some other equally definite quantity.

## UNITS OF MEASURE.

**The Cubic Foot Per Second,** called second-foot, is a unit of measure for flowing water. When a stream discharges 1 cubic foot of water in one second, there is a second-foot flow.

**The Acre-Foot** is a unit of measure for standing water, and is that volume which will cover one acre one foot deep. An acre-inch is one-twelfth of an acre-foot, or the volume which will cover one acre to a depth of one inch.

**The Miner's Inch** is unsatisfactory and rapidly losing favor as a unit for measuring water, because it is not a definite quantity. It varies with the conditions under which it is used, and is therefore being replaced by the second-foot. In several of the Western states the Miner's Inch has been defined by law as being a certain fractional part of a second-foot, and these values are given in the accompanying table of Hydraulic Equivalents.

## TABLE OF HYDRAULIC EQUIVALENTS.

1 cubic foot equals 7.48 gallons, or approximately 7½ gallons.

1 cubic foot of water weighs approximately 62½ pounds.

1 cubic foot per second equals 448.83 gallons per minute, or approximately 450 gallons per minute.

1 cubic foot per second flowing for 1 hour equals approximately 1 acre-inch.

1 cubic foot per second flowing for 12 hours equals approximately 1 acre-foot.

1 cubic foot per second flowing for 24 hours equals approximately 2 acre-feet.

1 acre foot equals 43,560 cubic feet, equals 325,851 gallons.

1,000,000 cubic feet (1 million cu. ft.) equals 22.95 acre-feet.

In California, Nevada, and Montana, 1 Miner's Inch (Statutory Inch) equals 1-40 of 1 cubic foot per second.

In Utah, Idaho, Arizona, and New Mexico, 1 Miner's Inch (Statutory Inch) equals 1-50 of one cubic foot per second.

In Colorado it has been generally assumed that 1 Miner's Inch (Statutory Inch) equals 1-38.4 of one cubic foot per second.

Bulletin 208 June, 1915

# The Agricultural Experiment Station

OF THE

# Colorado Agricultural College

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# A STUDY OF COLORADO WHEAT

*By* W. P. HEADDEN

## PART I

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FORT COLLINS, COLORADO
1915

# The Agricultural Experiment Station

FORT COLLINS, COLORADO

# A STUDY OF COLORADO WHEAT

*By* W. P. HEADDEN

## PART I

It is generally conceded that the flour made from Colorado wheat is inferior to that made from Kansas hard wheat or the better grades of Minnesota flour. Such is the opinion of the bakers and of the public. I have made inquiry regarding the difference in the bread-yield between Kansas and Colorado flours on the supposition that they were equally well milled. As nearly as I can learn, there is a difference of from 30 to 40 loaves per barrel.

Having established the fact that soil conditions are, in the main, responsible for the characteristic properties of our sugar beets, it seemed advisable to study our wheat crop to find out if possible, the factors that determine the quality of our Colorado wheats. In beginning this work, we assume that the popular estimate of our wheat for the purpose of bread-making, i. e., that it is inferior to the best, is established.

In looking over the literature we find no published results of work done on Colorado wheats since the early eighties. Mr. Clifford Richardson published in the Report U. S. Department of Agriculture, 1883, forty-five analyses of Colorado Wheats. Protein (Nx6.25) ran from 11.0 to 15.94, average 13.27, and in the Report of 1884, sixty-one analyses. The protein ranged from 8.93 to 14.00, average 11.79 percent. The average of eleven Minnesota samples in 1883 Report is 12.4 percent, with one as high as 17.15 percent, and for fourteen Minnesota samples in the Report of 1884 the protein is 15.14 percent. The Colorado samples recorded seem to have been furnished by Prof. Blount, at that time Professor of Agriculture in this institution. In the Report of the U. S. Department of Agriculture for 1885 there is reference made to the low protein content shown in the results published in 1884. The statement is made that the low protein content was due to a storm which knocked down the plants and prevented the assimilation of nitrogen. It seems that the average nitrogen content of the sixty-one samples analyzed was 1.8864 percent which, so far as the amount is concerned, by no means calls for any apology and it matters little whether the reason assigned for its being lower than for the previous year, 2.00 percent, is correct or not. While Mr. Richardson's analyses are now upwards of thirty years old, they are probably as serviceable as they ever were, still we have deemed it advisable to make analyses of our own wheats, grown under conditions which we have varied to suit the purposes that we have had in view.

This bulletin will deal largely with the composition of our Colorado wheats, but more particularly with those factors which establish its quality or characteristics. It is evident from the analyses published that the Colorado wheats are, as a rule, as rich in nitrogen as other wheats. They compare favorably with the Minnesota wheats in nitrogen content and in other analytical respects, but the flour does not make as much bread as the Minnesota flour, at least this is the claim of our bakers. Whether it is justified or not, it is customary to consider the crude protein as an index of the quality of the wheat. There are many statements made which cast doubt upon the correctness of this practice. Still it is almost universal, and a high-protein wheat is considered a good wheat. Our wheats are rich enough in protein, but they are considered soft or weak wheats. The object of our study is to discover if possible the factor or factors in our conditions on which this inferiority depends. Our primary assumption is that our climatic conditions are favorable, the vegetative period of the wheat is usually short, our summers are warm and the sunshine practically constant. We do not have excessive quantities of rain, and irrigation is necessary, except occasionally, when the winter wheat may make a good crop without irrigation.

The amount of winter wheat grown in the irrigated sections of the State forms only a small portion of the total, so the wheat of chief importance is the spring wheat.

The climatic conditions are such that we should expect wheat of high quality; the temperature is sufficiently high and uniform, the nights are cool, the rainfall small, the water supply largely under our control, while the sunshine is practically constant and fogs are so good as unknown.

Our soils are easily cultivated, at least for the greater part. They are also well supplied with plant food and yield excellent crops. I have no statistics at hand whereby to establish the average crop on our irrigated lands, but from such information as I have obtained, I think that the average of spring wheat on such lands will not fall so low as 30 bushels, and in many years it will be better than 35 bushels. The kernels are usually plump, but sometimes shrunken; they are apt to lack in flintiness; in this respect, however, they vary. Some land produces very mealy wheat while other lands under the same climatic conditions produce flinty wheat. By far, the greater portion of our wheat that I have seen is mixed, that is, contains both characters of berries. This condition is not peculiar to Colorado. It is present in almost every sample of wheat, spring or winter, that I have seen, and in many of them it is very prevalent. I have treated of this condition, designated as Yellow-berry, in Bulletin 205 of this Station.

Yellow-berry wheat is considered as in some way deteriorated wheat. I do not think that this opinion has been shown to be based upon any established facts. The only justification that I know of for it, is the fact that such wheats, or rather kernels, are lower in nitrogen than flinty kernels when grown on the same plot of ground. It may be true that the flinty berries, richer in nitrogen, actually make a better flour than the yellow-berry kernels but, up to the present time, I think that this is inferred rather than proved. While writers, with almost no exception, assume that a high protein content in wheat indicates a strong wheat, the most of them at the same time insist that the quality of the gluten and not its quantity is determinative of the value of the flour for bread-making purposes. Colorado wheats are not deficient in nitrogen according to the information at present obtainable; even those samples affected with yellow-berry, while lower in nitrogen than samples containing only flinty berries, are not so deficient as to indicate inferiority in the essential quality of break-making. The inference, so far as I have been able to ascertain, has not even been based upon the lower nitrogen content, but is a general assertion based upon the assumption that the yellow-berry is an abnormality.

The Californian wheats are generally spoken of as soft, weak wheats, but are commended for their color and flavor. We find the nitrogen content given for Club, 2.064; White Australian, 1.936; and Propo, 1.918 percent.* These figures are as high as we find given for the hard wheats.

In comparing data concerning protein present it is to be remembered that all of the older data is based on the factor 6.25, while much of the more recent data is based on the factor 5.7. The former makes the protein 1.1 times as much as the latter.

Notwithstanding the fair percentage of nitrogen present in our Colorado wheats, the general experience is that it is not of high bread-making qualities. The second task that we set ourselves in this bulletin is to determine the properties and characteristics of our wheats as they are produced for the markets. We shall first consider our soil conditions and the effects of the individual elements, nitrogen, phosphorus and potassium.

We shall use the term "weak wheat" to designate one which yields a flour of low bread-making quality without regard to whether it is soft or hard and we shall use the term "soft" to indicate a wheat whose kernels crush easily without regard to its bread-making quality—so we shall have the two pairs of characters, weak and

*California Bulletin 212, p. 366.

strong, soft and hard. These may be synononomous terms, but not necessarily so, though we find them so used.

The plan of our work includes field experiments in which we cannot control all of the conditions, and later a series of experiments in which we can control all of the conditions. By means of the field experiments we hope to ascertain what the normal characteristics of our wheat really are, both in regard to composition and to the bread-making qualities of the flour produced. We found at the very beginning that this phase of our work required much more extended experimentation than we really desired to undertake, but it was unavoidable. Besides, this seemed to be the only way to analyze the effects of the individual fertilizers usually applied in agriculture, i. e., nitrogen, phosphorus and potassium, and in our case a fourth element, largely under our control, water. Concerning the effects of these elements upon the character, composition and properties of wheat, little seems to have been done. The effects upon the yield have been studied. Some observations have also been made upon the part that the time of application plays in the yield and properties of the grain, this is especially true of the nitrogen; but these observations have been incidental to the experiments rather than a main object. We have been unable to study these points as we wished to; this is especially true in regard to the effects of the water applied. We have been exceedingly fortunate, however, in obtaining samples of wheat grown under controlled conditions so far as the application of water is concerned which answer our purposes just as well as though we had made the experiments ourselves.

We have applied the three fertilizers, nitrogen, phosphorus and potassium, in different quantities. The latter two were added at one time, but the nitrogen was not. The nitrogen work consisted of three series of experiments, in which the minimum quantity of nitrogen used was applied to all of the plots at the same time. Two of the series subsequently received another application, so that one series received a minimum amount, one series received twice and one three times the minimum amount.

So far as the relative amounts are concerned, these ratios are true for the phosphorus and potassium, but the total amount was applied at the time of planting.

The cultivation of the soil was another point necessary to consider. The land used is not virgin soil, but has been under cultivation probably as long as most of our lands, an estimate of between 35 and 40 years would probably be correct. Deep cultivation of our prairie soils is not usually practiced. This is a result of experience on the part of the early settlers, who found that they obtained the best results by shallow plowing. The result of this in our case was that the land, to any depth greater than an average of six inches, was as firm as it had ever been with a slight plow sole at about six inches. My aim was to plow this land to the greatest feasible depth and subsoil it to a depth of eighteen inches in the fall of 1912, allow it to mellow and settle during the ensuing winter and plant it in the spring.' I was not able to get this done, so I was compelled to plow and subsoil in the spring. As the season was quite wet, this made my planting late. Of the three sections of land on which I am making my experiments, I turned two of them to a depth of twelve inches and subsoiled four inches deeper, sixteen inches in all. The other section was turned to a depth of nine inches but was not subsoiled. All the advantages of fall plowing were lost, but I saw no disadvantages in the mechanical condition of the seed bed arising from the spring working of the soil. I did not do this spring plowing because I wished to, but because I had to begin some time to get the land in the condition that I desired.

This plowing turned up some six inches of subsoil and put it on top. Ordinarily this would be very disadvantageous, but in our case the subsoil is capable of making just as kind a soil as the surface portions, as there is no very great difference between the soil and subsoil from a chemical standpoint, but from a biological standpoint there is a very great difference in favor of the surface soil. So far as this feature was concerned, my deep turning of the soil was decidedly disadvantageous, but in another respect it was very much to my advantage. This land had been planted to oats and barley the preceding season; both crops had grown luxuriantly, lodged badly, were harvested late and there was a very heavy loss of grain. Even with my deep plowing there were many spots where the oats and barley crowded out the wheat. Had it not been for the deep plowing the oats and barley would have been very much worse. This land is a somewhat clayey loam with visible deposition of calcium carbonate and sulfate below the depth to which it previously had been plowed. On irrigating, it takes water readily, and on drying cracks badly. This last factor cannot fail to be of considerable importance, for these cracks often gape open as much as one-half or even three-quarters of an inch and extend into the ground for several inches. Many of them are as much as four inches deep. I cannot state that I saw any decidedly injurious effects from this cracking, but the segments of soil formed or separated from one another by these cracks dry out rapidly.

We made no study of the bacteriology of the soil but we know that the surface soil that we turned under possessed a decided ability to fix nitrogen and convert it into nitrates. From this standpoint the deep plowing was a decided disadvantage, if we may judge from the bacterial counts made on samples of this soil compared with those made on samples of soil from the same field which had not been plowed so deep.

The only object which I had in breaking up this land was to put it into what I considered good condition. The other and principal immediate objects have been mentioned, one of them was advantageous and the other probably not. The former was the suppression of the barley and oats and the other the diminution of the bacterial flora of a beneficient character. While we have reason to believe that the occupation of the land by cultivated crops influences the bacterial activity in the soil, both by the removal of the products formed, and perhaps also by being directly inimical to their development, still such activity continues with greater or less intensity. In this particular soil we have found nitric nitrogen corresponding to 160 pounds of sodic nitrate in the surface two inches of the soil and 342 pounds in the first foot of soil. This was in fallow spots occurring in a stand of beets. Perhaps the results obtained with land after cropping, compared with land cultivated fallow, may be more acceptable. The cropped land had been planted to wheat which was harvested in early August. Immediately after harvest the stubble was irrigated and disked and allowed to rest till October, when it was plowed and harrowed. The samples were taken from both sections 4 December. A part of the cropped land had received a dressing of phosphorus as superphosphate, and another of potassium as muriate. These facts make a very marked difference. The section cultivated fallow throughout the season contained nitric nitrogen equivalent to 518 pounds of sodic nitrate in the surface foot. The cropped land, which had received a dressing of phosphorus, contained 257 pounds of sodic nitrate taken to the same depth while that which had received the potassium contained 184 pounds. There is no question but that this is the result of fixation and nitrification in this soil and the differences show the effect of cropping on the one hand, though modified by the cultivation received after the removal of the crop, and cultivation fallow during the whole season on the other hand. The results also indicate the favorable effect of the application of phosphorus upon the bacterial activity of the soil. The application of 518 pounds of sodic nitrate per acre to wheat, immediately after sowing, would almost certainly lodge it and give small-grained, shrunken wheat, even if all other conditions were ideal. The consideration of these facts is important in our agriculture. I do not think that this question is as important to all other sections of this country as it is to us, but I believe it to be of very considerable importance to almost all sections of the State. While there is a question in regard to the application of observations made in one locality to the whole of so large a state as Colorado, to say nothing of other states, I still hold that they will, with little modification, be applicable to a very large portion of the west.

I learned much more by turning the land to a depth of twelve inches than I expected to and while I would not advise so radical a procedure as I adopted, the deep cultivation has not shown any disadvantage but on the contrary justifies itself in several ways.

This presents a general though incomplete outline of our field work and the special objects which we hoped to accomplish, *i. e.*, to produce wheat under field conditions on a sufficiently large scale to make the results thoroughly representative, and, through the study of these products to ascertain the properties and character of Colorado wheats. We further hope to control the cultural conditions in such manner that we may be able to establish the effects of nitrogen, phosphorus, potassium and irrigation upon the composition and quality of the wheat produced, and see if in any of these we find an explanation for the fact that our wheats do not produce as desirable a flour as Minnesota or Kansas wheats.

We have already shown in Bulletin 205, "Yellow-berry in Wheat; Its Cause and Prevention," that it is in our power to increase the yellow-berry or to suppress it and that the ratio between the available potassium and available nitrogen is the factor that determines the appearance of this characteristic. I studiously avoided making any assertion pertaining to the composition or quality of yellow-berry wheat in Bulletin 205 for the same reason that I now use the terms "weak wheats" and "soft wheats" with a more definite meaning than is usually done, and further for the very good reason that I did not know whether the yellow-berry, soft, starchy, mealy wheat is really inferior to the flinty, corneous or hard wheat or not. We left this question for discussion in the present bulletin. I adhered closely to the specific problem of the cause of yellow-berry and its prevention. This, however, is closely related to an important phase of my principal problems.

