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RAISING HOGS IN COLORADO

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BY

H. M. COTTRELL

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RAISING HOGS IN COLORADO

H. M. COTTRELL

ADVANTAGES IN COLORADO FOR RAISING HOGS.

The feeds raised in Colorado for fattening animals are the feeds which produce the choicest flavor in meat that it is possible to secure. Delicious flavor is the marked characteristic of Colorado-fed meat, whether it be beef, mutton, pork, or poultry.

Barley is adapted to every tillable section of Colorado, with the possible exception of the Arkansas Valley. It yields well, is a cheap crop to produce, and barley-fed pork, because of its flavor, sells for the highest prices in every market in the world where it is offered.

Field peas is one of the best yielding and cheapest grown crops in the mountain valleys that have an altitude of 6,500 to 8,000 feet. The flavor of pea-fed pork is considered by many epicures to be richer and more toothsome than that produced from any other feed. Barley yields well in all pea-growing sections, giving the feeders the benefits from both grains. These high valleys cover a large area, one, the San Luis, having a tillable area as large as the State of Connecticut.

Alfalfa thrives on a large part of the cultivated area of the State. Hogs make cheap gains on both the pasture and the hay, and alfalfa gives a choice flavor to the meat.

Barley, milo maize and wheat are profitable hog feeds, and are the surest grain crops for the dry land farming of the plains. Usually in the dry land sections much more can be made from wheat by feeding it to hogs than by selling it for grain.

Pork can be produced cheaply with proper management in Colorado. Barley, under irrigation, costs less an acre to raise than corn in the Mississippi Valley states, and will produce more pork. From 500 to 1,000 pounds of gain can be put on hogs during the season from an acre of alfalfa pasture. It costs, including the rent of the land, from $3 to $6 an acre to raise field peas, and feeders estimate that an acre of good peas, when pastured off, will put 400 pounds of gain on hogs.

MARKET SUPPLY AND DEMAND.

Denver is the chief packing center of Colorado, and hogs have been received at the Denver Union Stock Yards as follows:

	1906	1907	1908
Hogs from all sources	192,720	241,393	280,228
Hogs from Colorado points	17,000	33,951	61,049
Received from Colorado	8.82%	14.06%	21.78%

The larger part of the hogs received at Denver come from western Nebraska and western Kansas. Shipments of fresh pork are made every week throughout the year to Denver from Kansas City and Omaha, the average being two to three cars weekly. Experts in the meat business estimate that there are shipped annually from packing houses in the corn belt to Rocky Mountain territory and the Northwest, of which Denver is the gateway, pork and pork products worth from $12,000,000 to $16,000,000.

One hundred thousand hogs are needed each month in Denver territory to supply the demand for pork and pork products.

THE HOG THE COLORADO MARKET WANTS.

The Colorado packer wants a well-finished, fat, blocky hog weighing alive from 220 to 250 pounds. During the winter months there is a good, but limited demand for the city whole carcass trade, for well-finished hogs weighing alive from 150 to 175 pounds each.

Hogs weighing alive 220 to 250 pounds each, will supply cured hams weighing 16 to 18 pounds, and sides of bacon weighing 10 to 12 pounds each. These weights command a premium of 75 cents per hundred pounds above lighter hams and sides.

Well finished hogs, only, are wanted. The hog should be well fattened and rounded out, the flesh coming well down on the hocks, and the fat on the sides should be from 1 to 1½ inches thick. In a finished hog the flesh will be firm and hard to the touch, and the hair will be smooth and lustrous.

The flesh should be firm, the fat pure white, and the best consumers want a good proportion of lean.

Most of the Colorado hogs marketed in the past three years have been unfinished and too light in weight. A well finished hog will dress 80 per cent.; the average at the Denver packing houses in 1908 was 73 per cent.

The chief trouble has been that most Colorado farmers neglect their hogs through the summer, stunting them, and stunted hogs do not finish well. An unfinished, stunted hog weighing 150 pounds, will dress about 65 per cent. Bacon from such hogs sells at wholesale for one-half that from finished hogs. The bacon from the unfinished, light hogs, when cooked, consists of skin and flabby, soft meat, and the consumer is dissatisfied.

The flesh on the live, unfinished hog is soft and flabby to the touch, and the hair has a dead appearance. The meat from an unthrifty hog is always soft, and that from thin hogs is usually soft.

A common fault is uneven quality in a shipment, some hogs being of good weight and well fattened, and others small or thin. Unless the demand is pressing, a car load of mixed hogs will sell for the price which the poorest are worth.

Every defect in the form of the live hog, or in his condition, lowers the price of the marketable products from him, and brings a corresponding reduction in the price paid to the feeder. Every hog raiser should spend a day in the market with experts from the stock yards and packing houses, and learn to know how a choice hog appears and the feel of his flesh. The feeder should go to the packing houses and see the difference in the character of the cuts made from well fattened and from unfinished hogs.

THE BEST BREED OF HOGS FOR COLORADO.

The best breed is the breed that the grower likes best. There are more differences in the individuals of any breed than there are between choice animals of the different breeds. A good hog, well bred from a prolific strain of any of the popular breeds of hogs,

THE BERKSHIRE.
A Prize Winning Berkshire.*

will make money for the Colorado farmer when handled right.

There are four breeds that have been found to be particularly adapted to Colorado conditions: Berkshire, Duroc-Jersey, Poland-China, and Tamworth.

Whatever breed the feeder selects, he should stay with it, and not change or cross with another breed.

White hogs are generally not profitable in Colorado. The intense sunshine blisters and cracks their tender skins so that they become runts. Often this blistering is so severe that running sores are formed. A few Colorado farmers have made good profits from

*Owned by J. De Bon, Nashville, Tenn.

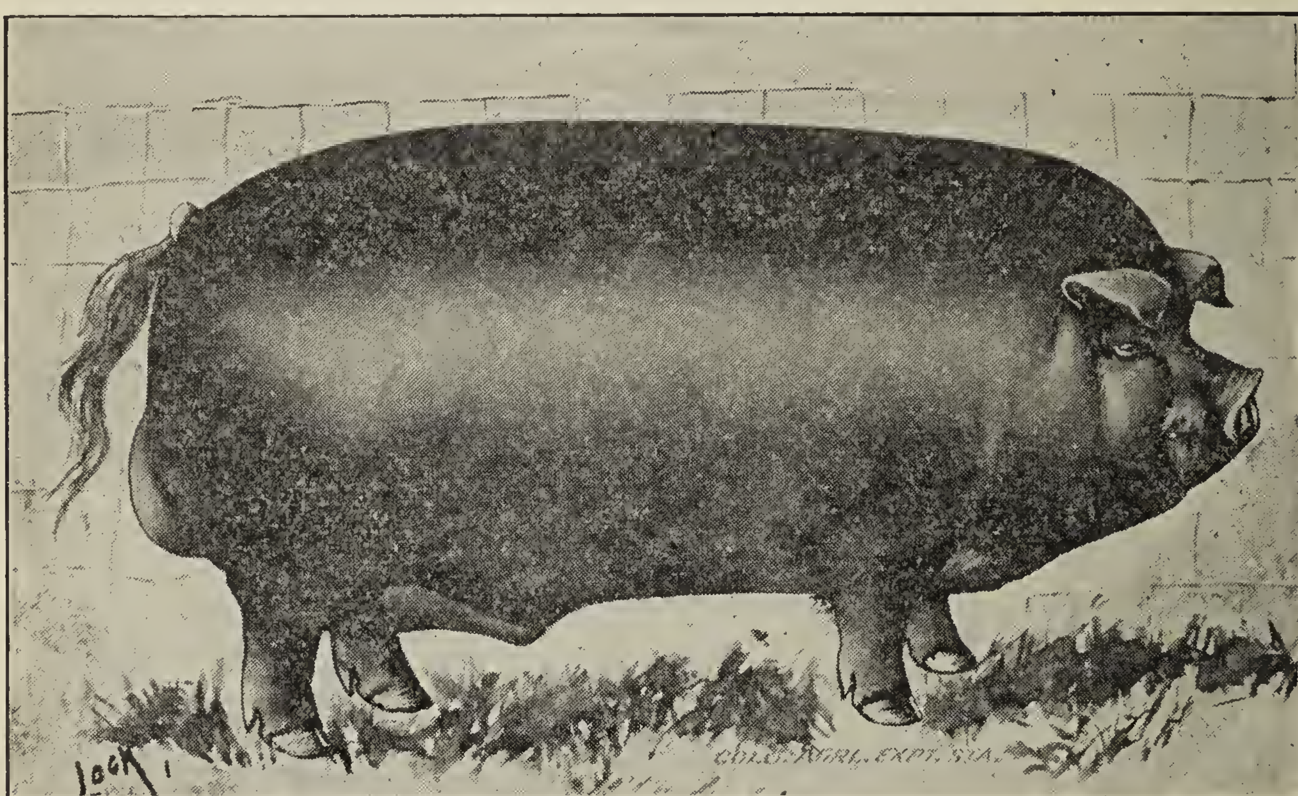
white hogs by keeping them in pastures having heavy shade.

The Berkshire is hardy and active, adapting itself to any condition suitable for raising hogs, and may be developed either into a bacon or a lard hog, according to the feed given.

It is more energetic than some of the other breeds, and on this account requires a better fence. Its activity makes it a good hog for pasturing and for following cattle in the feed lot, and this gives it a well developed muscular system that furnishes a good proportion of lean in the meat.

The Berkshire is a good feeder, matures early and may be fattened at almost any desirable age.

The sows are careful mothers and good sucklers. Originally



THE DUROC-JERSEY.
Prize Winning Duroc-Jersey.*

the Berkshire was very prolific, and many strains are productive today. Some families have been bred to concentrate the blood lines of prize-winning animals until they have become shy breeders, and in selecting animals for breeding, especial attention should be given to securing those with prolific ancestors on both sides. The Berkshire is strong in transmitting characteristics to the offspring.

The Berkshire is an attractive hog, black with white on face, feet and tip of tail. Its head, nose and legs are short, and for this reason the breed is a prime favorite with packers because of the small per cent. of waste from these cheap parts. The fat and lean are well distributed in the meat, making a high quality of pork.

The Duroc-Jersey is a typical lard hog of good length with a

*Owned by C. F. Burke, Rocky Ford, Colorado.

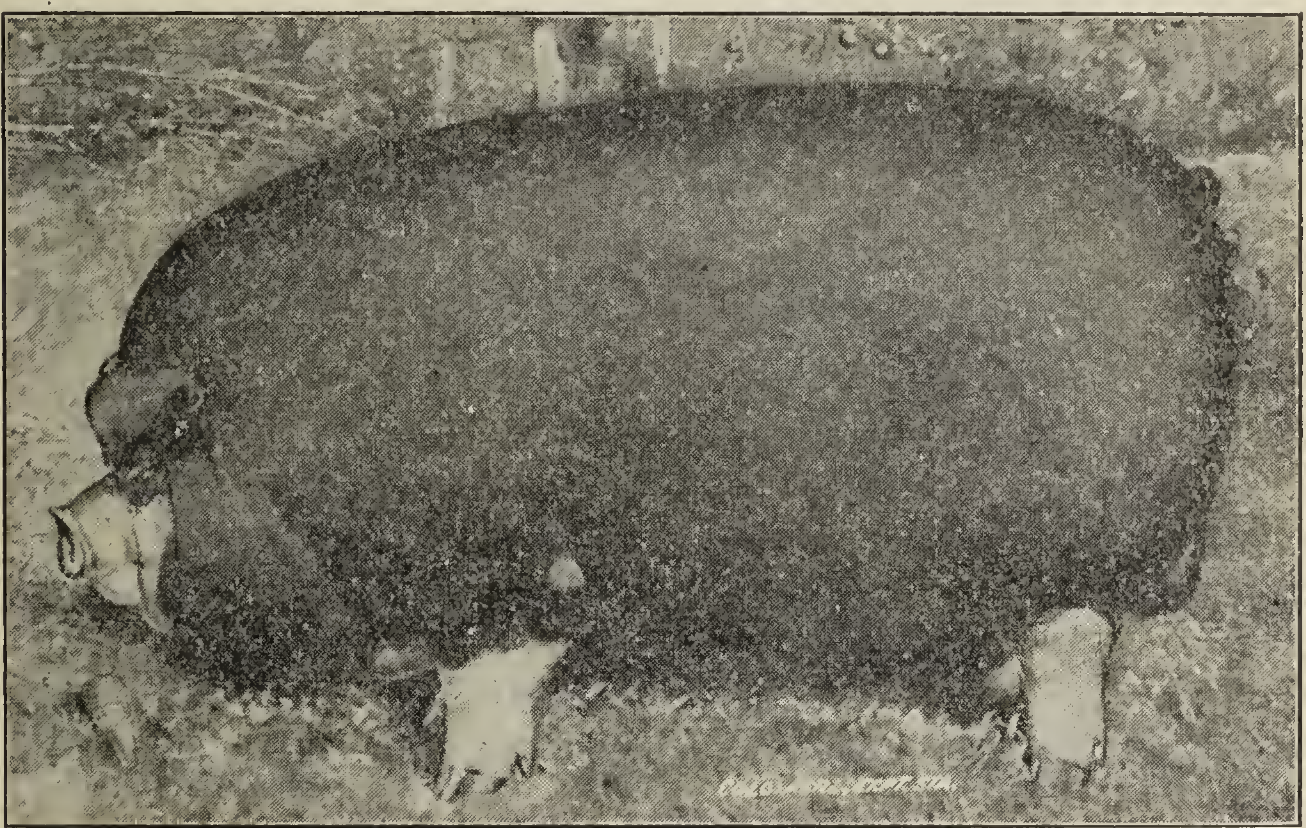
smooth, thick-meated body, built close to the ground. It is solid red in color.

It is an active, hardy hog, a good feeder and a good grazer. When well fed, it matures early, and if kept until full grown can be made very heavy.

The Duroc-Jersey is a prolific breed. Records taken from hundreds of sows by the U. S. Department of Agriculture show an average of nine pigs to the litter.

Mature sows can be handled in Colorado to have two litters a year, and the prolific character of the breed, together with its good feeding qualities, have made the Duroc-Jersey very popular.

The carcass often shows more bone than either the Berkshire or the Poland-China, and the meat is often not so fine grained.



THE POLAND-CHINA.
Prize Winning Poland-China.*

Duroc-Jerseys for breeding should have constitution and quality. Coarseness of bone and hair, particularly of the hair along the back, should be avoided. Hogs of this breed are inclined to have weak pasterns, and breeding animals should be selected that are strong in this respect.

The Poland-China is an almost perfect meat making machine. It is not excelled by any breed of any kind of live stock for converting feed into flesh. It has a voracious appetite, a good digestion, and is lazy—not using much of its energy in travel or excitement. It will stand heavy feeding and considerable neglect.

*Owned by H. C. Dawson & Sons, Endicott, Nebraska.

When properly handled, it is ready for the market at any time after six months of age, whenever the price is right.

It is a typical lard hog, with a thick, short, massive body, fine quality of bone, hair and skin, small, fine head and short legs. It is thick fleshed with heavy shoulders and hams, and broad, thick loins. The meat is fine grained, but with too large a proportion of fat in the matured animal.

The chief fault with many strains of the Poland-China is that through over-feeding of corn they have become poor breeders, having only one to four pigs in a litter. Such pigs are usually choice feeders, but the number in a litter is too small to make it profitable to keep the sow.

THE TAMWORTH.

Champion at World's Fair—Tamworth, Weight 1,000 Pounds.*

Where sows are selected from prolific strains and fed muscle and bone-making feeds, they are as prolific as any breed. Three Poland-China sows on the Colorado Agricultural College farm had thirty-one live pigs at one farrowing. Records compiled by the U. S. Department of Agriculture of several thousand Poland-China sows showed an average of 7½ pigs to the litter.

The Tamworth is a strictly bacon hog with a smooth, long, deep, thin body, and looks to most people like a "razor back." It has been bred to produce as large a proportion of its weight as possible in an even thickness of choice bacon.

The two strongest characteristics of the Tamworth are lean

*Owned by W. Weaver Morton, Russellville, Tennessee.

meat and large litters. For three years on the Colorado Agricultural College farm the average for all sows was ten live pigs to a litter. A two-year-old sow weighing 750 pounds had 18 live pigs at one farrowing. Fully matured sows, well cared for, can produce two litters a year. A Tamworth sow at the Iowa Agricultural College raised 33 pigs in one year. The Tamworth is solid red in color, and is hardy and active—a good hog to keep on pasture.

The first cross with a pure bred Tamworth produces an easy feeding, rapid growing hog that is generally popular. The second cross is usually unsatisfactory, the pigs in the same litter frequently being of entirely different types, some chunky and others extremely lengthy, with an unpleasant variety in mixtures of colors.

Most Colorado stockmen who have tried the Tamworths do not like them. As a rule, Colorado stockmen neglect their hogs in summer when the field work crowds, planning to give them extra attention in the fall. With this treatment the Tamworth becomes stunted, and once stunted he can never be made profitable, and had better be killed. The surplus fat on the lard hog will carry him over a period of neglect—the Tamworth does not have the lard.

SELECTION OF THE INDIVIDUAL.

The selection of breed is a matter of fancy; the selection of the individual animals for the foundation of the herd is the basis for profit or losses.

The first consideration should be to get both boar and sows from prolific strains, and of the type demanded by the market. Except during the few weeks when the pigs are suckling, it costs as much to keep a sow that has one to four pigs in a litter, as it does to keep one that has eight to ten pigs. The first cost of the new born pig is determined by the cost of keeping the dam, divided by the number of pigs in the litter.

Uniformity in type is essential for the largest profits. No two breeds or types feed exactly alike, and where there is a mixture there is a variation in finish and weight that lowers the selling price. Both the boar and all the sows should be pure bred, of one breed, and of the same type. Miscellaneous crossing is a sure way to reduce the profits.

There are three serious defects to avoid in selecting animals for breeding stock: Weakness through the heart, weak or swayed back, and weak pasterns. These are faults which the swine growers of the corn belt have learned from years of costly experience to avoid, and no other good qualities will compensate for these defects.

Most of the Colorado stockmen have had but little recent experience with hogs, and look only for good development in ham and shoulder. Breeders in the corn belt have learned this, and ship to Colorado breeding stock that on account of light heart, sway back, or weak pasterns is unsalable at home.

With Berkshire, Duroc-Jersey and Poland-China hogs, the most valuable parts are the hams, back, sides and shoulder. The animal should have a back broad and arched, deep, thick-meated sides, and heavy ham and shoulders. The different parts of the body should blend smoothly into each other and be evenly covered with flesh.

In selecting Tamworths, the animals should be strongly of the bacon type; the body of great length between shoulder and ham, the sides deep, and the shoulders and hams light, uniting evenly with the body, so that a straight edge placed on the ham and shoulder will touch the side along its entire length.

HOW TO START WITH HOGS.

For capital, labor and time required, there is no business of any kind in Colorado that is paying larger profits than raising hogs where the grower is an expert. As high as 300 per cent. net profit has been made in six months under ordinary farm conditions.

The possibilities of so large profits have induced many farmers and business men who have had no experience with hogs to go into the business.

Many of these beginners with no knowledge have started on a large scale and have lost money. Handling hogs profitably requires skill and experience, and the beginner should start slowly and not get these at too great a cost.

Select any one of the four breeds you like best—Poland-China, Berkshire, Duroc-Jersey, or Tamworth.

Get a good judge of hogs to select for you from one to five sows, not more. Select good individuals that come from prolific strains on both sides.

The man who has had no experience with hogs should start with one choice brood sow. His herd will increase as fast as his ability to manage it.

With careful management, from 12 to 20 pigs should be raised each year from a prolific, mature sow.

The beginner should study his hogs closely, becoming acquainted intimately with their habits, their likes and dislikes, learning what they need and what is bad for them.

Cheapness in production is the first point to be mastered by the beginner. In his breeding he should work for large litters, early maturity and quality.

Starting with one sow, it will pay to buy a mature one that has shown that she will produce good pigs and raise eight to ten at a litter. She should have two litters a year.

Cheap shelter can be made with straw, sod or boards. The beginner can watch his small lot of hogs carefully, and learn how to make them grow rapidly at least expense.

If any trouble occurs it can usually be seen in a small lot of pigs before it is past curbing. When there is a loss it cannot be heavy and the grower gets his experience cheaply.

The second year three or four of the best sow pigs should be saved with their dams.

The third year the grower should have learned enough about growing hogs to be able to handle ten sows and their produce, and after that he should know enough to slowly increase his hog herd to the limit of his farm.

Cheap shelter and fences should be used until the profits from the hogs will pay for better ones. No large building should be erected until hogs have been grown several years on the farm and the breeder is sure of what he wants and where he needs to locate it.

Success in hog raising is determined by intelligent daily, sometimes hourly, care, attention to many small details, and good judgment. When a farmer decides to become a hog raiser, he should plan to stay permanently in the business. Just before the last panic hogs were high and farmers in many sections of the State invested in them. Prices dropped, and many new beginners sold out even the brood sows. In six months prices were again high.

FEED AND MANAGEMENT OF THE BOAR.

The boar is more than one-half the herd, so far as influence goes. Each year he may show his strength or weakness in a hundred or several hundred pigs, and it is most important that he should be of the right type and in great bodily vigor with such strongly bred ancestors behind him on both sides that he will with certainty produce pigs of uniformly profitable type, good feeders that will mature early.

No matter how superior an animal a cross-bred boar may be he cannot be depended upon to transmit his qualities to his pigs. There is a constant likelihood of the pigs inheriting the characters of their scrub ancestors, and no farmer can afford to use any but a pure bred sire.

The boar should be evenly balanced, good in every point. The custom of selecting a boar unusually strong where the sows are weak and perhaps weak where they are strong, is a dangerous one. The pigs can most easily inherit the weak characteristics of both parents.

The newly purchased boar should be brought to his new home at least six or eight weeks before he is to be used and accustomed to his new surroundings.

As soon as he arrives, he should be thoroughly dipped or washed with some of the coal tar dips for destroying lice, and given the same treatment after ten days. For three weeks after arrival he should be kept at a safe distance from all other hogs on the farm; then, if found free from disease, he may be placed in quarters near them. Dipping and quarantine should be applied to every hog or pig that is brought to the farm, as it will often prevent serious losses from lice and disease that would otherwise be carried by the new purchase to the swine already on the farm.

The boar pig should be pushed with growing feeds, so that he will make a gain every day until he reaches full, mature weight. A mixture of any two or more of the following grains is good: Corn, barley, or milo maize, with wheat, peas, or shorts. A liberal supply of skim milk is especially good. He should have all the alfalfa he will eat every day, either pasture or hay. A small feed of roots or cooked potatoes is good. Stunting, even for a short time, will permanently injure his value. He should weigh 300 to 400 pounds when 12 months old.

After reaching full growth, the boar, when not in service, should be given bulky feeds that will keep him full, satisfied, and in good condition, but that will not put on fat. Alfalfa, roots, and a small daily ration of any kind of grain.

A few weeks before the beginning of the breeding season the grain feed should be gradually increased, giving a mixture the same as when he was growing, and the amount of roots and alfalfa should be slowly reduced. The animal should be put in perfect condition and good flesh, but not made fat. The best results are not secured from a sire that is either fat or thin.

During the breeding season the boar should have an abundance of food, using the same combination as recommended for him while growing, except that just sufficient succulent feeds (alfalfa and roots) should be given to keep his bowels in good condition. A full supply of succulent feeds at this time is likely to make him infertile.

A boar should not be used for much service until he is at least twelve months old. A fully matured boar produces the most vigorous pigs, other things being equal, and if properly fed and handled, may be profitably kept for several years. His tushes should be cut or knocked off as often as they show considerable size.

The boar should serve a sow but once, and two sows a day should be the limit for a mature boar, and then he should have a day's rest after every second or third day. He should be used before being fed. Handled in this way, a mature boar is sufficient for fifty sows. Over service results in pigs that are dead, weak, or puny at birth.

The boar should have comfortable shelter at all times—dry and free from draughts. His surroundings should be kept free from vermin. Remember, that from a breeding standpoint, he is half the herd. He should have daily exercise to keep him healthy and muscular. A half-acre pasture will furnish this. He will keep better natured and be easier to handle if allowed to run with the barrows outside the breeding season. If allowed to run with the sows during the breeding season, he will weaken himself by over service. At other times there is danger that he will injure the sows.

Keeping him in close, dirty quarters, or allowing him to range over the farm and neighborhood half starved, are both sure ways of making him valueless. Too much attention is rarely given to the boar, and his health and comfort should be looked after every day throughout the year.

It pays to train a boar from his first service to the use of a breeding crate. With it, any size and weight of boar can be mated with any size and weight of sow without injury to either.

FEED AND MANAGEMENT OF THE SOW.

A large litter of heavy, vigorous pigs at weaning time is the foundation of profits. The sow should be selected and from birth should be fed and handled to produce such litters.

The sow pig intended for a breeder should be pushed for the first year and given feeds that will make rapid growth, but that will not fatten. Such feeds as milk, alfalfa pasture, or hay, and moderate quantities of grain, such as wheat, peas, barley, milo maize, and shorts. She should weigh from 300 to 375 pounds at 12 months of age when in thrifty condition, but not fat. Ample exercise every day is necessary for health and to develop muscles and lungs. If the sow has made a good growth, she may be bred to drop her first litter when she becomes twelve months of age. She should be in perfect health and in good flesh when bred. The gestation period for the sow is 112 days.

While pregnant, the sow should be given muscle and bone-making feeds that will develop in the unborn pigs size and strong vital organs. The same feeds are needed for this purpose that are required by pigs after weaning. When the sow has good alfalfa pasture, only a small quantity of grain is needed. The sow should be kept in good flesh, but not fat. A heavy condition of flesh is favorable if it is put on with muscle-making feeds and the sow has been given ample exercise. Under feeding is extremely detrimental. The pigs from a half-starved sow are weak and undersized at birth, and are stunted while suckling from lack of sufficient milk.

Constipation in the sow while she is pregnant, or suckling, must be avoided. Pig eating is often caused by constipation. Laxative and bulky feeds, such as pasture or alfalfa hay, will prevent this trouble, and should form part of the daily ration. Exercise is necessary to keep the bowels in good condition. Small feeds of roots are good. Heavy feeding of roots is often the cause of weak or dead pigs at birth. Feeding frozen roots is likely to cause abortion. The pregnant sow should be fed, sheltered, exercised, and handled in such a way as to keep her in good flesh and health. Everything that facilitates this condition tends to secure pigs with greater vigor and more profitable as feeders.

A blow or a strain of any kind to the belly of the pregnant sow is likely to result in pigs dead at birth, or pigs born the wrong way, with the consequent injury to the sow, or her death. Sows had to step over a six-inch board in passing through an opening between their yard and pasture. There were many dead pigs at farrowing, and some of the sows died from trouble while giving birth. The ground next to a hog pen was eight inches lower than the floor, and the brood sows had to climb over this step—dead pigs and dead sows at farrowing time was the consequence. Potatoes were dug with a plow and the land left in ridges. Pregnant sows had to travel over these to get to a pea field. At farrowing time there were many dead pigs, and two sows died. A boar allowed to run with sows that are bred will frequently knock them around and bring the same trouble. Horses or cattle running in a lot with brood sows will often injure the sows the same way. Not over five to ten bred sows should be allowed to sleep together, as crowding in cold weather may result in losses at farrowing time. Pregnant sows should not be allowed to run with fattening hogs.

A breeding record should be kept, and two weeks before the pigs are expected the sow should be placed in a farrowing pen connected with a dry yard large enough to allow her to exercise. The feed should be somewhat reduced, without any sudden change, and her bowels kept loose. She should have dry, sunny shelter, free from draughts. The sow should be petted so that she will like to have her feeder handle her.

It is best to have the sows farrow at nearly the same time and then the owner can watch them day and night during farrowing time. There should be just enough bedding for comfort and dryness. Cut straw or chaff is best. Little pigs often get tangled in deep straw and are either crushed by the sow or die from exposure. Give the sow as little attention as possible while she is farrowing, unless she must have assistance. In severe weather place the pigs as fast as they come in a basket in which a blanket is laid over a warm stone. Keep them well covered, and after all are born and have become warm and dry, take them to their mother and place each one at a teat. Then cover the mother and pigs. During the first forty-eight hours watch carefully, and if a pig strays from its mother, put it back against her body where it will be warm.

Give the sow all the water she wants for the first twenty-four hours after the pigs are born, but no grain. Take the chill off the water in cold weather. For three or four days after the first twenty-four hours, give plenty of water, but feed grain and milk sparingly. Then slowly increase until, when the pigs are three weeks old, the sow is having all the feed she will consume. Give the pigs exercise and sunshine from birth, but do not allow them to get damp nor to be exposed to the wind.

When the sow is given a warm, rich slop, or other milk-producing feeds just after her pigs are born, a strong milk flow is forced. The new-born pigs get too much and have diarrhoea, which often kills them. They cannot take all the milk, and the sow's udder becomes inflamed and caked. When the pigs suckle, the pain becomes so intense that in desperation she jumps up, kills, and eats them.

Overfeeding and lack of exercise cause the thumps in young pigs, but usually in Colorado, when pigs are thought to have the thumps, they actually have pneumonia, due either to damp beds or exposure to draughts.

Good sows improve for several years in the number and size of the pigs they have at a litter. The U. S. Department of Agriculture compiled the records of over six thousand sows and found yearling sows averaged 6.65 pigs per litter, and five-year-old sows averaged 8.4 pigs per litter. At the Wisconsin Experiment Station year-old sows averaged 7.8 pigs per litter, with an average weight per litter of 14.2 pounds, while sows from four to five years old averaged 9 pigs per litter with an average weight per litter of 26 pounds. The common practice of farmers selling their old brood sows each year and reserving immature ones for breeding is a bad practice, as the older sows are much better mothers and their pigs have a strong advantage in greater vitality at the start.

The beginner had better arrange to have the pigs born in May, when the sows can be turned on pasture soon after farrowing. Most experienced Colorado hog raisers do not want pigs to come in March or in the first half of April on account of storms and winds. February is a good month for farrowing. The weather may be cold, but there is usually little wind and the yards are not muddy.

The period of gestation is 112 days, and the sow may be bred three days after the pigs are weaned. When mature sows are to have two litters a year, the sow, if bred October 12th, will farrow about February 1st. Allowing the pigs to suckle nine weeks, they will be weaned about April 4th, and the sow bred the second time three days later. The second litter will then be born about July 28th, and if suckled ten weeks, will be ready to wean about October 7th.

FEED AND MANAGEMENT OF THE GROWING PIG.

Pigs should not be weaned until they are at least eight weeks old, and if the sow is not to have a second litter, or if there is time enough in case she is, it is better to let the pigs suckle until they are ten or twelve weeks old. Farmers often get in a hurry and wean pigs when six weeks old; but unless there is an abundant supply of milk, and especially good care is given, the pigs are likely to become stunted, sometimes so severely that they never recover.

The cheapest way to put gains on young pigs is through the sow. She has a strong digestion and can turn coarse grains and pasture into easily digested milk.

The sow should be fed to produce a high yield of milk, and the pigs should be kept with her until they get to eating a full feed of both grain and pasture.

Pigs will begin to nibble at feed when they are about three weeks old. At this age they should be given a little milk in a trough separate from the mother. After they get to drinking the milk freely, add a little soaked whole grain—barley, wheat, peas, milo maize, or corn. Do not give more than they will eat up clean at one time, and clean the trough well before each feeding.

The boars should be castrated before being weaned.

When the time comes to wean the pigs, cut down the sow's ration to water and alfalfa hay. She will dry up without injuring her udder. When she is giving a large supply of milk and all the pigs are taken away at once, her udder is often ruined and she becomes unable to suckle another litter.

When first weaned, feed the pigs from three to five times a day. While with their mother, they took their meals at least every two hours, and too sudden a change is detrimental. After they get to growing vigorously, cut down to two meals a day, and when they weigh 75 pounds each and are on good pasture, feed once a day, and that at night.

When first weaned, feed the pigs some skim milk, if possible. It makes the change from mother's milk easier. Whole milk is good, but as butter fat is worth $400 to $960 a ton, it is expensive pig feed. Tankage will take the place of milk, when made about one-fifth the total weight of the grain fed.

A variety of feeds will give larger and cheaper gains than will any single feed. Peas, barley, wheat, rye, milo maize, and corn are the grains to use in Colorado. Soak from 24 to 48 hours, each time, feeding a mixture of at least two grains.

Do not sour the feed, and keep the troughs, pails, and barrels used in feeding sweet and clean.

Half the weight of a two-hundred pound pig should be made from pasture. Alfalfa makes the best pasture, followed by rape, clover, and a mixture of wheat, oats, and barley sown thickly.

A pig should be fed some grain every day. After he gets to growing well, a small quantity of grain is sufficient, but it is never profitable to keep a growing pig on pasture alone and without grain. The pig should make a regular daily gain from birth to fattening without a check of any kind. The growth should be made with the least possible daily feed of grain and the largest profitable amount of forage. Careful daily attention can only determine what these amounts should be.

Pigs need fresh, clean water always before them. If a well is not convenient, the water can be supplied cheaply in barrels to which are attached hog waterers. Do not water directly from a stream. It often carries disease.

They must have warm, dry, clean shelter, free from draught, every night in the year, and they need a shade from the midday sun.

FINISHING FOR THE MARKET.

From 60 to 75 days before the pig is to be marketed he should be confined in limited quarters and fed heavily on grain until he becomes well finished and fattened. Up to this time he should be kept growing every day, but fed as little grain and as much forage as can be done and maintain a thrifty growth, and he should be given ample exercise.

Fattening hogs will make the greatest gains when they have just enough exercise to keep their appetites sharp. A fattening hog should be limited to half an acre, and 25 fattening hogs kept on this area will do better than a greater number. The hogs should be sorted to lots of even size and age, and no matter how many are being fattened, not over 25 should be allowed to run together. Brood sows should not be kept with fattening hogs.

The hogs should be fed at regular hours, either two or three times a day, and at each feed should be given just a trifle less than they will eat up clean. The profits come from inducing the hog to consume a large quantity of grain and maintain a sharp appetite. The feeder will secure the best results by watching the hogs each time until they finish eating. He will then know whether the hogs are slow about cleaning up the feed, showing over feeding, or whether they clean up the feed quickly and need more.

The hogs should have all the clean, pure water they will drink at least three times a day. Colorado feeds are rich in protein, and a hog eating them needs much more water than when eating corn.

The hog should, before being marketed, be well fattened, smooth and well rounded with a good outer covering of fat, and be firm and solid to the touch. If the feeder will go into a pen of thin hogs and feel them along the loin and back, and then into a pen of well fattened hogs, he can quickly learn the "feel" that indicates a good finish. The hogs should be sorted to an even size and weight before being shipped.

FEEDING HOGS AT THE COLORADO EXPERIMENT STATION.

The results obtained from seven feeding experiments with hogs have been published.

Colorado Experiment Station Bulletin 40. W. W. Cooke.

1894-'95	Pounds Feed Required for 100 lbs. Gain	Gain Per Pig Pounds
California Feed Barley	540	88
Corn	560	76
California Feed Barley	430	105
Corn	430	113

1896-'97	Pounds Feed Required for 100 Pounds Gain	
	Grain	Skim Milk
Whole Corn	700	110
Ground Corn	540	110
Whole Bald Barley	500	130
Ground Bald Barley	360	80
Whole California Feed Barley	540	70
Ground California Feed Barley	430	110
Ground Corn and Feed Barley	410	80

Professor Cooke concluded that one-half more ground corn was required to make a pound of growth than when ground barley was fed, and that feeding corn and barley together produced a quarter more growth on a fifth less feed than feeding the two grains separately. Ground bald barley was one-half better than whole bald barley. Ground feed barley was one-twelfth better than whole feed barley, and ground corn was one-fifth better than whole corn.

Colorado Experiment Station Bulletin 74. B. C. Buffum, C. J. Griffith:

1900 1901	Pounds Feed Required for 100 lbs. Gain	Gain Per Head Pounds	Dressed Meat Per Cent	
Corn ⅔, Barley ⅓	544	110	86.1	Pigs at start weighed 150 to 160 pounds each. They ate a little more than ½ pound of hay per head per day. Hay chopped and mixed with slop. Pigs ate about one pound of beets per head daily.
Alfalfa Hay	49			
Corn ⅔, Barley ⅓	528	105	87.4	
Corn ⅔, Barley ⅓	555	96.4	87.1	
Sugar Beets	103			
Second Test				
Corn	643	65.5	78.6	
Wheat, Oats ½	487	85.6	79.2	
Barley			79.2	
Corn ½				
Shorts ½, Corn ½	609	73	77.4	
1902				
Sugar Beets chopped in small pieces..	6130	16.75	77	Pigs 100 pounds each at start.
Ground Wheat and Barley equal parts .	450	120.25	84	
Corn, shelled........	540	71.25	88	
Ground Wheat and Barley equal parts .	420			
Sugar Beets	400	98	84	

Prof Buffum concluded that sugar beets were unprofitable, either alone or in combination with grain. Pigs weighing 100 pounds each, fed 99 days all the sugar beets they would eat, and no other feed, made an average gain per head of 16.75 pounds. It required 61.3 pounds of beets to make one pound of gain, one ton of beets producing 32.6 pounds gain. Where sugar beets were fed with wheat and barley, one ton of beets took the place of 150 pounds of the mixed grain. With a mixture of ground wheat and barley worth $1.00 per 100 pounds, corn was worth 83.3 cents per 100 pounds. The grain showed a greater feeding value than that grown in the humid section.

Colorado Agricultural College, "News Notes." G. E. Morton:

	Pounds Feed Required for 100 Pounds Gain.				Gain Per Head Lbs. 12 Weeks
	Grain	Hay	Tankage	Sugar Beets	
Barley, Alfalfa Hay	469.4	59.8			109.3
Corn, Alfalfa Hay	556.0	74.1			99.1
Barley, Sugar Beets	483.9			469.9	88.9
Corn, Sugar Beets	591.7			518.6	76.7
Barley ½, Corn ½, Alfalfa Hay	450 3	61.4			119.5
Barley ½, Wheat ½	499.6				103.6
Barley ½, Peas ½	513 3				98.7
Barley ½, Shorts ½	476.1				106.1
Barley 9 10, Tankage 1 10	417.4		47.2		120.1
Corn 9 10, Tankage 1 10	394.1		42.8		132.5

The pigs averaged 80 pounds each at the start.