I stated that the growers could control the yellow-berry by increasing the nitrogen in the soil, as the cause is an undue proportion of available potassium compared with the available nitrogen. I also stated that one method of adding available nitrogen was to cultivate the land fallow; this statement applies to our conditions and I judge that it will apply very generally, but hesitate to make too broad a statement. The explanation that I offer is in the development of so large a quantity of nitrates in the soil that, though much may be washed beyond the reach of the plants or destroyed by reduction, there will still remain enough to counterbalance, for the one crop, the influence of the available potassium. This feature of the yellow-berry problem will be discussed further in this bulletin, and the composition and properties of such wheat will be treated of fully.

The experiments planned, consisted of three series with each of three varieties of wheat. Each series of experiments had four members including a check. The size of the plots was one-tenth of an acre. We made other experiments concurrently with these in which we used smaller plots. Casual reference may be made to these but they form no part of the series presented in this bulletin.

The soil chosen for these experiments varies some in character, but it is as nearly uniform as can ordinarily be obtained. The land is quite level and is easily irrigated. We have analyzed this soil, represented by samples taken from different portions of the field at various times. There are some differences, but whether they are great enough, compared with the total amount of the substances present, to justify one in giving them further consideration or not is a question. Absolute uniformity in areas of the size of the aggregate here used, about six acres, is not to be obtained. The mechanical and chemical analyses, including mass analyses of both the soil and subsoil, are given below.

There is but little use in discussing the amount of plant food present as indicated by the analyses, still it gives us a certain indefinite idea of abundance or lack of this food which, in a general way, may be of service. The amounts given are calculated for 8,000,000 pounds of soil, because the soil and subsoil together were taken to a depth of two feet. The total amount of potassic oxid present in this land taken to this depth is approximately 203,280 pounds, or 101.6 tons; of phosphoric acid, 16,080 pounds, 8 tons; of nitrogen, 8,240 pounds, 4¼ tons.

MECHANICAL ANALYSES OF THE SOIL AND SUBSOIL.

| Size of Particles. | Soil Percent | Subsoil Percent |
|---|---|---|
| Over 1 mm | 0.092 | 0.112 |
| From 1 to 0.5 mm | 0.865 | 0.456 |
| From 0.5 to 0.25 mm | 1.810 | 1.122 |
| From 0.25 to 0.05 mm | 45.790 | 49.883 |
| From 0.05 to 0.01 mm | 28.742 | 25.514 |
| From 0.01 to Clay | 10.062 | 9.617 |
| Clay by difference | 2.749 | 3.707 |
| Moisture and organic matter | 9.890 | 9.589 |
| | 100.000 | 100.000 |

AGRICULTURAL ANALYSES OF SOILS AND SUBSOILS.

| | Soil Percent | Subsoil Percent | Soil* Percent | Subsoil Percent |
|---|---|---|---|---|
| Insoluble | 54.653 | 57.068 | 63.485 | 63.547 |
| Silicic acid | 19.805 | 12.754 | 9.865 | 8.558 |
| Sulfuric acid | 0.047 | 0.049 | 0.094 | 0.069 |
| Phosphoric acid | 0.120 | 0.127 | 0.175 | 0.160 |
| Carbonic acid | 3.048 | 6.312 | 2.976 | 4.942 |
| Chlorin | 0.032 | 0.059 | 0.025 | 0.035 |
| Potassic oxid | 0.872 | 0.742 | 0.715 | 0.573 |
| Sodic oxid | 0.290 | 0.432 | 0.408 | 0.316 |
| Calcic oxid | 6.100 | 8.465 | 4.725 | 7.310 |
| Magnesic oxid | 1.355 | 1.448 | 1.258 | 1.376 |
| Ferric oxid | 5.601 | 3.499 | 5.663 | 5.337 |
| Aluminic oxid | 3.738 | 5.397 | 3.563 | 2.738 |
| Manganic oxid ($M_3O_4$) | 0.118 | 0.026 | 0.175 | 0.160 |
| Water at 100° C | ...... | ...... | 2.816 | 2.111 |
| Ignition | 5.072 | 3.887 | 3.918 | 2.143 |
| Sum | 100.851 | 100.265 | 99.861 | 99.375 |
| Oxygen equivalent to chlorin | 0.007 | 0.013 | 0.005 | 0.007 |
| Total | 100.844 | 100.252 | 99.856 | 99.368 |
| Total nitrogen | 0.147 | 0.069 | 0.143 | 0.063 |
| Humus | 0.462 | ...... | 0.675 | 0.262 |
| Humus nitrogen | ...... | ...... | 0.060 | 0.023 |
| Humus ash | ...... | ...... | 0.537 | 0.387 |
| Water soluble | ...... | ...... | 0.388 | 0.345 |
| Potassic oxid sol. in citric acid | ...... | ...... | 0.031 | 0.018 |
| Phosphoric acid sol. in citric acid | ...... | ...... | 0.021 | 0.015 |
| Potassic oxid sol. in N-5 nitric acid | ...... | ...... | 0.057 | 0.020 |
| Phosphoric acid sol. in N-5 nitric acid | ...... | ...... | 0.066 | 0.073 |

*This and its corresponding subsoil are composite samples.

MASS ANALYSIS OF SOIL AND SUBSOIL.

| | Soil Percent | Subsoil Percent |
|---|---|---|
| Silicic acid | 63.500 | 61.350 |
| Sulfuric acid | 0.446 | 0.178 |
| Phosphoric acid | 0.217 | 0.185 |
| Carbonic acid | 2.976 | 4.942 |
| Chlorin | 0.025 | 0.035 |
| Potassic oxid | 2.475 | 2.607 |
| Sodic oxid | 1.305 | 1.444 |
| Calcic oxid | 5.250 | 8.170 |
| Magnesic oxid | 1.680 | 1.796 |
| Ferric oxid | 6.263 | 5.805 |
| Aluminic oxid | 9.200 | 8.760 |
| Manganic oxid ($Mn_3O_4$) | 0.210 | 0.190 |
| Water at 100° C | 2.816 | 2.111 |
| Ignition | 3.918 | 2.143 |
| Sum | 100.281 | 99.716 |
| Oxygen equivalent to chlorin | 0.005 | 0.007 |
| Total | 100.276 | 99.709 |

We will assume that the plants take up all of their nitrogen in the form of nitrates so that the total amount of nitrogen is not so much the question as the rate of nitrification or the rate at which the nitrogen present may become available as plant food. Experiments made with this soil indicate a high power in this direction. The nitric nitrogen was determined at the time of planting and at intervals throughout the season of 1913, i. e., during the growth of the crop. We found at the time of planting very varying results, so much so that any statement relative to the amount of nitrates present not be correct for any other than the particular area taken. With this understanding it may be stated that the approximate amount of nitric nitrogen present at the time of planting was, for the two feet for which the phosphoric acid and potash has been calculated, about 35.16 pounds, corresponding to 211 pounds of sodic nitrate per acre. This amount of nitrogen was at that time available and capable of being appropriated by the young plants.

We used the three conventional solvents in our endeavor to obtain some data pertaining to the availability of the phosphoric acid and potash: hydric chlorid, 1.115 specific gravity; citric acid, 1 percent solution; and one-fifth normal nitric acid. These solvents, in the order given, indicated the presence of the following quantities of these two substances in the first two feet of the soil.

| | Potash Pounds | Phosphoric acid—Pounds |
|---|---|---|
| Hydrochloric acid | 51,520 | 9,880 |
| Citric acid | 1,960 | 1,440 |
| N-5 Nitric acid | 3,080 | 5,560 |

These quantities indicate a sufficiency of available plant foods to grow a large number of maximum crops, and explain the fact that the addition of phosphoric acid and potash, even in very liberal quantities, did not produce any observable effects upon the growing plants and only very small effects upon the yield of grain. These are so small that it is only by adhering to a very literal interpretation of the results that we can justify ourselves in claiming any advantage in crop from their use. There is no big, decisive and easily interpreted result produced by their application.

These analytical data are the basis of all of our experiments. They are as satisfactory as any others that we would be likely to obtain, for the mineralogical character of our soil makes it practically impossible to obtain any better or more concordant results, or others which might be more easily interpreted. This soil is exceedingly rich in felspathic sand. The felspar present is for the most part an orthoclase with some microcline. These minerals are readily attacked by decomposing agents, the action of water and carbon dioxide being easily demonstrated. Finely powdered felspar will yield potash to growing plants, as I have proved, using the oat plant.

We have not only grown oats in powdered felspar to maturity, with the production of seed, but we have taken our ordinary felspar and treated it just as we do soil samples with citric acid solution and with water to see how much phosphoric acid and potash it will yield to these solvents. Our results indicate that quite as much of these substances may be dissolved out of pure undecomposed felspar as out of our soils by a similar treatment. Felspar crushed to pass through a 60-mesh sieve yielded to a one-percent citric acid solution from 0.015 to 0.030 percent of phosphoric acid and from 0.018 to 0.051 percent of potassic oxid. The action of pure water, distilled water, on pulverized felspar is sufficient to become a factor in our soil problems.

The results in the preceding experiments led us to test the solubility of finely ground apatite in like manner. Apatite ground to pass a 100-mesh sieve yielded to one-percent citric acid 2.25 percent of phosphoric acid and to water 0.042 percent. A blank test made with the citric acid solution showed only an exceedingly minute trace of either phosphoric acid or of potash.

The mineral basis of our soils, according to these results, may play an unusually important part in our questions. Both the coarser and finer portions of this soil are composed largely of particles of felspar in a comparatively fresh condition, but according to the above results, they may serve as a source from which phosphoric acid and potash may be continuously supplied. It will be noticed that the mass analyses of the soil and subsoil give higher results than the analyses with hydric chlorid, specific gravity 1.115. This is probably due to the fact that the coarser portions of the felspar are large enough to protect the apatite contained in them from the action of the acid.

The moisture as well as the nitric nitrogen in the soil varies greatly. Both of these were determined from time to time throughout the season of 1913, and we intended to follow them throughout the season of 1914, but our working force was not large enough to do this and some of the field work done in 1913 could not be done in 1914. I would have preferred to have carried out the same schedule of investigation through the whole period of our field experiments, but we could not and I am not sure that we would have gained anything by doing so; concerning this, however, there may be room for difference of opinion.

### NITRIC NITROGEN AND ITS DISTRIBUTION.

The caption states exactly what we intend to present in this section of our work as best we can. While the greater part of the samples were taken in the small alleys left between the plots, the results obtained have been checked by samples taken from the ground occupied by the plants. While we realized the objections against taking the samples in this manner, it seemed best to do this, as we desired the crop quite as much as these data. In taking the number of samples that we deemed necessary, the injury to the crop, had they all been taken from the cultivated area, would have destroyed the results.

The width of each section is 132 feet, and no sample was taken within 20 feet of either end. The samples are composite, consisting of three subsamples. The borings were approximately 30 feet apart in a line across the section. These borings were made four feet deep. Other borings, not in the midst of the plants, were made to a depth of twelve feet, unless for some reason we could not accomplish it, which sometimes was the case, due to striking coarse gravel. The selection of the depth of four feet for the shallower borings was determined by the consideration that the wheat roots would probably not go to a materially greater depth. The twelve-foot borings were made to determine that the depth of the water plane was at least this deep, and to learn something of the distribution of the water, also of the nitric nitrogen and its total amount.

The following samples were collected in the spaces between the sections 29 April, 1913; this was three days after the grain was planted. This land is of course always fallow.

MOISTURE AND NITRIC NITROGEN IN SOIL AT TIME OF PLANTING.

| Depth | Sample 1 Moisture Percent | Sample 1 Nitric Nitrogen Parts per Million | Sample 2 Moisture Percent | Sample 2 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|
| 0 to 6 inches | 13.37 | 10.47 | 13.00 | 6.66 |
| 7 to 12 inches | 17.08 | 7.75 | 17.05 | 5.85 |
| 13 to 24 inches | 16.20 | 23.80 | 16.47 | 4.22 |
| 25 to 36 inches | 13.89 | 33.86 | 14.65 | 2.86 |
| 37 to 48 inches | 12.47 | 12.92 | 14.32 | 5.58 |
| 49 to 60 inches | 12.69 | 7.75 | 16.21 | 8.57 |
| 61 to 72 inches | 14.22 | 5.85 | 17.96 | 9.93 |
| 73 to 84 inches | 15.90 | 5.58 | 17.44 | 11.29 |
| 85 to 96 inches | 15.57 | 4.76 | 17.00 | 11.02 |
| 97 to 108 inches | 15.78 | 4.22 | 14.87 | 10.47 |
| 109 to 120 inches | 16.78 | 2.58 | 14.30 | 7.75 |
| 121 to 132 inches | 14.00 | 2.58 | 15.20 | 4.22 |

These two sections of soil were taken less than 150 feet apart. but there is a great variation in the quantities of nitric nitrogen present and its distribution is almost reversed; the maximum quantities being found in the second, third and fourth foot in the first case and in the seventh, eighth and ninth foot in the second case. The supply of nitric nitrogen within reach of any cultivated plant was very much greater in the first than in the second sample. While we do not know with certainty, it is very probable that the difference in distribution of the nitric nitrogen is due to a difference in the time of development, the supply of water and the permeability of the soil; the two latter factors facilitating the downward movement of the nitrates.

A second set of three samples was taken in the same manner as those already given on 27 June, twelve to fourteen days after we irrigated the field. The total nitrogen was also determined in this set of samples.

SAMPLE No. 1—27 JUNE, 1913.

| Depth. | Moisture Percent | Nitric Nitrogen Parts per Million | Total Nitrogen Percent |
|---|---|---|---|
| 0 to 12 inches | 16.88 | 4.49 | 0.1292 |
| 13 to 24 inches | 16.70 | 0.95 | 0.0653 |
| 25 to 36 inches | 15.97 | 0.54 | 0.0340 |
| 37 to 48 inches | 18.11 | 0.54 | 0.0258 |
| 49 to 60 inches | 19.87 | 0.39 | 0.0177 |
| 61 to 72 inches | 19.86 | 0.27 | 0.0218 |
| 73 to 84 inches | 18.05 | 0.68 | 0.0218 |
| 85 to 96 inches | 21.40 | 0.38 | 0.0218 |
| 97 to 108 inches | 18.84 | 0.00 | 0.0218 |
| 109 to 120 inches | 18.63 | 0.00 | 0.0218 |
| 121 to 132 inches | 17.96 | 0.00 | 0.0218 |

SAMPLE No. 2.—27 June, 1913.

| Depth. | Moisture Percent | Nitric Nitrogen Parts per Million | Total Nitrogen Percent |
|---|---|---|---|
| 0 to 12 inches | 15.96 | 2.04 | 0.1142 |
| 13 to 24 inches | 16.49 | 0.95 | 0.0571 |
| 25 to 36 inches | 16.41 | 0.68 | 0.0313 |
| 37 to 48 inches | 17.07 | 0.39 | 0.0204 |
| 49 to 60 inches | 18.78 | 0.39 | 0.0204 |
| 61 to 72 inches | 20.15 | 0.39 | 0.0204 |
| 73 to 84 inches | 20.04 | 0.68 | 0.0231 |
| 85 to 96 inches | 20.23 | 1.22 | 0.0299 |
| 97 to 108 inches | 14.78 | 0.68 | 0.0177 |
| 109 to 120 inches | 18.14 | 0.68 | 0.0150 |
| 121 to 132 inches | 19.75 | 0.68 | 0.0218 |

SAMPLE No. 3—27 JUNE, 1913.

| Depth. | Moisture Percent | Nitric Nitrogen Parts per Million | Total Nitrogen Percent |
|---|---|---|---|
| 0 to 12 inches | 14.39 | 3.13 | 0.1115 |
| 13 to 24 inches | 15.54 | 1.22 | 0.0530 |
| 25 to 36 inches | 15.61 | 0.95 | 0.0326 |
| 37 to 48 inches | 16.09 | 0.68 | 0.0231 |
| 49 to 60 inches | 17.60 | 0.54 | 0.0204 |
| 61 to 72 inches | 19.06 | 0.54 | 0.0163 |
| 73 to 84 inches | 18.41 | 0.39 | 0.0177 |
| 85 to 96 inches | 19.23 | 0.68 | 0.0258 |
| 97 to 108 inches | 19.84 | 0.95 | 0.0109 |

This section was taken to a depth of nine feet because at this point we struck coarse gravel and it was impossible to get the auger any deeper.