Professor Morton concludes: To sum the matter up, corn and tankage make a very cheap and satisfactory ration, producing the largest gains of any ration used. Barley and tankage makes a cheaper ration than barley and wheat, or barley and peas, but not quite so cheap as barley and shorts, although producing the second largest gains. Barley, corn and alfalfa hay proved a very satisfactory ration, being second only to corn and tankage in cheapness, and producing the third largest gains of any ration. The corn and alfalfa hay ration did not prove satisfactory, being the costliest ration used, with the exception of the beet rations. The beet rations were not in the running.

The amount of feed required for one hundred pounds of gain is given, so that one can figure the cost with the prices that prevail in his community.

Dry alfalfa hay was fed in racks, and comparing barley and alfalfa hay with barley and wheat, barley and peas, and barley and shorts; one ton of alfalfa hay had a feeding equivalent of 233 pounds of shorts, 1,000 pounds of peas and 1,467 pounds of wheat.

COLORADO HOG FEEDS.

Field Peas.—The chief pea feeding section in Colorado is the San Luis Valley, where the altitude is from 7,500 to 8,000 feet.

Field peas are seeded on unplowed ground in fields of 40 to 320 acres. No further attention is given except to irrigate once or twice. The vines grow and bloom, and the pods fill until killed in the fall by frost, when they cure on the ground without being cut. Hogs are turned into the field, gather the crops, and when fat are shipped to market.

It costs, including the rent of the land, from $3 to $6 an acre to raise peas, and feeders estimate an acre of good peas will put 400 pounds of gain on hogs when pastured off.

Sometimes the peas are harvested and stacked, and the unthreshed vines fed from the stack to hogs confined in yards. An acre of good peas fed in this way will put from 600 to 800 pounds of gain on hogs.

A new method of harvesting field peas at a low cost has been lately developed. The frosted vines are left on the field until they become well cured, and are then gathered without being cut, with the bull rakes used in haying. Some vines are left where the bull rake is started in, but as soon as a full forkful gathers on the rake, the vines are taken up clean without shelling; when a load is gathered, the rake is driven to the stack and the vines placed on the stack with an ordinary hay stacker. Three teams and five men with this method, can gather and stack 20 acres a day at a cost not to exceed $1 an acre.

The pork from hogs well fattened on peas is firm, sweet and tender, and has a most delicious flavor. The following figures show the actual cost per acre to a grower in the San Luis Valley:

Seeding	$ .35
Seed, 60 pounds at $1.75	1.05
Labor irrigating	.25
Water rent	.08
Rent of land	3.00
	$4.73

The crop was gathered and stacked, and the unthreshed vines fed to fattening hogs confined in a small lot. The hogs made a gain of over 700 pounds for each acre of peas consumed.

Hogs fed peas alone fatten unevenly, some finishing quickly, while others gain, but become unthrifty, showing that a diet of this one grain does not agree with them. Denver packers report that one-half the pea-fed hogs marketed from the San Luis Valley in 1908 were in an unfinished condition.

There are three reasons for this: Peas is a concentrated feed, rich in protein, and feeding them alone to hogs is like giving a man beefsteak only. Where the leaves are eaten with the grain, they help dilute the feed, and it is profitable to feed barley or wheat once a day. A few trials indicate that a light daily feed of potatoes or roots is beneficial for hogs fattening on peas.

Hogs drink a much greater quantity of water when eating peas than they do when given a starchy feed like corn. When hogs are confined in a small lot, and the peas are fed close to a trough of water ,they will take a drink of water between every mouthful or two of peas. When turned into large pea fields to fatten, hogs often have to travel from one-fourth to three-fourths of a mile to water and they wait too long between drinks. Most hogs will travel too much in a large field to finish well.

The peas are often stacked and the unthreshed vines fed through the summer to breeding stock and growing pigs. Sows on this feed give milk abundantly, but become very thin.

The quality of the pork and the cheapness of its production merit a wide development in pea feeding. San Luis Valley has a tillable area equal to the entire state of Connecticut; and if one-half this tillable area was devoted to hog raising, there could each year be marketed from the valley over three million well fattened hogs. The area of land in Colorado adapted to pea growing outside of the Valley is probably greater than that in the Valley.

Field peas thrive in Colorado at an altitude of 6,500 to 8,000 feet. They have, so far, not proved to be a profitable crop at lower elevations. Mr. J. H. Empson, Longmont, who raises hundreds of acres of peas for canning each year, and has made a careful study for 20 years of pea growing, stated to the writer that he believed that field peas would be a profitable crop on irrigated land at an altitude of 5,000 feet, if they were seeded in February. Later seeding would certainly fail.

Barley is adapted to every tillable section of the State, except possibly the Arkansas Valley. The feed and malting varieties of barley yield well in irrigated sections having an altitude of from 5,000 to 7,500 or 8,000 feet, and bald barley is adapted to the plains and to high altitudes. The yield of barley in the irrigated sections will produce more pork per acre than will the average yield of corn in the corn belt. Barley is produced at less cost per acre in the irrigated sections of Colorado than corn in the Mississippi Valley.

The English market is the most critical in the world for bacon, and Denmark sells to England each year bacon from barley-fed hogs to the value of over eighteen million dollars. Danish bacon from barley-fed hogs sells on the English market for an average of 46 per cent. above the average of the American bacon from corn-fed hogs. The high yield of barley, the cheapness of its production, its adaptability to all sections of the State, and the superior quality of the pork made from feeding it, should make Colorado a great hog raising state.

Barley feeding produces fine pork with choice flavor and a white fat—the three qualities demanded for the highest priced pork products.

The feed and bald barley are not as appetizing as corn, and hogs grow tired of them. It is, therefore, best to feed the barley in combination with some other feed or feeds. Alfalfa, peas and wheat maintain the appetite well. The Danish and Canadian feeders generally use skim milk or buttermilk, and both of these dairy products improve the quality of the meat.

Wheat tests made at many experiment stations show that pound for pound, wheat is equal to corn for making gains on fattening hogs. Professor Buffum found, at the Colorado Experiment Station, that a mixture of equal weights of wheat and barley was worth 17 per cent. more than corn for fattening hogs.

Wheat is largely used for fattening hogs in Western Colorado and on the Plains, and the pork from it is likely to be tough and to waste unduly in cooking. Part of this is probably on account of many wheat-fattened hogs not being well finished. The fat has a dingy color. Often the price of wheat, or the distance to market make it much more profitable to feed it to hogs than to sell it as grain. In such cases the hogs should be fed for 60 to 75 days with barley, field peas, or corn, as these feeds whiten the fat and improve the flavor and texture of the meat.

Wheat Bran.—This feed contains too much woody fibre to be a profitable feed for either growing pigs or fattening hogs. It is sometimes useful to feed to mature breeding animals, when bulk, with a moderate amount of nutrition is wanted, and may be used as a laxative feed just before farrowing. The leaves of alfalfa hay have every good quality of bran as a hog feed, are more nutritious and much cheaper.

Wheat Shorts and Middlings are especially good feed for suckling sows and young pigs, and for fattening purposes are worth about 8 per cent. more than an equal weight of corn.

Oats.—The meat of the oat is excellent hog feed. The hull has about the same value as straw. Usually the high price and the per cent. of husk make it unprofitable to feed oats to fattening hogs.

When oats are fed to hogs they should be ground, and for young pigs the hulls should be sifted out. Oats whiten the fat and give a good flavor to the meat, and can sometimes be used with profit as part of the ration in finishing hogs fattened on wheat or rye. A mixture of equal parts, by weight, of ground wheat and oats, make an excellent ration for growing pigs.

Emmer, usually called speltz, is a drought resisting grain crop, and is a good feed for horses, cattle and sheep, but a poor hog feed, as it has too much husk.

Milo Maize is one of the best drought resisting crops, and is well adapted as a grain crop for hog raising for the Plains. It should be either ground or soaked. One hundred pounds of milo maize is equal to ninety pounds of corn for fattening hogs. The average amount of pork that can be produced an acre per year is much greater under dry land farming with milo maize than with corn. Milo maize is constipating, and some laxative feed should be given with it, such as alfalfa hay, flax seed, in small quantities, sorghum fodder cured green, tankage or bran.

Rye makes a good feed for growing hogs. It has the same defects as wheat and should be prepared and used in the same way as wheat.

Tankage consists of the scraps and trimmings of meat and bone from the packing houses, cooked, the fat removed and the residue dried and ground. It is rich in protein and in mineral matter, and should be fed in small quantities mixed with grain. It is of special value when fed with starchy grains, such as barley, corn and milo maize, and when fed with these grains in the ratio of 95 pounds of grain to 5 pounds of tankage, will reduce the amount of feed required to make 100 pounds of increase in live weight from 20 to 35 per cent. Tankage-fed hogs finish well, the flesh is fine and the hair and skin thrifty.

Tankage is the best substitute for skim milk for feeding pigs just weaned, and should form one-fifth of the total weight of grain fed for a short period, and then one-tenth, until they get to eating alfalfa well.

Skim Milk.—No other feed is equal to milk for feeding pigs just weaned. It makes the change from mother's milk easier. Whole milk is good, but as butter fat in Colorado is worth from $400 to $960 a ton, it is expensive pig feed. Skim milk should be fed sweet and mixed with the grain. It has the greatest value when not over three pounds of milk are fed for each pound of grain, and when fed in this ratio, from 325 to 475 pounds of skim milk have a feeding value equal to 100 pounds of grain for feeding hogs.

Skim milk is a valuable feed for fattening hogs, and it improves the quality of the flesh. The high quality of both Canadian and Danish bacon is undoubtedly due, in considerable measure, to the feeding of skim milk or buttermilk to hogs throughout their lives. Milk is an easily digested feed, it aids in the digestion of the grain fed with it; it is appetizing and healthful, and fed to the growing pig promotes development of muscle and bone.

Buttermilk, fresh untainted, and not diluted or over salted, has a feeding value equal to skim milk.

Sugar Beets.—In experiments made at different times by Professor Buffum and Professor Morton, at the Colorado Experiment Station, it was found unprofitable to feed sugar beets to hogs.

Professor Buffum concluded that sugar beets were unprofitable either alone or in combination with grain. Fed alone, one ton of sugar beets were required to produce 32.6 pounds of gain, and when sugar beets were fed with wheat and barley, one ton of beets took the place of 150 pounds of grain.

Professor Morton reported that when sugar beets were fed with grain to fattening hogs, they proved wholly unsatisfactory.

At the Experiment Stations of Montana and Utah, sugar beets fed in small quantities with grain to fattening hogs were found to be valuable.

Professor Day, of Ontario, made many experiments in feeding roots, and found that in feeding roots with grain to fattening pigs, one ton of sugar beets was equal to from 250 to 330 pounds of mixed grain. He obtained the best results by feeding equal parts by weight of beets and meal. The influence on the firmness of bacon was very favorable.

Potatoes.—No tests have been made of feeding potatoes to fattening hogs at the Colorado Experiment Station. Several other stations have tried them, and it has been found that potatoes alone do not make a satisfactory feed, and that raw potatoes have little feeding value. Potatoes cooked until dry and mealy and mixed with raw grain make a palatable feed, and from 400 to 450 pounds of potatoes are equal to 100 pounds of grain.

Apples.—There are a good many cull apples available for feeding hogs in the fruit sections of Colorado. Three tests of feeding apples with grain were made at the Utah Experiment Station. In one, apples were of no value; in the second, 25 pounds of apples were required to make one pound of gain; and in the third test, apples were equal to grass pasture.

Squash.—In some sections of Colorado stockmen fatten hogs exclusively on squashes, feeding them raw. They report profitable returns per acre with meat of good flavor, but with an objectionable yellow color. We have been unable to secure any data upon the pounds of pork made per acre of squash.

Gleanings.—Many Colorado farmers have found it profitable to put a hog fence around their farms. After the crops are harvested, the hogs are given the run of the farm. They pick up the scattered grain in the stubble fields, graze on the alfalfa, and eat what beets and beet tops they want. Hogs given good shelter thrive well under these conditions, and often several hundred dollars' worth of pork is made from feed that would otherwise be wasted.

PASTURE FOR HOGS.

Grain is high priced in Colorado, and at least half the weight of a 200-pound hog should be made from forage. Raising a hog without pasture in Colorado usually is a losing business. At the same time, a growing pig should have some grain every day, no matter how good the pasture. Sometimes it is profitable to keep dry, mature sows on pasture alone, but it may be taken as a general rule that every hog should have some grain every day of his life.

The feeder should keep a close daily watch on his growing pigs and keep them steadily gaining in weight, using the least amount of grain and the largest amount of pasture that can be done and secure a regular, good growth.

No matter what the size of the pasture, it is best to divide it into at least two lots and change from one to the other as the hogs eat the feed down. Hogs do not thrive best on soiled pasture, and do better when changed often enough to keep the feed clean.

Rings may be put in the hog's noses to prevent them from rooting, but if the pasture is sufficiently large and some grain is fed daily, the hogs will do little damage from rooting and are better off for it.

Alfalfa makes the best hog pasture. It is best not to pasture it until the second or third years of growth, and in Colorado alfalfa will usually furnish good feed from April 20th to Christmas, and sometimes later.

When hogs are fed some grain daily, they will make from 500 to 1,000 pounds of gain during the pasture season from an acre of good alfalfa after deducting the gain which the grain will make if fed alone.

An acre of alfalfa pasture is sufficient for from five to twenty pigs, depending on their size, the richness of the land, the season, and the amount of water available for the growth of the plants. It does not pay to pasture too close, and a good plan is to allow an acre of alfalfa for each sow and her pigs, and cut for hay what they leave.

Dwarf Essex Rape is next in value to alfalfa for hog pasture. It is similar in appearance to cabbage that does not head. It is a rapid grower, starts up again quickly after being pastured down, and will withstand severe frosts. It does well under dry land farming if seeded so early that it becomes well developed before drought and hot winds come. The writer has found it green and thrifty in the

San Luis Valley in November under eight inches of snow.

Rape is an annual, and can be sown as early in the spring as oats. It may be sown at any time from March to September. When planted in rows two feet apart and cultivated, from three to five pounds of seed are required per acre. Sown broadcast and irrigated, from five to six pounds of seed are needed per acre. Oats, or a mixture of oats, wheat and barley, may be drilled in deeply and rape sown broadcast afterward and covered lightly.

Hogs should be turned on rape when it is from eight to ten inches high. If the hogs do not keep the rape eaten down, it should be clipped with a mower occasionally. Where hogs run in tall rape it is likely to make sores on their backs.

At the Wisconsin Experiment Station, where shotes were fed grain and pastured on Dwarf Essex Rape, one acre of rape was equivalent to 2,600 pounds of grain.

Grain Pasture.—In the San Luis Valley and on the plains grain is often sown for hog pasture, using double the amount of seed necessary for a crop of grain. Rye is hardy, makes the earliest pasture, but soon becomes tough and bitter. Winter wheat pasture lasts longer than rye pasture. Good results have been obtained by sowing in the spring, a mixture of winter wheat, oats and barley, and reseeding once or twice during the summer.

Sorghum, sown in narrow rows and thoroughly cultivated until a foot high makes a good hog pasture in the dry land section of the Plains.

Sweet Clover makes a good hog pasture on dry lands and on alkali land in irrigated sections. Especially good profits have been made pasturing hogs on sweet clover with a little grain on alkalied land in the San Luis Valley.

HAY FOR HOGS.

Alfalfa Hay.—A Colorado hog should have alfalfa every day in the year. When pasture is not available, the hog should have bright, early cut alfalfa hay. At the Kansas Experiment Station the writer fattened one lot of hogs on all the grain they would eat, and another lot on all the grain and all the dry alfalfa hay they would eat. The alfalfa was cut early and was fed just as it came from the stack, forkfuls of whole hay being thrown in shallow troughs, the pigs being allowed to eat the leaves, and the waste stems being thrown out. The hogs on grain alone gained 524 pounds, while the hogs fed grain and hay gained 909 pounds. One ton of alfalfa hay took the place of 868 pounds of grain.

Professor G. E. Morton reported a test made at the Colorado Experiment Station in which one ton of alfalfa hay had a feeding equivalent of 233 pounds of shorts, of 1,000 pounds of peas, and of 1,467 of wheat. Of course, alfalfa hay does not in itself have any such great feed value, but the hog eating alfalfa hay digests a greater proportion of the grain eaten.

The leaves only, are of value, the stems being too woody, and the hogs should be fed a sufficient quantity so that they will get all they want when they have eaten the leaves. For this reason it does not pay to cut or grind alfalfa hay for hogs, as these methods compel the hog to eat the indigestible stems. In a test made by the writer, hogs fed whole alfalfa hay ate 515 pounds of grain for each 100 pounds of gain, while those fed finely cut alfalfa hay required 538 pounds of grain for each 100 pounds of gain.

Alfalfa for hay for hogs should be cut when the first few blooms appear, cured with as little exposure to the sun as possible, and handled in such a way as to preserve the leaves. In feeding tests made by the writer with hogs fattened on grain and alfalfa hay, a ton of early, green-cured alfalfa hay was equivalent to 868 pounds of grain, and a ton of alfalfa hay cut late was equivalent to 333 pounds of grain.

Pea Hay.—In the San Luis Valley peas are harvested and stacked after the vines are killed by frost. The unthreshed vines are fed to brood sows and growing pigs through the summer. It is an advantage to feed the vines with the peas, and as in the case of alfalfa hay, the pigs should be fed enough so that they will eat the leaves only.

Sorghum Hay.—On the Plains, sorghum is thickly planted in rows, cut when the seeds are in the milk, and cured in large cocks. The green hay made by this method is a valuable feed to give in winter with grain.

WATER FOR HOGS.

Most Colorado hog feeds are rich in protein, and animals eating such feeds need a much larger amount of water than hogs fed on starchy feeds like corn. It is usually best to mix ground grain with water to make a thick slop, but no matter how much slop is fed, hogs should have easy access at all times to clean, pure water, separate from the feed.

It is dangerous to let hogs have access to irrigation ditches or streams, as these are great carriers of disease. A convenient way to water hogs is to mount a barrel on a small sled and attach a hog waterer. As many barrels and sleds can be used as are needed to maintain a full supply of water, and by this method the water can be placed in the pasture or feed lot where the hogs can reach it without travel. A hog should drink small quantities of water often, and not overload the digestive tract with large quantities, as he will when he has to travel a considerable distance for it.

PREPARATION OF FEED.

Grinding and Rolling.—The dry climate and intense sunshine in Colorado make the grain much harder and more flinty than those grown in the humid region. It is, therefore, usually not profitable to feed dry, whole grain. Rolling is preferable to grinding, and requires less power. Rolled grain is left in the form of flakes, while in grinding hard grains like Colorado barley, the ground particles of grain have sharp edges that are objectional. At the Colorado Experiment Station, Professor Cooke reported that ground bald barley was one-half better than whole bald barley; that ground feed barley was one-twelfth better than whole feed barley, and that ground corn was one-fifth better than whole corn.

Soaking.—The general experience of swine feeders in Colorado is that soaking grain from 24 to 48 hours has the same beneficial effect as grinding, at less cost, but with more trouble. Care must be taken in hot weather not to let the soaking grain sour, and in cold weather to keep it from freezing until eaten.

Cooking grain reduces its feed value. It has been found necessary to cook potatoes where any considerable quantity has been fed to hogs, and several feeders report good results from cooking sugar beets thoroughly, and then mixing the grain with the beets while they are still hot, but after the fire has been removed.

LICE ON HOGS.

Whenever a pig has good feed and surroundings and is not thriving, look for lice. Vermin will usually be found to be the cause of the lack of thrift. A great many of the losses laid to cholera, worms and mysterious diseases are actually the work of lice.

A stockman new in the hog business, bought several sows. He built good shelter and gave them good feed and care. They had 150 pigs, and all of these but 12 died before weaning time. After 138 had died, a veterinarian was called in to find what disease was killing the pigs, and he found that they had all been killed by lice. They were covered with vermin.

The writer inspected a herd of 300 hogs running on an alfalfa field and fed grain. They had a greyhound appearance, with rough hair, and were not over half so heavy as they should have been. After looking them over, the writer said that lice were stunting the hogs. The owner insisted that there was not a single louse on the whole herd. Several hogs were caught and were found to be very lousy.

The best cure and preventive is regular dipping, using some of the coal tar dips so extensively advertised and sold, or crude oil. When pigs are found to be lousy, dip twice, ten days apart, and then once a month through the year. Dipping with coal tar dips not only kills the vermin, but keeps the skin and hair in a healthful condition and is worth the cost of the operation, aside from killing the lice.

The most convenient method is to sink a galvanized iron vat, the top level with the ground, and leave a shute leading from the hog lot to the vat, and another from the dripping board to the lot.

The dipping mixture can be kept in the vat all the time and be protected by a cover when hogs are not being dipped. With such an arrangement, it is a short and easy job to dip 50 to 200 hogs. The dipping mixture will need to be changed three or four times a year.

In Colorado it is safe to dip in winter if done on a warm, sunny day, and the hogs are kept in the sun and out of the wind until dry.

Where only a few pigs are kept, they may be treated by washing them thoroughly with a cloth or sponge wet with the dipping solution.

Besides dipping, the hogs should have short posts set for them in their yards and pastures. Wrap the posts with old potato or bran sacks and once a week saturate these sacks with crude oil. A louse bites the hog, he rubs the spot on the sack and the oil kills the louse.

When hogs are found to be lousy, their sleeping, feeding and resting places should be thoroughly cleaned, all bedding burned, and these places sprinkled or sprayed with the dipping mixtures.

Pregnant sows should not be run through the dipping vat.

SHELTER AND CONVENIENCES.

The average change in temperature each 24 hours in Colorado is 20 degrees. For hogs this necessitates a dry, warm shelter, free from draughts every night, both summer and winter. Hog cholera is found in Colorado only in localities where it has been brought from other states; but the losses in hogs from pneumonia and rheumatism are as great in Colorado as the losses in the corn belt from cholera, and are caused by needless exposure.

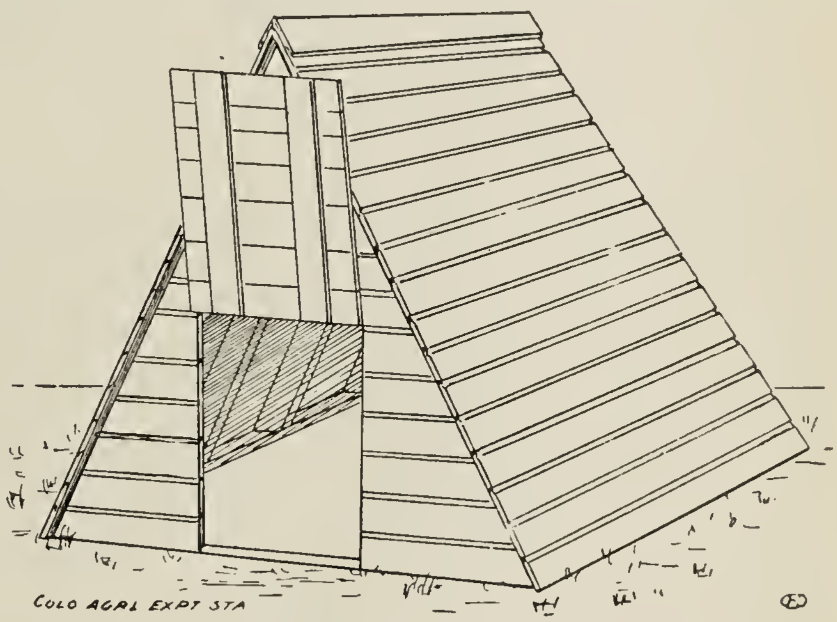
The beginner in hog raising should start with cheap shelter, and not put up any large buildings until he can do so from the profits of his hogs. Usually, after he has learned the business, he will not want large buildings. The shelter should be warm, light and dry, free from draughts, but well ventilated and easy to disinfect in case of disease.

Hogs should be comfortably bedded, but it is best to use just enough bedding to keep them warm, and to change it once or twice a week. Where a large quantity of bedding is supplied it becomes damp underneath, causing rheumatism; and dusty on top, giving the hogs a dry, hacking cough. Both dust and dampness are opposed to thrift.

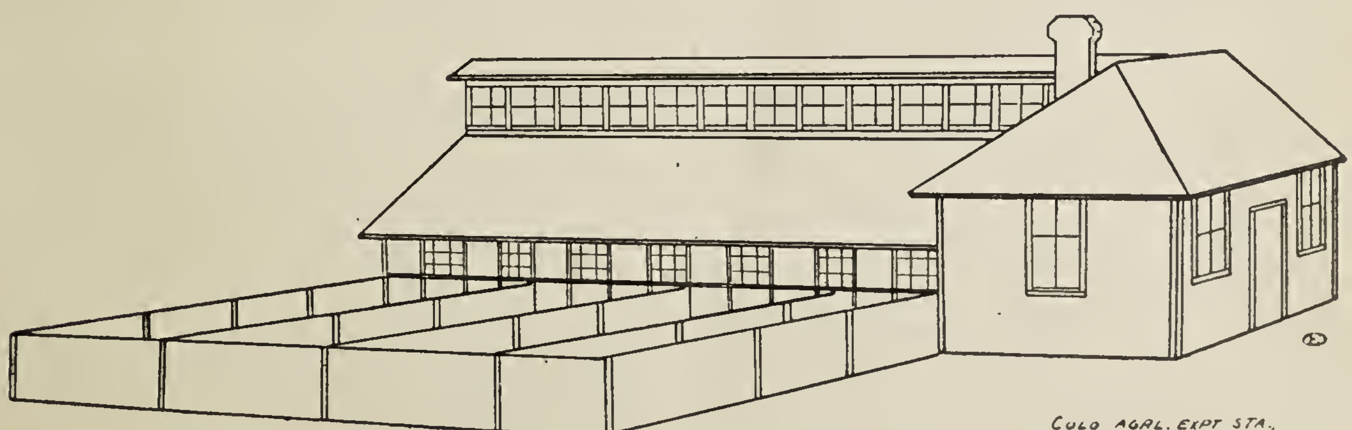
When hogs are not supplied with plenty of comfortable bedding in cold weather, they pile on top of each other to keep warm. In this way the under ones become heated, and when they get out into the cold air are easily attacked by pneumonia and rheumatism. If the attack is not sufficient to kill them, it makes them unthrifty. It is best to allow only a limited number of hogs to sleep together, and they should have such shelter and bedding that they can keep warm without becoming heated. Bathing in cold water in irrigating ditches is likely to result in rheumatism.

Hogs are more disturbed by wind than any other farm animals. Their shelter should thoroughly protect them from wind and from draughts.

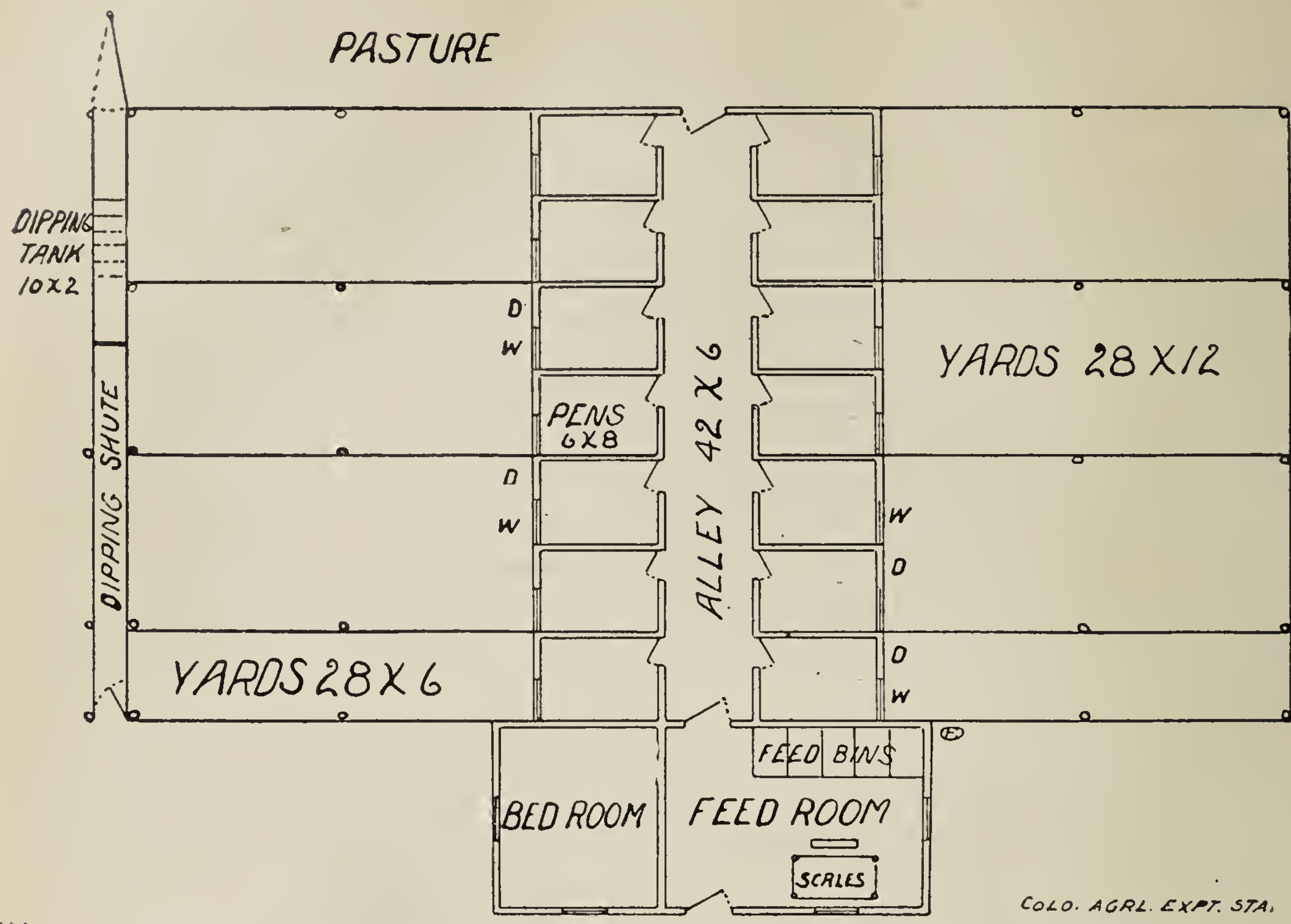
The Portable Hog House is cheap and convenient. It is eight feet wide, eight feet long, and the roof is eight feet in length, making the building seven feet high The door in front is two and a half feet wide, three feet high, and another at the back, near the top is 12x18 inches. The small door may be covered with heavy muslin, admitting air and light without draught. The frame is made of 2x4's and is covered with drop siding. No floor is used. When it is desired to move the building, it may be tipped over onto a low wagon or stone boat. This is the house we recommend for beginners. It is cheap, and often old material can be used in building it. It is easily moved and easily disinfected and can be changed so frequently that it may be kept on clean ground, free from disease. When a sow farrows in cold weather, a lantern hung to the roof will keep the building sufficiently warm.



Portable Hog House.



Piggery, Colorado Agricultural College.

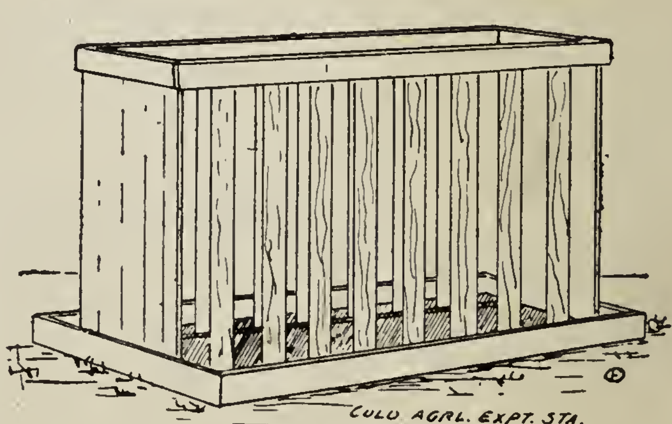


Ground Plan, Piggery, Colorado Agricultural College.

The Piggery of the Colorado Agricultural College, is a satisfactory building where a permanent one is wanted. The partitions between the pens are movable in case it is desired to use the building for fattening hogs. The doors leading to the yards are raised from the central alley by means of ropes and pulleys. A shute across the ends of one set of yards makes it an easy matter to dip hogs regularly. It is 6 feet to the eaves and 16 feet to the ridge above the pens. Additions to this house can be made when desired and the building remain just as convenient.

The Johnson Shelter for Fattening Hogs.—F. D. Johnson, Wray, Colorado, uses a portable shelter for fattening hogs that is the best for the purpose the writer has seen. It is a shed, open on the front only It is 16x16 feet, 4 feet high in front, and 20 inches high at the back. It has no floor, and is mounted on two runners 20 feet long, made of 4"x4" timbers. The front is boarded down 20 inches from the top. The roof is of battened boards and must not project beyond the sides or the stock will rub it off. The building can be moved easily by a team, and the low roof keeps the hogs from piling on each other and becoming over heated. This is the special advantage of this house and it is particularly adapted for hogs in the pea fields of the San Luis Valley.

Alfalfa Rack for feeding alfalfa hay to hogs. The rack is made of 1"x4" stuff. It is 3 feet high, 6 feet long and 16 inches wide. The top is open, the ends solid, and the 4-inch slats have four-inch spaces between them. The trough is 4 inches deep and extends 7 inches beyond the bottom of the rack.



Alfalfa Rack.

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Top-Working Fruit Trees

BY

O. B. WHIPPLE

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Top-Working Fruit Trees.

O. B. WHIPPLE

It is becoming more and more apparent that certain localities and soils are peculiarly adapted to growing particular kinds and even varieties of fruit. Commercial fruit-growing localities are making their reputation by being able to grow a few varieties well. So each new fruit country must go through an experimental stage when a host of varieties is being tested to determine those best adapted to its peculiar conditions. Then in the growth of each new fruit country there comes a time when the grower will have to solve the problem as to what to do with the undesirable varieties. Shall he pull them out or graft them over to better varieties? Systems of grafting-over old trees have long been practiced and experience has proven that, if properly done, top-working brings quicker returns than the replanting of young trees. It is not uncommon to see a fairly good crop on the three-year-old top of a top-worked tree. Trees properly worked-over give tops as desirable and sometimes more so than trees of the same variety grown from first-class nursery stock.

Top-working as a means of establishing a weak-growing variety on a stronger root system than its own is now coming into favor. The Rome (Beauty) when on its own roots is, on the best soil, an indifferent grower; but, when worked on some strong-growing stump, it makes a very satisfactory tree. Some varieties of apple, susceptable to attacks of root rots, could, no doubt, be successfully grown on roots of varieties which are apparently resistant. The Northern Spy seems to be a striking example of an apple tree root free from the attacks of woolly aphis and is sometimes planted and later worked over to other varieties. Broken and diseased limbs may be saved by grafting, and progressive fruit growers who desire to test new varieties can best do it by grafting a few cions into bearing trees.

Some years ago the fruit grower looked upon the practice of grafting as a mysterious art and upon the man who went about doing the work as a sort of a wizard; as a matter of fact, it is so simple that any careful orchardist can and should do it himself. All of our common fruit trees can be easily grafted or budded. The apple and pear may be intergrafted upon each other and the same may be said of the peach, plum, apricot and almond. But in practice, we do not carry on such wholesale mixing, it may be said that the apple and pear never make a good union. While such combinations may unite, the union may not be perfect enough to make a good top. We would not expect the top-working of apple to pear or vice versa to be a success. The writer has seen peach grafts start very vigorously upon apricot, and plums upon peach trees. I have observed plum trees top-worked to peach with perfect unions and the ten-year-old tops bearing excellent crops of fruit. In this case, the combination seemed to result in a dwarfing of the peach top, though the growth is by no means stunted. So in practice, we stick largely to the intergrafting of different varieties of the same kind of fruit.

To understand the principles underlying graftage, the orchardist should know how the stems of our fruit trees grow. He should understand that growth in diameter only takes place in a very small region between the bark and sap-wood. This part of the stem is called the cambium. In this thin layer of tissue the cells are still active and capable of diversion while the activity of each succeeding layer, on either side, grows less and less.

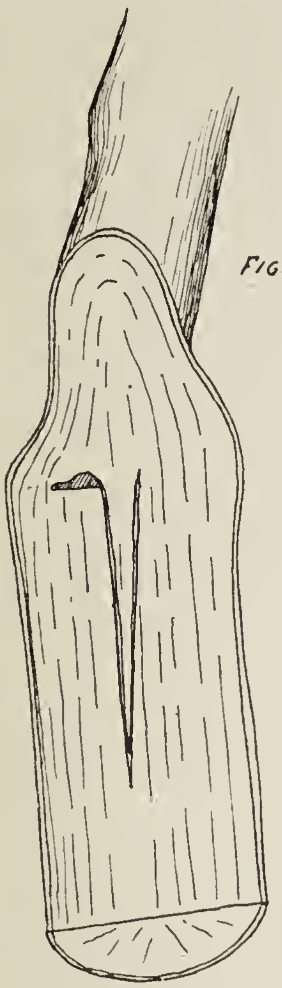


Fig. 1.

When the limb is split to insert a cion the cleft does not grow together along its entire length, as some may think. The cells in the cambium layer may produce a growth that may, to a certain extent, fill up the cleft and cover over the stub but the tissues of the stock and cion only make a true union where the cells of the cambium layers of the two come in contact. Fig. 1 is a pen drawing of a section through a stub grafted two years before. The stub was kerf-grafted and shows that no union has taken place between the woody tissues of the stock and cion.

The important point in grafting is to see that the cambium layers of the stock and cion are matched at some point.

When growth is active we say the bark "peals." Budding is done during this period, not only because the ease with which the bark separates from the wood simplifies the work of inserting the bud, but as growth is more active, the tissues of the bud and the stock are more likely to unite.

TOP-WORKING OLD TREES

In the working overof old trees it is well to bear in mind that trees which show a poor growth in the orchard are seldom worth the time it takes to graft them. This is very often true in the case of some varieties of apple. For instance, I have never yet seen a yellow Transparent stock grow a top worth the space it occupied. The same is almost invariably true of tops on Wagner, Duchess, Missouri (Pippin), Wealthy and Hyslop crab. In fact, it seldom pays to top-work any crab. Figs. 2, 3 and 4 are from a series of photographs of a Transcendent crab apple tree, the first showing some grafts one year old and some just set; the second figure, the same tree one year later (quite a promising tree); and the third figure the result at the end of the third season, almost the entire top blown off by a heavy wind. The grafts were Winesap and were sent in a kerf, not a cleft. As a rule the weaker growing varities are verv unsatisfactory stocks upon which to work other kinds.

Then the wisdom of top-working stone fruits would almost seem questionable. While good tops may be grown on either peach, plum, apricot or almond, it is doubtful whether these tops will bear much

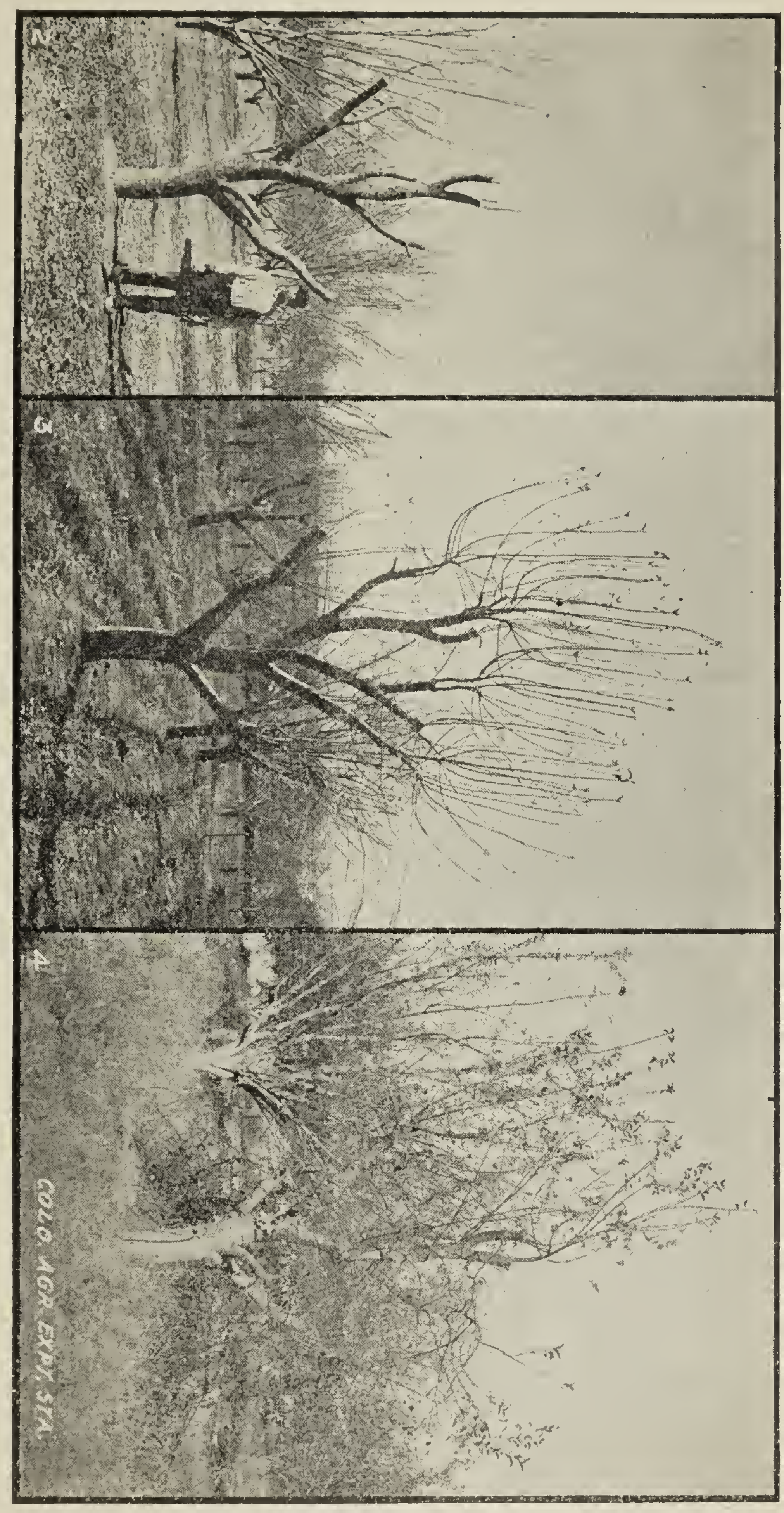


Fig. 2. An attempt at working over an old Transcendent Crab Tree, showing about as good a selection of stubs as is possible with such a subject.

Fig. 3. The same Tree one year later with quite a promising top, but the enlargements at the base of the cions show that the union is not perfect.

Fig. 4. As the top grows heavier the unions are not strong enough to hold it and this is too often the result by the third or fourth season.

quicker returns than young trees set in the place of the old ones. Still we would not care to discourage a practice most successfully followed by some growers, but will say that only strong-growing young trees under the most favorable conditions are worthy of such an attempt at renewal.

METHODS OF GRAFTAGE

Various methods of graftage may be employed in changing over the top of the old trees. Some method of cion-grafting is generally used, although it is not uncommon, in stone fruits especially, to bud into new growths. Of the methods of cion-grafting two are commonly used in the West; cleft-grafting and kerf-grafting. Those who have practiced grafting in the East as well as in the West, claim that the wood of Western fruit trees is much more brittle and that on account of excessive splitting, cleft-grafting is more difficult in the West. This has led to the introduction of a new system which is locally known as kerf-grafting.

Cleft-Grafting. The operation of cleft-grafting is very simple. The limb to be grafted is sawed off squarely leaving a smooth solid stump. The stub is split down about two inches with a grafting-chisel or knife. The chisel is removed and the cleft is wedged open with the wedge on the back of the knife or one provided for the purpose. The cion should be cut to contain three buds and should be of strong, well-matured wood of the previous season's growth. The lower end is then trimmed to a wedge leaving the first bud a little below the top of the wedge, and cutting the edge of the wedge opposite the bud a little thinner than the other. The cion is then driven firmly into place with the lower bud to the outside and a little below the top of the cleft, being sure to bring the inner bark on the outer edge of the wedge in contact with the inner bark on the stub. This is the important step in grafting, as it is between these parts that the union takes place. Sometimes the inexperienced grafter makes the mistake of setting the cion flush with the outer edge of the stock. On large stubs with thick bark it would be almost impossible to set a cion more illy matched than in this way. Some advocate setting the cion on a slant, the point of the wedge toward the center of the stub. This insures a contact of the cambium layers where they cross and is a good suggestion, since a point of contact is sufficient for a good union. With a cion properly set in each edge of the cleft—providing the stub is large enough—the wedge is removed. This allows the cleft to tighten on the cions, the greater thickness of the outer edge of the wedge-shaped portion of the cions insuring greater pressure at this point. With the removal of the wedge the cleft should hold the cions firmly in place. Wax should now be applied to all cut surfaces, even to the tips of the cions. Special pains should be taken to see that the stub is well covered between the cions and the cleft waxed as far as it extends down on the sides of the stub. This prevents drying out and it is quite important that it be thoroughly done.

Kerf-Grafting. This system of grafting differs little from inlaying. The stub is prepared as for cleft-grafting, but instead of splitting, saw cuts are made on opposite edges of the stub and trimmed to thin V-shaped grooves with a saddler's knife. The cion is then trimmed to fit, driven firmly into place and waxed as in cleft-grafting. With a little practice the cions may be set as firmly as in cleft-grafting. It is claimed that this method has the advantage in speed and that the cions are not as easily blown out in early summer. Cions are lost by both methods and if properly performed, one is probably as good as the other. It does have the advantage in that more cions may be set in large stubs and thus hasten the process of healing. The same care must be used in setting the cion to insure a union. The latter system seems especially adapted to working with stone fruits where splitting is even more noticeable than in the apple and pear. Sharp tools which give a smooth cut surface are essential in all grafting work.

Bark-Grafting. Some advocate another method of grafting known as bark-grafting. In this case, the stub is cut as before, the cion is cut with a long bevel on one side and slipped between the bark and sapwood. It is generally necessary to slit the bark at the point of insertion and very often the bark is removed from the base of the cion up to the top of the sloping cut. The stub is bound with waxed string or other material, to hold the cions firmly and it is then waxed as in the cleft-grafted stub. The system really has no advantages over the others, unless when compared with cleft-grafting in working large stubs.

Terminal-Grafting. Another style of grafting sometimes employed is that known as terminal-grafting. This work is generally done in the latter part of June or just as soon as new growth that has matured enough to show a terminal bud may be secured. On old trees, such wood may be found in June. A twig that has completed its growth may be picked out by the presence of a well-formed terminal bud at the tip and full grown, or practically full-grown terminal leaves. The cions are cut three or four inches long and the leaves practically all trimmed off. There are different ways of inserting the cion. The most common method is to cut a vertical slit in the bark of the stock, trim the lower end of the cion with a long sloping cut on one side, and then slip it under the bark at an angle of about 45 degrees with the slit. The cut surface of the cion should rest upon the wood of the stock. It is not necessary to wrap or even wax the wound.

The cions start into growth the same season but the top of the stock is left until the following spring. The method seems to work well. It may prove a practical way of supplying lower limbs on young trees headed too high. When one neglects to remove the top when such grafting is done in the lower part of old trees, these cions readily form fruiting wood, generally bearing the third season. It is a suggestion that it would be the proper course to take as a means of getting specimens of new varieties in the shortest length of time.

CHOOSING THE STUBS

There is much to be gained by the proper selection of stubs into which cions are to be set. A too common practice is to remove the whole top the first year and graft all the stubs. It is surprising that some good results come from such a practice. More often, however, this proves too much for the tree and it fails even after the grafts have made a good start. They may linger two or three years and then die from no other cause than the severe cutting back, though the growers are prone to attribute it to some other affliction. The cutting away of the greater part of the top seems to give good results and may even be advisable in top-working stone fruits. The pear will stand much more abuse in this respect than the apple. A far better plan in all cases, is to cut away only enough limbs to set cions for a good top. This will generally be about half of the tree, as six stubs will, in most cases, provide for a good top. The working of more stubs results in too dense a top or necessitates their removal later. The remaining limbs may be shortened but some foliage is needed to protect the stubs and trunk from sun-scald as well as to supply nourishment. If the stubs are well chosen the remaining limbs will do much to protect the young grafts from wind and especially from being brushed out by passing teams and orchard machinery. It is well to choose inside limbs for grafting as they are best protected, but care must be taken not to contract the head of the tree too much. It should be borne in mind that top-worked trees tend to grow upright, but it is a difficulty which may be largely overcome by judicious pruning.

After the cions have made one year's growth much of the remaining top may be removed, but it should seldom all be removed from old trees before the second year. If some stubs have met with accidents or have failed to start the cions, or if the shape of the tree or a scarcity of scaffold limbs has prevented a full top being placed the first spring, it may be completed the second.

Fig. 5. Showing proper selection of stubs.

While we sometimes see grafts doing nicely in stubs six inches in diameter, it is very doubtful whether such grafts will make a strong union or a long-lived tree. The wisdom of working limbs over three inches in diameter is to be doubted. In the choosing of stubs the grafter should remember that large wounds properly made, heal more readily than large stubs. Choose the smaller limbs for grafting even though the later removal of the top may necessitate the cutting of larger limbs lower down. It is better to raise the head of the tree than to work large stubs. Fig. 5 showing a two-year-old top on a pear tree will illustrate this point; notice the large wounds below the grafted stubs.

SEASON FOR GRAFTING

The ideal time for grafting is just as the buds are beginning to swell. While cions may be set earlier, there is danger of their drying out before a union is established. Should one care to prolong the season, it is better to run late than to begin early. The opening of the season will vary from the first of March to the first of April or even later in some parts of the state, and may be extended until the first leaves are practically full grown. Good results cannot be expected from cions set later than this. Some go through the orchard in winter and remove the tops of the stubs that are to be grafted, cutting them at least a foot above where the cions are to be placed. This saves some time, and by hauling the brush out before the grafts are set it saves some of them from being knocked out by careless men in removing it later. When ready to graft, the stub is recut from a foot to eight inches lower.

PROTECTING THE BODY

Since the removal of any considerable part of the top often exposes the body of the tree to the direct rays of the sun, it is well to whitewash the trunk and main branches. The whitewash reflects the rays of the sun and by such an application many cases of sun scald may be avoided. A good whitewash may be prepared by using one pound of good quicklime to each gallon of water. The addition of a pound of salt to each three gallons of the wash tends to make it stick better. This can best be applied with a spray pump. A good coating can only be secured with two applications, the second to follow as soon as the first is dry.

CION-WOOD

In this connection it is well to say a word about the selection of cion-wood for grafting. The man who is interested in his bearing orchard has early learned that the individual trees in the plantation show a great variation, especially in productiveness, and very often in the size, color and quality of the fruit. Some of this variation may be accounted for in various ways, but after all, we are coming to believe that, environmental conditions being equal, no two trees are alike in bearing habits. It is a natural variation. There are trees that never bear well and cions from such trees will, no doubt, produce trees very much like them. In the selection of grafting wood it is well to bear this in mind. Mark your favorite trees and select cion-wood from them.

The wood used should be one year old, strong and well matured, but not overgrown. The terminal shoots from trees that have made a growth of from twelve to eighteen inches make excellent cions. The question is often asked as to the use of watersprouts. The term watersprouts may mean different things to different people. By watersprouts we generally mean rank growth from adventitious buds; and such growths with immature tips, weak buds far apart, and pithy centers make very poor cion-wood. Otherwise, any new wood with well developed buds, comparatively close together, may be used for cions. The statement sometimes made that watersprouts never produce fruit is erroneous.

Cion-wood should be gathered in the fall, preferably as soon as the leaves have fallen, and stored until spring. The object is not to avoid winter injury, as some think, but to keep the cions in a dormant condition. Few realize that buds complete the resting period early in the winter and may, under favorable conditions, begin to swell before the first of January. While the unobserving man may say there is no difference in the buds of the young growth in early December and in February there may be quite a marked difference in some climates. Our open winters in the Middle West are especially liable to start early growth. The object of keeping the cions dormant is to allow time for a partial union before the buds are started into growth by the warm days of the grafting season. Cions with buds well swollen often throw leaf surface before a sufficiently strong union has been made to support them. The result is the exhaustion of the stored-up food supply and moisture of the cion to a point which may cause its death.

The cions may be stored in sand in a cool corner of the cellar or buried out of doors. The main object is to keep them cool and moist and away from fluctuating temperatures. An excellent plan is to bury them on the north side of a building or in some spot shaded most of the day. They need not be buried deep, from twelve to eighteen inches being sufficient in a well shaded spot.

GROWING THE TOP

It would hardly seem wise to leave the subject of top-working old trees without some comment on future treatment of the grafts. The setting of the cions is only the first step in working over the tree. Should we stop here, a most miserable failure or, at least, a poor top would be the result. Many a good catch is ruined by neglecting the pruning the first two seasons. During the first season the grafts should make a very rank growth and they will require some pinching back to save them from becoming top-heavy and consequently easily blown out. The common practice is to head-in the rapidly growing shoots when they have attained a length of from eighteen inches to two feet. This forces branches from below and if growth becomes too heavy these may need cutting back before the season is over. This pruning insures stockiness of the new growth and throws much of the energies of the top into a good union. The growth of suckers or watersprouts from the stock should not be allowed to any great extent. Should the stubs be exposed to the direct rays of the sun it is well to leave some of this growth, pinching it back to cause it to form a dense shade. Unless needed for protection it is well to rub the sprouts off as fast as they appear.

The following spring the system of pruning should resemble very much that of pruning young trees. The growth of the grafts should be cut back to usually not over eighteen inches in length. They may be cut even shorter if the growth has not been satisfactory. If all three buds have started from a cion, it is well to remove all but one to avoid crowding. As a rule the growth from the lower bud will be the strongest and should be retained. Should the formation of the top allow it, a second growth may be left. If the grafts have been set in near the head of the trees they will require some pruning in reference to spreading the top. The general tendency is for the top-worked tree to grow too compact. Cut the grafts back to one of the strong outside branches started by the first pinching back and it will give them a start in the right direction. What shall we do where two cions start in the same stub? Should the stub be less than three inches in diameter one should be removed at this time. Keep the stronger, or if there should be little difference, the one best situated to help make a good top. Cut the other off close, even to removing a small corner of the stump on that side, the wound will heal better. Should the stub be over three inches in diameter there is some argument in favor of leaving the extra graft another year. It will help callous over the stub, and may be removed the following spring leaving a comparatively small wound. If left longer, or until the two grow together, the result is a bad crotch and sometimes a pressure which may actually split the stub.

Subsequent pruning will consist in such cutting back as will help form a stocky and well shaped top. They will demand the same attention as young trees. Spread the top by pruning to outside buds or branches and do not pay too much attention to the small wood. Some of the small branches may require cutting out or clipping back, but remember, in it we have the start for early fruiting wood.

TOP-WORKING YOUNG TREES

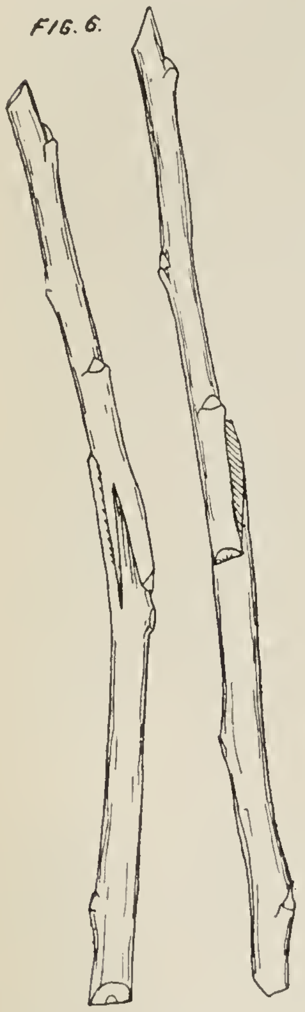
There is a growing conviction among the fruit growers that better results may come from planting vigorous young trees of some strong, growing kind to be later worked over to the desired variety. In the opening remarks on this subject, mention was made of the desirability of working weak growing kind on stronger root-systems, as well as top-working as a means of lessening loss from attacks of root rots and woolly aphis. The embarrassment of growing the orchard to a bearing age only to find some of the trees not true to name may be avoided by this plan of starting the young orchard. Then every fruit grower has observed that few trees of the same variety are alike in bearing habit and character of fruit. No doubt, many growers have some particular tree in their bearing orchard which is better than all others, that is nearer their ideal. By choosing grafting wood from this tree, a young orchard may be grown as near like it as is possible. There are productive and unproductive trees in every orchard and the careful selection of cions from productive trees will avail much as means of building up a fruitful orchard.

In top-working young trees it is a common practice to set the trees where they are to grow and after the scaffold limbs are well formed, to graft or bud into these the future top. Some Eastern men have advocated purchasing two-year-old trees in the fall (trees in which the head is already formed) to be grafted over indoors in December. In the West, and especially on a large scale, this system would hardly seem practical. The method of grafting in this case is whip-grafting.

GRAFTING

In grafting young trees in the field it is probably well to do it as early in the life of a tree as possible. As soon as a good strong framework can be secured the tree is ready for top-working. The small size of the stubs make cleft-grafting difficult and kerf-grafting almost out of the question. Some growers, however, report good success in cleft-grafting young trees after two year's growth from a yearling whip. In this case the stubs must be bound with waxed cloth or other material to hold the cion firmly, and then waxed as in cleft-grafting larger stubs.

FIG. 6.



Another style of grafting, known as whip-grafting, is well adapted to working these small stubs of young trees. The process is well illustrated in Fig. 6. With this style of grafting it may be possible to set the cions after one year's growth in the field, but it is doubtful whether much time will be gained by such practice. The cion should be as near the size of the stub as possible, if anything, a little smaller. The cambium of the stock and cion is matched only on one side, paying no attention to the other. The joint should be well wrapped with waxed cloth and to be doubly sure all air is excluded, may be painted over with a warm wax.

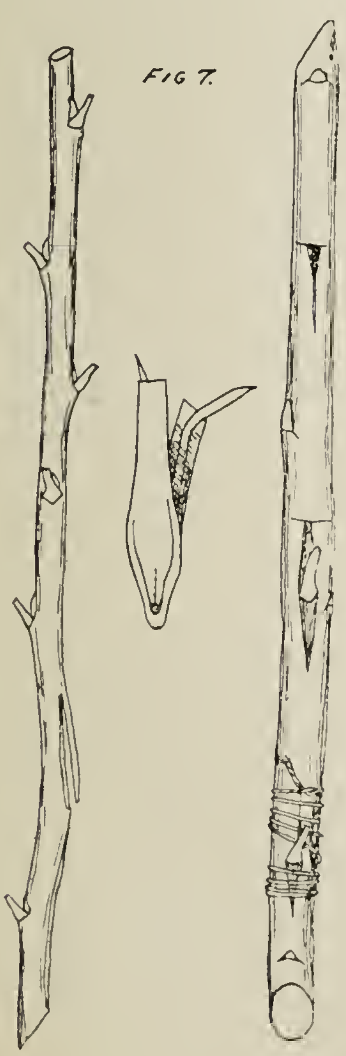
In grafting young trees it is a common practice to remove all of the top, placing cions in those arms one wishes to keep. It is always well to work a few extra stubs as accidents may befall some of the cions. The season for top-grafting the young trees is the same as for old trees. While top-working the old trees tends to hasten the bearing of the cions, it is doubtful whether top-working young trees induces earlier fruitfulness.

BUDDING

This is no doubt the simpler method of putting a new top on young trees. While the process of budding is a little more delicate than that of grafting, the average man can, with a little practice, get very satisfactory results. Buds should be placed as soon as the top is well formed, setting one or two in each scaffold limb that is to be retained. The buds are generally set from six to twelve inches from the main stem, depending on the formation of the head. Trees two years old when set may generally be budded the following fall, and should yearling whips make a strong growth, the arms may be large enough to receive buds in September. Any stem as large as a lead-pencil may be budded quite easily. Arms in which buds fail to start may be grafted the following spring. Should arms fail to appear in the proper place it is quite possible to supply them by setting buds directly into the body of the young tree. When the buds begin to push into new growth they will require about the same care as young grafts. They will need some pinching back to strengthen the stem and to overcome the tendency to become top-heavy. With the possible exception of young trees budded in late spring, all growth from the original stock should be removed as fast as it appears.

Buds may be set during the month of June or early July, or in August and September. For June budding the bud-sticks are cut as soon as well matured wood may be found. Good firm wood with well developed buds may generally be cut from bearing trees in the latter part of June. As soon as buds set in June or July unite with the stock, the bandage is cut and the part of the stock above the bud is removed. In spring-budding it is well to leave some of the new growth which springs from the arms below the bud. This takes the surplus sap and helps nourish the roots until the buds are well started. Wood from buds set in the spring may not mature well in our climate and is susceptable to winter injury during severe winters. With careful watering it is possible to mature the wood properly, but where practical, fall budding should be given the preference. In the case of peach trees, June budding is preferred where attacks of twig borers often destroy in early spring, buds set the previous fall. In the apple and pear it is probably more convenient to bud in the fall. Then, too, arms which are large enough to bud in early spring were large enough the previous September, so one really gains rather than loses time by budding in the fall.

In fall budding the buds are taken from the current year's growth. Buds may be inserted in wood of one, two or three years' growth. The stiffness of the bark of the other wood makes budding difficult. The heavy bark not only makes the insertion of the bud difficult, but in drying out it curls away from the bud exposing it to the air. The simplest form of budding is that known as Shield-budding or T-budding. The position for the bud is chosen with reference to the prevailing wind, protection from the sun's rays, or to best form the top of the tree. The most important factor should determine where the bud should be placed. It is well to place the bud on the shady side of the stock, if possible. Should the locality be subject to strong prevailing winds, the bud should stand more wind if placed on the side of the stock toward the wind. A T-shaped incision is made in the bark and the corners of the bark below the transverse cut raised to facilitate starting the bud. The bud is then cut from the bud-stick by starting the knife half an inch below the bud, cutting under and to about the same distance above the bud. This gives a long bud which is especially desirable in our dry climate. In cutting under the bud, the knife should be run deep enough to leave a small shield of wood. Fig. 7 will show the various steps in the process of shield-



budding. A simpler method of lifting the bud, at least for the beginner, is to start the knife as before, and cut sharply into the wood to about one-third the diameter of the stick and then upward under the bud making a tongue about an inch long. The knife is then run across the tongue half an inch above the bud, cutting through and lifting the bark at this point. The bud is then grasped between the thumb and first finger and lifted, leaving the wood on the stick, as shown in the same figure. While the removal of the wood from under the bud is no particular advantage, the method is simpler and gives the inexperienced budder a larger per cent. of good buds. The writer has lifted thousands of buds in this manner with the best of success. It is difficult to cut buds in this way from some varieties of cherry and plum trees with thin bark, but it works well on the apple, pear, peach, apricot and the heavy-barked plum. The bud is then slipped into place as shown in the figure and well wrapped with raffia or soft wrapping twine. About four wraps below and three above, so spaced as to close the whole opening, is sufficient. In wrapping, the common practice is to start below, and by crossing over the first end and running the last end under, the bud is wrapped without a knot. The tying material is usually cut in the desired lengths beforehand, and if raffia is used, it should be kept moist, as it ties better.

If on healthy young wood, the buds will unite within ten days or two weeks. Then the wrapping should be cut by drawing a knife across it on the side of the stock opposite the bud. Should the stock be making a slow growth, there need be no hurry about cutting the tie. The only thing to be guarded against is that the wrap does not cut into the bark. This pressure interferes with the flow of sap, and tends to throw the bud into premature growth, this often means a loss of the September bud. The bud set in August and September should remain dormant over winter. The following spring, just as soon as the buds on the top of the stock begin to push out, the original top of the stock is cut away. Should the stock be cut off too early in the spring, or too close, there is danger of the stub drying out to the injury of the bud. Some recommend the practice of leaving a longer stub to which the young growing shoot from the bud may be tied until it is well established. This saves some buds from being blown out, but necessitates a second cutting in mid-summer to allow the stub to heal over.

We have said that buds for fall budding should be taken from the current year's growth. The common practice is to cut the terminal growth from bearing trees. The leaves are trimmed off at once, leaving a small part of the leaf-stalk to handle the bud by. Bud-sticks trimmed in this way may be stored in a cool, damp place and kept for some time without injury. The leaf-stalks, however, will losen and drop off in many cases if stored over ten days. Of course, this does no harm, but some budders miss the little handle in inserting the bud. The first few buds at the base of the stick are generally poorly developed and should be discarded while those near the tip are too immature to be used. As a rule not over half of the new growth cut in early September will carry buds suitable for budding. The sticks should be carried in a damp cloth to avoid drying out.

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CEMENT AND CONCRETE FENCE POSTS

BY

H. M. BAINER
H. B. BONEBRIGHT

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CEMENT AND CONCRETE FENCE POSTS*

H. M. BAINER†
H. B. BONEBRIGHT‡

PART I.

INTRODUCTION.

The average life of the best wood fence posts that have not been specially treated is from 12 to 15 years; while the poorer ones often last but from 3 to 5 years. Good wood posts are gradually becoming harder to secure and the cost of them is increasing each year. The cost of maintaining the farm fences and especially the posts is a great one when we consider that they must be replaced so often.

The cheaper and poorer grades of woods used for fence posts can be treated and thus made to outlast the best grades of untreated timber. The cost of the untreated post will vary from 10 to 15 cents each and the cost of treating them according to experimental data at hand will add from 10 to 15 cents each to the first cost, thus making the total cost of the treated post from 20 to 30 cents.

With the present enormous and increasing demands made upon our forests for all classes of lumber, shingles, pulp wood, cooperage stock, mine timbers, lath, wood for distillation, poles and fence posts, there is no wonder that the prices for these products are becoming greater. The cost of the average fence post is almost double what it was a quarter of a century ago and in another quarter of a century, there is no doubt but that its cost will be double that of the present.

Iron fence posts cannot be generally used as substitutes, as their cost is prohibitive. Stone posts are used in some localities, but they do not give general satisfaction and they cannot be profitably shipped.

Cement and concrete posts are just beginning to be manufactured and used as substitutes, and there is no doubt but that they will become more generally used. It is true that they may be considered as expensive, but they are long-lived, present a good appearance, and can be made by the farmer, providing the necessary materials are available. It is the purpose of this bulletin to show how to make the posts and also to determine the best forms, mixtures, reinforcements, wire fasteners, cost, and general practicability.

MATERIALS TO USE.

Cement.—There are but two general classes of cements which could be used for post construction—Natural and Portland. The

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†Professor in Farm Mechanics.
‡Assistant in Farm Mechanics.

materials found in Natural cement are mixed by nature in approximately the correct proportions and when burned does not always make a cement of uniform strength. Portland cement is mechanically mixed in chemically correct proportions. Portland cement makes a uniformly stronger mixture than the Natural cement and is always used where great strength is required.

In cement fence post construction, it is desirable that the post be made as light and as strong as possible, and thus it is practical to use nothing but the best grade of Portland cement.

Sand.—Clean, sharp sand with grains varying in size from small to large makes the best mixture. By clean sand is meant that which is free from clay, loam, or foreign materials. These tend to retard the proper setting of the cement and destroy its adhesive quality. In many sections mica is found mixed with sand in large enough quantity to seriously interfere with the strength of a mixture made from it.

Sharp sand is composed of sharp, angular grains of all sizes and makes better mixture than that which is smooth and round, or "river worn."

A sand composed of fine and coarse grains mixed, is to be preferred, because less cement will be required to fill the voids than either used by itself.

Leaves, sticks, stones or gravel should be removed by screening.

Gravel.—The same general rules used in the selection of a good grade of sand will apply to gravel. It should be composed of clean, sharp pebbles of all sizes. For post construction, the pebbles must not be too large, as they will interfere with the proper placement of reinforcement.

Broken Stone.—Broken stone used for post construction must contain no large pieces as they will interfere with the placement of the reinforcement. It is necessary to use some sand with the stone to fill voids and thus save cement. It is not desirable to use soft sandstone, soft limestone, slates, or shales. Granites, hard limestones, and coarse gravel which has been crushed, is considered best.

Water.—The water used in making a cement or concrete mixture should be clean and free from alkali. Satisfactory experiments have not been conducted to show the effects of alkali water used in making a mixture of this kind, but enough is known as to its effect on cured cement constructions to justify not using it in the mixture.

PROPORTIONS.

On account of a difference in the total open space or voids in sands or gravel composed of different sized particles and also that more cement is required in some conditions than in others, it is often necessary to make a rough determination of the percentage of voids to the total aggregate. Where maximum strength is required about 10 per cent. more cement should be used than the total voids.

The determination may be made as follows: Secure a water tight box or pail of known capacity, fill it with the aggregate to be used so that when it has been well shaken it will smooth off even at the top. Pour water of known amount into this until full. The volume of water used in proportion to the total volume of the receptacle determines the total voids.

For example, suppose the total volume of the receptacle in which the aggregate is placed is 2,032 cubic inches and that it takes two gallons of water to fill it. One gallon of water contains 231 cubic inches and two gallons would contain 462 cubic inches. The total volume of water used, divided by the volume of the receptacle holding the aggregate represents the proportion of voids. Thus, 462 divided by 2,032 equals 22.73, or the voids make up 22.73 per cent. of the total volume. For the maximum strength 10 per cent. should be added to this. Ten per cent. of 22.73 equals 2.27. By adding this 2.27 to 22.73 we obtain 25, or in other words, 25 per cent. of the total volume should be cement. The mixture in this case would be represented by one part of cement to four parts of aggregate.

The proportions used in the constructions of the fence posts in this bulletin varied from 1 part cement and 3 parts of sand to 1 part of cement and 5 parts of sand. In others gravel was used in the proportion of 1 part cement, 3 parts sand, and 3 parts gravel. It is a difficult matter to use broken stone or gravel in large quantity and place the reinforcement properly.

Measure all materials in correct proportions. This may be done with a shovel, a pail, wheel barrow, or barrel. It will usually be advantageous to measure the water, especially where small quantities are mixed or where the same amount of mixture is made several times.

MIXING.

Hand Mixing.—Where the mixing is done by hand, a flat water-tight platform, or shallow box is convenient. Measure the sand and place it in a uniform layer and over this spread the proper amount of cement. Mix this thoroughly before adding water until it shows a uniform color. The rule is to shovel it over at least three times. Now spread out the mixture, making a sort of basin in the middle into which the greater part of the water may be poured. Work in the dry edges until the water disappears, then add enough more water in small amounts to make the mixture of the desired consistency. Do not mix more material than can be used in twenty minutes.

Machine Mixing.—It is usually customary to use mixing machines on large jobs. It is not only economical, but does better work. Where power is available it is often advantageous and economical to construct a mixer for small jobs, also.

A small mixer can be cheaply constructed which can be driven with a two or three horse-power gasoline engine. With this, it was found that two men were able to do the work of at least four men doing hand mixing, and the machine work was done more thoroughly.

In many instances, mechanical mixers, which are driven by hand power instead of by an engine are better than hand mixing with shovels or hoes. A mixer of this kind can be made from a barrel or box, pivoted in the center and driven by means of a crank on which one or two men can work.

The mechanical mixer first mixes the materials in a dry condition, then some provision is made for turning in the water without stopping the machine. With most mixers of this kind, one revolution does as much mixing as one turning by hand. Six turnings by hand are considered enough, and it is seldom that a machine is stopped with less than double this number of revolutions; in fact, it may be turned 15 or 20 times; thus this method of mixing is very much more thorough and desirable.

HOME MADE CONCRETE MIXERS

To many people, the idea of mixing the concrete by hand appears to be an unnecessary task. But the price of a modern concrete mixer is so large that it would not be good economy to purchase one for what little mixing is done on the average farm.

The ingenious farmer will find that a suitable mixer may be constructed at home with little expense and work. All that is necessary is the ability to put a few pieces of old machinery together in such a way that the barrel or box may be turned upon an axis and stopped at the desired time. This is very easy in case the power is furnished by hand, but in case of a power-driven mixer, more ingenuity is required.

The home made mixer shown in the cut illustrates how a few pieces of board and timber may be turned into a very serviceable machine. Two pieces of 4x6 form the sills. Upon these, two uprights about three feet high, are fastened. A 1½ inch pipe passes through holes bored in the top of the uprights. Upon this pipe the mixing box is turned, and through the pipe the water is added to the mixture at the desired time. The water is poured in at the top of the upright pipe and flows down and out through holes which are drilled in the lower side of it. The other end of the pipe is closed by a wooden plug. The ends of the box are made of pieces of 2x8 bolted together. A hole bored in the center of each end forms the bearings. The sides of the box are made of one-inch lumber and are simply nailed to the ends with 12d nails. One-half of the box is made so that it can be detached and lifted off when the mixer is to be filled, or emptied. The detachable half is secured to the other half by means of strong hooks so placed that by slipping this half about an inch to one side all of the hooks are loosened at once. After it is in position, the removable portion is held in place by means of a barn door latch.

The driving gear is simple but very effective. It consists of the rim taken from the wheel of an old "rubber tire buggy." With the tire removed the grooved rim makes a very satisfactory wheel upon which to run a ¾-inch rope belt. The belt is driven by a small shieve pulley which is fastened to the counter shaft. A belt tight-

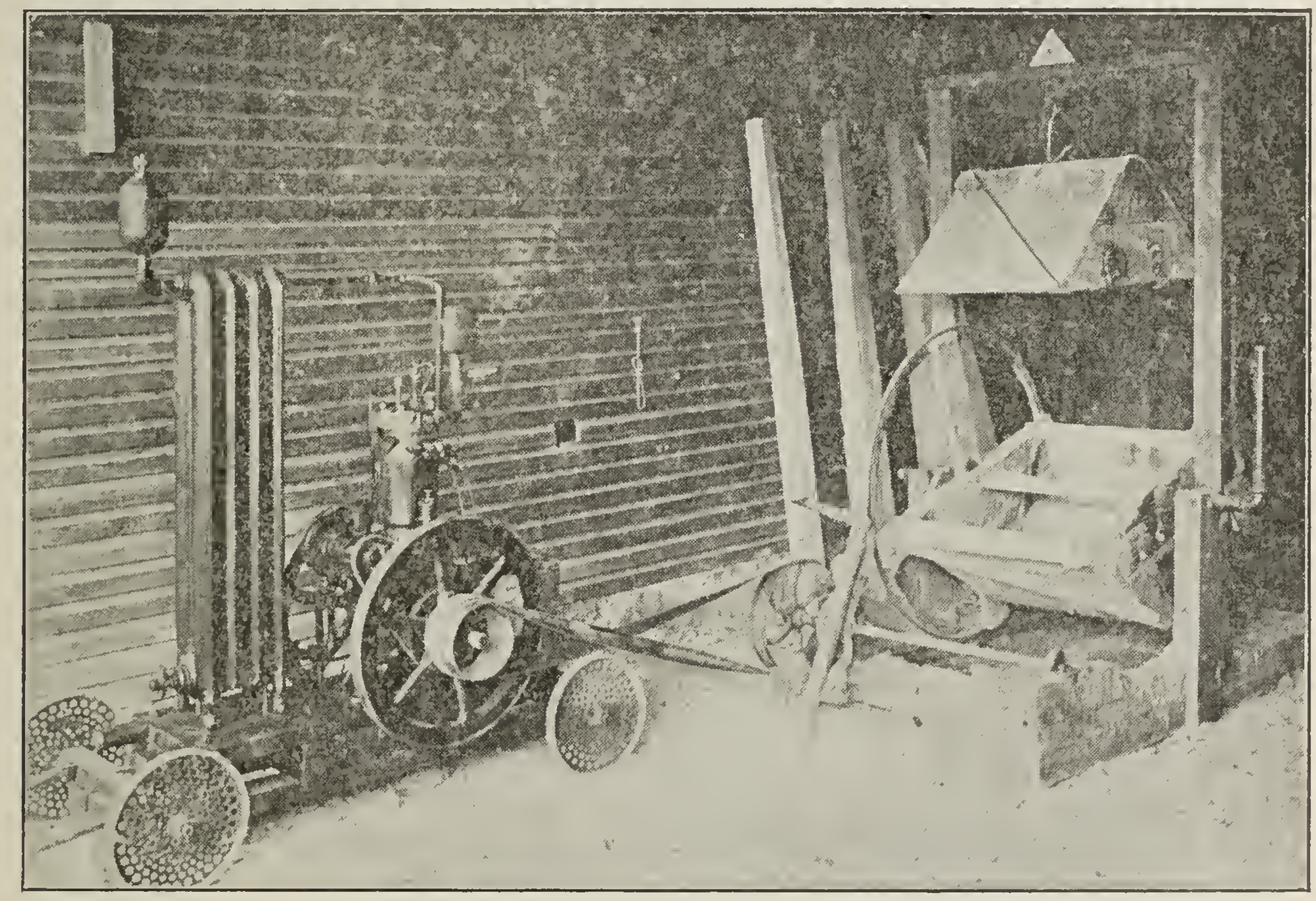

Figure 1.
Home made concrete mixer operated by 2-horse-power hand portable gasoline engine

ener is used upon the rope, and by using a very loose belt, the tightener is made to act as a friction clutch.