We cannot infer that the water applied has washed out an amount of nitrates equivalent to the difference between the amounts shown by the first two and the last three samples, at least I do not consider it safe to make such a supposition, but four-foot samples taken subsequently will make it evident that large amounts of nitrates have actually been washed out of the soil. The amount of water used in this irrigation was one acre-foot, and the condition of the soil was such that this amount of water was necessary to permit the water, with the head that we had, to just flow over the soil. In other words, the ground took in this much water. The extent to which the irrigation had increased the water supply is fairly indicated by the differences in the percentages of moisture on 29 April, when the first samples were taken and those found on 27 June, 12 to 14 days after one acre-foot of water had been applied.

The nitric nitrogen in any foot of the last three samples is comparatively small; even the surface foot contains only a small amount, though it is considerably more than we find in any subsequent foot. There was no nitric nitrogen in the last three feet of the first sample taken on 27 June, though this sample contained the largest amount in the surface foot at that time.

The preceding samples were all taken in fallow strips, for we left spaces between each set of four plots. We did this so that we could take such samples without tramping down an unnecessarily large amount of our wheat. The loss of area due to taking of samples was too large as it was, for we also took samples in the wheat plots proper and cut many samples of plants. We, therefore, have two more series of samples to show the moisture, nitric nitrogen and total nitrogen in the soil throughout the season. These two series were taken to a depth of four feet; one series was taken in the strips left between the plots and the other series in the plots themselves. Each of these series is divided into subseries corresponding with the three sections of land which we used for these field experiments. These sections of land are designated as 1700, 1800 and 1900 and contain about two acres each. There were two sets of samples taken in each section on the dates given. These samples were not taken from one spot, but were composite. Each sample analyzed was composed of three samples which were well mixed before the final sample was taken out. These precautions were necessary in order to obtain a representative sample. I believe that the samples hereafter given are quite representative and dependable. The first set of nitric-nitrogen determinations was made by the phenolsulphuric acid method, all the others were made by reduction with a zinc-copper couple. With these soils the latter usually gives a shade higher results.

SAMPLES TAKEN 29 APRIL, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 13.60 | 7.00 | 14.50 | 4.00 | 13.97 | 4.00 |
| 7 to 12 inches.... | 14.11 | 6.00 | 16.91 | 5.00 | 17.62 | 3.00 |
| 13 to 24 inches.... | 15.20 | 4.50 | 16.09 | 3.00 | 15.78 | 1.00 |
| 25 to 36 inches.... | 14.69 | 2.50 | 14.78 | 1.50 | 15.10 | 1.00 |
| 37 to 48 inches.... | 13.12 | 2.50 | 13.52 | 1.50 | 13.06 | 0.15 |
| | | | | | | |
| 0 to 6 inches.... | 14.68 | 8.00 | 14.22 | 8.00 | 14.58 | 3.00 |
| 7 to 12 inches.... | 15.79 | 7.00 | 17.02 | 5.00 | 17.67 | 4.50 |
| 13 to 24 inches.... | 14.54 | 4.50 | 16.52 | 2.50 | 16.45 | 1.50 |
| 25 to 36 inches.... | 14.69 | 2.50 | 14.78 | 1.50 | 15.10 | 1.00 |
| 37 to 48 inches.... | 14.81 | 1.50 | 14.50 | Trace | 14.32 | 0.05 |

SAMPLES TAKEN 12 MAY, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 16.74 | 5.58 | 16.90 | 11.02 | 17.18 | 6.39 |
| 7 to 12 inches.... | 19.18 | 6.94 | 18.57 | 10.20 | 18.48 | 6.12 |
| 13 to 24 inches.... | 17.51 | 2.58 | 17.08 | 5.30 | 15.94 | 2.04 |
| 25 to 36 inches.... | 15.10 | 1.22 | 15.37 | 2.04 | 14.59 | 1.22 |
| 37 to 48 inches.... | 12.93 | 0.95 | 14.47 | 1.22 | 13.23 | 0.68 |
| | | | | | | |
| 0 to 6 inches.... | 15.71 | 6.63 | 16.36 | 5.31 | 16.52 | 7.21 |
| 7 to 12 inches.... | 19.36 | 7.48 | 18.68 | 10.20 | 18.53 | 8.02 |
| 13 to 24 inches.... | 16.90 | 2.31 | 16.77 | 3.67 | 16.68 | 2.58 |
| 25 to 36 inches.... | 15.43 | 0.95 | 15.12 | 1.22 | 15.18 | 0.68 |
| 37 to 48 inches.... | 14.97 | 0.68 | 14.54 | 0.82 | 14.63 | 0.54 |

From the evening of May 8 to the morning of May 10 we had a rainfall of 1.05 inches.

SAMPLES TAKEN 26 MAY, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 15.37 | 8.02 | 15.05 | 7.62 | 13.66 | 6.80 |
| 7 to 12 inches.... | 16.74 | 9.38 | 17.83 | 9.11 | 16.98 | 6.66 |
| 13 to 24 inches.... | 15.71 | 3.67 | 16.86 | 3.13 | 16.19 | 2.86 |
| 25 to 36 inches.... | 15.02 | 1.63 | 15.60 | 1.90 | 14.92 | 0.95 |
| 37 to 48 inches.... | 13.78 | 0.95 | 14.14 | 0.82 | 14.14 | 0.54 |
| | | | | | | |
| 0 to 6 inches.... | 15.39 | 7.21 | 14.01 | 6.94 | 13.42 | 6.39 |
| 7 to 12 inches.... | 17.74 | 11.29 | 17.30 | 9.38 | 17.04 | 5.44 |
| 13 to 24 inches.... | 16.26 | 3.40 | 16.16 | 4.08 | 16.03 | 1.63 |
| 25 to 36 inches.... | 15.25 | 1.63 | 15.13 | 2.31 | 15.26 | 1.22 |
| 37 to 48 inches.... | 14.72 | 0.95 | 15.05 | 1.77 | 14.96 | 0.54 |

SAMPLES TAKEN 7 JUNE, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 12.51 | 8.30 | 10.77 | 9.93 | 11.06 | 9.66 |
| 7 to 12 inches.... | 16.17 | 6.94 | 16.01 | 9.93 | 16.08 | 7.48 |
| 13 to 24 inches.... | 15.36 | 3.13 | 15.36 | .... | 15.59 | 2.86 |
| 25 to 36 inches.... | 14.01 | 1.22 | 14.96 | 1.77 | 15.25 | 1.22 |
| 37 to 48 inches.... | 13.96 | 0.68 | 14.82 | 0.95 | 13.74 | 0.68 |
| 0 to 6 inches.... | 11.33 | 7.48 | 10.36 | 8.30 | 10.97 | 8.30 |
| 7 to 12 inches.... | 16.87 | 8.84 | 15.98 | 9.11 | 15.81 | 5.58 |
| 13 to 24 inches.... | 15.99 | 3.40 | 15.42 | 4.49 | 15.53 | 1.77 |
| 25 to 36 inches.... | 15.03 | 1.22 | 15.28 | 1.50 | 14.49 | 0.95 |
| 37 to 48 inches.... | 15.67 | 1.22 | 14.50 | 0.95 | 14.52 | 0.95 |

We began irrigating five days after the above samples were taken. The water was applied at this time, not because the plants showed any need of it, but because they were for the most part in boot and we deemed this an opportune time to apply it.

SAMPLES TAKEN 24 JUNE, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 11.27 | 4.49 | 11.33 | 7.07 | 11.84 | 2.86 |
| 7 to 12 inches.... | 14.44 | 2.31 | 15.71 | 4.90 | 15.14 | 1.77 |
| 13 to 24 inches.... | 14.89 | 0.82 | 15.08 | 3.54 | 15.25 | 0.68 |
| 25 to 36 inches.... | 15.08 | 0.00 | 15.20 | 2.86 | 15.57 | 0.68 |
| 37 to 48 inches.... | 14.92 | 0.68 | 15.24 | 1.16 | 16.04 | 0.54 |
| 0 to 6 inches.... | 14.07 | 7.48 | 13.90 | 6.26 | 12.42 | 2.72 |
| 7 to 12 inches.... | 16.73 | 3.67 | 16.92 | 4.35 | 15.49 | 1.50 |
| 13 to 24 inches.... | 15.90 | 1.77 | 16.53 | 2.18 | 15.90 | 0.68 |
| 25 to 36 inches.... | 15.99 | 1.22 | 15.59 | 2.18 | 16.03 | 0.68 |
| 37 to 48 inches.... | 17.63 | 1.50 | 16.55 | 1.16 | 16.92 | 0.54 |

SAMPLES TAKEN 14 JULY, 1913.

| Depth | Section 1700 Moisture Percent | Section 1700 Nitric Nitrogen Parts per Million | Section 1800 Moisture Percent | Section 1800 Nitric Nitrogen Parts per Million | Section 1900 Moisture Percent | Section 1900 Nitric Nitrogen Parts per Million |
|---|---|---|---|---|---|---|
| 0 to 6 inches.... | 7.30 | 6.12 | 8.16 | 5.98 | 8.29 | 11.15 |
| 7 to 12 inches.... | 13.80 | 3.13 | 14.05 | 3.26 | 13.71 | 4.90 |
| 13 to 24 inches.... | 14.17 | 1.50 | 14.57 | 2.72 | 14.79 | .... |
| 25 to 36 inches.... | 15.57 | 0.95 | 14.85 | 2.18 | 14.87 | 1.90 |
| 37 to 48 inches.... | 14.06 | 0.95 | 14.49 | 1.16 | 14.46 | 1.63 |
| 0 to 6 inches.... | 9.49 | 8.30 | 10.87 | 10.34 | 7.14 | 5.44 |
| 7 to 12 inches.... | 15.05 | 3.67 | 15.81 | 8.43 | 12.69 | 1.90 |
| 13 to 24 inches.... | 14.67 | 1.77 | 15.24 | 2.18 | 13.99 | 1.16 |
| 25 to 36 inches.... | 14.62 | 1.50 | 15.46 | 1.90 | 11.07 | 1.16 |
| 37 to 48 inches.... | 15.57 | 1.22 | 15.68 | 1.90 | 14.80 | 0.82 |

The total nitrogen in these sections of land was all redetermined on 1 July, 1913.

TOTAL NITROGEN IN SAMPLES TAKEN.

| Depth. | Section 1700 Total Nitrogen Percent | Section 1800 Total Nitrogen Percent | Section 1900 Total Nitrogen Percent |
|---|---|---|---|
| 0 to 6 inches | 0.1224 | 0.1278 | 0.1238 |
| 7 to 12 inches | 0.1142 | 0.1047 | 0.0843 |
| 13 to 24 inches | 0.0517 | 0.0680 | 0.0558 |
| 25 to 36 inches | 0.0340 | 0.0435 | 0.0394 |
| 37 to 48 inches | 0.0272 | 0.0258 | 0.0258 |
| 0 to 6 inches | 0.1278 | 0.1074 | 0.1278 |
| 7 to 12 inches | 0.0898 | 0.0898 | 0.0952 |
| 13 to 24 inches | 0.0558 | 0.0585 | 0.0517 |
| 25 to 36 inches | 0.0354 | 0.0367 | 0.0367 |
| 37 to 48 inches | 0.0231 | 0.0218 | 0.0231 |

All of the preceding samples were taken within the fallow strip left between the sets of four plots.

The nitric nitrogen found in the samples taken 7 June, five days before the irrigation, and in those taken 24 June, ten to twelve days after irrigation, gives a measure of the effect of the irrigation upon the nitrates in the soil to the depth to which the samples were taken, four feet. We have six samples, each composed by uniting three subsamples, eighteen subsamples in all, representing six inches or the foot, respectively, given in the tables. We will consider only the surface six inches. The average amount of nitric nitrogen per million for this section of soil before irrigation was 8.66 p.p.m. On 24 June, ten or twelve days after irrigation, it was 5.18 p.p.m., a difference of 3.48 p.p.m. An examination of the tables also shows that these nitrates had been moved either into the lower portion of this section or still deeper. An examination of the next series of samples given, that for 14 July, 1913, gives a very fair idea of the rate at which these nitrates were being replaced, for the surface six inches of these same plots now contains an average of 8.8 p.p.m. a little higher average than was found five days before irrigation. The whole section of soil sampled shows the same fact, but not always to so marked a degree. This accumulation of nitric nitrogen in the surface portions of this soil is not due to immigration of the nitrates from greater depths aided by capillarity. Direct experiment, Colorado Bulletin 186, p. 29, shows that capillary attraction will not move nitrates, under ordinary atmospheric conditions, more than 25 inches in thirty days and their distribution through the soil is the reverse of that which we find in our plots. The increased nitric nitrogen in the soil is due to nitrification. It was shown in Colorado Bulletin 178, p. 86, *et seq.*, also in Colorado Bulletin 179, pp. 14, 26 and 29, by W. G. Sackett, that this soil possesses such high fixing and nitrifying powers that these phenomena are, beyond question, important factors in the production of the nitric nitrogen found.

The amount of nitric nitrogen found in soil cultivated fallow, compared with the foregoing results on the one hand, and with the nitric nitrogen found in cropped soil on the other hand, is of interest in this connection.

The cropped land referred to in the following tables is the same land for which the nitric nitrogen is subsequently given as sampled 1 August, 1913, Defiance, Check, Section 1700. The wheat was harvested off of the land 6 August. The land was irrigated 28 August and disked a few days later. The land was plowed about 20 October, and the samples were taken 4 December, 1914. These facts are stated in order that the part played by the cultural conditions may be taken into proper consideration.

Six series of samples were taken from the adjoining section of land, three on 14 November and three on 4 December, 1914. This section had been cultivated fallow during the season preparatory for use in wheat breeding experiments. The area of these sections is two acres each.

NITRIC NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 14 NOVEMBER, 1914.

| | Nitric Nitrogen Parts per Million | | |
|---|---|---|---|
| Depth. | Sample I. | Sample II. | Sample III. |
| 0 to 3 inches | 6.36 | 8.52 | 7.37 |
| 4 to 7 inches | 20.71 | 28.63 | 22.03 |
| 8 to 13 inches | 9.24 | 18.73 | 14.74 |
| 14 to 19 inches | 5.63 | 3.89 | 3.88 |

SAMPLES TAKEN 4 DECEMBER, 1914.

| | | | |
|---|---|---|---|
| 0 to 3 inches | 11.12 | 7.44 | 14.32 |
| 4 to 7 inches | 31.13 | 18.42 | 25.71 |
| 8 to 13 inches | 17.11 | 15.67 | 18.73 |
| 14 to 19 inches | 6.57 | 4.79 | 6.43 |

TOTAL NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 4 DECEMBER, 1914.

| Depth. | Percent | Percent | Percent |
|---|---|---|---|
| 0 to 3 inches | 0.1293 | 0.1244 | 0.1230 |
| 4 to 7 inches | 0.1319 | 0.1265 | 0.1225 |
| 8 to 13 inches | 0.0974 | 0.1091 | 0.0987 |
| 14 to 19 inches | 0.0709 | 0.0705 | 0.0677 |

NITRIC NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

| | Nitric Nitrogen Parts per Million. | |
|---|---|---|
| Depth. | Sample I | Sample II |
| 0 to 3 inches | 6.39 | 5.42 |
| 4 to 7 inches | 11.74 | 7.92 |
| 8 to 13 inches | 11.82 | 8.93 |
| 14 to 19 inches | 6.69 | 3.44 |

TOTAL NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

| Depth. | Percent | Percent |
|---|---|---|
| 0 to 3 inches | 0.1258 | 0.1150 |
| 4 to 7 inches | 0.1223 | 0.1205 |
| 8 to 13 inches | 0.1203 | 0.1101 |
| 14 to 19 inches | 0.0820 | 0.0764 |

Each of the samples in these series was made up of three sub-samples. The accumulation of nitric nitrogen during the period of fallow is very evident. The facts stated in Colorado Bulletin 205, pp. 36 and 37, regarding the effect of fallowing upon the prevalence of yellow-berry in wheat, taken in connection with the demonstrated effects of nitrates are very suggestive and interesting. The following samples were taken in the same manner as the preceding ones, but in a line running lengthwise through the middle of the plots.

SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

| | Section 1700 | | Section 1800 | | Section 1900 | |
|---|---|---|---|---|---|---|
| Depth | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million |
| 0 to 6 inches.... | 14.03 | 2.72 | 12.79 | 2.99 | 12.51 | 3.13 |
| 7 to 12 inches.... | 14.36 | 1.22 | 14.63 | 2.58 | 14.49 | 1.90 |
| 13 to 24 inches.... | 14.95 | 0.68 | 15.16 | 0.68 | 15.22 | 0.54 |
| 25 to 36 inches.... | 14.95 | 0.39 | 15.29 | 0.39 | 16.07 | 0.27 |
| 37 to 48 inches.... | 15.67 | 0.27 | 15.84 | 0.27 | 15.75 | 0.27 |
| 0 to 6 inches.... | 12.57 | 4.76 | 12.24 | .... | 15.06 | 3.40 |
| 7 to 12 inches.... | 14.43 | 2.04 | 14.34 | 2.18 | 16.47 | 1.22 |
| 13 to 24 inches.... | 14.39 | 0.95 | 14.63 | 1.16 | 15.76 | 0.68 |
| 25 to 36 inches.... | 14.87 | 0.95 | 14.75 | 1.09 | 15.85 | 0.54 |
| 37 to 48 inches.... | 17.77 | 0.68 | 16.27 | .... | 16.33 | 0.54 |

SAMPLES TAKEN WITHIN THE PLOTS 14 JULY, 1913.

| | Section 1700 | | Section 1800 | | Section 1900 | |
|---|---|---|---|---|---|---|
| Depth | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million |
| 0 to 6 inches.... | 9.16 | 1.02 | 9.51 | 3.26 | 8.30 | 2.72 |
| 7 to 12 inches.... | 10.47 | 0.00 | 10.69 | 1.09 | 9.75 | 1.09 |
| 13 to 24 inches.... | 11.62 | 0.00 | 10.38 | 1.09 | 10.17 | 1.16 |
| 25 to 36 inches.... | 12.76 | 0.00 | 11.72 | 1.09 | 10.92 | 1.63 |
| 37 to 48 inches.... | 13.31 | 0.00 | 13.05 | 0.82 | 12.22 | 0.82 |
| 0 to 6 inches.... | 7.99 | 2.31 | 8.73 | 3.94 | 8.83 | 3.54 |
| 7 to 12 inches.... | 9.66 | 1.02 | 10.28 | 1.63 | 10.26 | 3.81 |
| 13 to 24 inches.... | 10.20 | 1.09 | 9.90 | 1.63 | 9.70 | 1.16 |
| 25 to 36 inches.... | 11.93 | 0.95 | 11.88 | 1.09 | 11.18 | 1.09 |
| 37 to 48 inches.... | 14.22 | 0.54 | 13.10 | 0.39 | 13.37 | 0.68 |

SAMPLES TAKEN WITHIN THE PLOTS 1 AUGUST, 1913.

| | Section 1700 | | Section 1800 | | Section 1900 | |
|---|---|---|---|---|---|---|
| Depth | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million | Moisture Percent | Nitric Nitrogen Parts per Million |
| 0 to 6 inches.... | 13.76 | 4.35 | 14.07 | 2.99 | 14.59 | 2.99 |
| 7 to 12 inches.... | 14.40 | 2.99 | 16.07 | 2.99 | 16.14 | 2.18 |
| 13 to 24 inches.... | 11.23 | 1.09 | 16.02 | 0.95 | 16.28 | 0.82 |
| 25 to 36 inches.... | 12.46 | 0.82 | 15.98 | 0.54 | 16.33 | 0.82 |
| 37 to 48 inches.... | 12.50 | 0.54 | 16.15 | 0.27 | 15.52 | 0.27 |
| 0 to 6 inches.... | 13.76 | 4.49 | 12.82 | 5.17 | 13.51 | 2.45 |
| 7 to 12 inches.... | 14.59 | 3.26 | 16.16 | 2.72 | 16.86 | 1.63 |
| 13 to 24 inches.... | 11.90 | 1.16 | 16.83 | 1.09 | 16.20 | 0.54 |
| 25 to 36 inches.... | 11.06 | 1.09 | 16.13 | 0.82 | 15.70 | 0.27 |
| 37 to 48 inches.... | 13.14 | 0.54 | 16.04 | 0.54 | 16.53 | 0.54 |

The land was not well leveled before planting and when we came to irrigate it there were a few spots on which it was impossible to force the water. These spots were comparatively small and I thought that the lateral movement of the water beneath the surface would effect a subirrigation, but in this I was wrong. The wheat on these spots matured as good wheat as the irrigated portion but the growth of the straw was very inferior to the rest of the plots in which they occurred. Because of the evident deficiency of water as indicated by the growth and color of the plants, I took a set of samples from one of these spots on 2 August, just a few days before harvest, and had the moisture and nitric nitrogen determined in them. The spot chosen was in Section 1700, Fife-Check plot. I have just given, in the last table, the moisture and nitric nitrogen for the regular samples taken the previous day, 1 August.

SAMPLE FROM UNIRRIGATED SPOT TAKEN 2 AUGUST, 1913.

| | Section 1700 | |
|---|---|---|
| Depth. | Moisture Percent | Nitric Nitrogen Parts per million |
| 0 to 6 inches | 12.17 | 8.70 |
| 7 to 12 inches | 12.00 | 8.43 |
| 13 to 24 inches | 8.56 | 2.99 |
| 25 to 36 inches | 7.78 | 2.18 |
| 37 to 48 inches | 11.32 | 1.09 |

It will be noticed that all of the samples taken 1 August were higher in moisture than those taken 14 July. This is not only true of all the shallower samples, but also of all of the samples; even in the fourth foot the moisture shows a very decided increase. I know of no cause for this except it be found in the fact that between 22 and 27 July we had a total rainfall of one and forty-three hundredths inches. Assuming that we had a rainfall of one and one-half inches, it would give us about 341,000 pounds of water per acre, provided it had all reached the ground, been absorbed and none had been evaporated, all of which is more or less contrary to the facts, for it did not all reach the ground, but lodged on the plants and was evaporated from their surfaces and some of that which did reach the ground had been lost by evaporation or by the activity of the plants and yet on 1 August there is an excess of moisture in the soil taken to a depth of four feet, over that present on 14 July, by over twice the amount that had fallen as rain and we are neglecting the activity of the plants for the whole of the intervening period. This slight rainfall is undoubtedly the cause of the moisture in the first foot of the unirrigated spot.

The nitric nitrogen is also very much higher in this dry spot than in the regular samples, almost as high at the surface as the fallow ground, and decidedly higher in the lower portions of the boring. This may be due to the fact that the wheat plants were not very vigorous and did not occupy the ground with their roots, a fact which may have favored nitrification. There was certainly no nitrates washed out of any portion of this soil by irrigating water; on the other hand the lateral movement of the irrigating water does not seem to have been sufficient to account for any accumulation by lateral secretion. If this actually took place to any extent at all, it would have been at the margins of the space, which we avoided, and took the sample as near the center of the dry area as possible.

MOISTURE AND TOTAL NITROGEN IN SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

| | Section 1700 | | Section 1800 | | Section 1900 | |
|---|---|---|---|---|---|---|
| Depth | Moisture Percent | Total Nitrogen Percent | Moisture Percent | Total Nitrogen Percent | Moisture Percent | Total Nitrogen Percent |
| 0 to 6 inches.......... | 14.03 | 0.1278 | 12.79 | 0.1115 | 12.51 | 0.1251 |
| 7 to 12 inches.......... | 14.36 | 0.1156 | 14.63 | 0.1115 | 14.49 | 0.1088 |
| 13 to 24 inches.......... | 14.95 | 0.0721 | 15.16 | 0.0626 | 15.22 | 0.0490 |
| 25 to 36 inches.......... | 14.95 | 0.0340 | 15.29 | 0.0313 | 16.07 | 0.0231 |
| 37 to 48 inches.......... | 15.67 | 0.0258 | 15.84 | 0.0286 | 15.75 | 0.0161 |
| 0 to 6 inches.......... | 12.57 | 0.1292 | 12.24 | 0.1265 | 15.06 | 0.1251 |
| 7 to 12 inches.......... | 14.43 | 0.1047 | 14.34 | 0.1006 | 16.47 | 0.1006 |
| 13 to 24 inches.......... | 14.39 | 0.0598 | 14.63 | 0.0598 | 15.76 | 0.0544 |
| 25 to 36 inches.......... | 14.87 | 0.0313 | 14.75 | 0.0380 | 15.85 | 0.0218 |
| 37 to 48 inches.......... | 17.77 | 0.0286 | 16.27 | 0.0286 | 16.33 | 0.0190 |

If we consider the water contained in the soil on 29 April and 27 June, about fourteen days after irrigation, we observe that the irrigated land contains the greater percentages of moisture at all depths down to the twelfth foot. These percentages are comparable as both sets of samples were taken from fallow ground. But if we can compare the amounts of nitric nitrogen present, we observe great irregularities in distribution and scarcely any comparison at all in the quantities present. There is one thing very apparent and that is the extent to which the application of one acre-foot of water has removed the nitrates. The moisture present in the April samples was due to a series of light rains insufficient to effect leaching of the ground, whereas an acre-foot of water applied under our conditions affected a very perceptible amount of leaching. I do not know the rate of percolation, but when this amount of water is applied, the surface portions of our soil become very soft, so soft that one will sink into it half-leg deep. There is no doubt but this mass of water passes downward rapidly, as the amount present exceeds the capacity of the soil that it successively occupies to retain it. We can compare the results in another way; we can compare the percentages of water found for the four-foot samples taken 7 June, five days before irrigation, and the top four feet of the samples taken 27 June, about fourteen days after the irrigating had been finished. The differences are much smaller than we would expect and will aggregate approximately one percent in favor of the samples taken after irrigation. Some of the water had been removed by evaporation, but the greater portion of it sank rapidly to such a depth that evaporation took place slowly and from the ground surface only. An acre-foot of water is sufficient to increase the moisture in eleven acre-feet of soil by about six and one-quarter percent. We have no such increase. In the fourteen days elapsing since its application it has either evaporated from the surface or percolated through the soil to a greater depth than eleven feet, and this water moving through the soil has taken with it the greater part of the nitrates. In the samples taken 29 April, we find in the third foot 33.86 parts per million, and in the same foot of another sample taken at the same time we find 2.86 parts per million, but in the seventh, eighth and ninth foot we find this reversed, the smaller quantities being in the first sample. The nitrates have been washed further down in the latter than in the former sample.

The effect of the crop upon both the moisture and nitric nitrogen in the soil is evident from the samples taken 14 July, within the plots and in the spaces between the plots. Evidently the shading of the ground causes the top six inches to show a slight excess over the surface of the unprotected ground, but the next six inches and the remaining three feet show differences in moisture up to five percent or rather more. The samples taken within the plots are low in nitric nitrogen, the maximum being 3.94 parts per million, while the corresponding sample from the space between the plots contained 10.34 parts per million. In regard to the lower water content of the soil within the plot, no one will question its being due to the action of the plants and the difference represents principally the water taken up by the plants and given up to the air. Concerning the nitric nitrogen, two things may have happened. The occupancy of the ground by the plants may have prevented the formation of the nitrates and there may never have been as large a quantity in the soil within the wheat plots as in the unoccupied space between the plots, or the plants may have used up the difference that we find between the nitric nitrogen content of the samples. We are sure that the latter process took place, but we do not know certainly that the former supposition is not true. It is maintained that it is true.

The differences in the total nitrogen present in the soil within the plots and in the spaces between the plots are so small, that we are inclined to attach no value to them, especially when we remember that it is exceedingly difficult to select two samples of soil that are really comparable in this respect, and the difficulty of making chemical determinations which are free from all errors. Very slight differences in percentages often have a significance, but our methods and operations are not so perfect that we are justified in attaching too much significance to differences that are, perhaps, no greater than our errors. The total nitrogen does not show sufficient differences to justify us in attaching much importance to them, but the percentages of moisture and the quantities of nitric nitrogen do justify such inferences as have been presented.

The question of how great variations may be found in a series of samples taken at very small distances apart has been considered. To put the question to a practical test, we selected an apparently uniform plot, 5 feet by 30 feet, and laid it off in 150 equal squares and took a sample to a depth of one foot from the center of each square. We have six blocks, each five feet square, which gives us twenty-five samples in a block. The total and nitric nitrogen was determined in each of these samples, which were taken 19 May, 1913. The results are shown in the table on the next page.

The smallest amount of total nitrogen found was 0.11016 percent, Sample 8, Block 6. One sample in Block 1 and two samples in Block 4 also contained this amount. The largest amount found was 0.14552 percent. This was in sample 13, Block 6, so that we have the minimum and maximum in adjacent areas one foot square. This difference amounts to 354.4 parts of nitrogen per million. The significance of this amount of nitrogen at a given time will depend upon the character of the compounds of which it forms a part. The amount of organic matter that it represents may be readily seen from the following: Nitrogen forms approximately one-sixth of proteid matter and an acre-foot of soil weighs about four million pounds. These factors give us for the nitrogenous organic matter corresponding to the difference found for the total nitrogen in these samples, four and one-quarter tons, or the equivalent of about seven tons of dried blood of average grade.

The difference for the average of the nitric nitrogen in twenty-four samples from Block 1, and twenty-five samples in Block 6, is 1.8 p.p.m. This may seem a small difference, but it is actually a larger amount than we sometimes find in cropped soils taken to the same depth.

The maximum variation in the nitric nitrogen found within this area, five feet by thirty feet, is from 5.44 to 14.18 p.p.m., a difference of 8.6 p.p.m., or a difference equivalent to 206 pounds of sodic nitrate per acre-foot of soil.

We also determined the variation in the amounts of phosphoric acid and potash within this area; but we reduced the number of samples to four from each five-foot square. The choice was arbitrary, but the same for each of the six blocks, in which the first,

VARIATION OF TOTAL AND NITRIC NITROGEN IN 150 SQUARE FEET OF SOIL.

| | Block 1 | | Block 2 | | Block 3 | | Block 4 | | Block 5 | | Block 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Number | Total Nitrogen Percent | Nitric Nitrogen p.p.m. | Total Nitrogen Percent | Nitric Nitrogen p.p.m. | Total Nitrogen Percent | Nitric Nitrogen p.p.m. | Total Nitrogen Percent | Nitric Nitrogen p.p.m. | Total Nitrogen Percent | Nitric Nitrogen p.p.m. | Total Nitrogen Percent | Nitric Nitrogen p.p.m. |
| 1........ | 0.13056 | 7.34 | 0.12648 | 6.32 | 0.13056 | 9.35 | 0.11560 | 7.97 | 0.13464 | 11.27 | 0.12920 | 11.66 |
| 2........ | 0.11968 | 6.12 | 0.14144 | 9.18 | 0.13736 | ..... | 0.11152 | 6.02 | 0.13328 | 9.86 | 0.13464 | 9.35 |
| 3........ | 0.11560 | 6.12 | 0.13056 | 6.99 | 0.12104 | 8.14 | 0.12920 | 7.14 | 0.13328 | 12.63 | 0.12376 | 7.82 |
| 4........ | 0.11696 | 6.97 | 0.12784 | ..... | 0.12512 | 7.97 | 0.13464 | 8.35 | 0.13464 | ..... | 0.12104 | 7.99 |
| 5........ | 0.13192 | 5.44 | 0.11968 | 6.02 | 0.12920 | 8.35 | 0.13464 | 7.38 | 0.11424 | 7.58 | 0.12376 | 9.69 |
| 6........ | 0.11832 | 8.33 | 0.12104 | 11.08 | 0.11560 | 8.55 | 0.13056 | 7.99 | 0.11560 | 7.32 | 0.13056 | 11.07 |
| 7........ | 0.11968 | 9.01 | 0.12240 | 11.08 | 0.11016 | 7.65 | 0.12240 | 10.88 | 0.13056 | 12.24 | 0.12920 | 7.97 |
| 8........ | 0.11832 | 9.33 | 0.11288 | 7.77 | 0.12104 | 9.33 | 0.12240 | 9.32 | 0.13736 | 10.20 | 0.11016 | 8.16 |
| 9........ | 0.13328 | 11.73 | 0.11832 | 9.13 | 0.13328 | 11.66 | 0.12920 | 8.16 | 0.13192 | 10.10 | 0.11016 | 7.97 |
| 10........ | 0.12104 | 9.69 | 0.12104 | 7.97 | 0.12376 | 9.29 | 0.12512 | 7.99 | 0.11152 | 7.97 | 0.13328 | 9.52 |
| 11........ | 0.12784 | 9.69 | 0.12648 | 6.41 | 0.13056 | 9.91 | 0.11152 | 8.16 | 0.12648 | 8.33 | 0.13464 | 10.10 |
| 12........ | 0.11016 | 6.41 | 0.11696 | 7.58 | 0.12784 | 8.84 | 0.11968 | 9.52 | 0.13600 | 10.88 | 0.13600 | 8.33 |
| 13........ | 0.11560 | 7.97 | 0.12784 | 7.65 | 0.12104 | 8.74 | 0.13056 | 11.56 | 0.12648 | 9.52 | 0.14552 | 14.18 |
| 14........ | 0.12784 | 8.35 | 0.13192 | 9.52 | 0.12512 | 9.32 | 0.13056 | 8.84 | 0.12920 | 7.93 | 0.14416 | 10.69 |
| 15........ | 0.13056 | ..... | 0.12684 | 8.35 | 0.11968 | 7.97 | 0.11560 | 8.16 | 0.12376 | 9.29 | 0.12784 | 7.97 |
| 16........ | 0.12240 | 10.20 | 0.14280 | 9.01 | 0.11288 | 8.94 | 0.12784 | 8.43 | 0.11696 | 7.31 | 0.12512 | 12.41 |
| 17........ | 0.11832 | 10.20 | 0.12104 | 10.61 | 0.12648 | 8.55 | 0.12648 | 8.61 | 0.13872 | 8.94 | 0.13056 | 10.30 |
| 18........ | 0.12376 | 10.71 | 0.13056 | 9.52 | 0.12104 | 10.30 | 0.14008 | 9.18 | 0.13192 | 8.35 | 0.13056 | 12.41 |
| 19........ | 0.12512 | 8.67 | 0.12784 | 9.29 | 0.11696 | 7.97 | 0.13056 | 8.43 | 0.13464 | 10.30 | 0.11696 | 11.05 |
| 20........ | 0.13328 | 9.35 | 0.11696 | 9.69 | 0.13736 | 10.54 | 0.12648 | 10.30 | 0.12512 | 8.55 | 0.12784 | 9.29 |
| 21........ | 0.13600 | 11.46 | 0.12104 | 8.55 | 0.13192 | 13.41 | 0.13056 | 7.97 | 0.12104 | 9.52 | 0.13872 | 12.24 |
| 22........ | 0.12240 | 7.97 | 0.11696 | 7.65 | 0.12512 | 8.74 | 0.13192 | 9.13 | 0.13056 | 11.46 | 0.13600 | 10.30 |
| 23........ | 0.11696 | 7.97 | 0.12920 | 11.39 | 0.13736 | ..... | 0.13328 | 7.97 | 0.13464 | 9.71 | 0.14144 | 9.52 |
| 24........ | 0.12376 | 10.03 | 0.12648 | 9.52 | 0.13056 | 9.91 | 0.12240 | 9.35 | 0.13464 | 9.18 | 0.13600 | 12.07 |
| 25........ | 0.13872 | 8.74 | 0.12784 | 9.33 | 0.13464 | 8.35 | 0.13056 | 11.73 | 0.12512 | 7.99 | 0.12784 | 9.52 |

eighth, eighteenth and twenty-fifth were chosen. The method of extraction was with hydric chlorid, specific gravity 1.115, for ten hours. Two samples out of each four were treated a second time, namely, samples 8 and 18 of each block. The second extraction takes up a further quantity of each of these substances, but particularly of the potash. We were aware of this fact before we made these analyses. The new portion of potash unquestionably comes from the progressive decomposition of the felspar. This fact puts every potash determination made in our soils by this method in more or less doubt. I do not believe, however, that it is a serious matter, for the amount of potash involved is so large that a considerable mistake will matter but little, besides, even fresh felspar yields potash to plants or even to water, so that a mistake of 10 to 15 percent of the total potash involved does not in this case seem to me a very serious matter. For the sake of clearness and brevity, I shall give only the twelve results obtained by the double extraction as sufficient to show the variation in the amounts of phosphoric acid and potash within small, consecutive areas to a depth of one foot. It has already been explained that each block is five feet square and contains twenty-five square feet, which are numbered from left to right, beginning at the upper left-hand corner.

VARIATION OF PHOSPHORIC ACID AND POTASH IN CONSECUTIVE AREAS

| Block | Sample | Phosphoric Acid Percent | Potash Percent |
|---|---|---|---|
| 1 | 8 | 0.140 | 0.775 |
| 1 | 18 | 0.140 | 0.736 |
| 2 | 8 | 0.143 | 0.745 |
| 2 | 18 | 0.143 | 0.785 |
| 3 | 8 | 0.132 | 0.751 |
| 3 | 18 | 0.157 | 0.713 |
| 4 | 8 | 0.134 | 0.722 |
| 4 | 18 | 0.145 | 0.787 |
| 5 | 8 | 0.147 | 0.743 |
| 5 | 18 | 0.145 | 0.745 |
| 6 | 8 | 0.131 | 0.698 |
| 6 | 18 | 0.153 | 0.739 |

The variation in these results for the phosphoric acid extracted from the soil by this method is 0.026 percent, and for the potash 0.089 percent. The absolute amounts of phosphoric acid and potash indicated by these percentages are sufficient to have, possibly, some influence, but we can scarcely think that we are justified in laying any stress upon them, because we know that their common source is the felspar and we cannot regulate the extent to which the solvent shall act upon it in a given time. The quantities actually involved are, for the phosphoric acid, 1040 and, for the potash, 3560 pounds for the acre-foot of soil sampled; whereas the total quantities soluble in the solvent used, are about 5600 pounds for the phosphoric acid and 30,000 pounds for the potash. With such quantities present the variations shown by our analytical results, even if these be absolutely correct, are too uncertain in their significance to justify us in seriously undertaking to interpret them. These samples show so little variation, even though quantities greatly in excess of those available to the plants may be involved, that there can be but little object in considering them further. Reference to the analyses of this soil given on a preceding page (11) will further justify us in assuming that, while there may be some variation in the supply of phosphoric acid and potash in small and adjacent pieces of this land, the range is too small to admit of definite assertions in regard to its effects, especially as our knowledge of results obtained with the application of these individual fertilizers to this land leads us to believe that there is an abundant available supply of them present. This is the testimony of the crops raised and not simply an opinion.

We have presented the last few paragraphs to exhibit, as far as we can depend upon our data, the variation in the amounts of nitrogen, nitric nitrogen, phosphoric acid and potash from foot to foot within a small area. We could not, because of lack of time, examine plants, especially the wheat grown on a similar plot, to learn whether the composition of the wheat varied in a corresponding manner. We find, however, in Bulletin No. 269 of the Bureau of Plant Industry, that Prof. E. G. Montgomery, in trying to determine the "Experimental Error in the Nursery and Variation in Nitrogen and Yield," has practicaly done this and finds, using the nitrogen content as his measure, that there is a decided variation from place to place within very small areas. Prof. Montgomery determined this difference in quadrangular areas and also in parallel rows. He adopted as his standards of classification all plants yielding grain below 2.2 percent—from 2.2 to 2.8; from 2.8 to 3; and all plants above 3 per cent. While these standards seem high they served his purpose well. The general result obtained was that the "highs" and "lows" tend to segregate, that is, there would be an area in which they would obtain, as a rule, high results, again an area in which they obtained low results. Concerning these variations he says: "Just why these wide fluctuations occur when every precaution is taken to grow plants under uniform conditions is not very apparent." Again he says: "It is difficult to explain why such great variations exist when there seems to be little or no tendency to transmit them. It seems apparent that the variations must be due to differences in environment. Since the ordinary factors of environment, as sunlight, warmth, moisture and apparent fertility of the soil, are constant for all plants under our nursery conditions, we must conclude that there are factors profoundly influencing the growth of plants beyond the ordinary range of observation." Later Professor Montgomery adds, "A number of interesting problems are suggested. Why should one plant, growing under practically the same environment as another, collect from the soil two or three times as much nitrogen." Again, "The three plants * * * are from the same mother growing in the same centgener, probably less than two feet apart, yet the actual grams of nitrogen gathered differ more than 100 percent. This difference is not inherited, as these plants rarely transmit this quality." Professor Montgomery does not ascribe this difference to the soil, and the quotations are not made for the purpose of intimating that he does, but simply to show that variations in the composition of individual plants, growing, as is here asserted, within two feet of one another, may be very great, and that the difference in their nitrogen content cannot be attributed to heredity. The inference that I draw from the facts given is that there was a relation between the soil and these variations, but we shall find occasion to come back to this subject at another time.

## SOME SURFACE SAMPLES OF SOIL AND THEIR BACTERIAL CONTENT.

It was proposed to study the relation between the moisture, the number of bacteria, the total nitrogen and the nitric nitrogen present from time to time. Our plan proved to be more generous in scope than our ability to perform. In addition to this Professor Sackett did not encourage me with the promise of any easily interpreted results, as the bacterial counts do not include all of the bacteria, one or more important classes being eliminated by the character of the culture medium used.

In this connection it may be well to note one of the effects of turning the land to such a depth as I did, twelve inches in two cases and nine inches in one case, whereby I put several inches of the subsoil on the surface, at least two inches by the shallower and five or six inches by the deeper plowing. This plowing was done in the spring immediately before seeding. I appreciated the disadvantages of the procedure, but as previously explained, I had, owing to circumstances over which I had no control, no choice if I wished to give the land a deep plowing. The result was that the surface of my plots represented unweathered subsoil with a comparatively meager bacterial population. We united twenty samples of this subsoil to form a composite one taking care that the samples should not be inoculated by admixture of surface soil or by other means. Professor Sackett kindly made the bacterial count which he reported to us as—bacteria 911,875, moulds 97,975 per gram of soil. These samples represented six inches of this subsoil. Later we took a few samples from different sections to the depth of three inches and determined the moisture, the total nitrogen and the nitric nitrogen and Professor Sackett made bacterial counts in a few of them. Whether the depth of three inches was well chosen is a question, but this would depend largely upon the immediately preceding weather conditions. The samples were all taken on the same date and we considered them comparable. The results were as follows:

MOISTURE, BACTERIA, ETC., IN SURFACE THREE INCHES OF SOIL.

| Section | Moisture Percent | Total Nitrogen Percent | Nitric Nitrogen Parts per Million | Bacterial Count |
|---|---|---|---|---|
| Corn | 7.880 | 0.12444 | 9.11 | |
| Corn | 8.859 | 0.12988 | 7.48 | |
| Corn | 7.102 | 0.12716 | 10.47 | |
| Sorghum | 7.206 | 0.12444 | 6.55 | |
| Winter wheat | 4.986 | 0.11968 | 2.58 | |
| Winter rye | 4.180 | 0.12172 | 2.72 | 834,000 |
| Spring wheat check | 4.825 | 0.13328 | 3.81 | 1,440,000 |
| Spring wheat $P_2O_5$ applied | 6.510 | 0.14552 | 3.67 | 2,483,000 |
| Spring wheat KCl applied | 5.614 | 0.13872 | 5.71 | |
| Soil taken eight inches deep | .... | ...... | ... | 1,560,000 |
| Subsoil 9 to 14 inches | ..... | ....... | .... | 476,000 |

These samples were taken 20 June, a time when 4,000,000 bacteria per gram may be taken as a fair average for an ordinary loamy soil. These soils are very much poorer in bacterial life than the average; this is true even in the case of the plot to which we had added phosphoric acid which seems to have favored their development very greatly. The subsoil is very much poorer than the entire sample given above—in fact, it contains practically only one-half as many bacteria which developed on the culture medium employed. It will be noticed that the soils of our spring wheat plots, while richer in total nitrogen, were decidedly poorer in nitric nitrogen than the corn and sorghum plots.

We have not been able, up to this time, to pursue the study of the relation between the moisture, crop, nitrogen supply, etc., to any greater extent than is indicated by the statements given, which are not sufficient to justify any conclusions but they suffice for the purpose for which they are introduced, which is to show that the turning of five or six inches of subsoil to the surface and planting in this immediately after turning, gave us, in all respects, unusual conditions for which, if we only knew how, allowances should be made.

*This subject is not permanently dismissed for I am satisfied that this is one of the most important factors in our problem, and if strength and opportunity be granted me, I shall prosecute it* *further, for herein lies, I am fully persuaded, the explanation for the variations in the total, as well as in the nitric nitrogen present in the soil from foot to foot, and also one of the causes of variation in the composition and quality of the wheat produced.*

These statements are made with a full knowledge and appreciation of the important influence attributed to "climatic conditions." While there can be no question about the importance of the factors, designated by this term, uniformity of climatic conditions does not mean uniformity in characteristic properties of the same variety of wheat. On the contrary, given uniformity of climatic conditions, we can influence both the physical properties and chemical composition of the wheat kernel by varying the relative amounts of the individual substances necessary for plant growth. We can, by supplying nitrogen, cause the kernel to be small, maybe shrunken, flinty, high in nitrogen and difficult to crush; or by increasing the potassium in the soil, we can cause it to be large, plump, high in starch, correspondingly low in nitrogen and easy to crush. These properties constitute those groups which, so far as I can gather, are characteristic of the two classes of wheat usually designated as "hard" and "soft" wheats. In making these statements at this time I disclaim the expression of any opinion concerning strong and weak flours; this is a matter for future consideration.

### NITROGENOUS COMPOUNDS IN THE DEVELOPING PLANTS.

In our study of the sugar beet* we found it comparatively easy to follow the development and disappearance of the various forms of nitrogen in the blades of the leaves, the petioles and in the root. We made the attempt to follow the development of the nitrogenous compounds in the wheat plant from the time of blooming till the plant was mature. The same methods were used in this as in the former case except that we made no attempt to determine the animo-group and we used only the stems, leaves and heads of the plants. The sheaths for the most part were taken with the stems. The plants came into bloom about 7 July, a few anthers appeared 6 July and they had practically all disappeared by 10 July, so I take it that the period of full bloom was from 6 to 8 July.

### RATIOS OF LEAVES, STEMS AND HEADS.

The effects of the individual fertilizers applied to the different plots were not discernible in the growth or color of the various plots of wheat except in the case of those to which sodic nitrate had been applied. These plots were decidedly greener, leafier and a little taller than the others. We could not detect any difference between the other plots. We took three sets of samples from two

*Bulletin 183, Colo. Exp. Sta.

sections and two sets from the third section in order to determine the green weight of the stems, leaves and heads. We confined these observations to the Red Fife. We chose the Fife because we judged it to be more nearly representative than the other varieties and because it was somewhat more advanced in development. The portion designated as leaves was obtained by stripping the stems by drawing them through the hand. In this manner we got the blade and part of the sheath, but this portion consisted mostly of blades. The first samples were taken 7 July, 1913, and the latest samples 5 August, but the wheat was so nearly ripe on this last date that the leaves formed only about 4.0 percent of the plant and are included with the stems. The percentages given in the following tables are for green weights.