This particular mixer is driven by a two-horse gasoline engine, which is belted to the counter shaft. The engine runs continuously and the mixer is started and stopped by means of the belt tightener.

The operator first fills the mixer about half full of sand, gravel and cement in the correct proportions. He next lowers the lid, which until this time has remained supported upon the hook. The lid is now pushed into place and the latch fastened. The supporting hook is next removed from the staple in the lid and hooked into a staple in the lid support. The machine is now ready to start, the clutch is thrown in, and the box revolves upon the pipe. When three or four turns have been made, water is poured into the upright pipe until the desired amount has been added. By this time the concrete is thoroughly mixed. The clutch is loosened, the box stops revolving, the hoisting hook is hooked in the staple of the lid, the latch is loosened and the lid raised to the top of the lid support by means of the counter weight and rope. Now, by slightly setting the clutch, the contents of the mixer are dumped into the box beneath. The operator of the machine may now refill the mixer, while the other workmen take care of the mixed material. In this way a large amount of material may be run through the machine and perfect mixing is guaranteed.

Many other systems of driving might have been used in place of the rope belt. The main gear of an old self-binder makes an excellent gear for a mixer. An old mower gear may also be put to good use in this connection.

It is not necessary to have the mixer driven by an engine or horse power. A crank may be attached and the machine turned by hand. Many prefer turning such a machine rather than mix the concrete with a shovel.

POURED POSTS.

There are two general classes of mixtures which may be used in the construction of posts; the poured and the tamped: In the poured mixture, enough water is used in mixing to make it thin enough to pour from a pail or scoop almost like water. The mixture is poured into a mold and allowed to remain in it until it has set, which is from one to five days, depending upon the time of year and the weather. In drying summer weather, from one to two days is usually sufficient. In cool or damp weather they must be left in the molds much longer.

In order to make several posts of the poured type at once, it is necessary to have several molds ready for use. With 6 molds only 6 posts could be made at once, and it would be necessary to wait until the cement was set before 6 more could be made.

It was found that to make a good poured post, the mixture should be stirred or shaken immediately after placing in the mold. This should be done carefully to prevent displacement of reinforcement wires. This helps to remove the air from the mixture and makes a post of smooth finish.

The experiment showed that a poured post of a certain mixture was stronger than a tamped post of the same mixture. It is enough stronger to justify anyone in constructing it in preference to the tamped one at the necessary additional expense for molds. The poured post is smoother, more nearly impervious to water, not so hard to cure, stronger, somewhat more expensive, and can be better recommended than the tamped one.

TAMPED POSTS.

The tamped post is one in which the mixture contains very much less water than the poured one. It contains just enough water to make it hold together well when tamped. In the manufacturing of this type of post, only one mold is necessary. The mixture is tamped into it, and the sides of the mold can be removed immediately, the post remaining on the bottom piece until the cement has set. Thus the same mold can be continuously used for making as many posts as are desired. The necessity for but one mold makes this type of post less expensive than the poured one. The results of the tests made, show that the tamped post is inferior to the poured one and cannot be placed in an equal class with it.

On account of less water being used in the mixture for a tamped post than in the mixture for a poured one, the tamped post requires more water and attention in curing. It is of more open texture, less impervious to water, not as strong, and not as desirable as the post of the poured type.

POST MOLDS.

In general, the molds in which cement or concrete posts are made may be divided into three main classes.

First, those molds which are designed exclusively for manufacturing tamped posts.

Second, those which are made exclusively for manufacturing poured posts.

Third, those which may be used for either tamped or poured posts.

In the first class of molds we find mostly the heavy cast iron forms which are built of strong and heavy material. The most of these molds are designed to be laid upon pallettes or upon a smooth floor. The mixture is first tamped in the mold to a depth of about one inch. The reinforcement is then placed and the mold is next filled, and the mixture tamped, so that only about one inch of material remains to be filled in. The second set of reinforcement wires is put in place next and the mold is tamped full to overflowing. The last step consists in smoothing off the top of the post with a trowel and removing the mold. This is done by unfastening some form of hook or clasp, slipping the sides of the mold a little distance away from the post, and then removing the molds to the position chosen for the next post.

The principal advantage of these molds lies in the fact that they being made of heavy iron need no center stays. This gives greater speed in operation, due to the fact there are no cross pieces to interfere with the placing of the reinforcement, the tamping of the mixture, and the smoothing off of the top of the post at the finish.

The cast iron molds being heavy, are rather hard to handle, and this feature, in connection with the high price of them, explains why they are not more commonly used.

In the second class of molds (molds for poured posts) we find a far greater variety. The more common forms are made of sheet

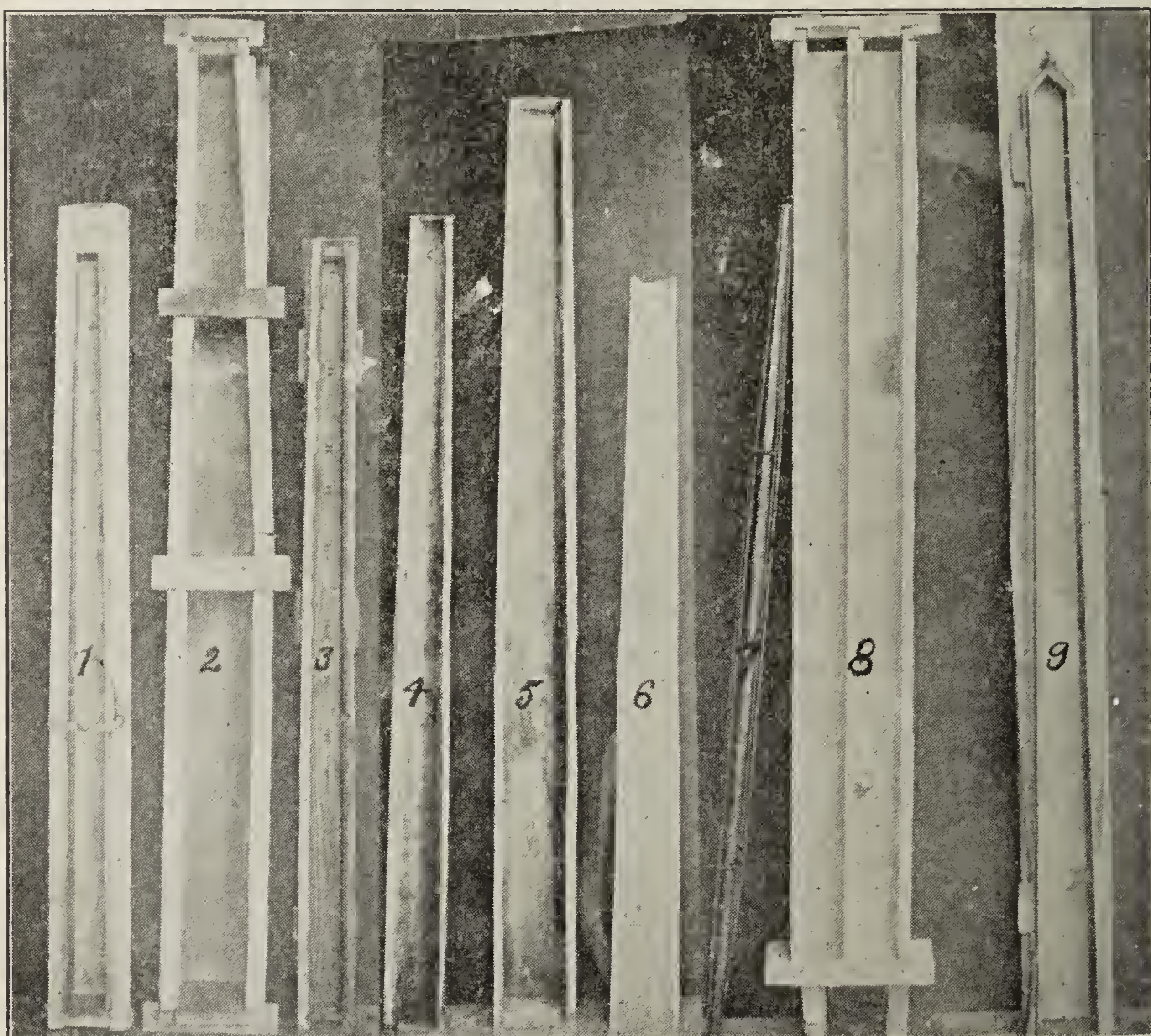

Figure 2.

Different Types of Post Molds.—1. A 5-inch home made mold for making poured or tamped posts. 2. An 8-inch home made mold for making corner posts. 3. A 4-inch commercial post mold. 4. A 4-inch heavy sheet iron mold. 5. A 7-inch heavy sheet iron mold for corner posts. 6. A triangular sheet iron mold. 7. A commercial reinforcing truss. 8. A double mold lined with sheet iron. 9. A heavy cast iron mold made especially for tamped posts.

iron, either galvanized or plain. For posts having a continual taper from top to bottom, sheet iron molds prove very satisfactory, providing sufficiently heavy material is used in their construction. A mold made of thin iron soon loses it shape and the posts made in them are necessarily unsightly. If properly taken care of, there is no advantage whatever in galvanized iron molds over those made of plain iron.

The advantages of the sheet iron mold are many. They are light to handle and easy to keep clean. If properly made they are nearly water tight. This insures the user against the possible loss of cement by leakage. As the cement travels to some extent with the currents of water, it can easily be seen how a leak in a mold may materially weaken a poured post by allowing a portion of the cement to be carried out of it. Another marked advantage of the sheet iron mold lies in the fact that the surface being smooth, im-

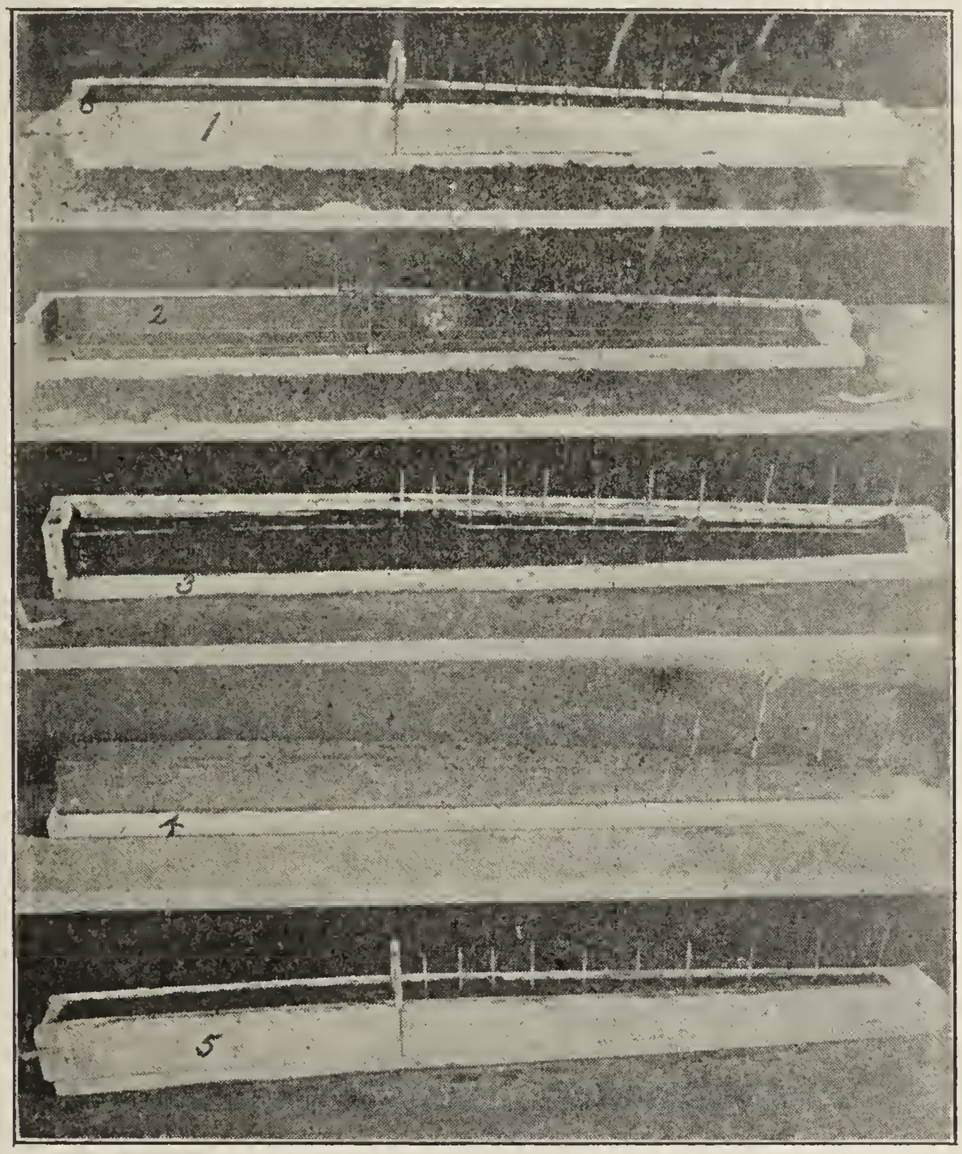

Figure 3.

1. Empty mold ready to be filled, showing tie hole pins in place. 2. First layer of mixture and first reinforcement wires in place. (Side of mold removed.) 3. Second filling of mixture and the second reinforcement wires in place. 4. Post completed, mold removed and the hole pins being pulled. 5. Post complete ready to remove mold.

parts a very smooth, glossy finish to the surface of the post. This not only adds beauty to the post, but aids in keeping out water, which might otherwise enter the cured post.

As the sheet iron molds are made in one piece, no pallette is necessary. At first glance this looks like a great advantage, but upon further consideration we find that the mold must be left upon the post until the mixture has set to such an extent that the post may be removed and handled without fear of breaking. In hot weather the post may be removed after 48 hours, but in cold weather a much longer time is required.

In making poured posts in these molds exactly the same process is followed as with tamped posts in molds of the first class just described; with the exception that the mixture is not tamped and greater care must be exercised in preventing the reinforcement from being misplaced.

Some forms of wood molds are made and used for the purpose of making poured posts only. Any desired form may be given to

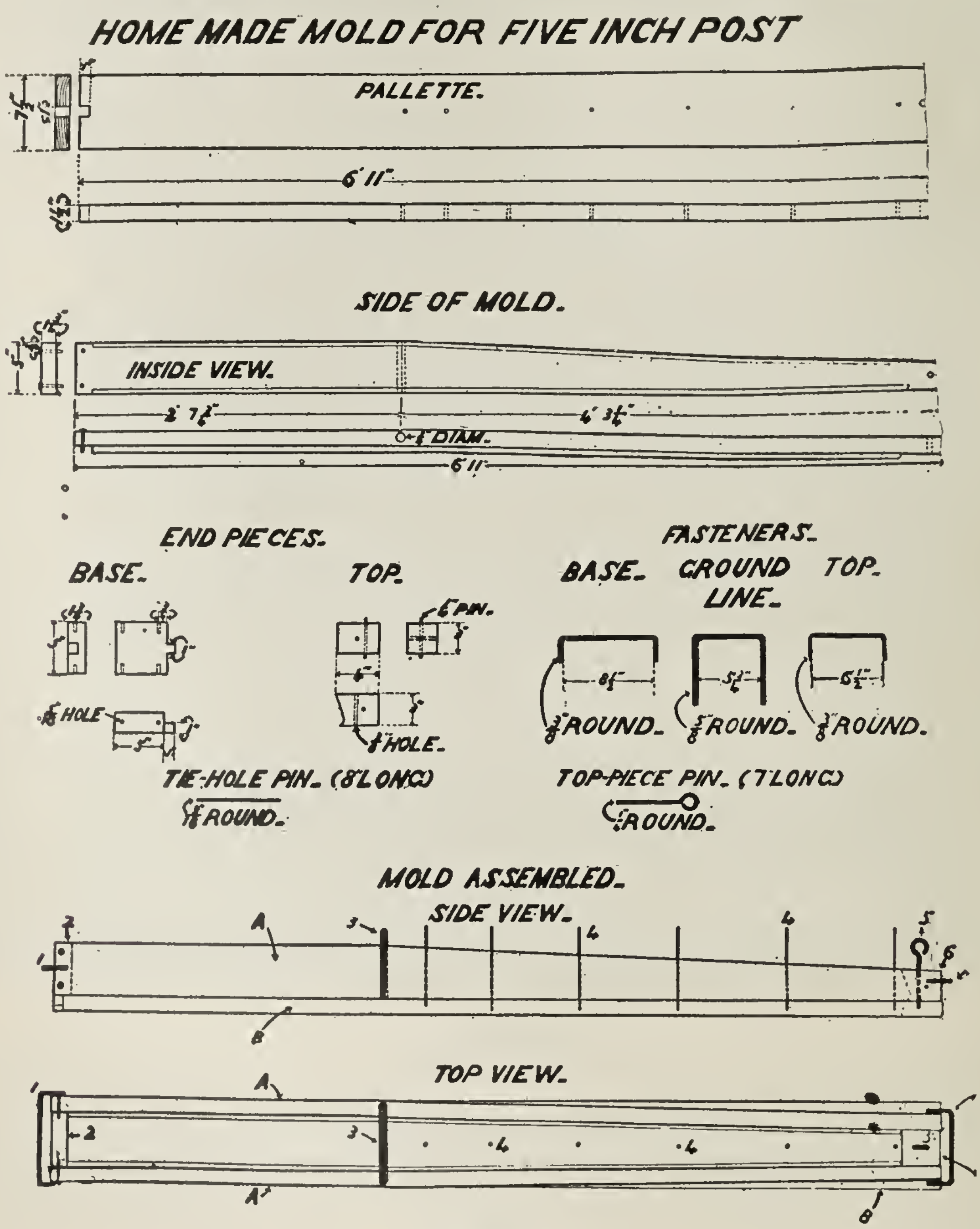

Figure 4.

A Home Made Mold Giving the Proper Shape to the Post.—1. Base fastener. 2. Base end piece. 3. Ground line fastener. 4, 4, etc. Tie hole pins. 5. Top piece pin. 6. Top end piece. 7. Top fastener. A. Side of mold. B. Pallette.

the post by properly shaping the mold. This point, in favor of the wood mold, is an extremely important one, as it permits the post to be made of uniform size from the bottom to the ground line, but with a rapid taper from this point to the top. Then, too, the sides of the mold may be removed after 24 hours and used again in connection with other pallettes; while the post which has not yet become sufficiently strong to be removed from the pallette lies unmolested in its original place until it is ready to move. This enables the maker of cement or concrete posts to produce at least twice as many posts with wood molds as with the same number of sheet iron molds, providing the required number of pallettes are at hand. The number, as well as the extent, of leaks in a wooden mold will depend upon the accuracy of construction, the care with which the molds are handled, and the care with which they are put together before filling.

The third class of molds (those which may be used for making either the tamped or the poured posts) are much the same as the wooden molds for poured posts, except that they are stronger. A mold which is to be used exclusively for manufacturing poured posts may be made of ¾-inch material and prove strong enough for the purpose; while if the mixture is to be tamped within the mold, at least 1½ inch material must be used. The extra thickness is required to prevent the molds from bulging at unsupported places during the tamping process.

The heavy cast iron molds could be used in making the poured posts as well as the tamped ones, but their original cost make them impracticable. The wooden molds serve the purpose equally well and are much cheaper.

Selecting the Mold.—The first and most important point to be considered in selecting the mold is the *shape and size* of it. Too many post mold manufacturers are turning out forms of molds that make "freak" posts, simply because it happens that they can manufacture them more easily and cheaply. It must be remembered that cement or concrete posts are made for long continued service and that simply because a certain mold works well is not a sufficient reason for purchasing and using it.

Next to the shape and size of mold we should look for ease of operation. Too many complications are likely to prove to be hindrances to the speed with which posts may be turned out. The simple mold almost always proves to be best, providing it has sufficient strength.

Care of Molds.—Before the molds are used they should be well coated with some kind of heavy oil. Crude petroleum is perhaps the best and cheapest material for this purpose. In case the petroleum cannot be obtained, a good oily mixture may be made by stirring about two pounds of axle grease into a gallon of gasoline. This mixture is applied to the molds with a brush. The gasoline evaporates, leaving a thin coat of axle grease spread over the entire surface of the mold. This oily mixture should be applied to the outside as well as to the inside of the mold, which makes it impossible for any of the material to cling to it. With the iron molds, the oil prevents rusting. In case the molds are made of wood, the oil helps to keep out the moisture, thus preventing shrinking and swelling, and also making them easier to keep clean.

As soon as the mold is removed from the post all material sticking to it should be scraped off and the inside surface covered with a thin coating of oil. In case tamped posts are being made, the oil need not be applied oftener than once for ten or twelve posts; but with poured posts, the oil should be applied each time the mold is removed. Great care should be taken not to allow the molds to become bruised or dented, as it not only causes the posts to have a bad appearance, but allows the mixture to adhere to the uneven spots; thus a great deal of unnecessary trouble is experienced in removing the posts from the molds.

If the molds are not to be used for a time, they should be thoroughly scraped and oiled, inside and out, and carefully laid away. When it is understood that the speed of operation and the value of the posts depend largely upon the condition of the molds, the importance of properly caring for them will be readily understood.

REINFORCEMENT.

Cement and concrete work has the property of resisting great crushing stresses, but when subjected to tensile stress, the best of it breaks very easily.

For this reason it becomes necessary to put some material possessing great tensile strength into the post, in order that the full crushing strength of the cement or concrete may be utilized. Iron is the most satisfactory material from which to make the reinforcement.

The reinforcement should be placed in the post as near the corner as possible. This places it as far as possible from the neutral axis, thus giving it the greatest advantage in strengthening the post. In order that the reinforcements may be properly held and protected by the cement, it is a good plan to place it from ⅜ to ¾ inch in from each side. This insures a good, firm grip of the cement upon the reinforcement.

The material used for reinforcement should be strong, light, and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch.

A great many special reinforcements are now being made, but the farmer should see to it that the reinforcement which he is to use is reliable, rigid, and easily secured.

The experiment showed that ordinary iron or steel wire was cheapest, strongest and easiest to procure. In order to provide a means by which the cement may cling firmly to the wire, it is best to twist two small wires together instead of using one large one.

If the twisted wire can be bought, cut to the right length and packed in bundles in the same way as bailing wire, it is best to procure it in this way. In case the twisted wire comes in rolls, it becomes necessary to straighten each piece before it can be used. In this case, it is best to purchase common smooth wire of the desired size and twist it on the farm. The twisting is easily done by tieing one end of each wire to the opposite spoke of the fiy wheel of some machine; a corn sheller or hand cider mill will serve the purpose very well. By tieing the other ends of the wires to a weight which may drag along upon the ground, from 100 to 200 feet of wire may be twisted in a very few minutes.

In case a small engine is available the twisting becomes still easier. The advantage of the home twisted wire over twisted wire which is bought in rolls, lies in the fact that the former is straight at the end of the twisting process, while the latter is bent and must be straightened.

The cutting of the wire is best accomplished as follows: Set a cold chisel (with the edge up) in a low, rough bench, and at a distance exactly equal to the length of the reinforcement wire from the edge of the chisel, nail a block to the bench. Take a light hammer in the right hand and seize the twisted wire with the left. Then drag the wire over the chisel until the end of it strikes the block, when a light blow directly over the chisel easily cuts the wire. The piece which is cut off is now laid to one side and the end of the main wire is drawn to the block and another piece cut off.

SPECIAL REINFORCEMENT.

Some have suggested that a piece of wood be placed in the center of the post as a reinforcement. This must be considered a failure, as the wood shrinks and expands by differences in moisture conditions. When it absorbs water, it is likely to swell and burst the post, and again when it dries it will shrink away from the cement.

Gas pipe has also been suggested as one of the best materials to use as a reinforcement. In case plenty of strong second hand pipe is at hand, this may be true. As the pipe is placed in the center of the post, it is not in position to act to the best advantage as a reinforcement, and for this reason it should be strong enough to withstand almost all the strain. New pipe would make the posts altogether too expensive.

Crimped wire is also claimed, by some, to be superior to that which has been twisted, but as the pull comes upon the wire there is a tendency to straighten the crimps. When the wires happen to be near the surface, there is great danger of the post being split by this straightening process.

Band iron and strap iron are also being used as reinforcement. In case the mixture has a good chance to get a grip on the iron, it will probably prove satisfactory, but unless the iron is roughened there is a danger of it slipping.

For very large posts, the twisted steel rods will prove as satisfactory as twisted wire. Smooth rods or smooth wire slip.

CURING THE POSTS.

In order for the cement to become thoroughly cured or "set," water must be supplied to aid in the action. This action goes on for a long time, some authorities estimating the total period at from 15 to 20 years. For the first thirty days the cement should be kept wet if the best results are to be expected. This means that the posts must be kept wet, and the question arises, what is the best system of keeping them in this condition?

The answer is a simple one. The most favorable conditions for conserving the moisture consists in curing the posts in a shed where the wind does not strike them. Under these conditions neither the sun's rays nor the wind have a chance to dry out the posts too rapidly. The only thing that now remains is to keep the posts in a wet condition.

After the posts are placed in an upright position in the curing shed, as described in "Handling the Posts," sprinkle them thoroughly every day. This may be done either by a hose and nozzle in connection with some form of pressure supply tank or by means of a garden sprinkler. In the latter case provision must be made so that the person doing the work may walk upon some structure above the tops of the posts.

The posts should be thoroughly sprinkled every day for at least 30 days.

HANDLING OF POSTS.

In removing the posts from the molds great care must be taken not to allow the posts to sag or crack. A post may be cracked in handling and still be fit for service, but it cannot be considered to be as valuable as an uncracked one.

There are two general methods of removing the posts from the molds.

The first method consists of laying the molds with the posts in them on a level bed of soft sand. The mold is then turned upside down and the post allowed to settle into the sand. The mold is next removed and the post allowed to lay undisturbed for several days. When the post is sufficiently strong it is placed in an upright position to be cured. While this method requires more space it is perhaps a little better for the posts than the second method.

The second method consists in removing the posts from the molds while in an upright position. The post is then allowed to lean against a wall or some other support. Thus only one handling is necessary. Care should be taken to have the bottom of the post close to the wall, as it is very likely to break if not kept very nearly in an upright position.

After the posts are cured and ready to set they should be moved from the curing shed and hauled to the fence line in a wagon having a strong, rigid bed. The bottom of the bed should be covered with a layer of straw to prevent breakage. Not more than three to four layers of posts should be placed in the wagon, depending upon road conditions. It must be remembered that a five-inch post weighs 100 pounds or more. When this is considered, we see how easy it is to load a wagon and also how sufficient weight may be placed on the posts in the lower layer to cause them to break.

In handling and setting care must be taken not to drop the posts. The weight of the post places unnecessary stress upon the different parts, and in case it is dropped there is great danger of it being cracked or destroyed.

A careless workman can easily do more damage to the posts than his services are worth.

WIRE FASTENERS.

In case of the wood post the method of fastening the wire consists of simply stapling the wire to it. In order to fasten a wire to a cement or concrete post a different system must be used.

With the ordinary wood staple in mind, one inventor has designed a small cast iron socket or staple holder which is placed where it is desired in the face of the post before the cement has hardened. When the post is set in the ground, the wire is fastened to it by simply driving an ordinary staple into the socket. The staples pull out much easier than they do from the wood post. The jar of driving in the staples tends to split and crush the post at the point where the cast staple holder is placed. Moreover, the cost of the staples and holders adds greatly to the expense of the post.

Another system consists of two staples which have the prongs bent to the side. The staples are placed about one-quarter inch apart, with the prongs projecting to the side. The line wire is placed between the two staples and a nail or piece of wire is driven down through the staples, outside of the line wire. As the tips of the staple touch the reinforcement wires, direct electric connections are established between the line wire and the ground at the bottom of the post. This, it is claimed by the patentee, insures the user against loss of stock by lightning. The system is called the "Double Staple." (See Fig. 5.)

A "single staple" may also be used, but the wire is fastened to the staple by a small "cold shut link," or wire ring. The latter system is not a very strong method of fastening, owing to the ease with which the cold shut links open. (See Fig. 5.)

Perhaps the most common method of fastening wires to cement or concrete posts consists of tieing in the line wire to the post by means of a piece of smaller wire called a "tie wire" (usually No. 14 or No. 15 wire). The single tie consists of wrapping one end of

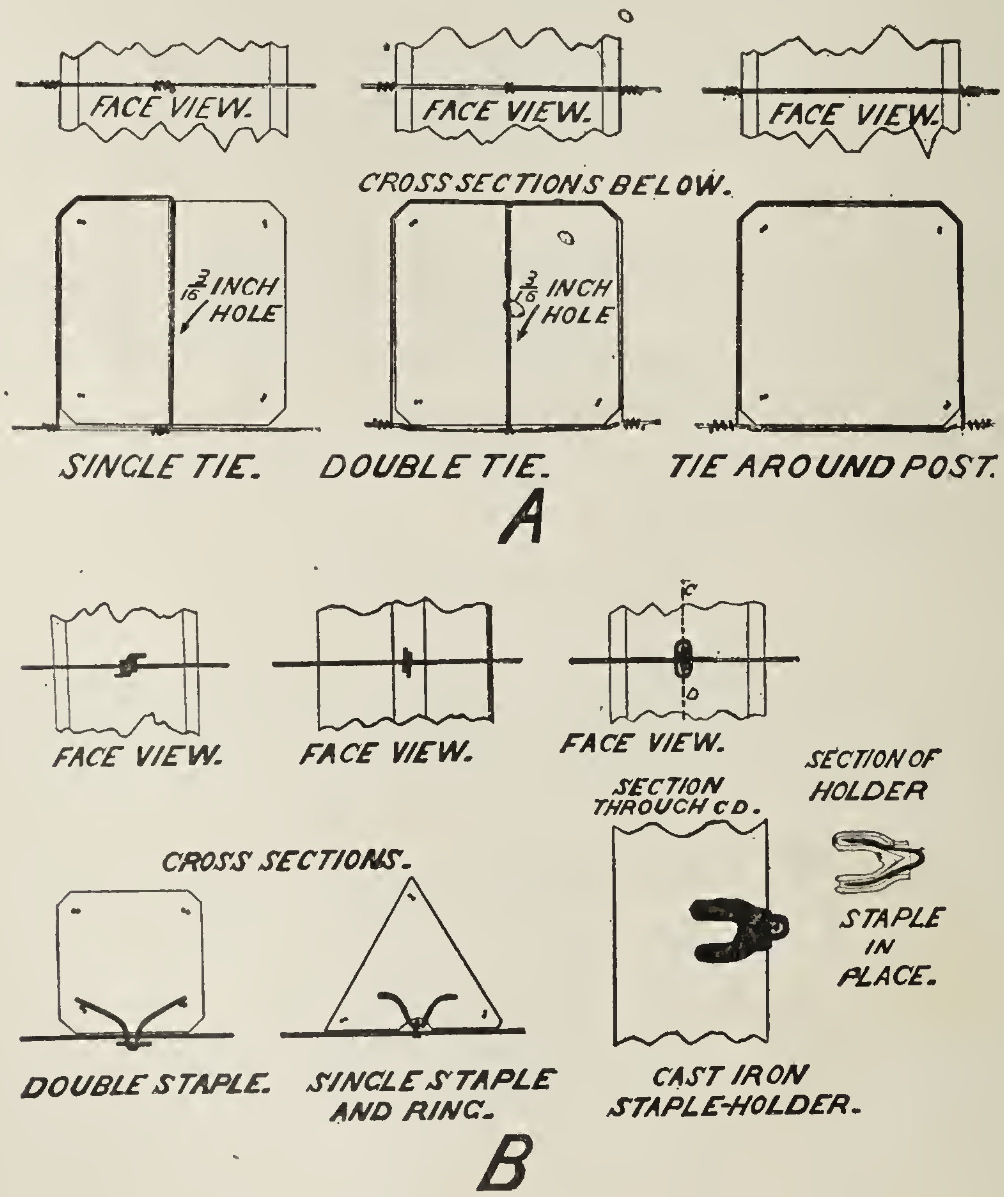

Figure 5.

Different Types of Wire Fasteners.—A, Home made fasteners. B, Commercial Fasteners.

the tie wire three or four times around the line wire, then passing the long end through a hole in the post and bringing it around to the face of the post where it is also wrapped around the line wire. (See Fig. 5.)

The tie around post is much the same as the single tie, except that the tie wire passes around the post instead of through the hole. (See cut.) Neither the single tie or the tie around post are very strong unless the tips of the tie wire are hooked over the body of the tie wire after the wraps have been made. This is known as the "special tie."

The strongest and perhaps the most satisfactory system of tie-

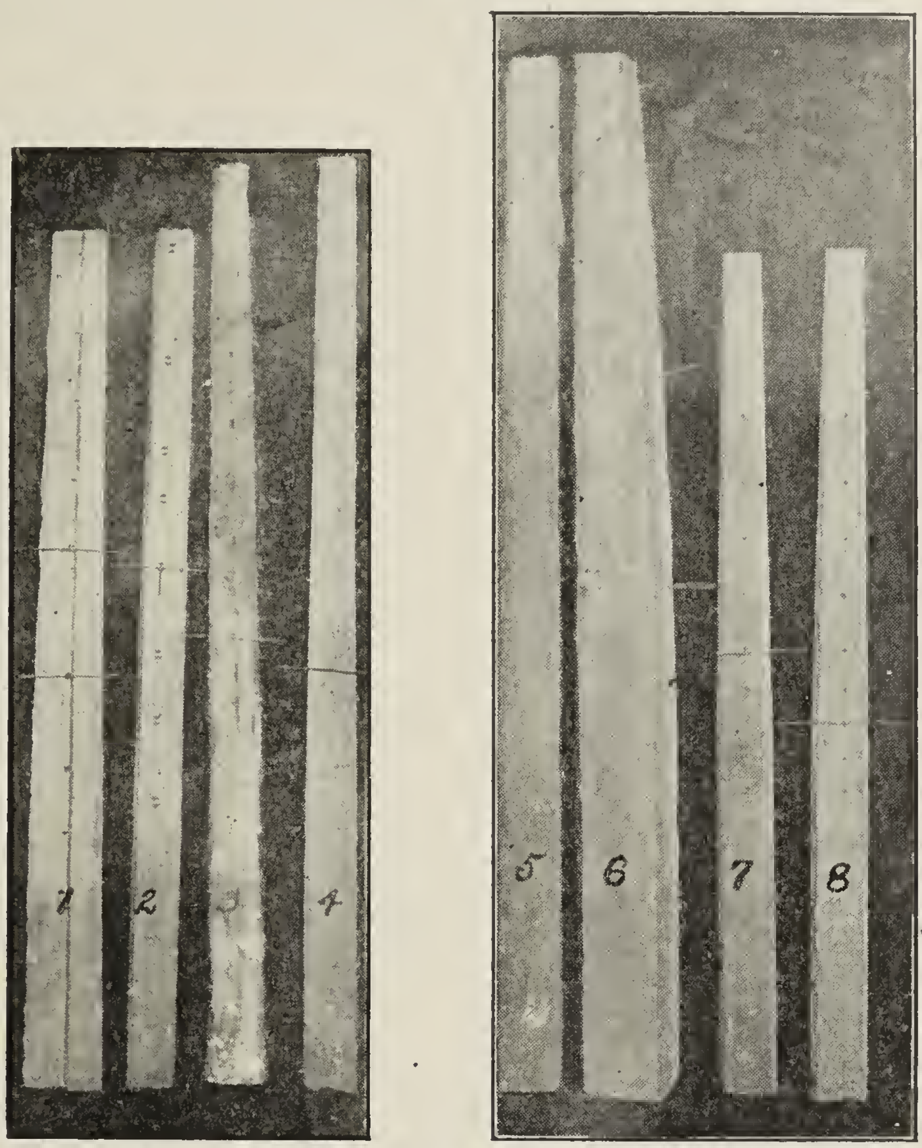

Figure 6.

Different Types of Cement Posts and Wire Fasteners.—1. Triangular post with single staple and ring wire fastener. 2. A square post with double staple fastener. 3. A seven-foot post with cast staple holders. 4. A seven-foot post with tie around post. 5. A 7-inch eight-foot corner post. 6. An 8-inch eight-foot corner post with staples cast in post. 7. A 5-inch tamped post with single tie wire fastener. 8. A 5-inch poured post with double tie wire fastener.

ing in the wire is the "Double tie." The tie wire is bent into the form of a long staple, straddled over the line wire and both ends passed through a hole in the post. One end is brought to either side and wrapped about the line wire at the face of the post. This system insures a solid fastening and is equal in strength to any ordinary wood post fastening.

The holes in the posts are formed by No. 6 wires being placed in the post while it is soft. These wires are called "Tie Hole Pins." (See cut.) They are removed from the poured post after the cement has set for 24 hours. The pins are removed from the tamped posts immediately before the molds are removed.

The following table shows the comparative holding strength of various wire fasteners, as determined by the tests:

WIRE FASTENERS (See description of same.)	KIND OF POST	No. Lbs. Required to Pull Fastener	REMARKS
Ordinary 1¾ in. staple	New Cedar	425	Ave. of three pulls. Staple was well driven into post.
Single special tie	Cement	520	Ave. of 2 pulls. Fence wire broke.
Double tie	Cement	510	Ave. of 2 pulls. Fence wire broke.
Double staple	Cement	245	Ave. of 3 pulls. Staples pulled.
No. 14 wire plain single tie	Cement	115	Ave. of 2 pulls. The wire untwisted.
No. 14 wire around post	Cement	110	Ave. of 3 pulls. The wire untwisted.
Cast staple holder with ordinary 1¾ in. staple driven into it	Cement	85	Ave. of 2 pulls. Staple pulled out of holder
Cold shut-link in single staple	Cement	83	Link opened in every case,. Ave of 3 pulls.

TAPER OF POSTS.

To obtain the maximum strength with the least amount of material, the cement post must be so shaped as to have its greatest strength at the ground line.

While it is easy to make a post which tapers from the bottom to the top it requires somewhat more material than is necessary and it is smaller at the ground line than at the base. Thus the gradual taper not only uses more material than is necessary, but it reduces the strength at the place where it is most needed.

By making the post of uniform size from the base to the ground line, no material is wasted. The post may then be tapered from the ground line to the top.

Many of the posts which are being made now taper only one-half inch on each side from the base to the top. It has been found that in a 5-inch post which projects 4 feet above the ground, a taper of one inch on each side from the ground line to the top, insures almost equal strength throughout. This design gives more strength with less material than those with the continuous taper.

TESTS OF THE CEMENT USED.

Several tests were conducted to determine the strength of the cement used at different times during the post experiment.

The Cubes and Briquettes were made in the same manner as the posts, *i. e.*, they were kept in the shed and thoroughly wet once a day for 28 days, at which time they were tested.

The following table represents inch Briquettes tested in tension. The figures represent an average of three tests:

SAMPLE NO.	MIXTURE		STRENGTH IN LBS.
	PROPORTION	KIND	
1	1—3	Tamped	172
1	1—3	Poured	186
2	1—3	Tamped	171
2	1—3	Poured	193
3	1—3	Tamped	176
3	1—3	Poured	184
1	1—2—3	Tamped	88
1	1—2—3	Poured	97

Three-inch cubes tested in compression. Figures represent an average of three tests:

SAMPLE NO;	MIXTURE		STRENGTH IN LBS. Per Square Inch.
	PROPORTION	KIND	
1	1—3	Tamped	971
1	1—3	Poured	989
2	1—3	Tamped	970
2	1—3	Poured	982
3	1—3	Tamped	980
3	1—3	Poured	1015
1	1—2—3	Tamped	357
1	1-2—3	Poured	375

PART II.

THE EXPERIMENTS.

These experiments were conducted for the purpose of determining the method of building the best posts at the least cost.

Apparatus.—Various commercial molds of different shapes and construction were secured. In each of these molds several posts were made in order to determine the practicability of the mold; also the best combination of mixtures and reinforcements.

The Farm Mechanics Department designed, built and used a simple home made mold which makes a post of uniform size from the base to the ground line with a rapid taper from the ground line to the top. (See Fig. 4.) The department also designed and built a simple home made concrete mixer which was used in the experiment. (See Fig. 1.)

A shed which was closed on all sides with a sliding door on the east was used as the work and curing room.

TABLE NO. 1—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost for cement per post, 16.2 cents; sand, 3.7 cents. Fort cost of reinforcement, see table.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Breaks Above or Below Ground Line.	Cost of Material in Post	New Wire is figured at 4c per Lb. and Old Wire at 2c per Lb.
No. 10, 4 twisted strands of 2 wires.	2½ lbs	10c	250	307	Ground Line Ground Line 1 in. below.	29.9c	Wires broke they did not slip.
No. 10, 8 strands crimped.	2½ lbs	10c	243	254	6 in. below, Ground Line 3 in. above	29.9c	All wires slipped slightly before breaking.
No. 6, 4 long wires hooked at ends.	2⅔ lbs	10.6c	137	232	6 in. above Ground Line 1 in. below	30.5c	All wires slipped wires not crimped.
New Barbed 4 long strands	1⅔ lbs	6.6c	148	188	Ground Line 2 in. below 2 in. below	26.5c	Post 130 days old wires broke.
Old Barbed 4 long strands.	1⅔ lbs	3.3c	143	158	Ground Line Ground Line 4 in. below	23.2c	Wires broke.
Old Barbed 4 long and 2 short.	2 lbs	4.0c	167	200	10 in. above 4 in. above 16 in. above	23.9c	Mixture gave way above extra wires.
Old Barbed 4 long and 4 short.	2¾ lbs	5.5c	148	229	18 in. above 18 in. above 20 in. above	25.4c	All wires broke above extra wires.
No. 10, twisted 4 long and 2 short.	3 lbs	12c	128	290	1 in. below 3 in. below 5 in. below	31.9c	Extra wires did no good.

Materials.—The sand and gravel used was clean and sharp, with all sizes of grains varying from small to large. There was a very small percentage of mica in the sand, which was objectionable. One brand of Portland cement was used for making all posts.

A total of 238 line posts and 8 corner posts were built and tested during the experiment, the records of which are found in the following tables:

TABLE NO. 2—Tamped Posts.

These posts are of the same size and composition as those in Table No. 1, excepting that they are tamped instead of poured.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c Per Lb. and Old Wire at 2c Per Lb.
No. 10, 4 twisted strands of 2 wires	2½	10.0c	162	240	1 in. above 15 in. above Ground Line	29.9c	Mixture broke wires did not slip or break
No. 10, 8 strands crimped	2½	10.0c	197	263	Ground Line 2 in. above 10 in. above	29.9c	Wires slipped
No. 10, twisted 4 long and 2 short	3	12.0c	130	160	30 in. above 30 in. above 30 in. above	31.9c	Mixture broke extra wires did no good
No. 6, 4 long hooked at ends	2⅔	10.6c	133	184	10 in. from top Ground Line Ground Line	30.5c	Straight wires, all wires slipped
New Barbed 4 long strands	1⅔	6.6c	70	123	Ground Line 2 in. above Ground Line	26.5c	Wires broke
Old Barbed 4 long strands	1⅔	3.3c	98	128	Ground Line Ground Line Ground Line	23.2c	Wires broke
New Barbed 4 long and 2 short	2	8.0c	83	198	Ground Line 6 in. below 1 in. above	27.9c	Wires broke
No. 15, 4 strands of 3 each twisted	1⅛	4.5c	82	125	Ground Line 7 in. above 3 in. above	23.6c	All wires broke did not slip

The Test.—In making the test, the posts were placed under as nearly fence conditions as possible. All line posts were set and firmly tamped into the ground so that 4 feet and one inch projected above the surface. By means of a wire, a dynamometer was attached to the post exactly 4 feet from the surface, as shown in Fig. 7. A steadily increasing force was applied to the dynamometer by means of a block and tackle, until the first visible crack appeared in the post when a reading was made. The force was then increased until the post gave way completely when the final reading was made.

TABLE NO. 3—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length 6 feet 6 inches. Cured weight, 110 to 115 pounds. Mixture, 1 part cement and 4 parts sand, by measure. Cost for cement per post, 22 pounds, 13.2 cents; sand, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Material in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands or 2 wires twisted No. 10	2½	10.0c	147	222	28 in. above 30 in. above 42 in. above	26.9c	Mixture gave way, wires not well placed.
4 long and 2 short twisted strands No,10	3	12.0c	237	322	8 in. below 7 in. below 11 in. below	28.9c	Mixture and wires about equal strength,
4 long straight wires hooked at ends No. 6	2⅔	10.6c	170	222	Ground Line 3 in. below	27.5c	Wires slipped
4 long old barbed wires	1⅔	3.3c	70	95	Ground Line 3 in. below 5 in. below	20.2c	Wires broke, they were poorly placed.
4 long and 2 short old barbed wire	2	4.0c	98	127	18 in. above 20 in. above 13 in. above	20.9c	Wires broke. Poor wire.
4 long and 2 short new barbed wire	2	8.0c	138	172	20 in. above 19 in. above 12 in. above	24.9c	Wires well placed. Cement broke.
4 long strands of 3 twisted wires No. 14	1⅔	6.6c	68	105	Ground Line Ground Line 3 in. below	23.5c	Wires broke.

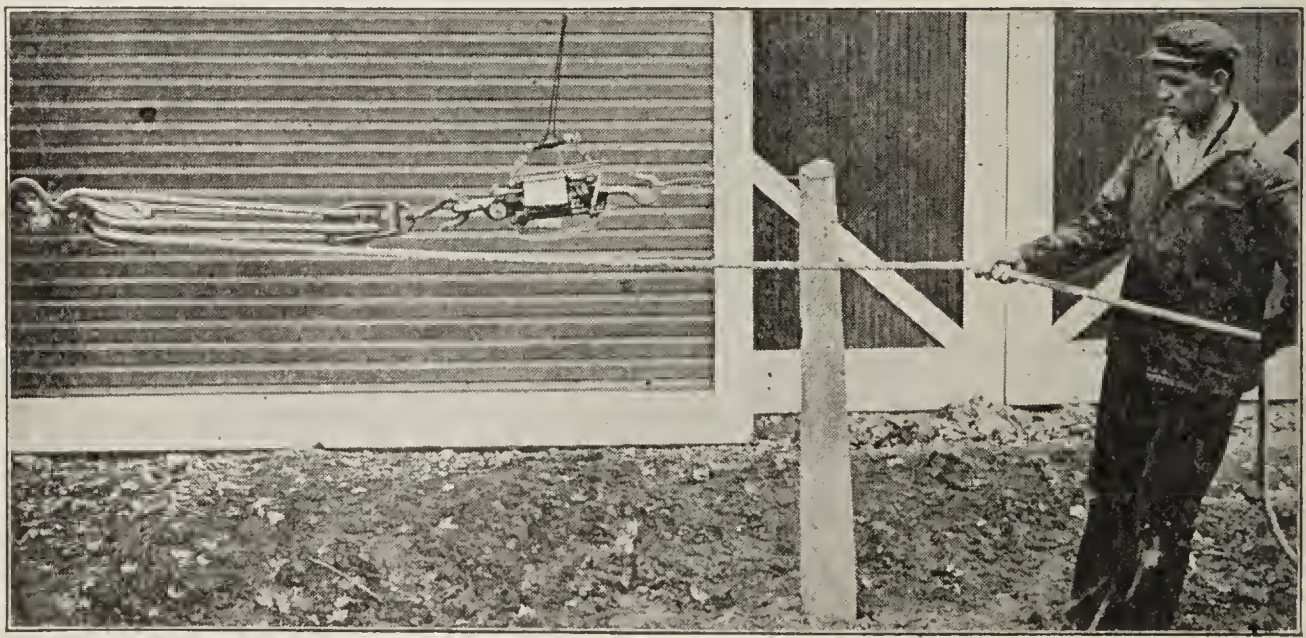

Figure 7.

Method Which Was Used in Testing All Line Posts.—The distance from the ground line to the point at which the hitch was made is four feet. The dynamometer records the exact number of pounds of pull required to break the post.

In making the posts, enough of the mixture was provided for the construction of three posts at once. The three were cured alike, for 60 days and were tested at the same time. The tables show the average results of the test on the three posts as one.

In the reinforcement the short wires mentioned are two feet long and are placed in the post so the top extends about 12 inches above the ground line and the bottom about 12 inches below. One of these extra wires is placed in the face side of the post and the other in the back, so that they help to bear the strains on the post.

In case of four extra wires, one is placed in each corner of the post with the other reinforcement wires.

Cost of Materials.—In figuring cost of materials the following prices were used:

Sand and gravel, $1.00 per cubic yard.
Cement, 60 cents per sack.
New reinforcement, 4 cents per pound.
Old barbed wire, 2 cents per pound.

TABLE NO. 4—Tamped Posts.

These posts are of the same size and composition as those in Table No. 3, excepting they are tamped instead of poured.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post in Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Material in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 long strands of 2 wires twisted, No. 10	2½	10.0c	122	192	Ground Line Ground Line 2 in. above	26.9c	Wires broke
4 long straight strands, No. 6	2⅔	10.6c	103	162	Ground Line Ground Line	27.5c	Wires slipped
4 long strands old barbed wire	1⅔	3.3c	117	137	14 in. above 30 in. above Ground Line	20.2c	Wires broke
4 long and 2 short old barbed wire.	2	4.0c	122	142	12 in. above 12 in. above 13 in. above	20.9c	Wires broke
4 long new barbed wire	1⅔	6.6c	140	160	Ground Line Ground Line Ground Line	23.5c	Wires broke
4 long and 2 short new barbed wire	2	8.0c	80	170	11 in. below 16 in. above 13 in. above	24.9c	Wires not well placed
4 long and 4 short old barbed wire	2¾	5.5c	112	196	18 in. above 8 in. below 24 in. above	22.4c	One post broke 8 in. below also 23 in. above Gr. L.

TABLE NO. 5—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 110 to 112 pounds. Mixture, 1 part cement and 5 parts sand, by measure. Cost for cement per post, 17 pounds, 10.2 cents; sand, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Material in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands 2 twisted wires, No. 10.	2½	10.0c	197	235	2 in. below Ground Line 4 in. above	23.9c	Mixture broke. Reinforcement wires poorly placed
4 long and 2 short twisted strands No.10	3	12.0c	197	220	3 in. below 5 in. below Ground Line	25.9c	Extra wires did no good. Mixture broke.
4 long strands old barbed wire	1⅔	3.3c	95	113	Lost 1 in. below 7 in. below	17.2c	Wires broke, not well placed.
4 long and 2 short old barbed wire	2	4.0c	97	137	4 in. above 10 in. above 7 in. below	17.9c	Mixture and wires about equal strength
4 long strands new barbed wire	1⅔	6.6c	78	123	2 in. below 16 in. above 4 in. above	20.5c	Mixture and wires about equal strength.
4 long and 2 short new barbed wire	2	8.0c	75	140	10 in. above 8 in. above 18 in. above	21.9c	Wires broke
4 long strands of 3 twisted wires No. 14.	1⅔	6.6c	103	130	Ground Line 2 in. below 3 in. below	20.5c	Wires broke
4 long and 2 short strands 3 twisted No. 14	2	8.0c	103	175	14 in. above 13 in. above 14 in. above	21.9c	Wires and mixture about equal strength

TABLE NO. 6—Poured Posts.

Size, 4x4 inches at base, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 80 pounds. Mixture, 1 part cement and 4 parts sand, by measure. Cost for cement, 13.5 pounds, 8.1 cents; sand, ⅔ cubic foot, 2.5 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 twisted wires No. 10	2½	10.0c	80	168	2 in. below Ground Line Ground Line	20.6c	Mixture broke on two posts, wires broke on the other
4 long strands old barbed wire	1⅔	3.3c	50	65	5 in. above Ground Line 3 in. above	13.9c	Wires broke
4 long strands new barbed wire	1⅔	6.6c	82	88	Ground Line 6 in. below Ground Line	17.2c	Wires broke on one and mixture on two posts.
4 long strands of 3 twisted wires No. 14.	1⅔	6.6c	58	62	2 in. below Ground Line 5 in. above	17.2c	Wires broke, Mixture broke on one post.

TABLE NO. 7—Tamped Posts.

These posts are of the same size and composition as those in Table No. 5, excepting they are tamped instead of poured.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 twisted wires No. 10	2½	10.0c	75	97	6 in. below 8 in. above 8 in. below	23.9c	Mixture gave way, posts split.
4 long and 2 short twisted strands No. 10	3	12.0c	73	98	2 in. below 3 in. below	25.9c	Mixture gave way, posts split.
4 long strands old barbed wire	1⅔	3.3c	88	117	4 in. below 2 in. above Ground Line	17.2c	Wires broke
4 long and 2 short old barbed wire	2	4.0c	77	113	13 in. above 15 in. above Ground Line	17.9c	Mixture and wire about equal, one wire poorly placed
4 long strands new barbed wire	1⅔	6.6c	60	108	1 in. below Ground Line Ground Line	20.5c	Mixture and wires nearly equal strength.
4 long and 2 short new barbed wire	2	8.0c	47	103	12 in. above 16 in. above Ground Line	21.9c	Wires in 2 posts poorly placed.

TABLE NO. 8—Poured Posts.

Size, 4x4 inches at base, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 80 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost for cement, 18 pounds, 10.8 cents; sand, ⅔ cubic foot, 2.5 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 twisted wire No. 10	2½	10.0c	162	183	Ground Line Ground Line Ground Line	23.3c	Mixture and wires about equal strength.
4 long strands old barbed wire	1⅔	3.3c	73	108	2 in. below 2 in. above 2 in. below	16.6c	Wires broke
4 long strands new barbed wire.	1⅔	6.6c	82	105	4 in. below 2 in. above Ground Line	19.9c	Wires broke
4 long strands of 3 twisted No. 14	1⅔	6.6c	78	102	Ground Line Ground Line Ground Line	19.9c	Wires broke
4 long, 2 short strands of 3 twisted No. 14	2	8.0c	162	185	10 in. above 12 in. above 4 in. below	21.3c	Wires broke
(Specials) 4 long twisted strands No. 9.	2¾	11.0c 11.0c	140 cracked	140 125	Ground Line Ground Line	24.3c 24.3c	These posts were secured from the manufactu'r.

TABLE NO. 9—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement 3 parts sand and 3 parts gravel, by measure. Cost of cement per post, 14 pounds, 8.4 cents; sand and gravel, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 wires twisted No. 10	2½	10.0c	177	218	Ground line Ground line 4 in. below	22.1c	Wires broke on 2 and mixture broke on one.
4 long and 2 short twisted strands No. 10	3	12.0c	188	330	4 in. above 12 in. above 4 in. below	24.1c	Wires broke
4 long strands old barbed wire	1⅔	3.3c	88	110	Ground line Ground line Ground line	15.4c	Wires broke
4 long and 2 short old barbed wire	2	4.0c	70	118	20 in. above 24 in. above 15 in. above	16.1c	Wires broke, not well placed.
4 long strands new barbed wire	1⅔	6.6c	103	143	4 in. below Ground line Ground line	18.7c	Wires broke
4 long and 2 short new barbed wire	2	8.0c	115	123	Ground line 3 in. above 10 in. above	20.1c	Wires broke
4 long strands of 3 twisted wires, No. 14	1⅔	6.6c	102	123	Ground line 27 in. above Ground line	18.7c	Wires broke
4 long 2 short strands of 3 twisted No. 14	2	8.0c	85	143	Ground line 7 in. below 4 in. below	20.1c	Mixture broke on two and wires broke on one.

Figure 8.

A few types of broken posts showing: (A) The splitting off of the tamped post. (B) The bursting due to the buckling of the tube of a commercial truss. (C) A post in which mixture and reinforcement were about equal. (D) A post in which smooth wire reinforcement was used, the wires slipped, thus allowing the post to bend. (E) Post removed from mold too soon.

TABLE NO. 10—Poured Posts.

Made in sheet iron mold, which makes a post round on one side and flat on the other. Size 5x5 inches at base, tapering to 3x3 inches at top. Length, 7 feet. Cured weight, 75 to 80 pounds. Mixture, 1 part cement and 3 parts sand by measure. Cost for cement per post, 18 pounds, 10.8 cents. Sand, ⅔ cubic foot, 2.5 cents. For cost of reinforcement, see table below. The reinforcements in this post are supposed to be placed in three places, two next to the flat side and one on the oval side of the post. This makes the flat side stronger. In the test, one post of the three was pulled away from the flat side toward the round side, and two from the round side toward the flat side.

Those marked (a) were pulled away from flat side, and (b) towards it.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
3 long No. 19 ⅝ in. band iron	2¼	9.0c	135 (a) 120(b)	190(a) 125(b)	Ground line Ground line	22.3c	Posts from manufacturer, band iron broke.
3 long strands of 2 wires twisted No.10	1⅞	7.5c	85(b) 95(b) 125(a)	125(b) 135(b) 180(a)	Ground line 3 in. below Ground line	21.8c	Wires broke
3 long strands old barbed wire	1¼	2.5c	70(b) 65(b) 70(a)	70(b) 80(b) 105(a)	Ground line Ground line Ground line	15.8c	Wires broke
3 long and 3 short old barbed wire	2	4.0c	100(b) 120(a) 100(b)	115(b) 155(a) 110(b)	18 in. above 12 in. above 20 in. above	17.3c	Wires broke above extras
4 long strands old barbed wire	1⅔	3.3c	crack'd 85(a) 125(b)	120(b) 125(a) 155(b)	2 in. above 1 in. below Ground line	16.6c	Wires broke
4 long and 4 short old barbed wire	2¾	5.5c	120(b) 115(a) 120(b)	165(b) 120(a) 160(b)	15 in. above 14 in. above 7 in. above	18.8c	Mixture broke
4 long strands, 2 each, twisted No. 10	2½	10.0c	130(b) 180(b) 150(a)	175(b) 230(b) 200(a)	Ground line Ground line Ground line	23.3c	Mixture broke

The last 3 sets of posts contained 4 reinforcements instead of 3. It will be noticed that the one extra wire made a great difference in the strength of these posts; they are more nearly equal strength from both directions.

AMOUNT OF LABOR REQUIRED FOR MAKING POSTS.

No definite statements can be made as to the amount of time required to make a cement or concrete fence post. The amount of time will vary with conditions, handiness of materials, methods of mixing, etc. According to data obtained in the experiment, two men mixing by hand, with everything reasonably handy, can make from three to five 5-inch poured line posts per hour. Figuring labor at $2.00 per day, ten hours for each man, the cost for making a post would amount to about 10 cents each. Three men with a small home made mixer and a two-horse-power gasoline engine for driving it would be able to make at least twice as many posts as two men working by hand and the cost for making would be very much less.

TABLE NO. 11—Poured Posts (Triangular).

These are triangular posts made in triangular sheet iron molds. Size, 7 inches on each side at the bottom, tapering to 5 inches on each side at the top. Length, 6 feet 6 inches. Cured weight, 85 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost for cement per post, 19 pounds, 11.4 cents. Sand, ⅔ cubic feet, 2.5 cents. For cost of reinforcement, see table below. In the test, one post of the three was pulled away from the flat side towards the opposite corner and is marked (a); the other two were pulled from one corner towards the opposite flat side and are marked (b).

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
3 long strands new barbed wire	1¼	5.0c	65(b) 90(a) 70(a)	100(b) 90(a) 105(a)	2 in. below 2 in. above 2 in. below	18.9c	Wire broke Mixture crushed Mixture crushed
3 long and 3 short old barbed wire	1¾	3.5c	45(b) 35(b) 30(a)	50(b) 55(b) 100(a)	15 in. above 15 in. above 15 in. above	14.9c	Wires broke Wires broke Mixture crushed
6 long old barbed wires 2 in each corner	2¼	4.5c	80(b) 110(b) 130(a)	120(b) 190(b) 130(a)	2 in. above 2 in. below 2 in. below	15.9c	Wires broke Wires broke Mixture crushed
3 long No. 14 3 strands twisted	1¼	2.5c	70(b) 85(a)	90(b) 145(a)	4 in. above 4 in. below	13.9c	Wires broke Mixture crushed
4 long new barbed wires*	1⅔	6.6c	110(b) 75(a)	135(b) 85(a)	Ground line 6 in. above	18.0c	Mixture split Mixture crushed
4 long No. 14 3 strands twisted	1⅔	6.6c	165(b) 160(b) 115(a)	175(b) 180(b) 140(a)	Ground line Ground line Ground line	18.0c	Mixture crushed Wires broke Mixture crushed
4 long No. 15 3 strands twisted	1⅛	4.5c	130(b) 130(b) 105(a)	150(b) 175(b) 105(a)	Ground line Ground line 1 in. above	15.9c	Wires broke Wires broke Mixture crushed

THE EFFECT OF ALKALI ON CEMENT AND CONCRETE POSTS.

It has been found that some soils contain an excessive amount of alkali, which has a tendency to destroy concrete work. While no experimental work has been done to test the effect of such soils upon cement or concrete posts, it has been conclusively proven that cement drain and sewer tiles which come in contact with water which has percolated through these alkali soils are soon destroyed.

While it might be possible that the action on cement or concrte posts would be slower than in case of the tiles, it is probable that the posts would eventually be destroyed.

For further information in regard to the effect of alkali on cement construction see Bulletin No. 69 of the Montana Agricultural College Experiment Station, and Bulletin No. 132, Agricultural Experiment Station of the Colorado Agricultural College.

*Where 4 wires are used for reinforcement, the extra wire is placed in the corner opposite to the side on which the fence wires are fastened.

TABLE NO. 12—Poured Posts.

These posts were made in special sheet iron lined wood molds put out by a certain manufacturer. The reinforcement recommended for these posts is a special trussed tube, which is sold by the manufacturer at 15 cents each at the factory. The results of the test on three posts in which this truss was used is shown below in connection with other similar posts with wire reinforcement. Size of post, 3½x4½ inches at base, tapering to 3½x3½ inches at the top. Length, 6 feet 6 inches. Cured weight, 80 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost of cement per post, 18 pounds, 10.8 cents. Sand, ⅔ cubic foot, 2.5 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST			COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	First Crack in Lbs.	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Material in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
Special Commercial Trussed Tube	3, 6-oz.	15.0c	105	150	Ground line Ground line Ground line	28.3c	In every case trussed tube bent caused post to crack.
4 long strands new barbed wire	1⅔	6.6c	130	137	Ground line Ground line Ground line	19.9c	Wires broke, Wires poorly placed in one post.
4 long strands 3 twisted No; 14 wires	1⅔	6.6c	75	107	1 in. below 1 in. below Ground line	19.9c	Wires broke, Wires poorly placed in one post.
4 strands of 2 wires twisted No. 10	2½	10.0c	110	160	3 in. below Ground line 2 in. below	23.3c	One wire broke in each post.

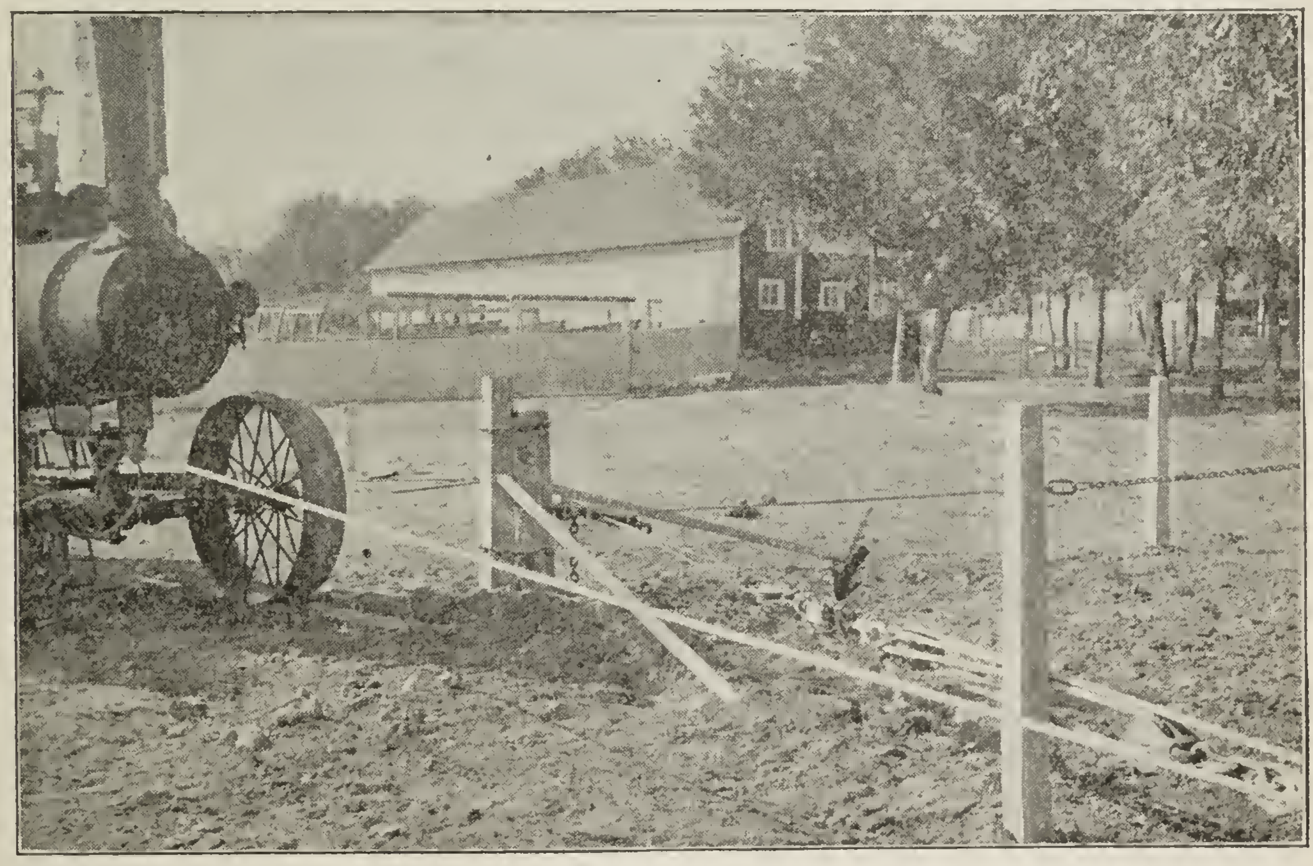

Figure 9.

A 7-inch corner post braced with a 2-inch gas pipe 14 feet long; 5-inch brace post. The exact number of pounds of pull exerted by each of the two fences is recorded by the dynamometer shown under the arrow.

THE THREE-CORNERED POST.

The three-cornered post, which is advocated to some extent, does not have as many points in its favor as it may seem. In the first place an equal amount of reinforcement in each corner of the post cannot make a post of equal strength from two opposite directions. If a force is brought to bear against one of the flat sides of the post towards the opposite corner, the material in the corner will crush long before the wires will break on the side from which

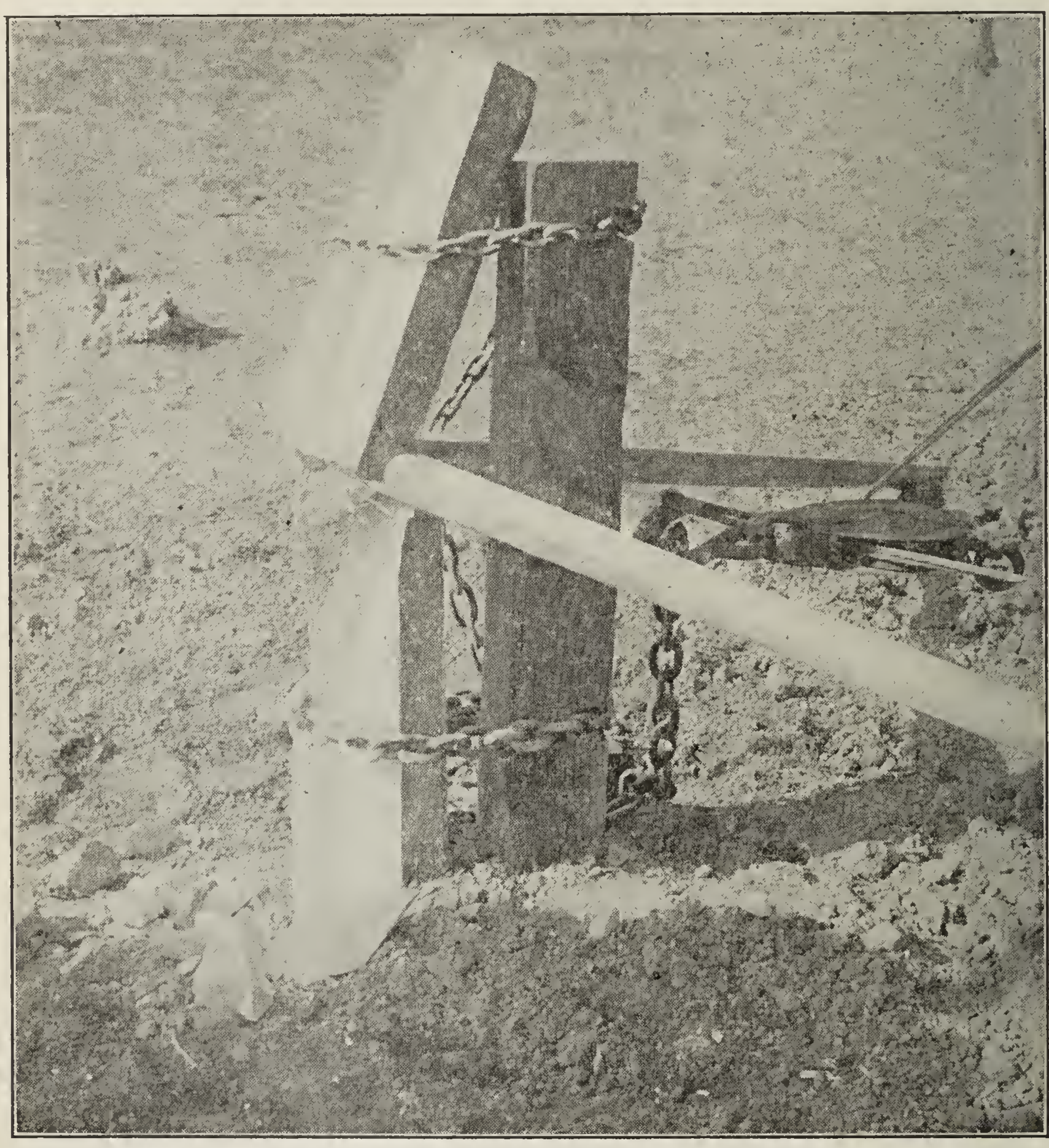

Figure 10.
The post shown in Fig. 9 after the test. Two-fifths of the pressure is exterted above the brace and three-fifths below.

the force is exerted. On the other hand, if a force is brought to bear against one corner of the post towards the opposite flat side, the single reinforcement in the corner will break before the mixture has begun to crush on the flat side.

An extra reinforcement in the corner on which the force is exerted towards the opposite flat side will make it practically as strong as the flat side. But when the force is again applied to the flat side towards the single corner which is doubly reinforced, the mixture in the corner gives way too soon and it is no better than with but a single reinforcement.

TABLE NO. 13—Corner Posts.

Size, 8x8 inches from base to ground line, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 360 pounds. Mixture, 1 part cement, 2 parts sand, and 3 parts of gravel, by measure. Cured 90 days. Cost for cement per post, 51 pounds, 30.6 cents; sand and gravel, 3 cubic feet, 11.1 cents. For cost of reinforcement, see table below. Test shows pull exerted in pounds as by each of two fences pulling at right angles.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs.	Location of Break	Cost of Material per Post	All reinforcements figured at 4c Lb. excepting old barbed wire at 2c.
2-8 ft. and 2-5 ft. pieces ½ in. rod on tension side	16	64c	poured	7200	8500	at brace	$1.057	Short wires extended from below ground line to above brace line
Same as above	16	64c	tamped	5050	5600	at brace	1.057	Short wires extended from below ground line to above brace line
14 strands old barbed wire on tension side.	8	16c	tamped	6300	7300	at brace	.577	Mixture broke
Same as above	8	16c	poured	5900	7400	at brace	.577	Mixture broke
10 twisted strands No.10 on tension side	8	32c	tamped	5400	7300	4 in. below brace	.737	Mixture broke
Same as above	8	32c	poured	6300	6650	4 in. above brace	.737	Mixture broke

Size, 7x7 inches at base, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 250 pounds. Mixture, 1 part cement, 2 parts sand and three parts gravel, by measure. Cured 90 days. Cost of cement per post, 36 pounds, 21.6 cents; sand and gravel, 2 cubic feet, 7.4 cents. Fort cost of reinforcement, see table below.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs.	Location of Break	Cost of Material Per Post	All reinforcements figured at 4c Lb. excepting old barbed wire at 2c.
8 strands old barbed wire 2 in each corner	4½	9c 2c lb.	poured	2700	3600	at braces	$ .38	Mixture broke
8 strands new barbed wire 2 in each corner	4½	18c 4c lb.	poured	3225	4050	at braces	.47	Mixture broke

HOLLOW POSTS.

It has been suggested that the cement and concrete posts should be made hollow. The hollow post would require less mixture and it would also be lighter. As the material in the center of the post does not have a good opportunity to act to the best advantage in compression, it is argued that the strength of the hollow post would be nearly as great as that of the solid post.

In case time is of little value it would probably prove more economical to build hollow posts. As the amount of reinforcement is not affected by the change from the solid to the hollow post, only the saving in cement, sand and gravel need be considered. It is an easy matter to compute the saving accomplished by the making of hollow posts, and then by knowing the cost of labor, the economy of building them may soon be calculated. With cement at 55 cents per sack and sand at $1.00 per yard, one cubic foot of 1 to 4 mixture costs 18 cents. If a 1½ inch hole were to be left in the center of a post 7 feet long about 1½ cents' worth of material would be saved. With labor at 15 cents per hour, 6 minutes might be given to the extra work of making the post with the hollow core.

In case of alkali soils the hollow center gives additional exposed surface upon which the alkali may act. In a 4-inch square post with a 1½ inch core, the extra surface amounts to about 28 per cent. of the original lateral surface.

Finally there is a serious question as to the relative strength and durability of the hollow post as compared with the solid one.

CORNER POSTS AND GATE POSTS.

In the building of a fence with cement or concrete posts, the corner and gate posts must be especially strong, so as to prevent the pull of the wires coming upon the line posts. All the pull of the wires should be borne by the corner or gate posts. With this in mind the designer should aim not only to build a very strong post, but the system of bracing should receive special attention.

As the cement posts are not as strong as wood posts, we cannot use the same bracing systems, which are so commonly in use in wood post fence construction. It has been found advisable to place the brace so that it supports the post at a point very little, if any, above the middle of the post. For the reason that the posts are strong in compression, but do not stand as much pull as wood posts, it proves advisable to place the brace against the brace post at least one foot below the ground line; thus the post distributes the pressure at the end of the brace against an area of ground equal to the surface covered on the opposite side of the post.

There should be several wires connecting the brace post and the corner or gate post together. These wires should be placed under the ground at a depth of about one foot. By having these wires tight the corner post cannot move unless the brace post moves, and as this is securely fastened to it, the whole becomes a unit, offering a rigid resistance to the pull of the fence.

In case of a corner post, the wires may be fastened by wrapping them around it, but the most satisfactory way is to cast wire staples in the post. These staples should extend into the post far enough to be wrapped around one or more of the reinforcement wires.

The hinges for gates may also be cast in the posts when it is desired to do so.

Corner and gate posts are usually reinforced in the same way as line posts. It is unnecessary, however, to place reinforcement wires on the inner sides of the corner posts, as the outer sides bear almost all of the tension.

With the tapered posts, it is desirable to construct the face sides straight; this brings all of the taper on the other two sides. Small lugs or shoulders should be cast on each brace side of the post, against which the brace is placed.

The ordinary five-inch line post proves to be strong enough to act as a brace post for an eight-inch corner post.

The following table gives a summary of breaking strength and cost of materials of some of the best poured posts, which were made and tested in this experiment.