RATIO OF STEMS, LEAVES AND HEADS FOR RED FIFE.

| Date | Fertilizer per acre | Stems Percent | Leaves Percent | Heads Percent |
|---|---|---|---|---|
| Sections 1700 | | | | |
| 7 July, 1913 | Nitrogen, 120 pounds | 65.40 | 18.47 | 16.13 |
| | Phosphorus, 60 pounds | 66.57 | 14.26 | 19.17 |
| | Potassium, 200 pounds | 65.24 | 12.99 | 21.77 |
| | None | 70.84 | 14.58 | 14.58 |
| 21 July, 1913 | Nitrogen, 120 pounds | 56.64 | 12.65 | 30.71 |
| | Phosphorus, 60 pounds | 54.48 | 8.50 | 37.02 |
| | Potassium, 200 pounds | 54.73 | 9.40 | 36.47 |
| | None | 54.60 | 9.91 | 35.48 |
| 4 August, 1913 | Nitrogen, 120 pounds | 56.27 | ..... | 43.73 |
| | Phosphorus, 60 pounds | 54.00 | ..... | 46.00 |
| | Potassium, 200 pounds | 57.35 | ..... | 42.65 |
| | None | 53.80 | ..... | 46.20 |
| Section 1800 | | | | |
| 7 July, 1913 | Nitrogen, 80 pounds | 60.22 | 15.59 | 24.19 |
| | Phosphorus, 40 pounds | 69.05 | 13.49 | 17.46 |
| | Potassium, 150 pounds | 66.60 | 14.99 | 18.41 |
| | None | 69.39 | 13.49 | 17.21 |
| 25 July, 1913 | Nitrogen, 80 pounds | 59.88 | 8.56 | 31.56 |
| | Phosphorus, 40 pounds | 56.25 | 7.23 | 36.52 |
| | Potassium, 150 pounds | 54.66 | 6.43 | 38.91 |
| | None | 55.92 | 9.86 | 34.22 |
| 5 August, 1913 | Nitrogen, 80 pounds | 58.76 | ..... | 41.24 |
| | Phosphorus, 40 pounds | 57.41 | ..... | 42.59 |
| | Potassium, 150 pounds | 58.67 | ..... | 41.33 |
| | None | 56.97 | ..... | 43.03 |
| Section 1900 | | | | |
| 13 July, 1913 | Nitrogen, 40 pounds | 63.01 | 12.52 | 24.47 |
| | Phosphorus, 20 pounds | 62.07 | 10.09 | 27.84 |
| | Potassium, 100 pounds | 61.57 | 10.13 | 28.30 |
| | None | 62.77 | 9.70 | 27.53 |
| 30 July, 1913 | Nitrogen, 40 pounds | 56.70 | 7.10 | 31.16 |
| | Phosphorus, 20 pounds | 55.68 | 6.64 | 37.68 |
| | Potassium, 100 pounds | 53.47 | 5.15 | 41.38 |
| | None | 54.74 | 7.05 | 38.21 |

We could only make an approximate determination of the total green matter per acre by cutting the plants on a given small area and weighing the same. We did this as accurately as we could and obtained the following figures on 15 July, 1913, for Section 1700: Nitrogen applied, 120 pounds per acre, 10.1 tons; phosphorus applied, 60 pounds per acre, 8.3 tons; potassium applied, 200 pounds per acre, 7.4 tons; check, which received no fertilizer, 7.0 tons. The tables given above, together with these approximate figures, serve to give an idea of the effects produced upon the production of green matter by the fertilizers applied and some idea of the relative development of stems and heads.

### THE DRY MATTER IN THE PLANTS.

The dry matter in the plants was also determined, but we had to use other samples. The earliest sample taken for this purpose was cut 7 July, 1913, at the time of blooming. The results are given in the following table for the whole plant till 28 July, but on this and subsequent dates the stems and heads were weighed separately.

DRY MATTER IN WHEAT PLANTS GROWN WITH DIFFERENT FERTILIZERS.

| Date | Section | Variety | Fertilizer per acre | Air-dry matter Percent |
|---|---|---|---|---|
| 7 July, 1913 | 1700 | Defiance | 120 pounds nitrogen | 27.02 |
| 7 July, 1913 | 1700 | Defiance | 60 pounds phosphorus | 30.78 |
| 7 July, 1913 | 1700 | Defiance | 200 pounds potassium | 31.71 |
| 7 July, 1913 | 1700 | Defiance | None | 30.00 |
| 9 July, 1913 | 1700 | Red Fife | 120 pounds nitrogen | 29.47 |
| 9 July, 1913 | 1700 | Red Fife | 60 pounds phosphorus | 34.22 |
| 9 July, 1913 | 1700 | Red Fife | 200 pounds potassium | 34.06 |
| 9 July, 1913 | 1700 | Red Fife | None | 34.29 |
| 9 July, 1913 | 1700 | Kubanka | 120 pounds nitrogen | 32.66 |
| 9 July, 1913 | 1700 | Kubanka | 60 pounds phosphorus | 33.60 |
| 9 July, 1913 | 1700 | Kubanka | 200 pounds potassium | 32.42 |
| 9 July, 1913 | 1700 | Kubanka | None | 32.66 |
| 10 July, 1913 | 1900 | Defiance | 40 pounds nitrogen | 29.38 |
| 10 July, 1913 | 1900 | Defiance | 20 pounds phosphorus | 33.60 |
| 10 July, 1913 | 1900 | Defiance | 100 pounds potassium | 32.34 |
| 10 July, 1913 | 1900 | Defiance | None | 32.34 |
| 10 July, 1913 | 1900 | Red Fife | 40 pounds nitrogen | 30.55 |
| 10 July, 1913 | 1900 | Red Fife | 20 pounds phosphorus | 36.25 |
| 10 July, 1913 | 1900 | Red Fife | 100 pounds potassium | 33.83 |
| 10 July, 1913 | 1900 | Red Fife | None | 33.75 |
| 10 July, 1913 | 1900 | Kubanka | 40 pounds nitrogen | 31.34 |
| 10 July, 1913 | 1900 | Kubanka | 20 pounds phosphorus | 32.11 |
| 10 July, 1913 | 1900 | Kubanka | 100 pounds potassium | 33.05 |
| 10 July, 1913 | 1900 | Kubanka | None | 30.86 |

DRY MATTER IN WHEAT PLANTS, STEMS AND HEADS SEPARATE.

| Date | Section | Variety | Fertilizer per acre | Dry matter stems | Dry matter heads | Ratio of green stems to heads |
|---|---|---|---|---|---|---|
| 1913 | | | | | | |
| 28 July | 1700 | Defiance | 120 pounds nitrogen | 42.30 | 46.54 | 1.5 |
| 28 July | 1700 | Defiance | 60 pounds phosphorus | 48.03 | 52.30 | 1.2 |
| 28 July | 1700 | Defiance | 200 pounds potassium | 45.97 | 49.80 | 1.3 |
| 28 July | 1700 | Defiance | None | 43.65 | 48.40 | 1.3 |
| 31 July | 1700 | Red Fife | 120 pounds nitrogen | 44.77 | 54.74 | 1.3 |
| 31 July | 1700 | Red Fife | 60 pounds phosphorus | 49.98 | 56.80 | 1.2 |
| 31 July | 1700 | Red Fife | 200 pounds potassium | 43.84 | 60.06 | 1.2 |
| 31 July | 1700 | Red Fife | None | 45.45 | 55.88 | 1.3 |
| 29 July | 1800 | Defiance | 80 pounds nitrogen | 42.05 | 44.87 | 1.9 |
| 29 July | 1800 | Defiance | 40 pounds phosphorus | 53.97 | 52.52 | 1.3 |
| 29 July | 1800 | Defiance | 150 pounds potassium | 47.40 | 49.11 | 1.5 |
| 29 July | 1800 | Defiance | None | 43.89 | 47.78 | 1.5 |
| 29 July | 1800 | Kubanka | 80 pounds nitrogen | 51.81 | 53.37 | 1.3 |
| 29 July | 1800 | Kubanka | 40 pounds phosphorus | 47.28 | 54.80 | 1.2 |
| 29 July | 1800 | Kubanka | 150 pounds potassium | 57.96 | 56.77 | 1.3 |
| 29 July | 1800 | Kubanka | None | 51.69 | 58.12 | 1.3 |
| 30 July | 1900 | Defiance | 40 pounds nitrogen | 49.45 | 47.42 | 1.7 |
| 30 July | 1900 | Defiance | 20 pounds phosphorus | 53.53 | 50.83 | 1.3 |
| 30 July | 1900 | Defiance | 100 pounds potassium | 47.26 | 47.92 | 1.4 |
| 30 July | 1900 | Defiance | None | 51.93 | 49.58 | 1.3 |
| 30 July | 1900 | Red Fife | 40 pounds nitrogen | 51.99 | 54.52 | 1.8 |
| 30 July | 1900 | Red Fife | 20 pounds phosphorus | 51.76 | 54.80 | 1.6 |
| 30 July | 1900 | Red Fife | 100 pounds potassium | 48.23 | 56.90 | |
| 30 July | 1900 | Red Fife | None | 49.47 | 55.51 | |

There is no question but that the tendency of the nitrate is to lessen the percentage of dry-matter in the plant. This is quite evident in the earlier samples and it is still true in the later ones though less pronounced and regular.

The samples of Defiance given in this table all seem to be remarkably low in dry matter. These are, however, the results obtained and I have no explanation to offer unless it be due to immaturity of the variety which requires about ten days longer for its normal development than the Red Fife. The preceding samples were dried in a large steam drier and then permitted to stand exposed to the atmosphere till they had absorbed as much moisture as they would under our atmospheric conditions before being weighed.

A few samples taken at random were used to ascertain how much moisture such samples contained. The average for seven samples used was 7.482 percent (Max. 8.652, Min. 5.566 percent). The samples grown with the application of nitrate contained higher percentages of moisture than the others, but the few samples tested do not justify the extension of this observation to all samples as a general rule.

## THE EFFECTS OF FERTILIZERS AS INDICATED BY THE NITROGEN CONTENT OF THE PLANT.

The data previously given lead to the questions suggested by this caption. The most important questions that present themselves in our work during a given year pertain to the part played in the nutrition and development of the plant by the inorganic constituents available in the soil. Perhaps we should consider the absolute supply and the ratio of the respective substances.

The climatic influences for any given year are eliminated by the fact that they are the same for all series of experiments made during that year and our varying results in the different individual experiments cannot be attributed to the differences in this respect. All will agree that nitrogen is the inorganic constituent of the soil most easily traced during the development of the plant and at the same time the most important one both directly as a plant food and indirectly by its influence upon the appropriation of other ash constituents, and also upon the subsequent processes within the plant, depending upon the relative quantities of these present. In order to follow these processes we adopted the nitrogen content and its various forms, the amino group excepted, as the criteria whereby to judge of the influence of the nitrogen applied in the soil. It is our intention to try to follow these throughout the development of the plant from the time of bloom till the wheat is ripe and even into the flour. In order to accomplish this purpose we shall give the total nitrogen, the proteid nitrogen, the nitrogen present as ammonia and as amid.

We omit the amino-group in our analysis of the plant because we judge it, from our experience with the beet plant, to be of little significance and its determination as involving such large errors as to be of doubtful value.

The forms of nitrogen determined are given in the tables that follow. The variety studied was the Red Fife. We were compelled to confine our efforts to the one variety for the simple reason that we could not do any more samples while they were fresh and before there could be any question of material changes. In all cases in which the green samples had to stand, even for a few hours, we chloroformed them heavily.

A number of determinations were made, using the whole plant, but we found it quite impossible to obtain good agreement in the results because of variation in the samples as weighed out.

TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANT.

| Crop 1913 | Fertilizer per acre | Total Nitrogen Percent Stems | Total Nitrogen Percent Leaves | Total Nitrogen Percent Heads | Proteid Nitrogen Percent Stems | Proteid Nitrogen Percent Leaves | Proteid Nitrogen Percent Heads |
|---|---|---|---|---|---|---|---|
| 7 July | 120 lbs. nitrogen | 0.4304 | 0.9302 | 0.7670 | 0.2579 | 0.6767 | 0.4972 |
| 7 July | 60 lbs. phosphorus | 0.3420 | 0.8214 | 0.6990 | 0.2007 | 0.5788 | 0.4320 |
| 7 July | 200 lbs. potassium | 0.3182 | 0.8282 | 0.7194 | 0.1926 | 0.5462 | 0.4537 |
| 7 July | None | 0.3318 | 0.8146 | 0.7058 | 0.2062 | 0.5843 | 0.4483 |
| 7 July | 80 lbs. nitrogen | 0.3896 | 1.3110 | 0.7534 | 0.2742 | 0.9114 | 0.5299 |
| 7 July | 40 lbs. phosphorus | 0.3250 | 0.9942 | 0.6990 | 0.2361 | 0.7583 | 0.4755 |
| 7 July | 150 lbs. potassium | 0.2866 | 0.8078 | 0.6922 | 0.2035 | 0.5788 | 0.4320 |
| 7 July | None | 0.3386 | 1.0186 | 0.6922 | 0.2388 | 0.6441 | 0.4863 |
| 13 July | 40 lbs. nitrogen | 0.3699 | 0.7725 | 0.9153 | 0.2633 | 0.4972 | ...... |
| 13 July | 20 lbs. phosphorus | 0.3019 | 0.5957 | 0.8405 | 0.1599 | 0.3939 | 0.6060 |
| 13 July | 100 lbs. potassium | 0.2666 | 0.5005 | 0.6773 | 0.1708 | 0.3231 | 0.5788 |
| 13 July | None | 0.2910 | 0.5141 | 0.8473 | 0.1953 | 0.3830 | 0.5897 |
| 21 July | 120 lbs. nitrogen | 0.3645 | 0.6909 | 0.9289 | 0.2415 | 0.4814 | 0.6387 |
| 21 July | 60 lbs. phosphorus | 0.2366 | 0.6093 | 0.8065 | 0.1436 | 0.4101 | 0.5679 |
| 21 July | 200 lbs. potassium | 0.2149 | 0.4529 | 0.8541 | 0.1505 | 0.3993 | 0.5843 |
| 21 July | None | 0.2856 | 0.5821 | 0.8065 | 0.2171 | 0.3830 | 0.5679 |
| 25 July | 80 lbs. nitrogen | 0.4733 | 1.2893 | 1.0037 | 0.4762 | ...... | 0.7311 |
| 25 July | 40 lbs. phosphorus | 0.2965 | 0.8337 | 0.8540 | 0.2307 | 0.6332 | 0.6550 |
| 25 July | 150 lbs. potassium | 0.2666 | 0.8269 | 0.8813 | 0.1926 | 0.6115 | 0.6931 |
| 25 July | None | 0.2421 | 0.5685* | 0.8133 | 0.1768 | 0.4265 | 0.6985 |
| 29 July | 40 lbs. nitrogen | 0.3237 | 0.9357 | 1.0105 | 0.2307 | 0.2222 | 0.7420 |
| 29 July | 20 lbs. phosphorus | 0.2312 | 0.6773 | 0.9629 | ...... | ...... | 0.7475 |
| 29 July | 100 lbs. potassium | 0.1986 | 0.5889 | 0.9289 | 0.1382 | 0.4918 | 0.6659 |
| 29 July | None | 0.2421 | 0.7929 | 0.8825 | 0.1550 | 0.7094 | 0.6767 |
| 4 Aug. | 120 lbs. nitrogen | 0.2611 | 1.5953 | 1.5001 | 0.1718 | ...... | 1.1446 |
| 4 Aug. | 60 lbs. phosphorus | 0.2366 | | 1.3023 | 0.1355 | | 1.0358 |
| 4 Aug. | 200 lbs. potassium | 0.1700 | | 1.3382 | 0.0947 | | 0.8508 |
| 4 Aug. | None | 0.2149 | | 1.4389 | ...... | | 1.0739 |
| 5 Aug. | 80 lbs. nitrogen | 0.3155 | | 1.2961 | 0.2035 | | 1.0140 |
| 5 Aug. | 40 lbs. phosphorus | 0.1809 | | 1.2621 | 0.1055 | | 1.0031 |
| 5 Aug. | 100 lbs. potassium | 0.1958 | | 1.3573 | 0.1164 | | 1.0847 |
| 5 Aug. | None | 0.2339 | | 1.1193 | 0.1327 | | 0.8889 |

*This determination was repeated with closely agreeing results.