MIXTURE	DESCRIPTION	REINFORCEMENT								
		4 Long No. 10 Twisted	4 long 2 short No. 10 twisted.	4 long New Barbed Wire	4 long Old Barbed Wire	4 long 2 short new barbed	4 long 2 short Old Barbed	3 long No.19 5/8 in. band iron	4 long 4 short Old Barbed	6 long Old Barbed
1 to 3	Ground line 5x5 top 3x3	307 lbs. 29.9c	290 lbs. 31.9c	188 lbs. 26.5c	158 lbs. 23.2c	none none	200 lbs. 23.9c			
1 to 4	Ground line 5x5 top 3x3	222 lbs. 26.9c	322 lbs. 28.9c	none none	95 lbs. 20.2c	172 lbs. 24.9c	127 lbs. 20.9c			
1 to 5	Ground line 5x5 top 3x3	235 lbs. 23.9c	220 lbs. 25.9c	123 lbs. 20.5c	113 lbs. 17.2c	140 lbs. 21.9c	137 lbs. 17.9c			
1 to 3	Base 4x4 top 3x3	183 lbs. 23.3c	none none	105 lbs. 19.9c	108 lbs. 16.6c					
1 to 4	Base 4x4 top 3x3	168 lbs, 20.6c	none none	88 lbs. 17.2c	65 lbs. 13.9c					
1 to 3-3	Ground line 5x5 top 3x3	218 lbs. 22.1c	230 lbs. 24.1c	143 lbs. 18.7c	110 lbs. 15.4c	123 lbs. 20.1c	118 lbs. 16.1c			
1 to 3	Base 5x5 top 3x3 horse shoe shape	202 lbs. 23.3c			133 lbs. 16.6c			157 lbs. 22.3c	148 lbs. 18.8c	
1 to 3	Triangular Base 7x7 top 5x5			110 lbs. 18.0c						147 lbs. 15.9c

Strength of Cement posts compared to new wood posts tested under like conditions.

KIND OF POST	SIZE OF POST	BREAKING STRENGTH	REMARKS
(1) Best cement post tested	5x5 in. at ground line tapering to 3x3 in. at top	av. of three 322 lbs.	
(2) Cement	Same as above	av. of three 307 lbs.	
(3) Cement	4x4 in. at base tapering to 3x3 in. at top	av. of three 185 lbs.	The post was 3.6x 3.6 in. at ground
(4) Split cedar (new)	3.6x3.6 in. at ground line	av. of three 613 lbs.	Same size at ground as No. 3 above
White pine (new)	4x4 in. at ground line	2000 lbs.	
Red spruce (new)	4½x4½ in. at ground line	2400 lbs.	
Red spruce (new)	5x5 in. at ground line	3350 lbs.	

CONCLUSIONS.

Poured posts are easier to make than tamped ones. They are somewhat more expensive because one mold will make but one poured post per day, while the same mold may be used for making as many tamped posts as the builder can mix and tamp in the same time.

According to the tests made poured posts are a little over 25 per cent stronger than tamped ones of the same size, mixture and reinforcement.

Poured posts are not so porous as the tamped ones and are therefore more nearly water proof, thus making them better able to withstand the action of frost and alkali.

The poured post is enough better in every respect to justify its construction and use in preference to the tamped one.

Most commercial molds make a post which tapers from the base to the top, but the most economical mold is one which casts a post as large at the ground line as at the base, tapering from the ground line to the top. For a description of this form of mold, see Fig. 4.

The best form of post is one which is equally strong from all directions. The square, or round post, fulfills this requirement. The triangular post does not meet the requirements because it cannot be economically constructed so as to be equally strong from all directions.

To be economical, the amount of reinforcement should be in proportion to the size of the post and strength of the mixture. See tables.

The material used for reinforcement should be strong, light and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch.

The smooth reinforcement tends to slip even if hooked at the ends.

Two or more wires twisted together make as satisfactory a reinforcement as can be obtained.

Crimped wire tends to strengthen and thereby breaks pieces out of the post at the point of greatest stress.

The reinforcement should be placed in each corner of the post at a depth of from ⅜ to ¾ of an inch from the surface.

There are several commercial wire fasteners now found on the market, the most of which are either cumbersome or expensive. For a simple and satisfactory fastener, see cut of fasteners. (Fig. 5, A.)

The posts should be cured in the shade for at least 60 days, the first 30 days of which they should be sprinkled daily.

Bulletin 149 June, 1909

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

PART I.

CARRYING RANGE STEERS THROUGH THE WINTER.

PART II.

SUGAR BEETS FOR FATTENING STEERS.

BY

W. L. CARLYLE

AND

G. E. MORTON.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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PART I

CARRYING RANGE STEERS THROUGH THE WINTER

W. L. CARLYLE and G. E. MORTON

INTRODUCTION

Cattlemen are at variance in their opinions as to whether range steers should be winter fed as calves and as yearlings, when they are to be carried over for fattening as two-year-olds. And an equal divergence of opinion exists as to whether it is wise to carry steers to that age before finishing. The experiment detailed in PART I of this bulletin was outlined by Prof. W. L. Carlyle in 1905 and carried out under his direction until its completion in 1908. Professor J. A. McLean and the writer, who succeeded him, carried out the winter feeding work with the steers. The writer is the only one of these three at hand at the publication of the bulletin, and as he did not see the first two years of the experiments, he finds it difficult to make as thorough a writ-up as he would like. The data presented is sufficient, however, to indicate the answers to one or two questions concerning winter feeding of store steers.

PLAN OF THE EXPERIMENT

In the fall of 1905, 20 head of representative steer calves were secured from the herds of W. H. Gerdts, Cope, Colo.; E. M. Ammons, Littleton, Colo., and I. B. Griffith, New Castle, Colo. Three calves were Hereford grades, and were brought to the College for winter feeding. A like number of representative steers of the same crop were brought to the College from these herds in the fall of 1906, and again a like number in the fall of 1907, with the exception that the five head from Mr. Griffith's herd were not secured in 1907, because of shipping difficulties.

Each summer the steers, which had been winter fed at the College, were turned out upon enclosed range, owned by the College and located on the foot hills west of Fort Collins.

In this way some of the steers were winter fed as calves, as yearlings and as two-year-olds; some were fed as yearlings and as two-year-olds; and some fed only as two-year-olds.

Again, some of the steers fed as calves were finished off as yearlings, while others were not marketed until they were twos.

The following table shows the weights and gains made by the steers each season:

AVERAGE WEIGHTS AND GAINS OF ALL STEERS FOR EACH SEASON

	Average Weight Fall of 1905	Average Weight Spring of 1906	Average Gain Winter 1905-06	Average Weight Fall of 1906	Average Gain Summer 1906	Average Weight Spring of 1907	Average Gain Winter 1906-07	Average Weight Fall of 1907	Average Gain Summer 1907	Average Weight Spring **1908**	Average Gain Winter 1907-08
Steers Fed as Calves, 20 Head..............	404	663	259	804	141	1094	290	1145	x62	1368	223
Steers Fed as Yearlings, 20 head............				664		984	320	1046	*95	1407	361
Steers Fed as Two-Year-Olds, 15 Head......								911		1146	235

x The average weight of six head which were kept over, their average weight in the spring of 1907 being 1083 pounds. The other 14 head were sold in the spring of 1907, average weight 1099 pounds.

* The average weight of the 14 head which were kept over, their average weight in the spring of 1907 being 951 pounds. The other six head were sold in the spring of 1907.

In discussing the table, we will first take up this question:

If you expect to feed steers out at two years of age, does it pay to winter feed them either as calves or as yearlings?

The steers fed during the third winter only—the winter during which they were fitted for market—gained 235 pounds per head and weighed 1146 pounds, while those fed the second and third winters, gained 361 pounds the third winter and weighed 1407 pounds. The latter not only weighed 261 pounds per head more because of their previous feeding, but were in better shape to put on good gains the winter they were finished out, putting on 126 pounds per head more weight than the steers fed the third winter only. Another point in their favor was that the extra weight was in fat rather than in frame, as they were valued at the close of the third winter, when ready for market, at $6.20 per cwt, while the steers fed the third winter only, were valued at $5.75 per cwt. These valuations were made by Mr. Henry Gebhardt, of Denver, without knowledge of what lots the steers were from.

Mr. Gebhardt, at the same time, placed a valuation of $6.10 upon the steers brought in to the College in the fall of 1905 and fed all three winters. These steers made a gain of only 223 pounds per head the third winter,—less than either of the other lots; and they showed an average weight of 1368 pounds per head, or 39 pounds per head less than the steers that were not winter fed as calves, and 222 pounds per head more than the steers that were not winter fed either as calves or yearlings. These results plainly show that winter feeding the calves was not profitable when the steers were to be held over to be finished off as two-year-olds, for the lot that were not winter fed as calves, but were fed the two succeeding winters, not only made the largest gain during the last winter, but showed the heaviest average weight, and were in best market condition.

We can state then, so far as the gains made by these steers are concerned, that when the aim in view was to finish the steers as two-year-olds, the feed put into them as calves was wasted, but feeding them the winter they were yearlings put them in shape to make better gains the next winter and made better market steers of them. This result does not coincide with the view of those cattlemen, who believe that if only one winter's feed is to be given previous to the winter of finishing, that feed should be given the calves in order to retain upon them their baby flesh. But a study of the weights and gains of the steers brought in as calves will bring out the reason, I believe, for the poor showing made by these steers the third winter.

WEIGHTS AND GAINS OF STEERS FED THREE WINTERS AND THOSE FED TWO WINTERS

Weight	Steers Fed Each Winter		Steers Fed Two Winters	
	Weight	Gain	Weight	Gain
Fall of 1905 (Calves)	404			
Spring of 1906	663	259		
Fall of 1906	804	141	664	
Spring of 1907	1094	290	984	320
Fall of 1907	1145	62	1046	95
Spring of 1908	1368	223	1407	361

You will note the heavy gain put on by the calves during the first winter's feeding—almost as much as they put on the next winter as yearlings. As a consequence, they weighed, the fall that they were yearlings, 140 pounds per head more than the steers of the same crop brought in from the range as yearlings. The next spring they were only 110 pounds heavier, the next fall 99 pounds heavier, and the spring they were marketed, 39 pounds lighter than the steers brought from the range as yearlings. This gradual decrease in the margin between the two sets of steers indicates that the winter feeding as calves hastened the steers to maturity and consequently lessened their power for gain each successive season at a rapid rate.

Another way to look at the question is to compare the gains made each year by the same lot of steers. The lot fed as calves made a gain of 400 pounds per head the first winter and succeeding summer; the next year they made 352 pounds gain per head—already starting down hill you notice—and the last winter they made a gain of only 223 pounds per head, or 36 pounds per head less than they made the winter they were calves.

Considering the year when they were one year old, they made a gain of 431 pounds as against a gain of 285 pounds when two-year-olds. And the steers that were not fed until they were yearlings made a gain of 456 pounds the year that they were twos.

WEIGHTS AND GAINS OF STEERS OF THE DIFFERENT BRANDS

All Steers are of the Same Age, Calved 1905. See Note

	Fall 1905	Year 1905-06	Winter 1906-07 to April-2nd	Summer 1907		Winter 1907-08
				June 7thx	Oct. 26th*	
VI—1905				(3)		
Total (10)	3527	7646	9930	3125	3320	4230
Average	353	765	993	1042	1107	1410
Average Gain		412	228		65	303
VI—1906				(6)		
Total (10)		6857	9595	5790	6360	8390
Average		686	960	965	1060	1398
Average Gain			274		95	338
VI—1907						
Total (10)					9265	11360
Average					927	1136
Average Gain						209
U—1905				(1)		
Total (5)	1870	3999	5155	1210	1240	1240
Average	374	800	1031			
Average Gain		446	231		30	0
U—1906				(5)		
Total (5)		2968	4218	4625	5090	7165
Average		594	844	925	1018	1433
Average Gain			250		93	415
U—1907						
Total (5)					4400	5830
Average					880	1166
Average Gain						286
1—L 1905				(2)		
Total (5)	2690	4398	5427	2165	2310	2740
Average	538	880	1085	1083	1155	1370
Average Gain		342	205		72	215
1—L 1906				(3)		
Total (5)		3464	4455	2905	3200	4150
Average		693	891	968	1067	1383
Average Gain			198		99	316

NOTE—For convenience the steers are designated by the year during which they were brought from the range. For example U—1906 means the U—steers brought to the College from the range in the fall of 1906, the steers then being yearlings.

*June 7th was the date upon which the steers kept over were put out to pasture.

xThe figures in brackets in this column are the number of head of steers not sold and put out on pasture June 7th.

Thus any way one wishes to look at the problem, the feeding of calves does not appear profitable if they are to be held over for finishing as two-year-olds. The amount of feed used is not considered in the discussion above, because the interpretation of results could in no way be affected by the cost of the feed, save for the general statement that the greater the cost of feed for calves, the greater would be the loss to the feeder.

FEEDING TWO WINTERS OR ONE

In considering winter-feeding for two winters compared with feeding the third winter only, we must note first of all that the steers fed as yearlings weighed 261 pounds per head more at marketing than the steers fed the last winter only, and were worth 45 cents per cwt. more than the latter. They were both heavier and fatter. Whether this extra weight and fatness paid for the feed put into them as yearlings is problematic. The feed for the steers, brought to the College in different seasons was not kept separate, so that the feed per head as shown in the following table is an average for all the steers:

AVERAGE FEED AND GAIN PER HEAD
2nd and 3rd Winters

Season Winter	Number Head	Average Weight at Close Winter	Average Gain During Winter	Feed Per Head in Pounds			Cost of Feed Per Head
				Corn	Alfalfa Hay	Sugar Beets	
1906-07...	20 (held over)	991		992	2644	1306	$19.89
1906-07...	20 (sold)	1087		1203	2536	2270	24 04
1906-07...	40 (all)	1039	307	1138	2660	1921	22.83
1907-08...	35	1289	284	1252	2835	1998	24.60

NOTE—Price of corn, $1.00 per hundred; price of alfalfa, $5.00 per ton; price of beets, $5.00 per ton.

AVERAGE FEED AND GAIN PER HEAD 2ND AND 3RD WINTERS.

The steers denoted in the second column of this table as "held over," comprised six head of the steers fed as calves, and 14 head of those brought in as yearlings. The average feed per head for these during the second winter was 992 pounds of corn, 1306 pounds of sugar beets, and 2644 pounds of hay, or in round numbers ½ ton corn, 2¼ tons of hay, and 2/3 of a ton of sugar beets. At the prices listed, this feed cost about $20.00 per head ($19.89). With alfalfa hay at $10.00 per ton, the cost of feed would be raised to about $26.00 per head.

Now for returns. Assuming that the feed during the third winter, for the two lots under discussion, was approximately equal, as assumption not out of the way, the extra income from the steers fed two winters may be credited against the first winter's feed. Referring again to Table A, we find the steers fed the second and third winters weighed 1407 pounds per head at the close. This weight at an advance of 45 cents per cwt. over the other steers, means $6.33 credit. Then 261 pounds extra weight at $6.20 gives $16.18, or a total of $22.51 to credit against the feed. And yet another item is to be taken into consideration, the College range is not good range late in the summer, which accounts for the low gains made each summer. Any range man would expect to secure larger gains than are shown by the spring and fall weights of these steers. So that with this evidence before us, I believe the winter feeding as yearlings was a paying proposition. It is by no means proven, but the indications are strongly in that direction. With so many problems involved in this one experiment, it is difficult to make a clean cut conclusion on each issue. While we have convincing proof that the winter feeding of calves, destined to be fed each winter until sold as two-year-olds, was a losing proposition, all we can say concerning the question at issue is this: The winter feeding of yearlings destined to be fattened and sold as two-year-olds, resulted in heavier, fatter and more marketable steers; and besides producing good gains during the winter in which the feeding was done, produced residual feeding effects shown by very heavy gains the winter they were finished. And so far as we can tell from the results at hand, such feeding will ordinarily produce a profit if feeding stuffs are not too high priced.

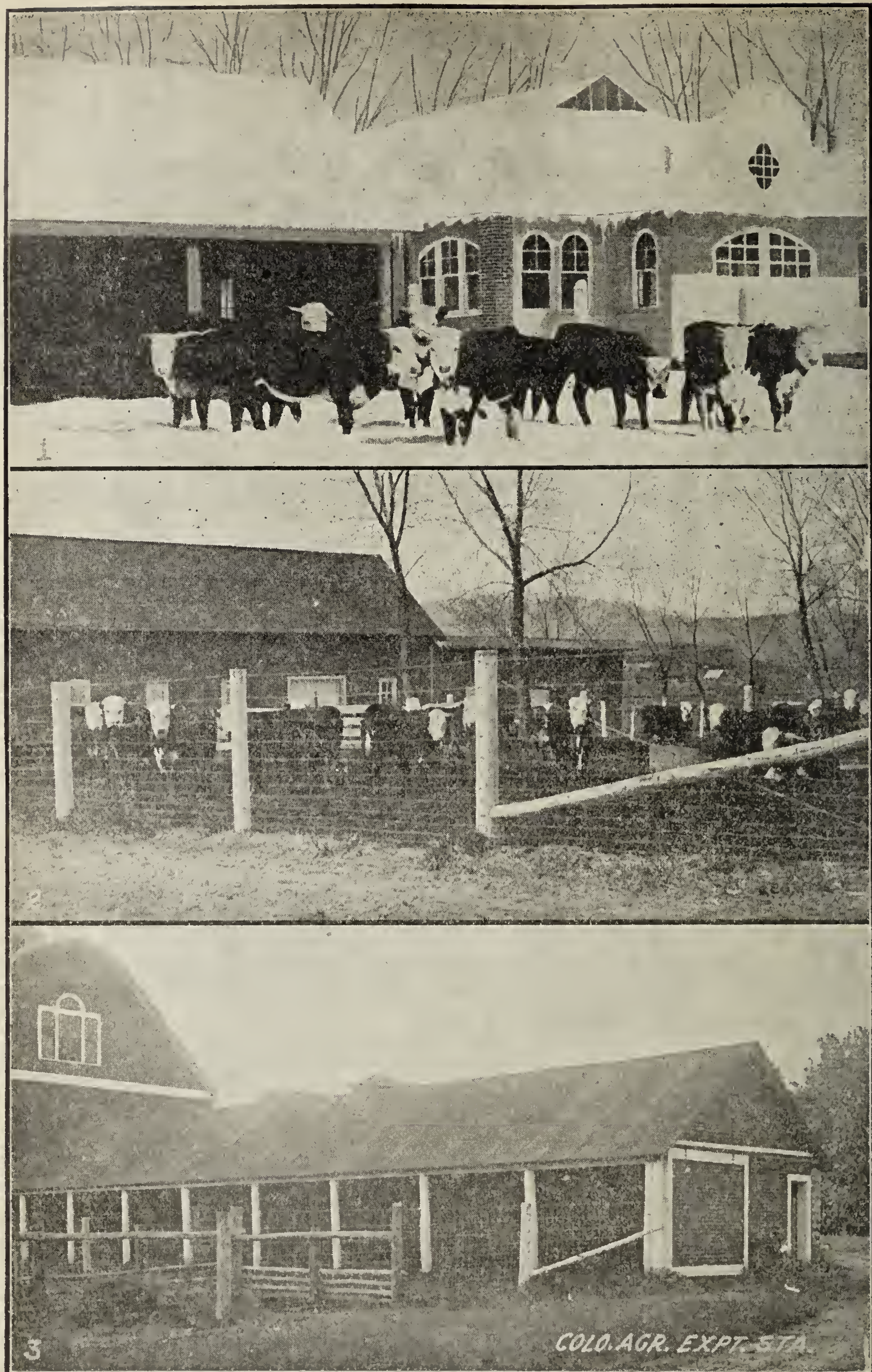
FATTEN YEARLINGS OR TWO-YEAR-OLDS?

But another question arises: *Does it pay better to winter feed as calves and finish as yearlings, or winter feed as yearlings and finish as twos?*

This question involves many more points than those taken up in this feeding experiment, so that it cannot be answered fully here. But we can furnish some data of use to the cattleman in figuring the problem for himself. The problem as it lies before the cattleman is this: If he fattens his steers as yearlings, he must charge all loss of cows and calves and depreciation of value in the young cows against this one year's running of the steers; while if he carries the steers two years he may distribute this charge over two years. On the other hand if he feeds as yearlings he gets cheaper gains on his steers, as one will on all young animals, and he releases his capital so that it is turned over every year instead of every other year. He does not need to make so large a profit on the yearlings, because he will make that profit twice as often.

The light which this experiment throws on that problem, consists in a definite knowledge of the gains made by steers during the different seasons as is shown in Table A.

The steers winter fed as calves made a gain during that winter and the following summer of 400 pounds; while the steers not fed until the winter they were yearlings made a gain during that winter and the following summer of 415 pounds. With practically equal gains, the calves undoubtedly put on their gain much more cheaply than the yearlings. By referring to PART II of this Bulletin it will be seen that yearlings put on their gain at about two-thirds the cost of the gain put on by two-year-olds. The second winter's feeding shows two-year-old steers weighing 1046 pounds per head in the fall, making a gain of 361 pounds per head during the winter; while yearling steers weighing 804 pounds per head made a gain of 290 pounds. The two-year-olds gained 34.6 per cent. of their live weight, while the yearlings gained 37.3 per cent. of their live weight. This again is in favor of the younger steers.



Upper picture—Steers when calves.

Centre picture—Steers coming two-year-olds.

Lower picture—Open shed in which steers slept and were fed grain. Hay racks in foreground.

During the winter of 1905-06 the calves were fed upon beet tops until the 15th of February, running in the fields with stock cattle. When taken from the beet fields ten head were fed a ration of four pounds daily of ground corn with alfalfa hay; while the other ten head were fed a ration of twenty pounds per head of sugar beets. Both lots made approximately the same gains, the only differenece being that the lot fed beets ate somewhat less hay. For the purposes of this discussion, it is sufficient to say that the amount of feed consumed by the younger animal is less than that consumed by the older. And from this standpoint of feeding alone, it seems more economical to winter feed as calves and finish as yearlings than to winter feed as yearlings and finish as two-year-olds.

FINISHING YEARLINGS

If you intend to finish steers as yearlings, is it profitable to feed them hay and grain the winter that they are calves?

The steers winter fed as calves gained 30 pounds per head less during the winter they were yearlings, than the steers gained that were not winter fed as calves; but they averaged 110 pounds per head more in weight than the latter and sold for 25 cents per cwt. more. This offers no satisfactory conclusion without a knowledge of the cost of feed. However, the calves fed during their first winter gained 259 pounds per head that winter, and yet were only 140 pounds heavier the next fall than those not winter fed. This indicates a poor summer gain, which their gain of 141 pounds per head undoubtedly was. The steers in this experiment lost a great deal of flesh when first turned on the range and did not thrive at any time during the summer as range cattle wintered on hay would have done. The only conclusion that one can come to with the insufficient data at hand, is that whether or not there be profit in winter feeding of calves destined to be sold as yearlings, depends upon the condition of the range upon which they were run. It is more a question of grass and storms than one that can be settled definitely for all conditions.

MARKET VALUE OF THE STEERS

The last spring of the experiment when all of the steers were coming three-year-old, Mr. Henry Gebhardt, of Denver, put a market valuation on the three lots of steers, without knowledge as to how each lot had been handled. He valued the steers that had been fed every winter at $6.10 per cwt.; those fed two winters at $6.20 per cwt., and those fed one winter at $5.75 per cwt. These prices indicate the comparative condition of flesh of the various lots, and the valuation given corresponds to the final weights of the three lots.

These market prices mean that the steers which were not fed as calves, but were fed the winter that they were yearlings, then put back on the range, and finished out as two-year-olds, not only made the most rapid gains and were heaviest when put upon the market, but were fattest, having put on a large proportion of their gains in flesh and fat.

FAT, BONE AND LEAN MEAT IN A RIB CUT

Rib roasts, comprising the 8th and 9th ribs and measuring 5 inches in width, were taken from the carcasses of the two steers.

One steer, A, which had been fed both the winter he was a yearling and the succeeding winter, was killed in April, weighing 1440 pounds. The other steer, B, which was fed only as a two-year-old, was held until August after steer A had been killed, when he reached the 1400 pound weight.

The rib cuts taken were dissected with the following results:

	Lean Meat	Fat	Bone
Steer A..........................	8 lbs. 13 oz.	8 lbs. 12 oz.	2 lbs. 4 oz.
Steer B..........................	9 lbs. 2 oz.	7 lbs. 5 oz.	3 lbs.

These figures show little difference between the steer which had been fed two winters, and the one fed only one winter. What difference there is shows more bone and lean meat in the animal fattened rapidly at a later stage of life. There was practically no difference in the appearance of the rib cuts from the two steers.

PART II.

SUGAR BEETS FOR FATTENING STEERS.

The steers used in the experiment, described in Part I, were fed during each winter with a view to finding the value of sugar beets in replacing part of the corn used with the customary corn and alfalfa ration in Colorado. European and Canadian feeders regard roots highly as an aid in finishing cattle, but in America it has been difficult to popularize their use. Many inquiries have come to this Station, however, as to the value of sugar beets for stock feed, and in conversation with feeders, I find that many are firmly convinced that sugar beets possess a feeding value of from $5.00 to $10.00 per ton. Results of experiments conducted in other states indicate a much lower value than this for feeding, and the following experiments were conducted with a view of ascertaining the true value of sugar beets for feeding under Colorado conditions. The results obtained throw considerable light upon this question.

EXPERIMENT I

In this trial of 16 weeks, Lot 1 was fed six pounds of corn and 30 pounds of sugar beets per head each day, while Lot 2 was fed 12 pounds of corn. This meant replacing half the corn with sugar beets in the proportion of 5 pounds of sugar beets to one pound of corn. The steers were yearlings.

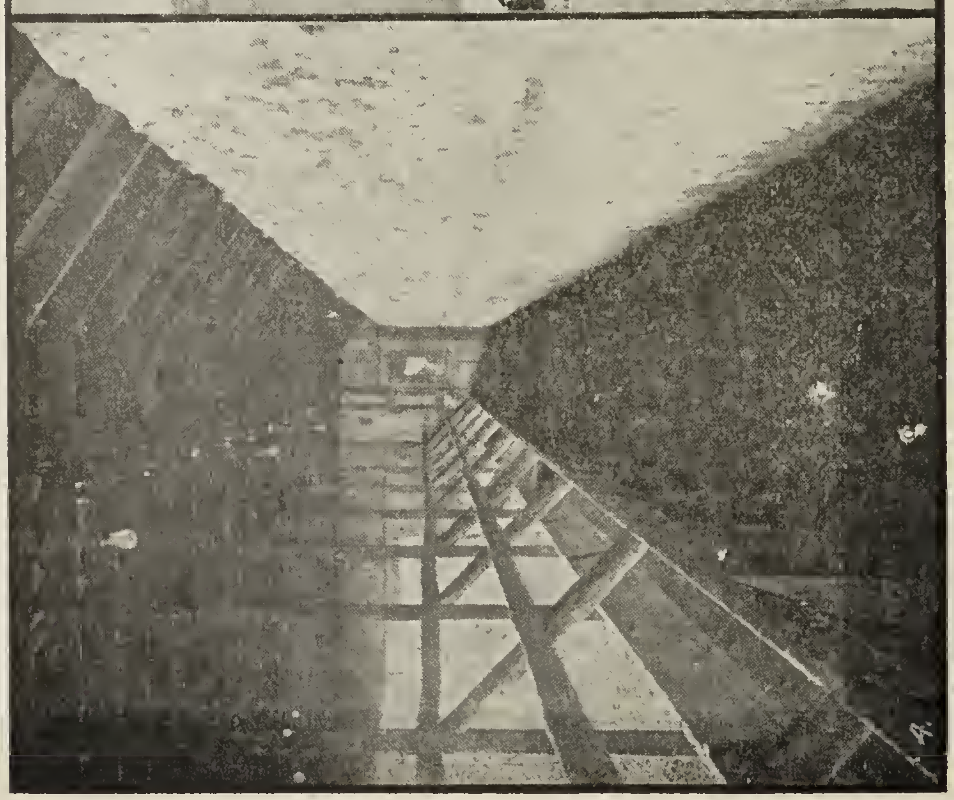
FEED, GAIN, AND COST OF GAIN

Lot	No. in Lot	Total Gain in Weight	Total Feed Pounds			Average Gain Per Head	Pounds Feed Required For 100 lbs. Gain			Cost of Feed 100 lbs. Gain
			Corn	Sugar Beets	Alfalfa Hay		Corn	Sugar Beets	Alfalfa Hay	
1....	*	4714	9245	52234	30194	239	196	1108	641	$6.33
2....	**	4256	18851		30640	216	443		720	6.23

* At first 18 head, after 3rd week, 20 head.
** At first 17 head, after 3rd week, 20 head
Note—Corn at $1.00 per cwt., Beets at $5.00 per ton, Alfalfa Hay at $5.00 per ton.

The steers fed the sugar beets made somewhat better gains than the others, averaging 23 pounds heavier at the close. By inspection of the columns showing feed required for 100 pounds gain, we find that 1108 pounds of sugar beets replaced 247 pounds of corn and 79 pounds of alfalfa hay; or 4.5 pounds of sugar beets replaced 1 pound of corn and .32 pounds of hay in the production of 100 pounds gain in live weight.

Figuring corn at 1 cent per pound, sugar beets at $5.00 per ton, and hay at $5.00 per ton, the sugar beet ration cost $6.33 for every hundred pounds gain produced, while the corn ration cost $6.23. These results indicate that if corn costs more, or sugar beets less than these prices, it will pay to substitute sugar beets for half of the corn ration.



Interior of Steer Shed, Showing Grain Trough

Range on Which the Steers Were Run in Summer

SECOND TRIAL 1907-1908

This trial lasted 22 weeks. The steers were two-year-olds. Lot 1 was fed 12 pounds of corn per head each day, while Lot 2 was fed 6 pounds of corn and 30 pounds of sugar beets.

FEED, GAIN, AND COST OF GAIN

Lot	No. in Lot	Total Gain in Weight	Total Feed Lbs.			Average Gain Per Head	Pounds Feed Required for 100 Pounds of Gain			Cost of Feed For 100 lbs. Gain
			Corn	Sugar Beets	Alfalfa Hay		Corn	Sugar Beets	Alfalfa Hay	
1....	17	4425	28454		52653	260	643		1190	$9 41
2....	17	4655	15375	69931	46560	259	330	1502	1000	9 55

Note—Corn at $1.00 per cwt., Beets at $5.00 per ton, Alfalfa Hay at $5.00 per ton.

The two lots of steers made equal gains. 1502 pounds of sugar beets replaced 313 pounds of corn and 190 pounds of hay in the production of 100 pounds gain, or 4¾ pounds of sugar beets replaced one pound of corn and ¼ pound of hay. Figuring prices of feeds the same as in the previous trial, the sugar beet ration cost $9.55 for every hundred pounds of gain produced, while the corn ration cost $9.41. The greater cost in comparison with the former trial is undoubtedly due to the greater age of the steers.

This trial is so closely in accord with the previous trial with regard to the amount of beets necessary to replace half the corn ration, that we may state with reasonable certainty, that sugar beets when fed with a half ration of corn, have a feeding value of about one-fifth that of corn; it will take from 4½ to 5 pounds of sugar beets to give the results produced by one pound of corn.

The steers used in the second experiment were priced by Mr. Henry Gebhardt, of Denver, without a knowledge as to the manner in which they had been fed. He valued the steers fed on sugar beets and corn at 10 cents per hundred weight less than the steers fed corn, so that the finish of the steers in one lot was not much different from that in the other.

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On the Measurement and Division of Water

BY

L. G. CARPENTER

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ON THE MEASUREMENT AND DIVISION OF WATER*

By L. G. CARPENTER†

Questions concerning the measurement and division of water probably give rise to more trouble than all other questions combined in an irrigated country. While frequently the amount of water in dispute is small it may be and often is, a serious matter. It certainly is a source of irritation, causing constant friction between the management of a canal and the consumers, and between neighbors. It is more troublesome because of the well-known fact that a stream of water always looks larger in the neighbor's ditch than in one's own. It is irritating because neither disputant can convince his opponent or even satisfy himself, and hence for the lack of knowledge of how to determine the fact, assertion takes the place of demonstration. A more widely distributed knowledge of methods will remove much of these troubles, as it already has.

When the water supply is scanty, error may be a very serious matter, for the crops of the user may depend on a small quantity of water, and gives cause for strenuous dispute. This has been the case from time immemorial and the serious disputes thus arising are embalmed in a curious manner in one of our words in common use. In old Roman times, an artificial water channel, therefore a ditch, was a "rivus," and the users from such a water course were "rivals;" and the conflict in interest indicated in this word, comes from the typical case of users from the same irrigation ditch. This same difference in interests persists today as it did at the time when their disputes became notoriously difficult of settlement.

The problem of a just distribution of water is therefore one of the most important, as well as one of the most difficult problems of canal management. Frequently, in fact generally, the measurement becomes one of approximation. The practical need is to obtain a method that is sufficiently exact for the given conditions and also—which is sometimes of greater practical importance—to secure one which will inspire confidence.

The measurement of water and the division of water may be two distinct though closely related problems, so that a method which is intended for measurement serves also for division. It should be clearly understood that no one method will apply to all situations. Methods suitable to a canal of heavy fall and with a heavy fall in the laterals, cannot be available where the fall is

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*The first edition of this bulletin was issued in October, 1890, a reprint in July, 1891. The third edition, with additional tables and considerable revision, was issued as Bulletin 27 in 1894. The trapezoidal weir first described in the early editions of this bulletin has been very widely adopted on the American continent.

†738–740 Equitable Building, Denver.

small or where the land to be supplied is nearly on the same level as the canal. Methods to be used where the water is clear may be impossible in streams carrying large quantities of silt. Likewise, the methods must often be adapted to satisfy conditions of local contracts or to accord with local customs. No system will work without intelligent supervision. A poor method may work out satisfactorily, provided the man in charge has experience and good judgment. Sometimes even a good system will not be free from trouble unless administered by capable men. Hence one of the necessary requirements in canal management is to educate the superintendents and riders so that they have sufficient understanding of the principles of measurement to apply them to the exceptional cases. The men also need the confidence of the users. Users are suspicious, and hence it is as important, perhaps more important, for the successful management of a canal, to have a system which appears to be fair as to have one which is fair, but is not apparent. Hence an important feature is a measurement which shall be simple and which may be understood by the user. It thus saves unpleasant disputes and arguments, strengthens the faith in the ditch rider, and relieves him from clamor of those who think that the way to get their share is to claim more than they are entitled to.

The bulletin will describe some methods of the division of water adapted to the use of small ditches and laterals, and also methods of measurement which may be used in large ditches. It especially explains the use of the weir, the conditions under which it should be placed and the extent to which it can be relied upon, and also tables for its use.

In the previous editions of this bulletin, descriptions were made of the rectangular and of the trapezoidal weir with sides inclined at one-fourth to one. The description of this weir in 1890 was the first description of this form of weir in English. Because it had been proposed by the engineer of an Italian canal, I called it after him, the Cippoletti weir. From the description and recommendation given in Bulletins 13 and 22, its use has widely spread over the irrigated sections. It has been adopted by various experiment stations, by the state engineers of all of the western states, and by the United States Department of Agriculture, but in most cases without credit to the author or to the station. The recommendation given in Bulletin 13, (1890), and Bulletin 27, (1894) has sometimes been taken too broadly, but as a whole the endorsement there given has been justified. The statement there made that I considered it to be the most advantageous of any module for irrigation purposes, should not be taken to mean that it is the most accurate. The only advantage over the rectangular weir is that its discharge is proportional to the length. This is a great convenience in the practical operation of a canal, with many suspicious consumers, who do not understand the facts of hydraulics. It avoids the attempts to explain the effect of end contractions called for in the rectangular weir, and the difficulty found by the ditch riders to do this helped to increase suspicion rather than inspire confidence.

It should also be clearly understood that there is no one form of opening which is intrinsically better than another. There may be many other forms with accuracy as great or equal to the rectangular weir. At present, however, the rectangular weir has been subjected to experimental tests under so many conditions that its peculiarities are well known and this is true only to a limited extent of other forms. The flow of water over weirs has been most rebellious to theory. But as their discharge has been measured under different conditions, and the requirements for placing are so simple they can be established with confidence in the accuracy of the results. Tests have been made in such number that more confidence can be felt in it than in any other form of opening, and hence, while the knowledge of other forms may be increased in the future and thus other forms of opening come into use, some form of weir is the one best worthy of confidence at the present time. In this bulletin the triangular notch is also shown more at length. It is capable of use for small laterals and has some advantages over the rectangular weir for that purpose. The conditions for placing it are the same as for the weir, and tables are newly calculated for the discharge. The advantage of the triangular notch over the weir is that only one measurement is necessary—that of the depth—while in the case of the weir, both the length and the depth need to be measured. The triangular notch is not adapted to large quantities of water, but inasmuch as one with a depth of one foot will discharge over two cubic feet of water per second, it gives as much as most individual laterals call for, and therefore can be used on ditches as distributing weirs, where the rectangular or trapezoidal weir is used on the larger lateral or main canal.

The importance of measurement, both to the community and to the public wealth, scarcely needs mentioning. Where water has been plentiful in the streams and ditches, as was the case in the beginning, the necessity for close measurement was not felt, for there has been water enough for all but with greater demand for water, with the pressing necessity to make every drop available, and with the increase in the value of water, we are led to consider more efficient means of measurement and distribution. This is the history of the development of every irrigated community from earliest times and will continue to be so. The need is increasingly exacting, for the pressure for water progressively increases.

The prevention of waste is a matter of public importance. The land suitable for irrigation so much exceeds the water supply, not only in Colorado but throughout the West, that the agricultural development depends on the use of the supply to its fullest capacity. Though the building of storage reservoirs, the stopping of waste, improved methods of irrigation which were all recommended in Bulletin 13, (1890), have been carried out to a great extent and the agricultural products, if not the agricultural area, has greatly increased, and much improvement in measurement has come, the pressure remains about the same. A larger saving will be effected in the future as it is found that less quantities of water are needed; subdivision into smaller and smaller streams becomes necessary and measurement will become more exact, and it will be justifiable to expend larger sums for exact devices.

Aside from the accuracy, a good system of measurement saves a large amount of water. A careful account is known to be the basis of sound finance. An accounting, in itself, produces economy for it causes an arrest of thought, and directs attention to the matters under consideration, and reveals the source of waste. It is also true in water administration. The very fact that water is measured checks extravagance. If it be not measured the idea is easily fostered that it is not valuable enough. The mere fact that measurement is made and an account kept, makes each user more careful. In ditches where no attempt has been made to control the use by individuals, it is surprising to notice the saving caused by keeping an account and thus showing how much each has used and to compare one with another. In cities it is well known that the mere installation of water meters and keeping account of the water used by each individual, often reduces the consumption to one-third what it was before, and yet no one has suffered. When water is plentiful, a system, or lack of system, works without trouble. The practice then is to give water enough to stop complaint. When the water becomes scarce, then inexactness in measurement means that someone gets more than his share. This means that some one else gets less; and the result may be serious upon the crops.

In all parts of the State where the pressure for water is felt, there has been a great increase in the value of land, and this is almost entirely from the increase in the value of water. Reservoirs have been built at an expense of millions of dollars to take advantage of streams of water that a few years since were considered to be insignificant. This increase in the value of water has only begun, and therefore the conditions which justify pains and expense to obtain accurate measurements, will increase. Companies will go to much greater expense for this particular purpose than they now consider justifiable. It is true that the present practice is generally behind what could reasonably be expected from present conditions.

Even now in the exchange between reservoirs in northern Colorado, the companies have found it justifiable to employ a skilled person for that particular work, at considerable expense. The statement made in the first edition may be repeated:

> "There will never be an easier time for arranging satisfactory measurements than now; for the demand will not be less, and with time and the increase in the value of water, there will be many who will feel that they have rights vested in certain methods of measurements which may be intrinsically unjust."

For many years I have had occasion to pass over the ditches in Colorado in detail. This was generally in company with the ditch rider or superintendent. Thousands of miles were thus traversed. In so doing, I made the methods of distribution the subject of special observation and inquiry. In general, it was found that the methods were exceedingly unreliable. There has been a great improvement both in the methods and in the qualifications of the ditch riders, yet the same statement may still be made. In many canals the measurement depends on the eye and judgment of the ditch rider. In others, the measurement is nominal and really worse than none, because it gives a false idea of accuracy, and, so long as it prevails, it stands in the way of the introduction of a better system.

This bulletin was originally prepared because of the need then observed, of greater knowledge of methods of measuremnt, and was based upon the study of the devices as they existed, and of the methods used in other states and other countries. There is a chance for great improvement. I have found discrepancies amounting to as much as 400%. No method should be considered meeting the conditions of today unless it is correct within 5% or 10%. The practice is not often so accurate as this, and yet it is not difficult to bring it within 5%. Increase in accuracy means more pains and therefore more expense, but with the value of water, more expensive methods are justifiable and precautions can be taken which would have been out of consideration in times past.

On this subject, as well as on others in the line of irrigation, the experience of Italy is suggestive, even if it cannot always be taken as an example. Their physical conditions have much that is similar to ours. Our development has followed hers, though we have condensed her growth of six centuries into fifty years. The physical laws governing the flow of water, the principles involved in the distribution and measurement, are the same. We are finding certain laws and regulations to be necessary which they found to be necessary centuries ago. They have outgrown their first crude methods. One of their most widely used modules was based upon an erroneous idea. It was early introduced into Colorado and used on some of the earlier ditches.

The need for measurement dates back to the beginning of irrigation. The methods were necessarily adopted without much hydraulic knowledge. That they were fairly satisfactory, reflects credit upon those who had to make them. This is especially true in regard to the well-known Milanese module produced by Soldati, and adopted by the magistrates of Milan. But we find fairly workable methods, crude to be sure, but adapted to the conditions, among the ancient Romans, among the Moors, and among almost all users of all nations who have tried to make a fair division of a fluctuating quantity. The modern Italian canals, like the Cavour Canal, the Canale Casale, Canale Villoresi, have adopted methods of measurement depending upon the weir. While the old measuring box or module is still used on the ancient canals of Lombardy, it has had to be modified to meet modern conditions. Other provinces or coommunities have generally other methods. In some cases users have acquired rights under a particular manner of measurement. They are afraid of any change for it may affect their rights and thus arouses intense opposition. Soldati met with so many difficulties in the attempts to reform the system of measurement and with such violent abuse that he met the fate of the reformer who attempts to change the settled customs of a people. This may be, and often is, a kind of conservatism but becomes a violent opposition among those who think they are affected. The same kind of conservatism is shown in Colorado. The same varied customs which gave rise to the abuses in Italy which Soldati tried to check are becoming fixed. There are numerous canals in which there are different classes of users. Their rights are different. Water is measured to them in different manners, or at least on a different basis. This introduces problems of measurement much more complicated, but not different in kind, and sometimes makes a difference in the method required. Thus, as an illustration, one canal which may be taken as fairly typical indicates the character of the questions of measurement which arise. That canal includes the following classes of rights:

1. What may be termed as preferred rights. A number of users entitled to unlimited water without measurement and without assessment. These are due to special contracts whose origin generally lie in the fact that the canal has been the successor of an earlier ditch and the users in the earlier ditch have relinquished their ownership for this consideration.

2. The ordinary stockholders, each entitled to a proportionate part of the water remaining after the first class has been supplied. Sometimes the amount of water is limited to a prescribed amount. In this case, serving as an illustration 4 shares is limited to 1.44 second feet, intended for 80 acres of land.

3. A class of residuary rights—persons who are not entitled to any water until classes 1 and 2 have received their amount; they are entitled to whatever is in excess. These are surplus rights without vote in the management.

4. Persons using the canal as a common carrier. A case arises, for example where the water of a reservoir is run through the canal to its stockholders, who may or may not be stockholders in the canal. There may be several different and independent sources of water each requiring independent treatment. The charge for carriage may be for money or for a fraction of the water carried.

The classes of the first three kinds have been common in Italian practice for generations. Some of these privileges existed in the time of the Caesars and are mentioned in Frontinus account of that period. They have developed with us and will in any irrigated country, because the situation naturally gives rise to the conditions calling for them.

Hence it may be realized that the problem of distribution, which is necessarily a difficult one, becomes additionally complicated. It may be realized that the solution is not exact, especially as additional complications are introduced from the ever-varying losses from evaporation and from seepage; from the fluctuating needs of different users, which vary from hour to hour; from the fluctuating supply entering the canal, due to the effect of the varying draft of other ditches and from the diurnal fluctuation in the river itself; and to the complicating effect of the time which is required for water to pass down the canal, which in some of the larger ones may be several days.

In the measurement of water from ditches there are two distinct classes of measuring boxes—one is the dividing box and the other the measuring box or module. The object of the former is to furnish a definite portion of the water flowing in a ditch. The need of this form of box is more common in small ditches owned by two or three neighbors, or in minor ditches with a limited number of stockholders. The intention is to give one person, for example, one-fourth, or some other fraction, of all the water that enters the ditch, this fraction being in proportion to his interest. It is thus best adapted to short ditches or cases where the number of people are few and where the expense of a ditch rider or patrolman is to be avoided.

The other class of box is the measuring box, whose object, in general, is to give a certain definite quantity of water, as one cubic foot per second. Sometimes the attempt is to deliver a constant quantity of water. This purpose, however, is not usually necessary or desirable. Under conditions in the western part of the United States, the quantity taken by the ditch, and therefore by the laterals, is constantly varying. In most cases a user is entitled to a certain fraction (depending upon his number of shares of the capital stock) of the whole amount of water. Most contracts reduce to such a statement in the last analysis. If there be 600 shares outstanding, then omitting the more complicated cases which, however, are the common ones, each share is entitled to 1-600 of the available supply. Hence in nearly every case the problem becomes essentially one of equal division, complicated by various other conditions. There are few cases in which the consumer can demand a constant flow of a definite quantity. This requirement is not necessary and is rarely desirable. In most canals, where there are a large number of users, the simplest way of giving each person his share is to measure out a definite quantity. The manager or ditch rider determines how much water is available, after allowing for the loss by seepage and evaporation which experience has shown for that particular ditch. Perhaps he may be limited by the amount in the stream and this may be fluctuating. Then knowing from the reports of the ditch riders how many shares will call for water, he divides the available amount of water by the number of shares so calling, and thus determines how much is available for each share. The object is, then, to measure to each his proportional amount. Like the depositors in a bank, it is rarely that all users call for water at the same time. If the supply of water for the canal is constant and the demand is constant, then the flow to which each share is entitled is constant. Practically, however, this is never the case; hence, it is more important that the boxes be capable of exact measurement and of adjustment than it is that they give a constant flow. The fluctuating conditions are met by setting the boxes or adjusting the gates once or twice per day or oftener in strenuous times. At best this is an approximation. I am inclined to think that with the development of a practicable register of low cost, less attention will be given to the daily adjustment. This is already done in the case of reservoir water.

The class of measuring boxes adapted for measurement has been called by the Italians, "Modulo." It is more convenient in its French form, "Module," and this name therefore, is used to designate those boxes whose object is to measure the quantity of water delivered, or to give a constant flow. The word, "Divisor" will be restricted to the class of boxes, previously referred to, whose only object is to divide water.

There will always be cases where the Divisors are the most convenient, especially in the small ditches. In all other cases modules of one kind or another will be found to be the better. The problem is to determine the one best adapted to the special conditions, which is most reliable, most accurate, and which has the fewest objections.

In the case of divisors it is evident that there is no unit of measure, and that none is needed, for the object is to give the user some fractional part of the water flowing in the ditch, whether there be much or little.

In the module, on the contrary, some unit of quantity is needed, and this, with us, is a cubic foot per second, a unit which has now become established through all the western states. The term "inch" has been widely used in the western states and gives a notion of unit, but does not have any of the essential characteristics. The essential character of any unit is that it has a definite value and is one which can be reproduced. Also, in case it is multiplied, ten units should be ten times one unit. There is the "water inch," or "miner's inch," the "statutory inch," and the "customary inch" with infinite variations, used in such a multitude of meanings that it is an almost hopeless task to express an exact idea of quantity. The term has been convenient to use, notwithstanding its inaccuracy. It was used in Italy for thousands of years in essentially the same meaning.

In the case of flowing water it is manifest that the amount passing through a given channel depends upon the speed of the water, as well as upon the section of the channel. In the inch system of measurement, account is taken of the cross section and not of the speed of the water. Some attempt is often made to regulate the speed by providing that the pressure of water over the opening shall be always the same. In such cases the area of the opening in square inches is counted as inches of water. As there are other conditions affecting the velocity of the water, there is still room for very large differences in velocity, and consequently the same unit may mean very different quantities of water.

An inch of this kind is recognized in the Statutes of Colorado, and defined in the laws of 1868 as follows:

> "Water sold by the inch by any individual or corporation shall be considered equal to an inch square orifice under a 5-inch pressure, and a 5-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 aperature through which such water shall 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 and not less than one-eighth of an inch to the foot."

In other states, statutory inches have been recognized, generally being a development of a practice that arose among miners, and thus has been frequently called a "miner's inch." Thus in

Nevada it represents the flow through an orifice two inches high, with a head above the opening, of six inches. In other cases, the head has been four inches, six inches, eight inches, and sometimes the opening is extended to the surface of the water and no pressure is used. The whole area of the opening is then counted as "inches" of water. In this system, an opening six inches high and sixteen inches long would be, for example, 96 inches, and one six inches high by eight inches long would be 48 inches. If the system met the proper conditions of unit, the flow through one opening should be twice as much as the other. As a matter of fact the one opening will give considerably more than twice the other. This is due to the fact that the retardation by the sides of the opening from friction is relatively greater in the smaller one than in the larger. There are other conditions also, which may affect the quantity materially. The law does not prescribe the size or fall of the channel bringing water to the boxes, nor how rapid shall be the descent away from it—only providing that it shall be not less than one-eighth of an inch to the foot.

In some cases the term, "customary inch" has been used, and generally has represented the area of the cross section of the channel in square inches. This leaves out of account the rapidity of flow, which is of exceedingly great importance. In one water district in this state, the decrees of the ditches, has been expressed in "customary inches," a term which has not been convertible into definite quantities. It contains the germs of serious disputes, for while it may be expressed in cubic feet per second, the results would not be accepted without much objection.

Fortunately a better understanding of the objections to the "inch" has become wide spread, and the attempt to measure in inches is very rarely made. In California, a statute was once passed defining the inch in terms of its ratio to a cubic foot per second, and the inch under their conditions, was defined as 1-50 of a cubic foot per second.

In the ordinary form, an inch describes a method of measurement rather than a quantity of water. There is a common impression in this State that a Colorado Statute provides that 38.4 statute inches is the equivalent to one cubic foot per second. This is a mistake, for no statute has fixed this or any other ratio. As a matter of fact the ratio may vary all the way from 35 to 44. The basis for this impression seems to be a statement made in the second annual report of the State Engineer in 1884.

The State laws widely provide that in the statement of appropriations, the quantity shall be given in cubic feet per second. Notwithstanding this, the decrees in some districts have been given in other terms. This term, "cubic feet per second," is often expressed as "second feet," and now the term, "Cusec," a term originating in India, is making way by its brevity.

DIVISORS.

A division into a definite fraction can rarely be exact, but frequently, the convenience of an approximate division more than counterbalances any inaccuracy there may be. If the water is to be divided into two equal portions, by placing the two lateral ditches in identical relations to the main ditch, in a straight and uniform channel, the division is exact. Emphasis should be paid upon the *identical* relation, for many divisions are seen where the conditions are not the same, as, e. g., one branch continues straight, the other may make an abrupt turn, one may pass through a covered box, etc. In these cases some advantage is given to the ditch having the freer discharge. The effect of these differences is greater than is generally supposed. It is, however, generally not difficult to meet these conditions if the parties desire. By repeating the process, the water may be subdivided into four, eight or sixteen parts. But where it is required to divide the water into two unequal, or into three or more portions, equal or not, the division becomes one of approximation only. The difficulty arises from the fact that the water has not uniform velocity across the whole channel. The center has greater velocity than that near the banks. If, therefore, equal openings be made across the channel, those near the center have the greater discharge. Making the central openings smaller only partially avoids the difficulty, for as the relative velocities of the center and sides differ with different quantities of water in the ditch, this arrangement would still be inexact for any depth except that for which the adjustment is made.

In its most common form the divisor consists of a partition dividing the channel into two portions. These portions are usually inexact in proportion to the respective claims. This, in effect, assumes that the velocity is uniform across the whole cross section, which is not the case, even in a uniform channel, and much less so in one irregular or in poor repair. Such a division is to the disadvantage of the smaller consumer. This is commonly the case in the divisors used in Colorado.

The improvement in the ordinary methods of division is to make the velocity uniform across the channel. This is brought about in several ways. Sometimes by putting a board or drop at B-C, (fig. 1), making the division as the water drops over a weir; sometimes by increasing the width of the channel above B-C, so that there will be a still pool or reservoir, which will bring the water approximately to rest, and sometimes by a stilling-board, and sometime by making two or three such drops or falls. The purpose of all is the same, and that is to make the velocity of the water uniform across the entire section of the ditch. Great pains are taken in some of the old Moorish boxes in Spain, the methods running back for centuries. Special care is taken to make the ditch straight for a distance of 50 or 100 yards above the point of division, paving the sides and bottom and increasing the cross section so as to lessen the velocity. In such cases the division is made quite exact. The principal error is then most likely from the difference in the freedom with which the water passes down the main ditch and enters into the side channel. If there be a drop at B-C, the effect from this cause may be neutralized or made insignificant. If there is no drop at B-C, the retardation in the lateral channel may have considerable effect and the change in favor of the main channel may be quite noticeable.

In some cases, however, this is just, for the users who receive water farther down the channel are subject to greater losses. If equal owners are to receive equal amounts then the user nearest the head of the canal should be given less than the amount proportional to his interest to allow for loss in carriage for the greater distance. Whether this is the proper basis of division depends upon the understanding of the users, and very possibly would be different in different ditches. The users only can determine whether the individual is to bear the loss of carriage to his headgate, thus giving advantage to the upper user, or whether this loss is to be shared by all. The special circumstances of each case may determine which is the just principle for that ditch, depending on the method of construction, the history of the development and the understanding.

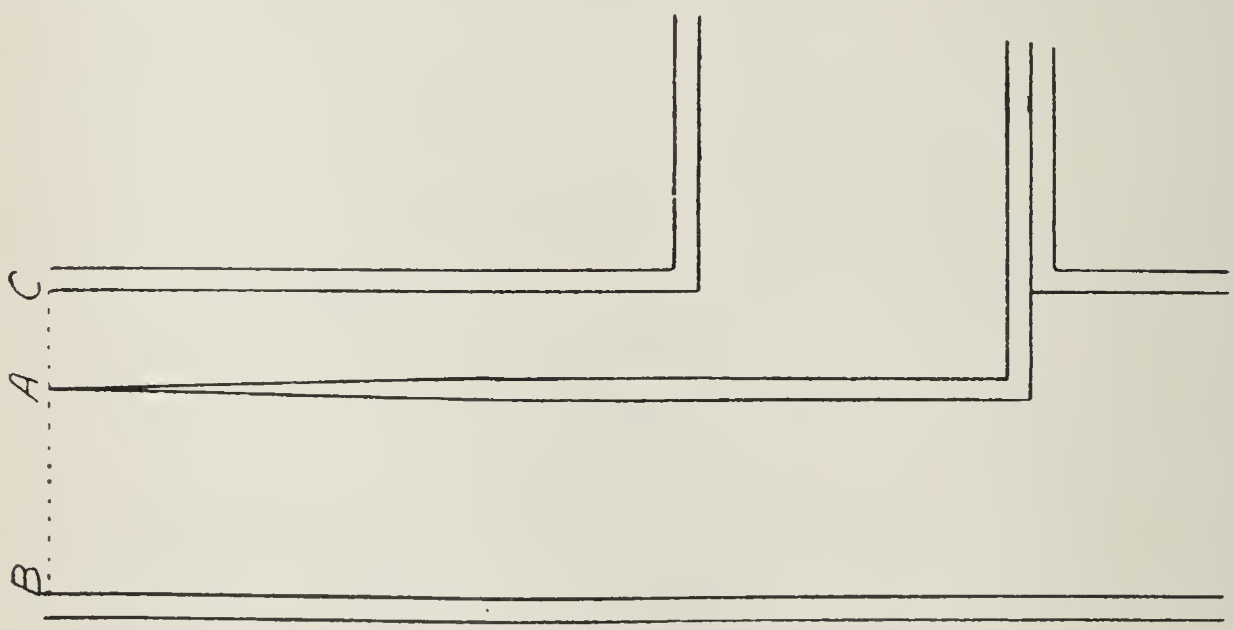


Fig. 1.—A Common Form of Divisor.

Figure 1 represents one of the most common forms of divisors, The partition board A is movable, and may be placed at different distances from the side C, so that the user can vary the proportion of water which he receives. A cleat of some kind is often used to prevent the board from being moved beyond a certain limit. Where the ditch is wide and shallow there is sometimes a simple truss used, with a depending cleat. Sometimes a wire or chain restricts the movement. In these cases it is assumed that the amount of water going to the side channel is in proportion to the distance the movable partition is from the side, and the ratio is the same to the distance across as the volume is to the volume in the whole ditch. This is not, in general, true, because the velocity across the cross-section is not uniform.

Sometimes where this is recognized, and it is necessary to make close division, the water is brought to a state of approximate rest, or to a state of approximate equal velocity throughout the channel. In the case of some divisors, as in one seen on the Farmers' Union Ditch, in the San Luis valley, a weir-board over which the water drops is placed above the division board. This secures an approximate equality. The fall below the point of division should be sufficient to prevent the backing up of the water.

If water is brought to a complete state of rest, or very nearly so, and flows over the weir without lateral contraction, this method will give as satisfactory results as any divisor with which I am acquainted. An increase in the size of the ditch just at the division box will aid in bringing the water to rest. Boxes of this kind were used by Hon. J. Max Clark, of Greeley, as early as 1867.

The divisor which is in use at Elche, in Spain, is one which has developed from their conditions in that province. At Elche there is a peculiar system of water management. The water is owned independently of the land. The amount available is divided into a certain number of shares, and the use of each of these for twenty-four hours is sold each day in the market place to those who want water. In consequence the amount which enters any lateral varies from day to day, and the method of division requires a convenient way of varying the proportion.

Where the division is to be made, the sides and bottom of the canal are made of cut stone for a distance of about fifteen feet. There are two falls in the canal of twelve to sixteen inches respectively, about five feet apart, the upper one being about seven feet from the upper portion of the masonry. The canal for a distance of 150 to 200 feet above has little or no fall, so that the water reaches the first fall with almost no velocity, and passes over undisturbed and perfectly smooth. Furthermore, there is no contraction at the ends, so that the discharge is nearly in proportion to the length.

The arrangement for making the division consists of a partition which is permanent masonry, and divides the canal below the falls into two channels. At the upper end of this partition is a movable piece of wood coming to a point which is pivoted to the end of the partition, and can be held so that its upper end will include any assigned portion of the channel within certain limits. The length of the beak of wood is made so that it reaches to the upper drop when in line with the axis of the partition. The beak is set so as to include the desired portion of the channel and thus remains for twenty-four hours.

A Masonry Regulator with Iron Gates, near Arles, in Southern France.

At Lorca there is a system of sale something like that at Elche, for a portion of the area under cultivation, in which the amount which enters any ditch may vary from day to day. A divisor which may be called a needle divisor is used. The same care is used in the preparation of the channel as in the previous one described. A permanent masonry partition is placed in the channel. The proportion which enters the lateral channel is varied by varying the relative width of the main and lateral channels. This is done by inserting or taking out a series of narrow boards placed vertically. These are of uniform width. They are held in place both at top and bottom, and are carefully fitted to prevent leakage. The stream is to be divided so that a certain number of hilas, according to the result of the sale, may enter the channel. No account is taken of the difference introduced by contraction. The discharge is assumed to be proportional to the size of the opening. The same principle is used occasionally in Colorado. One divisor near Greeley divides into four channels. It is not so good as the old Spanish ones because of neglect to look after details. The value of the water now justifies a considerable expense in a permanent divisor.

Time Method of Division.—On small ditches or laterals where the amount of water is not too great for one user to manage, and especially where the flow is uniform or nearly so, a time method of division may be used to advantage, and gives a more equitable division than boxes of the types described. Besides it allows the use of water in large enough quantities to make the use much more economical. For when a stream is divided it often happens that the parts are too small to accomplish much. It thus becomes desirable in almost all localities in times of low water to arrange so that one will combine the streams of several for the time during which he is irrigating. There is then some prospect of doing some good. The time method of division is especially applicable to small ditches where the amount of water is small. In such case the exchange is systematized. Each one takes the whole stream of water for a time proportional to his share in the ditch. The period is usually so arranged that the rotation will be completed in some definite time, as a week or two weeks, or such other time as the experience of the locality has shown to be desirable for an irrigation to be repeated. The water will then be given out at night or day according to schedule, and in order that the inconveniences may be fairly distributed, the period of rotation may be made to include a fractional day, so that those whose turn comes in the night during one rotation come in the day during the second, and vice versa. Thus, suppose the period of rotation be taken as one week, or for reasons above given, 7 1/2 days, and the number of shares be fifteen, of which some own one, others two and some three shares. In this case each share would give its owner the right to use the water for one-half day, or twelve hours; the owner of two shares would be entitled to its use for twenty-four hours, and the owner of three shares to thirty-six hours. Where there are a large number of rights or of users the same period would be carried out, but to a greater extent. As carried out in the countries where it is applied, the division is sometimes carried out to minutes. A time table is prepared at the beginning of the season, and each is furnished with a copy of it. The water is shut off or turned on the different gates according to schedule. The user must be ready to take it at the proper time or lose the water until his turn at the next rotation.

This method is best applicable evidently in the cases where the amount of water flowing into the lateral is constant. This is rarely the case for the main ditch, and consequently the small laterals, are affected by the fluctuations of the main stream, shown in Bulletin 55. Where water is distributed from reservoirs, then the flow may be kept uniform. The necessity for restriction to certain times is distasteful to many. But by common consent, methods are used which are leading to this system. With the increasing pressure for the greatest benefit from the amount of water available this method will gradually extend in use under the conditions where it is best adapted. With the varying streams and varying flow, the method is not so equitable as the division of water as it comes. It is already becoming customary in ditch administration in Colorado, to keep records of the amount of water which is taken into the canals. It will become increasingly desirable and even necessary. For the larger ditches the amount of water which is taken into the ditch for different depths, is officially determined by the state engineer or his deputies. A similar rating of the lateral ditches may be made, or weirs may be used with greater accuracy. It will be possible to use a modified time distribution, so that each will be given the water long enough to give the same quantity. The unit could be varied, so as to bring the irrigations a convenient time apart. The successful operations of such a system would require an intelligent superintendent, who has the confidence of the users, and a wide-spread knowledge among the users.

In the distribution of water from small reservoirs, where there are but few interested, and where the different owners do not care to use the water at the same time, some such arrangement is necessary. With the weir measurement it is possible to keep account of the amount used by each person, so that the water may be divided in proportion to the rights of each.

This practice is spreading, and it is found that where once begun it is rarely abandoned. Within its own limitations it is an excellent method.

MODULES.

It is not possible to secure a module satisfactory in every respect or to meet all conditions. The following are desirable conditions which should be met by a module. Most of these conditions were recognized centuries ago by the magistrates of Milan. Some are manifestly of different importance.

1. Its discharge should be capable of being expressed in cubic feet per second.

2. The ratios of the discharge between two outlets should be correctly given by the module.

3. The same module should give the same amount of water wherever placed.

4. It should be capable of use both in large and in small canals.

5. It should be capable of adjustment so as to discharge any fraction of its capacity, and thus be used in distributing water pro rata

6. Any tampering should leave indications easy to recognize.

7. It should be simple so as to be operated by ordinarily intelligent men.

8. It ought not to require complicated calculation.

9. It ought to occupy a small space.

10. Its discharge ought not to be materially affected by fluctuations in the supplying canal.

11. Its cost should not be great, nor ought it to require much fall.

12. It not to be easily put out of order, and if so, the indications of its inaccuracy should be easily determined.

These conditions are evidently not of equal importance. Some may be dismissed; the first conditions become increasingly important.

The question of expense mentioned in No. 11 is a relative one and may or may not be of importance. As before pointed out, it becomes of less importance as the development of the irrigated section becomes greater, the need for accuracy more felt, and the value of water greater. The conditions that a small amount of fall be required is a physical condition which sometimes is impossible to meet. Often land lying close to a canal is to be served when probably no fall is available. For those places, special modules may be required, or special methods. The conditions that calculation ought not to be required may become of no particular weight when suitable tables are provided.

The condition No. 10 is one which is of more importance to ditches where equal division is made among the users. It is not of much importance in the larger canals or in those which have a ditch rider or patrol who can frequently adjust the gates. It sometimes is of importance for canals which have special contracts. It is a condition which has generally been considered the most important in the early stage of measurement from canals. In almost all countries, the first attempt is to give orifices of equal size to equal users, and then to make the quantity discharged by these equal orifices the same. To do this it has been necessary to keep the pressure of water on these orifices the same. Hence the module of Milan, the miner's inch of the various states. This condition is now less important. In our practice it is rarely attempted to make the discharges absolutely constant, but rather to perfect devices which can be adjusted by the frequent visit of the ditch rider.

The devices for maintaining a constant flow are essentially of two classes. First; those which attempt to maintain the pressure of water constant with the orifices unchanged. Second: Those which vary the size of the opening.

Nearly all modules are of the first class, as the difficulties are simpler.

One was used on the Isabella Canal of Spain, of the second class, which seems to have been satisfactory. The old Italian modules, the miner's inch of the western states, is of this class. There have been many different kinds of openings, but in all, the principle was essentially the same. In the Soldati module of Milan, dating from 1585, an attempt was made to maintain the depth of water over orifices constant, by the use of a second gate and a regulating chamber. The orifice was on the lower end of the regulating chamber and the gate between the canal and the chamber would be raised or lowered so at to maintain the water to constant height. This same device has been used in some boxes in Colorado, especially in the one formerly known as the "Max Clark box," but now rarely used. It is an automatic device. If the gate is left unregulated, the flow from the orifice will increase or diminish in exactly the same ratio as if it came from the main canal. Its convenience is in the use of the regulating gate. The gate needs to be regulated with variation in the level of the supplying canal. This principle has been worked out with many variations in Italy and has led to the adoption of a complicated box with many accessories so as to still the waves, to lessen the velocity, etc.

A serious objection to this form is in the supposition that the discharge is in proportion to the size of the opening. It was natural to suppose that doubling the size of the opening would double the amount of water, and this supposition runs back to the earliest Roman times. The attempt to keep the flow uniform reduces the inequality but does not cause it to disappear, for while the fluctuation in the head in the second chamber is not as great as in the canal itself, yet the fluctuation in quantity in the lateral is as great as in the opening coming from the ditch itself, for the opening is correspondingly larger. The value of this principle as a regulator is therefore apparent rather than real. Its principal value is in the second regulating gate near the canal, and the fact that it is possible thus to choke or regulate the quantity received from the canal into the regulating chamber. However, unless such a box is regulated with every variation in the level of the supplying canal, it does not furnish a constant flow, which has been one of its supposed principal merits.

This box, however, represented a great advance in the practical measurement of water for irrigation purposes. It was brought forth after the great inequality in the division of water was recognized in the sixteenth century and was adopted in 1585. However, the interference this was supposed to cause with vested rights led to great trouble and to the condemnation at that time of Soldati, who proposed and urged it, though it is now recognized as having been essentially just.*

Experience showed that the discharge of the Milanese module was not in proportion to the nominal discharge. A person, for example, who drew one hundred oncia received more than ten times as much as the one who drew ten. It was, therefore, soon provided, that the discharge through any one orifice should not exceed a given number of oncia, generally six. The oncia varies from 34 to 47 liters per second, according as the orifice discharge from one to six oncia. A similar variation is true of the statute inch in this state. The advantage is entirely in favor of those who draw the large quantities.

There are other causes of variation, as in the distance the opening is above the bottom of the box, in the thickness of the sides, in the manner of its discharge. All of these render this module inaccurate and unreliable and is leading to its abandonment.

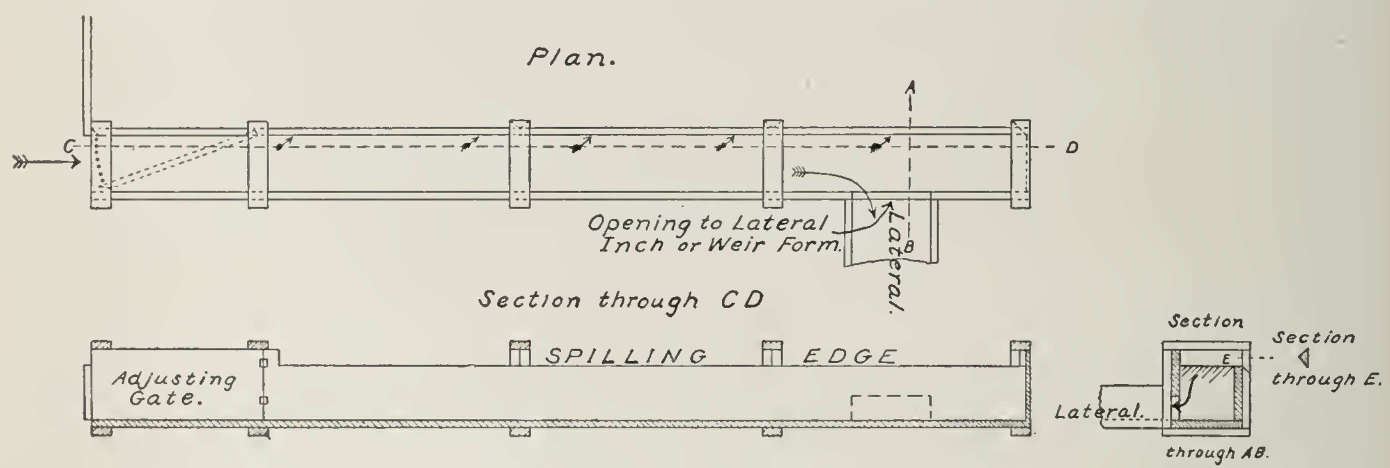
A module based on an entirely different principle was used on the Marseilles Canal in France and described in the earlier editions of this bulletin. This module consisted of a hollow vertical cylinder kept at a constant distance below the surface of the water by a float. The cylinder passed through a water-tight packing. It was noted in Bulletin 13 that this module would probably be insensitive. On a personal visit to the Marseilles Canal, it was learned that it had been abandoned for that reason. A modified form was attempted in Australia, where the connection was made by a bellows arrangement of leather. These and many other devices have been proposed, but do not seem to be especially valuable. It has been proposed to use a form of Venturi meter, a device invented by Clemens Herschel. The present objection is to the cost. A modified form of this has been proposed by Mr. R. G. Kennedy, of India, in an attempt to meet conditions given to him by the writer.

Other ways of modifying the size of the opening have been tried. In one, the water passed through a hole in which was a plug of metal, which was lifted by a float. The hole was circular. The diameter of the plug varies at different points, so that the size of the opening reduced as the head increased. In this case there is little or no friction. It is mentioned as an illus-

*The history of this event and the trouble arising therefrom is given in Bruschetti's Storia del Irrigazione del Milanesi, in his complete works, Vol. 2, pages 118 to 135. It is condensed in Buffon's des Canaux d' Irrigation d' Italie Septentrionale.

tration of a type more ingenious, however, than valuable, though it has less objection than some of the others. It would also require, like the Marseilles module, a considerable available fall.

A satisfactory means of preserving a constant head from a lateral is known as the spill box, or excess weir, which has been used somewhat in this state. This is an attempt to maintain the head constant and thus to give a constant flow. Any variation in discharge is caused by varying the length of the opening. It has been used in this state for the discharge of water in terms of the statute inch, and thus requiring the statutory head. It, however, could be used to deliver water by the weir method, and especially with the trapezoidal weir. The device is really a method of preserving a constant head. In the case of a small ditch, as



Plans of the Spill-Box.

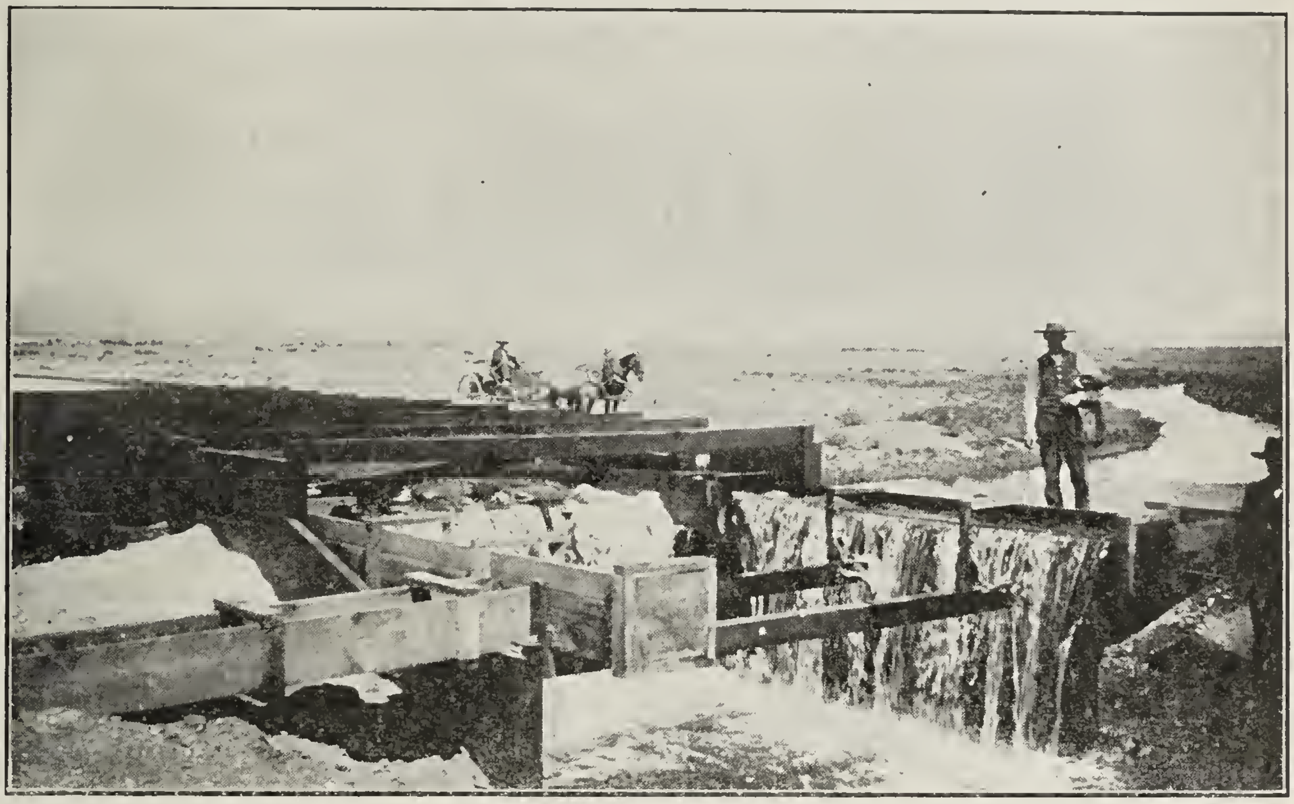
shown in the figure, gates are located so as to force water into the spill box. On the side next to the lateral is a long sharp edged board whose crest is at the required height above the bottom of the opening. The length is such that the excess water spills back to the lateral. The sensitiveness depends upon the length of the box, and upon the regulation of the gates. It requires a sufficient available fall in the ditch so that the water will drop back into the ditch.

As made in the San Luis valley, the spill box is about 16 feet long. It generally requires a fall of about a foot. By making the crest longer, the device may be made more sensitive. As used in the San Luis valley, a hinged gate was used instead of the board and sometimes the boxes were used in pairs, as shown in Figure. This did not change the principle but saved expense in structures. The principle was first brought out by A. D. Foote, now of Grass Valley, Cal., and adapted to needs of canals by W. H. Graves, then of Monte Vista.

THE WEIR MODULES.

The form of module which is the most accurate is the weir or overfall. The knowledge of the flow through this, as through any other opening, depends primarily upon experiments previously made and upon the certainty that it was placed under the same conditions.

There are, nevertheless, several different types of weir, any one of which may be used satisfactorily. The important condition is that it should be placed under conditions duplicating those of the original tests. It is simple, does not easily get out of repair, and can be easily tested. It is, therefore, making its way steadily as the most satisfactory form of measurement. In Colorado, in



A Double Spill Box—On a Lateral of the Monte Vista Canal Where It Crosses the Rock Creek Ditch.

This shows the spilling of the excess water, when more than the required depth.

the West in general, in Australia, India, Italy, Alberta and British Columbia, it is the measurement most generally used. The Cippoletti or trapezoidal weir is a special form of weir proposed in order to avoid one of the difficulties found in the introduction of the rectangular weir.