The ratio of the green parts and also the dry matter in the stems and heads have been given in previous tables. No attempt has been made in these data to find the relative amount of kernels and their composition, as the dry weight of the wheat as threshed and the weight of the grain, while belonging to another step in the investigation, was considered sufficient for our purposes. Had our time permitted it, there is no question but that it would have been of interest to establish the relative weights of chaff and grain in at least, the last two samples, for these plants were fully matured. The leaves had dried to such an extent that it was not longer feasible to make a separate portion of them. In addition to lack of time it would have been almost impossible to separate the grain from the chaff without drying which would have changed, at least, the statement of our data. For these reasons these data are probabaly more serviceable in their present form than they would have been had I changed this form for part of them.

AMMONIC AND AMID NITROGEN IN GROWING WHEAT PLANTS.

| Crop | Fertilizer | Ammonic Nitrogen Percent | | | Amid Nitrogen Percent | | |
|---|---|---|---|---|---|---|---|
| 1913 | per acre | Stems | Leaves | Heads | Stems | Leaves | Heads |
| 7 July | 120 lbs. nitrogen | 0.0052 | 0.0122 | 0.0133 | 0.0054 | 0.0090 | 0.0144 |
| 7 July | 60 lbs. phosphorus | 0.0065 | 0.0101 | 0.0139 | 0.0003 | 0.0052 | 0.0112 |
| 7 July | 200 lbs. potassium | 0.0046 | 0.0122 | 0.0152 | 0.0041 | 0.0125 | 0.0117 |
| 7 July | None | 0.0060 | 0.0112 | 0.0144 | 0.0000 | 0.0108 | 0.0115 |
| 7 July | 80 lbs. nitrogen | 0.0054 | 0.0117 | 0.0125 | 0.0030 | 0.0082 | 0.0114 |
| 7 July | 40 lbs. phosphorus | 0.0043 | 0.0125 | 0.0128 | 0.0033 | 0.0060 | 0.0098 |
| 7 July | 150 lbs. potassium | 0.0035 | 0.0112 | 0.0128 | 0.0041 | 0.0095 | 0.0122 |
| 7 July | None | 0.0046 | 0.0097 | 0.0117 | 0.0035 | 0.0071 | 0.0095 |
| 13 July | 40 lbs. nitrogen | 0.0071 | 0.0242 | 0.0193 | 0.0060 | 0.0095 | 0.0199 |
| 13 July | 20 lbs. phosphorus | 0.0052 | 0.0131 | 0.0158 | 0.0043 | 0.0065 | 0.0169 |
| 13 July | 100 lbs. potassium | 0.0043 | 0.0101 | 0.0212 | 0.0133 | ...... | 0.0120 |
| 13 July | None | 0.0054 | 0.0112 | 0.0177 | 0.0049 | 0.0097 | 0.0182 |
| 21 July | 120 lbs. nitrogen | 0.0049 | 0.0144 | 0.0224 | 0.0046 | 0.0114 | 0.0166 |
| 21 July | 60 lbs. phosphorus | 0.0048 | 0.0122 | 0.0158 | 0.0075 | 0.0080 | ...... |
| 21 July | 200 lbs. potassium | 0.0048 | 0.0154 | 0.0190 | 0.0043 | 0.0093 | 0.0146 |
| 21 July | None | 0.0046 | 0.0136 | 0.0181 | 0.0038 | 0.0069 | 0.0133 |
| 25 July | 80 lbs. nitrogen | 0.0054 | 0.0205 | 0.0185 | 0.0063 | 0.0101 | 0.0207 |
| 25 July | 40 lbs. phosphorus | 0.0027 | 0.0098 | 0.0140 | 0.0030 | ...... | 0.0122 |
| 25 July | 150 lbs. potassium | 0.0033 | 0.0090 | 0.0178 | 0.0028 | 0.0076 | 0.0150 |
| 25 July | None | 0.0027 | 0.0041 | 0.0116 | 0.0024 | 0.0098 | 0.0116 |
| 30 July | 40 lbs. nitrogen | 0.0038 | 0.0131 | 0.0147 | 0.0022 | 0.0061 | 0.0095 |
| 30 July | 20 lbs. phosphorus | 0.0027 | 0.0090 | 0.0128 | 0.0053 | 0.0071 | 0.0079 |
| 30 July | 100 lbs. potassium | 0.0027 | 0.0030 | 0.0116 | 0.0035 | ...... | 0.0098 |
| 30 July | None | 0.0018 | 0.0063 | 0.0122 | 0.0019 | 0.0079 | 0.0103 |
| 4 Aug. | 120 lbs. nitrogen | 0.0071 | 0.0270 | 0.0245 | 0.0067 | 0.0110 | 0.0185 |
| 4 Aug. | 60 lbs. phosphorus | 0.0065 | | 0.0180 | 0.0043 | | 0.0154 |
| 4 Aug. | 200 lbs. potassium | 0.0048 | | 0.0146 | ...... | | 0.0140 |
| 4 Aug. | None | 0.0056 | | 0.0174 | 0.0031 | | 0.0139 |
| 5 Aug. | 80 lbs. nitrogen | 0.0057 | | 0.0131 | 0.0050 | | 0.0116 |
| 5 Aug. | 40 lbs. phosphorus | 0.0045 | | 0.0161 | 0.0034 | | 0.0160 |
| 5 Aug. | 150 lbs. potassium | 0.0050 | | 0.0146 | 0.0041 | | 0.0160 |
| 5 Aug. | None | 0.0039 | | 0.0095 | 0.0030 | | 0.0122 |

The plants gathered on 5 August were mature, so mature that the crop was harvested on the 6th August. An inspection of the table shows that the time during which these samples were taken can be divided into two periods corresponding with the universally recognized divisions of development, the growing and ripening periods. The earliest samples were taken at the period of full bloom, 7 July; the latest samples were taken at the period of full maturity.

Our object in this feature of our work had two phases, one to follow the changes in the plant during the two periods just mentioned, and the other, the principal one, which we had in view, to determine the effects of the individual fertilizers upon the development of the plant and its composition. This is the reason why we used, in these experiments, no combinations of fertilizers. The object of this investigation as first proposed is to determine, if possible, what factors or factor in our conditions it may be that determines the character and quality of our wheat. It may prove to be the case that we have no justification in fact for assuming that Colorado wheat has any general character so fixed and invariable as to entitle it to recognition, either in a favorable or an unfavorable sense. This is still, to me, though the concensus of millers and bakers is to the contrary, an open question. It seems to me not only possible, but very probable that the variation in the composition and properties of samples of wheat grown on different lands in the same section may be as different as other samples from widely separated sections of the state or even from different states. In other words I doubt whether there is any standard which we can assert is characteristic of Colorado wheat. I must, however, acknowledge that the testimony of all the bakers that I have consulted is that the flour made from our wheats is an undesirable bread-making flour, falling from thirty to forty or more loaves per barrel behind flours which are first-class for this purpose. While these statements are somewhat anticipatory of subsequent work, the results of which are not yet known, they may not be wholly amiss in this place though we have presented no facts pertaining to the wheat, except those which it possibly may have in common with the plants, in respect to its nitrogen compounds.

We may consider the results obtained with the four sets of samples taken prior to the 25th July as representing the period of development of the plant, and those obtained with samples taken on the 25th July and subsequent dates up to 6th August, as representative of the changes during the ripening period.

According to the results obtained by Wilfarth, Roemer and Wimmer, it is probable that our earliest samples were taken at about the period when the crop contained the maximum amount of nitrogen, and from this period on, if their observations be correct, both the percentage of nitrogen in the plant and the total in the crop should diminish. Our results, taking stems, leaves and heads separately, agree with this statement. Of the sixty samples of leaves and stems given, there are only two instances in which we find any departure from this. These are found in the stems and leaves of one set of plants taken on 25th July in which, for some reason, we have high results. The heads as here given include the kernels and here we find an increase in the total nitrogen. When the period of ripening sets in we observe a rapid decrease in the amount of total nitrogen present in the stems and leaves, which is evidently not compensated by the increase in both the weight and the percentage of nitrogen in the heads. Wimmer, in the article already referred to, after pointing out the similarities and differences between the results obtained with barley and spring wheat says in regard to the total nitrogen in spring wheat at harvest time, "But here also, we find at the final harvest only 80.66 percent of the maximum amount of nitrogen previously appropriated."

What is true of the total nitrogen is also true of all the several forms of nitrogen. The one exceptional sample, already mentioned in connection with the total nitrogen, is consistent with itself throughout, i. e., all forms of nitrogen are relatively high. There is one sample that is somewhat lower than we would expect and this, too, is, in the main, consistently low throughout. These features, though interesting, did not constitute the question that we set out to determine. This question was—what effects, if any, do the individual fertilizers produce upon the composition of the plant and wheat.

Of late years, great stress has been laid upon the assumed fact that climatic conditions rather than the soil conditions constitute the principal factors in determining the composition and characteristics of the wheat grown. Our direct purpose is not to combat this idea, but to determine what the effects of nitrogen, phosphorus and potassium really are under our Colorado conditions.

It is too evident to need statement that there are fundamental conditions of climate and of soil fertility requisite to the growth of a crop of wheat and we cannot eliminate these. All that we can do is to change the relative supply of nitrogen, phosphorus or potassium under identical conditions of climate, using the same variety of wheat.

In making the preceding statement, I have the following consideration in mind: It is not just to compare samples of wheat taken on a given date unless they are of the same variety or it can be proven that they are in the same stage of development which would be exceedingly difficult to establish for different varieties. Our experience in 1914 with the two varieties, Defiance and Red

Fife, illustrates the importance of this point. We had a shower on the 28th July, which was of very short duration, but violent. The Fife and Defiance were planted on the same day and on contiguous plots of ground. The Fife matures about eight or ten days earlier than the Defiance. This shower did not appear to affect the Fife in the least, while it very severely injured the Defiance by inducing a strong development of rust, and inducing premature ripening. The difference in the results was apparently wholly due to the difference in the development of the respective varieties. The Defiance was still in a stage sensitive to this fungus, while the Fife probably escaped injury because of its advanced development. Perhaps some allowance should be made for the different powers of resistance to this fungus possessed by these different varieties. The principal cause of difference, however, is doubtlessly to be found in the different degrees of maturity at the time of the rain. The data relative to the nitrogen tabulated above will serve to show the same, especially in regard to the stage of development.

This study of the nitrogen in the plant from the time of bloom to maturity exhibits the answer to our main thesis, i. e., that the nitrogen content of the plant is materially affected by the fertilizers used.

The plan of experimentation was as follows: Three sections of land, lying side by side and uniform in quality, were divided into equal plots and four plots in each section were sown to one variety of wheat. In our nitrogen work on the plant we have used Red Fife only. The plots in one section received the maximum amount of the respective fertilizers, those of the next section received the medium amounts and those of the third section received the minimum amounts. Our results would have been more valuable had we been able to sample the whole twelve plots at the same time, but we could not do this and our results are faulty insofar as we cannot eliminate the changes which took place between the dates on which the different samples were taken. For instance, two members of a set were taken on 7 July and the third one was taken six days later, 13 July. These samples are not, strictly speaking, comparable. Still the effects of the fertilizers on the nitrogen content of the plant and the various forms of it determined are very clear.

Every fourth plot throughout the series was a check plot, and it is the products of these plots that constitute the bases of our comparisons. An examination of the results obtained with the stems and leaves shows:

First, that phosphorus exercised but little influence upon the amount of nitrogen in these parts of the plant. This is essentially true of all the forms of nitrogen determined.

Second, the application of nitrogen to the soil increased the nitrogen in the plant quite materially over that present in the plants grown on the check plots. This was true for each of the different applications made.

Third, the application of potassium depressed the amount of nitrogen present in the plants below that present in those grown on the check plots.

These facts hold, but not to the same extent, for the period of ripening of the grain. These statements are also applicable to the heads, though in this case we have a continuous increase in the amount of nitrogen present instead of a decrease as in the other parts of the plant. As the plants approach maturity, the differences in the amount of nitrogen present in the heads from the plants grown on the different plots becomes less certain. This is especially true of those from the plots which had received applications of phosphorus or potassium and of those from the check plots. The plants that were grown with the application of nitrates, remained richer in nitrogen in all parts throughout the period of investigation than the other plants, without any material exception.

## THE ASH CONSTITUENTS OF PLANTS.

It is not proposed to follow the movement of the ash constituents in the plant, but simply to endeavor to determine in what sense and degree the amount of these constituents may be affected by the fertilizers used in our experiments. The observations given in this place do not include the kernels, only the plants. It is assumed that the amount of these constituents reaches a maximum at a certain stage in the development of the plant and from this time on decreases till the plant is mature. This is the case with the individual constituents in a very marked degree, except in the case of phosphorus, which recedes by only about one and one-half or two percent. That the ash constituents in the growing plant must be present in a soluble condition seems necessary in order that they should function, as we suppose them to do, and also that they should move out of the plant and return to the soil. We assume in this statement that these ash constituents return by the way of the plant itself and not by exudation or washing out by rain or by the dying and falling off of parts of the plants. With these questions we have nothing whatsoever to do, but simply to inquire in what sense and degree our fertilizers may affect them. For this purpose a number of samples were examined, but not all in the same manner. The first method used was to char the air-dried plant, extract with water and subsequently burn. This method gave the following results:

MOISTURE, SOLUBLE AND INSOLUBLE ASH IN AIR-DRIED PLANTS.

| Crop 1913 | Variety | Fertilizer Lbs. per Acre | Moisture Percent | Soluble Ash Percent | Insoluble Ash Percent | Total Ash Percent |
|---|---|---|---|---|---|---|
| 8 July | Defiance | 120 nitrogen | 8.493 | 6.220 | 2.455 | 8.675 |
| 9 July | Red Fife | 60 phosphorus | ..... | 4.206 | 2.678 | 6.889 |
| 9 July | Red Fife | None | 5.566 | 4.007 | 2.193 | 6.200 |
| 9 July | Kubanka | 200 potassium | 6.759 | 4.436 | 3.514 | 7.950 |
| 10 July | Defiance | 40 nitrogen | 8.652 | 5.165 | 2.612 | 7.778 |
| 10 July | Red Fife | 100 potassium | 7.428 | 3.340 | 3.651 | 6.991 |
| 10 July | Kubanka | 40 nitrogen | 8.379 | 3.758 | 2.473 | 6.213 |
| 10 July | Kubanka | None | 7.097 | 4.485 | 2.973 | 7.458 |

The table shows that from 50.0 to 75.0 per cent of the total ash is soluble in water. This amount is not only very high but also includes a large amount of silica which separates out on evaporation to dryness. For these reasons it seemed of some interest to determine the composition of this water-soluble ash; and at the same time to determine how its quantity and composition was affected by the addition of nitrogen compared with the water-soluble ash of plants grown without any fertilizer.

In the preparation of the preceding ashes, the ground plants were first charred and then extracted. The charring of the mass of organic matter containing so large an amount of silica and alkalis might have given rise to soluble silicates and for this reason alone the percentages of soluble and insoluble ash are not conclusive in regard to their solubility in the plant before ignition. We assume it as self evident that the mineral constituents, even the silica, are taken up as solutions and that they must continue to exist in the plant in this condition till they are either appropriated by the plant, *i. e.*, used in the formation of its various constituents, or, as in the case of the silica, are deposited in the cell walls in an insoluble form. But how long they continue to remain unchanged in regard to their solubility is not known. In order to determine whether the soluble ash obtained was formed by the ignition or existed in the plant as water-soluble salts, I extracted the ground plants with warm water. The water was not in contact with the plants for more than sixteen hours in all, so that fermentative changes probably did not bring the ash constituents into solution. The aqueous extract was evaporated to dryness, the dried mass ignited and treated as usual. The extracted plants were dried and the ash in them was determined, but not analyzed further than this, that it was treated with hydric chlorid and the amount of soluble and insoluble ash determined.

Two samples were treated in this manner. One was grown with the application of nitrates and the other without the application of any fertilizer, but both were of the same variety and taken on the same date, 8th July, 1913.

WATER-SOLUBLE ASH OF AIR-DRIED WHEAT PLANTS.

| | Plants Grown with 120 lbs. of Nitrogen per Acre Percent | Plants Grown Without Any Fertilizer Percent |
|---|---|---|
| Ash constituents soluble in water | 5.363 | 4.277 |
| Ash constituents insoluble in water, but soluble in hydric chlorid | 0.400 | 0.327 |
| Insoluble ash (silica) | 2.561 | 2.487 |
| Total ash | 8.324 | 7.091 |

ANALYSIS OF WATER-SOLUBLE ASH.

| | Percent of Air-Dried Plant | Percent of Air-Dried Plant |
|---|---|---|
| Silicon | 0.282 | 0.377 |
| Iron | 0.003 | 0.003 |
| Manganese | 0.002 | 0.001 |
| Calcium | 0.134 | 0.090 |
| Magnesium | 0.088 | 0.066 |
| Phosphorus | 0.204 | 0.225 |
| Potassium | 2.396 | 1.752 |
| Sodium | 0.035 | 0.028 |

No provision was made in the preparation of this ash to prevent loss of phosphorus and yet the water-soluble phosphorus is very high. Whether it existed in the plant as phosphoric acid or not does not appear, but it seems probable that the most of it did, and yet very considerable quantities of iron, calcium and magnesium were present in the aqueous solution, which scarcely would be the case under ordinary conditions. We know that the magnesium is a part of the chlorophyll molecule and is probably not precipitable by phosphoric acid while in this combination. Possibly a like explanation might be offered in the other cases. There is no question but that the plants grown with the application of nitrogen have larger leaves which are of a much deeper green color and yield an extract much more heavily charged with coloring matter than those grown without it. Consonant with this we find the magnesium and calcium both higher, in the plants grown with the application of nitrogen, by at least one-third.

It is a recognized fact that the application of sodic nitrate to wheat results in the production of a soft, weak straw and a tendency for the wheat to lodge. Whether this result is due to suppression of silica in the straw or to some other effect upon the growth of the plant, for instance the production of large, thin-walled cells, especially in the lower internodes of the plants, with very heavy leaves and heads is, to my knowledge, nowhere stated. The softness of the straw and its lack of harshness to the touch suggests that the silica in the straw is small in amount, whether this be the cause of the weakness or not. The following determinations of total silicon were made to ascertain whether and to what extent the silicon in the straw may be suppressed by an increased supply of nitrogen in the soil.

SUPPRESSION OF SILICON IN STRAW DUE TO NITROGEN.

| Date of Harvest | Variety | Nitrogen Lbs. per Acre | Moisture Percent | Silicon Percent | Difference |
|---|---|---|---|---|---|
| 28 July, 1913 | Defiance | 120 | 9.395 | 1.656 | |
| 28 July, 1913 | Defiance | None | 8.274 | 1.817 | 0.252 |
| 31 July, 1913 | Red Fife | 120 | 9.544 | 1.029 | |
| 31 July, 1913 | Red Fife | None | 7.564 | 1.236 | 0.207 |
| 29 July, 1913 | Defiance | 80 | 8.177 | 1.190 | |
| 29 July, 1913 | Defiance | None | 8.711 | 1.649 | 0.459 |
| 6 Aug., 1914 | Defiance | 120 | 9.802 | 1.192 | |
| 6 Aug., 1914 | Defiance | None | 9.533 | 1.708 | 0.516 |
| 6 Aug., 1914 | Red Fife | 120 | 9.724 | 1.134 | |
| 6 Aug., 1914 | Red Fife | None | 9.205 | 1.391 | 0.257 |
| 6 Aug., 1914 | Kubanka | 120 | 9.515 | 1.169 | |
| 6 Aug., 1914 | Kubanka | None | 9.550 | 1.557 | 0.388 |

While there is in each of these cases a depression of the silicon in the straw due to the nitrogen applied it seems too small, especially if we consider the large amount in the plant, to cause the softness and weakness noted. This statement considers only the question of the total amount of silicon present. It is possible that there may be a difference in the form in which the silicon may be present due to the action of the increased supply of nitrogen. Further, there might be a difference in its distribution in the different parts of the plant. Silicon for instance deposited in the glumes or in the blades of the leaves or in the upper portion of the stems would not tend to prevent lodging if the lower internodes were so deficient in silicon that they could not support the plants in an upright position. We assume in this statement that it is true that the stiffness of straw is due to the silicon in it.

There is a decided difference in the tendency of the different varieties to lodge. The Red Fife has scarcely lodged at all on our plots even with the maximum application of nitrogen. The Kubanka has lodged some but not badly while the Defiance has lodged badly with the minimum application of nitrogen. That this is due to the nitrogen applied there can be no doubt for in every case so far (about twenty of them), the limits of the application of the nitrogen were sharply marked in the case of the Defiance by the lodging. The amount of silicon in the whole straw, however, is fully as high as in the other varieties, so it would not seem to be a question of the total amount of silicon present.

The effect of fertilizers upon the amount of silicon contained in the first internode below the rachis indicates that the Red Fife is influenced less than the Kubanka which is in keeping with the observation that the Red Fife resists the action of nitrogen in producing lodging or weakness of the straw. I have figures for Red Fife and Kubanka, showing the effect of fertilizers upon the amount of silicon in the upper portion of the stem, but none for Defiance.

SILICON IN THE TOP INTERNODE OF THE STEM.

| Date of Harvest | Fertilizer Lbs. per Acre | Red Fife Si Percent | Kubanka Si Percent |
|---|---|---|---|
| 31 July, 1914 | 120 nitrogen | 0.535 | 0.543 |
| 31 July, 1914 | 80 phosphorus | 0.559 | 0.612 |
| 31 July, 1914 | 150 potassium | 0.509 | 0.826 |
| 31 July, 1914 | None | 0.508 | 1.174 |

SILICON IN DIFFERENT PARTS OF STRAW.

| Date of Harvest | Variety | Part of Plant | Fertilizer per Acre | Silicon Percent |
|---|---|---|---|---|
| 6 Aug., 1914 | Kubanka | Leaves | 120 pounds nitrogen | 2.846 |
| 6 Aug., 1914 | Kubanka | Leaves | None | 3.520 |
| 31 July, 1914 | Kubanka | Top of stem | 120 pounds nitrogen | 0.543 |
| 31 July, 1914 | Kubanka | Top of stem | None | 1.174 |
| 6 Aug., 1914 | Kubanka | Middle of stem | 120 pounds nitrogen | 0.381 |
| 6 Aug., 1914 | Kubanka | Middle of stem | None | 0.658 |
| 6 Aug., 1914 | Kubanka | Bottom of stem | 120 pounds nitrogen | 0.402 |
| 6 Aug., 1914 | Kubanka | Bottom of stem | None | 0.684 |

This variety, Kubanka, was chosen for these determinations because it seemingly responds to the effects of nitrogen in regard to the silicon to a less degree than the Defiance and to a greater one than the Red Fife and we assume the results to be of more general application than those obtained with the other varieties. These results show that an increase in the supply of available nitrogen suppresses the amount of silicon contained in these different portions of the plant.

There is some difference shown in the relative amounts of soluble and insoluble silicon in plants grown with and without addition of nitrogen to the soil. It seems to be the fact that the application of sodic nitrate suppresses the amount of silicon soluble in water to a greater extent than it does the insoluble silicon. This, however, is only a tentative statement based on the work that has so far been done.

The distribution of the ash in the different parts of the plant, the extent and manner in which it is affected by the application of nitrates has been studied in part, but not thoroughly. The results obtained, however, agree with those already presented, indicating that the effect of the nitrogen upon the intake of inorganic constituents by the plant is very strongly modified.

SOLUBLE AND INSOLUBLE ASH IN PARTS OF WHEAT PLANT.

| Variety | Date of Harvest | Fertilizer per Acre | Part of Plant | $SiO_2$ per cent | HCl. Sol. per cent | Total Ash per cent |
|---|---|---|---|---|---|---|
| Kubanka | 6 Aug., 1914 | None | Chaff | 13.762 | 2.595 | 16.357 |
| Kubanka | 6 Aug., 1914 | None | Leaves and sheaths | 7.500 | 5.135 | 12.635 |
| Kubanka | 6 Aug., 1914 | None | Top section of stem | 1.986 | 3.892 | 5.878 |
| Kubanka | 6 Aug., 1914 | None | Middle section of stem | 1.401 | 3.915 | 5.361 |
| Kubanka | 6 Aug., 1914 | None | Bottom section of stem | 1,457 | 2,614 | 4,071 |
| Kubanka | 6 Aug., 1914 | $NaNO_3$ | Chaff | 9.526 | 2.495 | 12.021 |
| Kubanka | 6 Aug., 1914 | $NaNO_3$ | Top section of stem | 1.156 | 4.080 | 5.236 |

The effect of the sodic nitrate, corresponding in this case to 120 pounds of nitrogen per acre, is evidently in the same direction as indicated by our preceding data, *i. e.,* to a suppression of the silicon and a relative increase in the amount of soluble ash.

These results are the same for the later stages of growth and even for the ripe plant.

We notice that at an early stage in the development of the plant, the period of bloom, the phosphorus and silicon are higher in the plants that received no fertilizer and that the potassium is much higher in those which received an application of nitrogen.

That portion of the ash constituents insoluble in water, but soluble in hydric chlorid was not analyzed. It was, however, evaporated to dryness and again taken up with dilute acid to see if any silica had been dissolved by the hydric chlorid, which was insoluble in water. The result in both cases was negative, so it would seem that the silica existed in the plant at this time in two forms, one soluble in water and the other insoluble in concentrated acid. The soluble form is much less in the plants grown with the application of nitrogen than in those grown without it. The insoluble portion was already deposited in the cell-walls. This fact was easily observed in the microscopic examination of the properly prepared ash in which the stomata with their guard cells, the epidermal cells, the collenchymatous cells with their thickened angles, hairs and other parts were easily recognized. These various cells were apparently not so distinct, or heavily built up with silica, as in samples taken later.

It was not at first intended to extend the examination of the plants to include the mineral constituents, but the facts already stated made it advisable to include these determinations in our presentation of the effects of the fertilizers applied. The statement of the mineral constituents of the straws does not include the sulphur and chlorin, and is to this extent incomplete. These substances would have been included had we in the beginning supposed that we would have any good reason for considering this feature at all.

I have had some difficulty in finding data which show what the variations may be in the mineral constituents of wheat straw under ordinary conditions. The most of the data I have found has been taken from Wolff's "Aschenanalysen" without any explanations as to what the data represent. The figures given below to represent the general analysis of the ash of wheat straw, have been taken from Van Slyke's "Fertilizers and Crops."

The methods followed in the determination of the mineral constituents of the straw will be given at a future time. It may, however, be stated here that we found it impossible to determine the phosphorus by direct incineration in the presence of so much silica and carbon.

THE MINERAL CONSTITUENTS OF AIR-DRIED WHEAT STRAW.

| | Ca Per cent | Mg Per cent | Fe Per cent | Mn Per cent | K Per cent | Na Per cent | P Per cent | Si Per cent |
|---|---|---|---|---|---|---|---|---|
| General Analysis. | 0.21 | 0.08 | 0.02 | ..... | 0.48 | 0.05 | 0.12 | 1.45 |
| Defiance— | | | | | | | | |
| 31 July, 1913. | | | | | | | | |
| Nitrogen ...... | 0.22 | 0.08 | 0.03 | 0.012 | 1.81 | 0.04 | 0.07 | 1.54 |
| Phosphorus ... | 0.11 | 0.03 | 0.01 | 0.002 | 0.99 | 0.02 | 0.06 | 2.08 |
| Potassium .... | 0.13 | 0.03 | 0.01 | 0.001 | 1.09 | 0.01 | 0.09 | 2.19 |
| Check ......... | 0.16 | 0.05 | 0.02 | 0.009 | 1.20 | Trace | 0.08 | 1.94 |
| Fife— | | | | | | | | |
| 31 July, 1913. | | | | | | | | |
| Nitrogen ...... | 0.21 | 0.09 | 0.02 | 0.002 | 1.53 | 0.12 | 0.12 | 1.76 |
| Phosphorus ... | 0.14 | 0.05 | 0.01 | 0.002 | 1.00 | 0.02 | 0.06 | 2.09 |
| Potassium ..... | 0.15 | 0.05 | 0.02 | 0.002 | 1.23 | 0.01 | 0.09 | 2.36 |
| Check ......... | 0.19 | 0.08 | 0.02 | 0.009 | 1.05 | 0.02 | 0.12 | 1.97 |
| Kubanka— | | | | | | | | |
| 6 August, 1914. | | | | | | | | |
| Nitrogen ...... | 0.16 | 0.03 | 0.01 | 0.003 | 0.96 | 0.14 | 0.03 | 2.40 |
| Phosphorus ... | 0.11 | 0.02 | 0.01 | 0.002 | 0.72 | 0.05 | 0.02 | 2.70 |
| Potassium ..... | 0.08 | 0.02 | 0.01 | 0.001 | 0.77 | 0.09 | 0.02 | 3.00 |
| Check ......... | 0.18 | 0.07 | 0.01 | Trace | 1.05 | 0.09 | 0.03 | 2.60 |

The manganese determinations are given for the purpose of showing that this element is uniformly present but the percentages are not correct as they represent only that portion of the manganese that was carried down as an oxalate with the calcium oxalate. The portion of manganese thus carried down varies greatly even when only small quantities are present, as in these cases, but the results serve perfectly for the purpose for which they are given.

The amount of sulphur given by Van Slyke is five one-hundredths of one percent.

It appears from the results presented that the mineral constituents of the plant as represented by these straws are decidedly influenced by the relative food supply furnished by the soil. I am aware that this view was held for a long time as almost self-evident, but so much stress has been placed of late years upon the effects of "climatic conditions" as influencing the composition of the wheat kernels, which has been and will doubtlessly continue to be the chief object of study in connection with this plant, that the influence of the soil and its composition has been relegated to a comparatively subordinate position.

The application of sodic nitrate has increased the total amount of ash and produced, in addition to its effects upon the nitrogenous constituents, three effects upon the mineral constituents of the plants, which appear from data given in this connection. The three effects here alluded to are the depression of the silicon and the increase of the potassium and calcium. The increase of the latter two elements is very pronounced in two of the three vareties of wheat used in the experiments. Another result is that the sodium is uniformly increased by the application of sodic nitrate, but the total amount of sodium present in any case is so small and our ignorance of the part that sodium may play in the nutrition of the plant is so great that we are compelled to consider it an open question whether this is not to be considered an accidental constituent which has been increased by its association with the nitrogen applied. The application of the sodic nitrate has also, as a rule, increased the magnesium while its effect upon the amount of phosphorus in the plant seems to be nil.

The application of phosphorus and potassium to the soil seem uniformly to have lowered the amount of phosphorus in the plant which is, perhaps, a matter for some surprise.

The amount of potassium in the plant does not appear to have been influenced perceptibly by the application of either phosphorus or potassium. That the variety experimented with has some influence is suggested rather strongly by the results obtained with the Kubanka, though these samples were grown in 1914 and were entirely ripe when gathered.

We have now given the composition of our soil, the soil moisture, the total water received during the season of 1913, the nitric nitrogen in the soil for different dates throughout the season (1913) to two depths, namely, to the depth of four feet, represented by series of samples taken on ten different dates, and to the depth of twelve feet represented by five series of samples taken on two dates, also the total nitrogen in the soil at different dates. Concerning the ash of the plant, we have given the amount soluble in water, the total, the distribution of silicon in the plant and the relative quantities of the constituents.

The data so far given are almost wholly for the experiments of 1913 and the results represent the effects of our conditions of soil under identical climatic conditions.