Practically all forms of weirs are based upon the experiments of J. B. Francis at Lowell in 1858.* His experiments are an instance of the value of careful work for though there are many attempts to develop other formula, all such formula are based upon his experimental results. His experiments were made to determine a better measurement of water suitable to the needs of the manufacturing enterprises at Lowell with capital of millions of dollars. The stream was divided among these large users. This justified the expense needed to perform the experiments with care and with such attention to minute sources of error that they were above criticism. The same conditions have continued since the time of

*Lowell Hydraulic Experiments

Francis and experiments have continued at Lowell. While the subsequent experiments have not been published, a personal examination of the appliances seems to show that there might be much of great value. Tests were made by Mr. Francis of the flow over weirs and the water was measured in a large basin containing some 12,000 cubic feet. By taking account of the contraction at the sides and at the crest of the weir, Francis succeeded better in producing a formula which represented the discharge.

The equation assumed and agreeing closely with his experiments is given with the form.

$$Q=aLH^{3/2}$$

Where Q is the quantity of water in cubic feet per second, L, the effective length of the weir in feet. It is not necessarily the same as the actual length of the weir. It is mentioned more fully on the next page.

a is a coefficient supposed to be constant. The limitations in length and depth state conditions within which it is practically constant.

H, the depth of water flowing over the weir, in feet. Because of the contraction, this must be measured far enough from the weir to be free from its influence. If the water approaches with a current, this depth needs to be increased by a correction indicated by theory. The object is to give the equivalent depth if the water came from rest. This correction is troublesome to make. In practice it is better to so check the velocity of the current that the correction will be so small that it may be neglected. Table H in the appendix gives the amount of this correction which is needed to multiply the results obtained by the indicated operations in the measured quantities, in order to give Q the discharge.

From his experiments, an abstract of which cannot convey an idea of the care and skill used in the experimentation, Francis adopted the value of 3.33 for a; 3⅓ would agree a little more closely, and is slightly more convenient for independent calculation.* The value of 3.33 is almost universally adopted. The difference in the results by using these two coefficients is one-tenth of one per cent.

The formula of Francis then becomes

$$Q=3.33\ LH^{3/2}$$

or with the modification above mentioned, $Q=3\frac{1}{3}\,LH^{3/2}$ where the letters mean the same as above and with the same restrictions. The first one is the one properly termed the Francis formula. The second one is the one I have used, based on his work and agreeing slightly better with his results.

Q represents the discharge in cubic feet per second.

L and H are both measured in feet and decimals, not in inches.

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*The actual value from his results is 3.3318. He adopted 3.33. 3 1-3 is slightly more convenient for mental calculation and I have used it in the table in Bulletin 13 and since.

Sometimes it is convenient to make measurement of the depth in inches. Scales graduated in decimal parts of feet are not common. In such case the following formula may be used. Q is the discharge in cubic feet per second in both cases.

Where depth is measured in inches, and length of *the weir is given in inches,* then

Q (sec. ft.) = .0798 L (in inches) $H^{3/2}$ (in inches).

Where the depth is measured in inches, but the length is *given in feet.*

Q (sec. ft.) = .006675 L (in feet) $H^{3/2}$ (in inches).

An additional word needs to be said regarding L.

L is the *effective* length of the weir, which in case of the rectangular weirs, is not necessarily the same as the actual length.

The various experiments made by Francis may finally all be classified and put in the following abstract:

SUMMARY OF FRANCIS' EXPERIMENTS ON WEIRS*

Depth has in all cases been corrected for velocity. Supply canal 14ft wide.

Serial Number.	Depth of Water on Weir in Feet	Coefficient for the Series	Length of Weir in Feet	Number of Contractions	COMMENTS
1- 4	1.56	3.318	10	2	SERIES A.
5-10	1.25	3 334	10	2	Crest of Weir is 5 ft. above floor of channel of approach.
11-33	1.00	3.322	10	2	
56-61	0 80	3 325	10	2	
72-78	0.62	3.328	10	2	
36-43	1.06	3 353	10	2	SERIES B.
62-66	0.83	3 340	10	2	Same as A except that crest is only 2ft. abovefloor.
79-84	0.65	3.326	10	2	
44-50	0 98	3 341	10	0	SERIES C.
67-71	0 80	3 339	10	0	Canal made same width as Weir Suppressing end Contractions. Otherwise as in A.
51-55	1.00	3 327	10	0	SERIES D. Water cannot expand after passing Weir.
34- 5	1.02	3 360	8	4	Water 5 feet deep.
85- 8	0 68	3.337	8	4	Water 2 feet deep. In both sets, two boxes separated by a partition 2 feet wide giving 4 contractions.

*The author of this bulletin is responsible for the summary and the classification in these series.

Comparison of series B and A shows the effect of nearness of floor on the vertical contraction.

Series C and D correspond to the cases where weirs are erected in the middle of flumes; C to the case where the weir is at the lower end; D where at middle.

These experiments have been made with such care that they are standard and are uniformly recognized as being results which can be used with confidence in discussions of the accuracy of the weir.

The greatest depth tested was about 18 inches, and the least 7 inches. Series A and B correspond to the ordinary cases. From these, Francis concluded that the coefficient to be used in the formula might be taken as 3.33 while the length L is not the length of the crest, but is less by an amount which increases with the depth of water over the weir. It is noticed in his trials that the length of the weir is less than the width of the canal, thus giving the conditions for what is termed a complete end contraction.

Francis presented his formula (i. e., with the constant coefficient) as being applicable to cases where the depths do not exceed two feet nor fall short of three inches, and where the depth over the weir is small as compared with the length.

Experiments have since been made at the Cornell Hydraulic Laboratory which show that this formula may be used without material error up to depths of four and even five feet on the weir, provided the other conditions are observed. In these cases the flow over these weirs has been measured by the discharge over rectangular weirs agreeing with the conditions fixed by Francis.

Some explanation needs to be made concerning the contraction of the stream and its effects on the flow. If water passes through an orifice it will be noticed that it becomes narrower at the opening and then expands. If it passes over a weir with a sharp edge, the sheet of water immediately below the crest becomes thinner. This is termed the vertical contraction. At the sides, it also narrows and then expands. This is spoken of as the lateral contraction. The amount of the lateral contraction becomes greater as the depth of water is greater. Francis attempted to take several disturbing effects into account in the correction to L.

While the correction is not entirely satisfactory, it is close enough for practical purposes so that the formula may be used with confidence, provided the weir is placed according to proper conditions. The amount of the contraction is also affected by the distance that the sides of the box are from the end of the weir. In Francis' experiment, the weir 10 feet long was in a box 14 feet wide. If the box were narrower and the weir the same, the side contractions would be less and the effect is to increase the flow somewhat. When the distance to the sides of the box is two or three times the depth of water on the weir, the contraction remains practically constant and is said to be complete. If the box becomes narrower, the contraction is incomplete.

The amount of this contraction when complete increases with the depth of water flowing over the weir. It is difficult to measure directly. The tests to determine its amount were unsatisfactory and consequently weirs are sometimes made to eliminate lateral contraction entirely. On the assumption that the contraction is one-tenth of the depth the calculated discharge agreed so closely with the measurements as a whole that this convenient factor was adopted. If there are two contractions, one at each end, the reduction of length would correspond to one-fifth of the depth of water flowing over. With this assumption the flow may be found within one per cent. within the limitations given by Francis.

Thus we may take an example from the abstract of Francis' experiments on page 25. In the case of the serial numbers 1-4, the depth is 1.56 feet. There are two contractions, hence the effective length of the weir used in the calculation of the discharge, is not 10 feet, but 10 feet shortened by .31 feet (2, the number of contractions, x 1/10 of 1.56). The effective length to be used in the calculation is accordingly, 9.69 feet. With the same weir, in the series 56-61, the effective length is 9.84, though the length of the weir is the same in both cases.

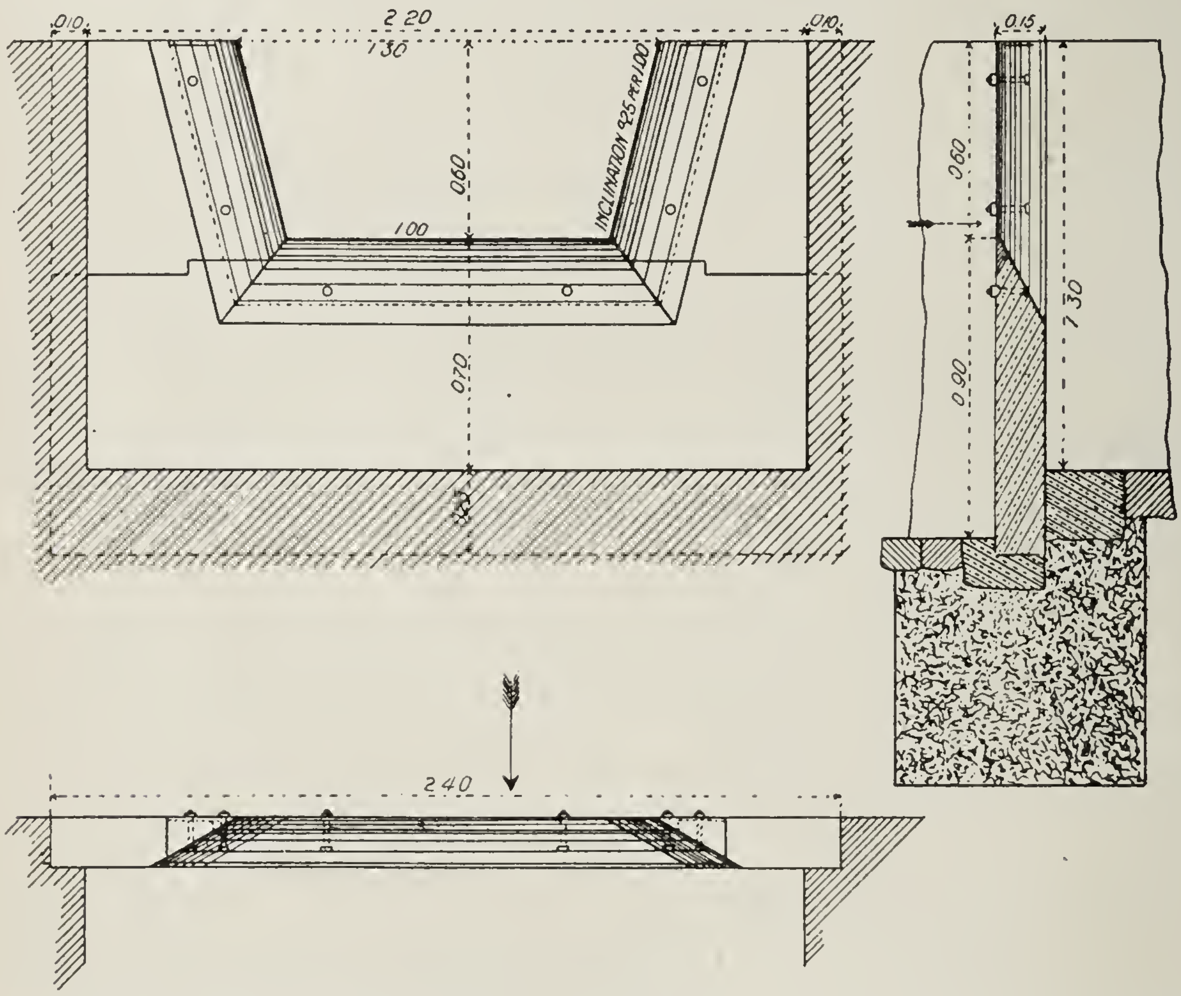
It is because of the correction to the length in the rectangular weirs in the Francis formula that the weir method of measurement was slow in being adopted. It is evident that a weir twice as long as another will give more than twice as much water, with the same depth. This proved a stumbling block in the popular mind, and stood in the way of its use.

The advantage of the Cippoletti form of trapezoidal weir is that the discharge varies directly as the length of the weir, so that if one weir is twice as long as another, the discharge will be twice as great. This is a great practical advantage in its use on canals, because it helps to lessen the suspicion frequently met with.

This weir is one proposed by the Canale Villoresi, one of the great Italian canals in the valley of the Po. This canal was built about 25 years ago as a "high-line" canal to water land above existing ditches. It waters about 125,000 acres just north of Milan. In the permit to this canal, the company was required to propose a module based on the weir. The problem was put in the hands of Cesare Cippoletti, the engineer in charge of construction, who, from the experiments of Francis, attempted to determine a form of weir and conditions so that the results would be correct enough for ordinary purposes, and so that no single cause would produce an error of one-half of 1 per cent. This is often spoken of as a trapezoidal weir but because there are many forms of trapezoids, I proposed that the name of the engineer should be connected with it, in the first edition of the Bulletin, and it is now very generally known in English speaking countries as the Cippoletti weir.

Cippoletti proposed to use a trapezoidal form with such angles that the increase in the flow caused by the triangular areas at the ends should balance the loss due to contraction. If this could be done, the correction for contraction is made automatically and the flow would be in proportion to the length of the sill. From the adopted coefficients of contraction it is found that this inclination would be practically one-fourth to one or three inches to one foot. This is not quite exact, but the difference is so small that it is convenient to use this for ordinary purposes.

I made some experiments on weirs of this form, but of small size, before the first edition of this Bulletin. Other experiments were made by T. V. McVickers under the direction of Prof. Church



The Cippoletti Trapezoidal Weir—Dimensions Based on Unit Length of Sill.

of Cornell University. The most complete ones were made by Messrs. A. D. Flynn and Dyer of the Worcester Polytechnic School or Worcester, Massachusetts, who experimented with weirs from three to nine feet long and with depths of 18 inches. These indicated that the average error was above the one per cent. indicated by Cippoletti, but that the discharge is in proportion to the length of the weirs. This is the feature which makes this particular form of weir valuable for irrigation purposes.

The weir measurement is accurate *provided the proper conditions are observed,* hence the importance of an understanding of the conditions and their careful observance, both in construction and in operation. The formulae are most reliable only within the limits set by Francis, that is, within depths ranging from 3 to 24 inches for complete contractions, and for weirs not much exceeding 10 feet in length, but subsequent tests show that they may be used for greater depths and lengths without material error. The theory of the flow of water under even more simple conditions is still too incomplete to make it safe to extend the formula much beyond experimental lines. Within these limits the coefficient may be taken as constant. Outside of these limits, the coefficients would probably require a different value. In the Francis formula, the coefficient is taken as constant.

In most cases weirs are not placed with sufficient care. On the Canale Villoresi, the weirs I examined were made of cut stone with cast iron plates used for the sides and sill. The value of water justifies the construction of permanent and substantial weirs in this State and much more pains than is generally taken.

Conditions.—The following conditions relate to both types of weir. When these conditions are followed, the formula above given and the tables attached to this Bulletin may be used with confidence that the result is correct within 1 per cent.

1. The channel leading to the weir should be regular, of constant cross-section, its axis passing through the middle of the weir, and perpendicular to it; this straight reach to be of such length that the water flows with uniform velocity, without internal agitation or eddies. This should be not less than fifty or sixty feet in length, more if possible.

2. The contraction should be complete on both sides and bottom. This is necessary that the coefficient "a" in the formula may be free from uncertainty. To secure complete contraction it is necessary:

(a). That the opening of the weir be made in a plane surface, perpendicular to the course of the water;

(b). That the opening itself have a sharp edge on the upstream face. For this purpose, if the thickness at the point of discharge is not more than one-tenth the depth for depths from 5 to 24 inches, it may be considered as sharp;

(c). That the height of the sill of the weir of the canal be at least three times the depth of water on the weir;

(d). That the length of the weir should be three, or still better, four, times the depth of the water flowing over;

(e). That the depth of water flowing over the weir be not less than 3 inches;

(f). That distances from the sides of the flume shall be not less than 2 times the depth.

3. The velocity of approach must be small. For weirs three feet long and depth of 12 inches, it ought not to be more than one-half foot per second; for weirs of six feet long and depth of 24 inches it ought not to be above 8 inches per second. In all these cases the cross-section of the canal of approach ought to be at least seven times that of the weir. Other conidtions affecting the velocity of approach are included in c, d and e in condition 2 above.

4. The layer of falling water should be perfectly free from the

walls below the weir, in order that air may freely circulate underneath. For short weirs it is sufficient that the lateral walls of the lower canal be free from the sides of the weir. In such case, when air freely passes underneath, the level of the water in the lower canal has no effect on the discharge unless it reaches to the level of the crest of the weir.

5. The depth of the water should be measured accurately at a point where the suction of the flow does not affect the level of the surface and where it is free from influences like the wind, or the movement of the water, which affect the true level. The height should be read to within 1-300 of the depth in order that the error may be within one-half of 1 per cent., or 1-67 to be within 1 per cent. This means to one-fifth of an inch when depth is one foot.

6. The weir needs to be carefully constructed. It should not vary more than 4° from being perpendicular to the channel. Its sill should be horizontal.

Table I. will aid in obtaining proper proportions between the channel of approach and the weir.

The conditions affecting the flow may be divided into three classes; those which always tend to increase the discharge, those which always tend to decrease, and those which may either increase or decrease, as the case may be, and thus in the long run, tend to balance.

The flow of the weir is decreased by eddies or by obliquity of the weir to the sides.

The quantity is increased by the velocity of the approaching water, by nearness of the sides to the end of the weir, or the bottom of the box to the crest, or by any condition which prevents a complete contraction at the sides or at the crest. If sand or silt collects in front of the weir board, this decreases the contraction and increases the quantity. If the water below the weir board backs up so as to prevent air from having access underneath the sheet of falling water, then the vertical contraction is lessened and the discharge is increased.

If the crest is not sharp or its thickness more than one-fourth of the depth of the water on the crest, the vertical contraction is lessened and the flow is increased. When the thickness still further increases the effect is to decrease the flow.

It is evident that the changes that are likely to happen increase the flow of water over that given by the formula. These are difficult to avoid and in general cannot be entirely eliminated. It is because of this that Cippoletti proposed to make an arbitrary increase of one per cent. in the formula. This is not necessary and it would seem to be better to use the ordinary Francis formula, making the weir as near perfect as possible and making allowance, if necessary.

The correction to be allowed to the tables may be estimated in some cases by the following considerations: If the weir is not vertical, the discharge is increased or diminished according as the inclination is down or up stream. For inclination of 45°, the effect is to cause a decrease of 7% if it be up stream, and an increase of 10% if down stream. For less inclinations, the correction is correspondingly less, being less than 4% if the slant is not over 18°. It is easy to maintain practically vertical.

If the box or channel of approach is narrower than required by condition 2f, the flow is increased. If the width is reduced to 1 1/2 times the depth, the flow is increased by about one-third of one per cent. and still more if narrower.

If the condition 2c is not complied with, the increase amounts to one-half of 1 per cent. if the distance of the sill from the bottom is reduced to 2.5 times the depth of the water over the weir; and the increase amounts to 1 per cent. if this height is reduced to two times the depth; 1 1/2 per cent. if it is equal to the depth; and 2 per cent. if it is one-half the depth. This is the height of the sill above the bottom on the up stream side. If filled in with sand, the surface of the sand should be considered as the bottom. Table II. in the appendix gives means for estimating the effect for any other depth.

The temperature of the water has a slight effect, but for all ordinary conditions may be neglected. An increase of temperature seems to increase the discharge through action of the surface tension of the liquid. With large openings, the effect is less than with small openings.

The velocity of approach is, all things considered, the most difficult to reduce within reasonable limits. These errors are the most difficult to allow for and they are the source of the most considerable errors under ordinary conditions. It is not possible to entirely prevent some velocity in the approaching water. It is desirable, however, to cause it to flow from rest as near as possible. The velocity is reduced by increasing the size of the approaching channel or by making a basin in front of the weir. This is sufficently reduced by making the cross-section of the basin seven times as great as the opening of the weir.

When this is the case, the effect of velocity of approach may be neglected. For many cases this cannot be entirely prevented. Often the greatest trouble comes from sediment in the water, which is deposited in front of the weir board. Thus, even if the weir has been placed originally under proper conditions, the effect of the silt may be to change those conditions and cause the weir to be unreliable. In some streams the trouble is serious, and almost prevents the use of the weir. It can usually be met by arranging the weir board so that it may be raised and flush out the sediment. The ditch rider should understand the effect of the silt, and that the discharge under those conditions is greater than would be indicated by the tables.

It is troublesome to compute the allowance for velocity of approach. The better way is to avoid the necessity by keeping within the bounds indicated by condition No. 3, page 29. If correction needs to be made then use tables I. and II. of the appendix which are prepared to aid in making the correction.

The following method due to Fteley and Stearns I have found to be satisfactory and easily used.

The correction for velocity of approach may be made by using $H+\frac{3}{2}h$ in place of the measured depths in the weir formula, $Q=3.33\ LH^{3/2}$ instead of H as the depth to be taken. Where $h=V^2\div 64.4$; V being the average velocity in the canal found by dividing the quantity by the area. All expressed in feet. It gives a much larger correction for velocity than is furnished by the Francis correction, but it agrees much better with measurements I have made for high velocities. The experiments on which Francis' formula was based were limited to velocities of 2.5 feet per second. Table II. gives the per cent. increase in discharge caused by different velocities. It will be seen how great this correction becomes, sometimes causing an increase of several hundred per cent., and consequently shows the importance of keeping the velocity within low limits.

To aid in the practical allowance for velocity of approach, two tables have been prepared and are printed as tables I. and II., of the appendix. Table II. shows the allowance in per cent. to be made to the quantities given in tables III. and IV. The increase with a given velocity varies with the depth of water over the weir, being greater for small depths. A velocity of one foot per second increases the discharge over a weir when the water is flowing three inches deep, over 14 per cent.; if flowing over the weir one foot deep, only 3.5 per cent. Table I. shows the average velocity as the water passes through the weir, or it shows what is the velocity in the channel if the section is the same as that of the weir, as it frequently is. A comparison of the two tables will show the proper section to give the channel in order that the resulting error shall be within reasonable limits.

If condition No. 4 is not met, there is an appreciable increase in flow.

The effects of the conditions already given are sufficient to show that the conditions increasing the discharge are more numerous and more difficult to remedy than those which have the opposite effect. If there has been carelessness or ignorance in placing the weir, it would commonly be shown in making the weir too low or making the opening too long compared with the width of the basin or canal above the weir, or in allowing it to silt up, the effect of all of these is to increase the discharge. Likewise, if the crest of the sill is not sharp or is slightly rounded on the upstream side, there is an appreciable effect. A serious fault of the weir is, that carelessness in making or neglect in maintaining it, tend inevitably to increase the discharge. It is not to the interest of the consumer to see that the proper conditions are maintained.

The measurement of the depth of the water is difficult to make accurately. Frequently this is done by placing a post some distance above the weir and the depths measured on it. This should be at least six feet above the weir. As the water is constantly subject to fluctuations this can not usually be done with sufficient accuracy. The best place to measure the water would be in a well to one side of the basin and connected with it by means of a small tube. This well may be nearer than six feet to the plane of the weir because the pressure of the water will bring the water level with the surface further up stream. It should be from 3 to 12 inches in diameter or square, depending on how it is to be used. A float may be made with an arm extending above the surface graduated to read zero when the water is level with the crest of the weir. The rules commonly to be had in the market are for the use of mechanics and divided to 16ths of an inch. Rules divided to decimals of a foot would be better for this purpose.

These conditions all pertain to the rectangular weir, as well as to the trapezoidal. The Cippoletti or trapezodial form of weir is simply different in the form of the opening. It has been shown that the side contraction is greater as the depth of the water over the weir is greater. The broadening of the opening is such as to automatically allow for that contraction, so that the calculation is based upon the length of the weir without allowing for contraction.

SUBMERGED OR DROWNED WEIRS.

Many times the water backs to or over the crest of the weir. This is sometimes accidental, and sometimes is due to the fact that it is necessary to run water on land close to the main canal without sufficient drop. While it is not desirable to depend on submerged weirs, as these are called, yet within moderate limits the results of such weirs can be depended on and the ordinary tables used.

The first effect of backing over the crest is to increase the discharge, because the air underneath the falling sheet is displaced and the air pressure tends to increase the amount more than the decrease due to the discharge under water. Then when the submergence is about one-seventh of the total head, these effects balance and the discharge is again the same as that given by the tables. With greater submergence there is more decrease, so that when the submergence amounts to one-quarter of the head the discharge is decreased by 5% and only by 10% when the submergence amounts to 40% of the head.

The various formulae for submerged weirs are not satisfactory, partly because they call for accurate measurement of the submergence, which is difficult and untrustworthy. The table here given of the corrections to be applied to the ordinary weir tables does not call for any close measurement and thus it enables the submerged weir to be used in many cases with fair satisfaction where it has been considered inapplicable. The amount of backing up can usually be told within moderate limits. Whether, for instance, this submergence is 25% or 30% of the total head makes little difference; the correction to the tabular value is 5% in one case and 6% in the other. With greater amounts of submergence the error in estimating would bring in greater variations in the estimate of the discharge, but we are then approaching conditions which it is generally possible to avoid.

SUBMERGED WEIRS.

Corrections to apply to the ordinary weir.

$\frac{h}{H}$	Correction per cent.	$\frac{h}{H}$	Correction per cent.	
.01	+0.6%	.45	—13. %	H is total head over weir.
.05	+1.0%	.50	—16. %	h is amount of back water
.10	+0.7%	.55	—19. %	h ÷ H is proportion of depth or head, expressed decimally, which is back water.
.13	+0.0%	.60	—22. %	
.15	—0.6%	.65	—26. %	
.20	—2.0%	.70	—30. %	
.25	—5.0%	.75	—35. %	
.30	—6.0%	.80	—41. %	
.35	—9.0%	.85	—48. %	
.40	—10. %	.90	—56. %	
		.95	—68. %	

+ or — indicates whether the correction is to be added or subtracted from the tabular values of Tables III to VI.

Example of the use of the table: The water on a weir is 12 inches deep, but the weir is drowned to the depth of 3 inches. What is the discharge, the other conditions being good and the weir 3 feet long.

An ordinary weir for this case would have a discharge per table IV., of 9.99 second feet. Here "h" is 25% of H and the correction is 5%, to be subtracted, thus giving a result of 9.49 cubic feet per second.

By using this table it is possible to make use of the weir in many laterals where there are not good conditions for the ordinary weir.

WEIRS NOT LEVEL.

From settling or other causes it sometimes happens that weirs are not level, and it may be necessary to get the best results possible for the time being. The tables may be used for that purpose with a small amount of calculation by the following formula: H_1 and H_2 are the depths at the ends of the sill, H_1 being the greater; Q_1 is the quantity for the depth H_1 with a weir of corresponding length, obtained by the use of the tables, and Q_2 is the quantity if the depth had been H_2. Hence in such case, find the discharge corresponding to the depth at each end by the use of the tables. Multiply each of these quantities by the corresponding depth; subtract these two results and divide by the difference in the depths of the two ends, and take 2/5 of this quotient. The depths should be expressed in decimals of feet.

$$Q = \frac{2}{5}\left(\frac{Q_1 H_1 - Q_2 H_2}{H_1 - H_2}\right)$$

THE TRIANGULAR WEIR OR NOTCH.

A weir in the form of a triangular notch can be used in many cases to advantage. As the perimeter always bears the same ratio to the area the friction remains constant for different depths. This notch does not seem to have been used practically. It, however, might be used to a greater extent for laterals from canals. For that reason table II., the first of this kind that I know of, is given for a right angled notch that will enable it to be used.

The best form of notch would be a right angled notch with the corner downward. For a depth of one foot it will give a discharge of 2.5 cubic feet per second, which is as much or more than an ordinary lateral takes, and consequently may be used for that purpose. It is not applicable for large discharges.

The equation for the flow through such an opening is:

$$Q = 15m\ T\sqrt{g}\ h^{5/2}$$

where m is the coefficient of contraction, T the tangent of one-half the angle, G the acceleration of gravitation and H the depth. Giving M the value 0.592, the formula becomes:

$$Q = 2.54\ Th^{5/2}$$

where Q is the discharge in cubic feet per second and the head on the notch is measured in feet. This should be measured at a point several feet upstream from the notch, the same as in the case of the weir.

If the notch is a right angle notch we then have the equation of discharge: depths in feet.

$$Q = 2.54\ h^{5/2}$$

As this notch is especially adapted for small discharges it would be best adapted to conditions where the water is not over 12 inches in depth. It is then convenient to be able to express the quantity in cubic feet per second, with the depth measured in inches.

In this case the discharge in cubic feet per second would be:

$$Q = .0051\ h^{5/2}$$

where h is in inches.

This notch should be placed to conform to the conditions of the weir, that is, it should be placed at right angles to the current;

the edge should be sharp on the upstream side; it should be at some distance above the bottom of the channel; the two sides of the weir should be equally inclined to the vertical and there should be free flow of the water away from it. The point of the notch would not need to be as much above the bottom of the channel as the ordinary weir.

RATING FLUMES.

Weirs can not be conveniently used to measure water into canals, or even into large laterals. The fall required makes them inapplicable in most cases. Hence the method used is some form of rating flumes. These are recognized by law and the state officers may require them to be constructed.

A rating flume is commonly a flume built in the ditch some distance below the head gate with a rod graduated to show the depth. Measurements are made with a current meter to determine the quantities at several depths, and tables may then be prepared which will show the quantity at intermediate depths. There should be at least four such guagings made. If the conditions are good the results when plotted to scale, fall on a regular curve, and from that curve the quantities for intermediate depths may be taken with considerable confidence. A table is then prepared giving the quantities for different depths, and especially indicating the depth required to give the various appropriations of the canal. I have agree within one per cent.

The results depend on the skill of the gauger, on the accuracy of his meter, and the skill exercised in its "rating," and then on the conditions of the rating flume so that conditions are essentially the same at different times for the same depth, and there are no irregularities in the flow.

The flume should be far enough from the head gate to avoid the rush of the current which sometimes may be felt for considerable distances when the stream is high and the gates nearly shut; it should be in a straight reach of the canal, so that the current is central in the canal and free from eddies or boils due to roughness; it should not fill up with sand in some stages, to be scoured out at others.

The purpose of the flume is primarily to secure a constant bottom and cross section. Often this may be done by a simple construction, or even in rocky channels by one or more timbers across the bottom of the canal to fix the points of reference. It is common to make the sides of the flume vertical. In large canals or where the velocity is great, this may cause a considerable perturbation or contraction in the current. Hence I have sometimes caused such flumes to be built with the sides flaring so as to correspond to the slope of the canal bank, and thus the water passes through smoothly and without ripple. In such cases it is desirable to measure the depth in a well of still water connectly freely with the water in the flume. Without some such method the results are often discordant.

The results with fairly moderate quantities of water ought to be correct within 5%, and with proper care in construction of weir and its rating, to still less error. It is not so reliable for smaller channels and smaller quantities, but still may often be used with advantage where the weir cannot be used. One of the principal reasons why it is not adopted for measuring water to consumers is that the rating of these flumes calls for considerable skill as well as an instrumental equipment not frequently available. The errors in small ditches like laterals are also much larger than in large ones. Hence it is not to be used for this purpose, though for measurement into canals or into the larger laterals it may be entirely satisfactory. There may be reasons which force one to choose rating flumes as the last available method for the conditions, as, for instance, where sand or silt fills up the weir box, or where no fall is available. If there were enough need, I have no doubt that the rating flumes for small ditches could be developed so as to be nearly as accurate as the weir under the ordinary conditions. It would require special current meters adapted to the conditions.

COMPUTATION OF QUANTITY FROM THE SECTION AND FALL.

It is often necessary to determine the amount which a canal will carry, or to decide on the size required. For this purpose the formula commonly known as Kutter's is generally used. The results are to be taken with considerable latitude, and as will be seen are not exact enough to serve as a basis for division of water. These variations may be easily as much as 20%, and even then require accurate determinations of the slope of the water surface, (not the bottom of the canal) not commonly available, while the ordinary demands of the ditch call for accuracy within 5% or 10%.

The calculation by computation attempts to determine the velocity of the water, while the quantity, which is usually wanted, is the product of the velocity and the area of the cross-section. These should be expressed in feet-per-second, and in square feet, in order that the result be in cubic-feet-per-second which is usually wanted.

It is a matter of common observation that the velocity of water depends upon the section, upon the grade, and also upon the roughness. That is, given two canals of the same grade, the larger one will have the greater velocity. It is common observation that when a canal is enlarged it scours and checks must be built. The sides have a retarding influence somewhat in proportion to the ratio between the cross-section of the channel, and the length of the line of contact between the water and the surface. This ratio is termed the "hydraulic mean depth" or the "hydraulic mean radius" and is represented in formulas by "r."

The velocity also increases with the slope or inclination which is represented by "S" or "i," and is the fall per 100 feet expressed decimally.

The relation between the velocity and the hydraulic radius and slope is not a direct one, that is, doubling the fall does not double the velocity. But to double the velocity, the fall must be four times as great, or the hydraulic radius four times as great as before.

The condition of the surface of the channel in contact with the water also affects the velocity, for where the surface is rough it is visibly reduced. While such a relation was perceived, the old formulae attempted to include the first two relations only, and became

$$V = c\sqrt{ri}$$

The coefficient "c" was given values based on what experience had shown as applicable. There were commonly three values of "c" used, for small, for moderate and for large canals, and the results were very unsatisfactory.

Some fifty years ago two French engineers with the aid of the government made an elaborate series of tests on a small canal where the conditions could be changed, and especially the surface of the channel. Darcy and Bazin were the names of these engineers, and from the tests, all on small channels, none over three feet wide, obtained the effect from varying the surface. They made a number of classes depending on the surface and produced a formula which is still extensively used by French and Italian engineers, The formula did not give sufficient guide to engineers to apply the formula to the numerous conditions arising in practice.

Kutter's formula is another step to determine the value of "c" to be used. It is based on the work of Darcy and Bazin, but attempts to express the complicated relations between this coefficient and the size of the channel, the grade, and the roughness (by introducing a coefficient of roughness), all of which have an influence. The relation is complex, but it is not necessary to give here as the value is always found by the use of tables.

The coefficient of roughness is represented by "n." It varies from .009 from smoothest boards to .035 for a rough canal in poor order. For most open channels with which we have to do in irrigation it is comprised between .018 and .030, or commonly between .020 and .025. The results obtained depend entirely on the selection of "n," and the choice of this requires knowledge of the value under corresponding conditions. Under the best of conditions the result is subject to much uncertainty.

Thus the table gives the values of "c" for a few cases, and shows the great variation which comes with a different value of "n." Thus with a moderate sized ditch, hydraulic mean depth of two feet, the coefficient "c" would be 98 with "n" .017, and only 66 for "n" .025. One result is 50% over the other. These would be a difference of 27% made by selection of .020 or .025.

There is a very common inclination by courts and lawyers to accept any results by the Kutter formula as beyond question, but these show how much the result depends on the coefficient "n," and this choice can only be made with much reserve, and with knowledge of results of actual tests in similar conditions.

Nor does it follow that "n" remains the same in the same canal at different depths, or that it remains the same with the same depth for any length of time. Thus I have found "n" to vary from .022 to .027 in the same canal, the greater value of "n", and hence the smaller value of "c" with the increased depth. This was attributed to the fact that with the greater depth the water partially overflowed the bank and was retarded by underbrush. The growth of weeds during the summer often makes a noticeable effect on the carrying capacity of a canal for the same depths.

Hence, while the Kutter formula is of great usefulness, it must be used with intelligence, with a knowledge of its limitations, and realizing that the results under the best of conditions may be considerably in error. The expression for "c" in English measures is complicated, but this arises partly from the fact that it was derived in French measures, and the constants were simple in that system, but have become more complex in the transfer of units. Had the formula been derived in English units in the first place, or if some one should go to the trouble to obtain the expression so as to use English units, the apparent complexity would be much reduced. However, with the access to tables now easy, the engineers do not have occasion to use the formula itself, and this complexity does not matter.

It should not be forgotten that the whole purpose is to get "c" in the formula on page 38. Books like Trautwines Civil Engineer's Pocket Book have tables extensive enough for common use; other more elaborate tables have been prepared. The attempt to compute "c" to decimals is time wasted, for the error in the judgment of "n" may introduce a much larger error. Practically some forms of diagrams are accurate enough and much quicker to use.

VALUES OF "C" GIVEN BY KUTTER'S FORMULA.

	Fall 1.06 ft. per mile				Fall 2.11 ft. per mile				Fall 5.28 ft. per mile			
Rough-ness "N"	.017	.020	.025	.030	.017	.020	.025	.030	.017	.020	.025	.030
Hydraulic Depth ½ ft.	69	56	43	34	71	58	45	35	73	59	46	36
1 ft.	83	69	54	44	85	70	55	45	86	71	56	45
2 ft.	97	82	64	54	98	83	65	54	98	83	66	54
3 ft.	105	89	72	59	105	89	71	59	105	89	71	59
4 ft.	111	94	76	63	110	94	76	63	110	93	75	63

OTHER FORMULAE.

Attempts have been made with some success to develop formulae in which the coefficient is constant for the same class of channels, irrespective of size and slope, but with varying exponents of "r" and "i," not constant as in the one on page 37. Such are Sullivan's, Tutton's, the Williams-Hazen, where the exponents of "r" are 3/4 in Sullivan's, 2/3 in Tutton's, 0.63 in W.-H.; and the exponents of "i" 1/2 in both Sullivan's and Tutton's, and 0.54 in W.-H..

These formulae give much promise but are not convenient to use without tables which are not available execpt in the case of the Williams-Hazen,* and in each case requires the transformation of known measurements into the terms of these formulae so as to have a guide for the selection of "c" in that class of cases. Until there is a larger collection of special measurements, and also an expression in the special formulae, it is better to be contented with Kutter's.

*Hydraulic tables by Williams and Hazen, Pub. Jno. Wiley & Sons.

APPENDIX.

EXPLANATION OF TABLES.

Tables I. and II. are to give means of correcting the errors to the velocity of approach without the troublesome calculations indicated in the text.

Table I. gives the average velocity through the opening of a weir for different depths. It may be used to determine the velocity of the water as it approaches the weir. This may be found by comparing the cross-section of the channel of approach with the cross-section of the weir. If this is the same then the velocity given in the table would also be the velocity of approach. If the cross-section is, say, three times the area of the weir, then the velocity would be one-third of that given in the table. If the cross-section is seven times as great as the weir, as recommended in the text, then the velocity of approach would be one-seventh of the average velocity in the section of the weir, and thus for depths of two feet, the velocity of approach would be less than three-fourths of a foot, in which case the correction would be small.

Table II. is computed from the Fteley formula and expresses the correction to be given to the results of Tables III. to VI., due to the velocity of approach. This correction is expressed in per cent. The formula is based on experiments limited to 2.5 feet per second.

Tables III. and IV. give the discharges over weirs of unit length. The discharge of weirs of any length may be obtained by multiplying the quantity given for the proper depth in these tables by the length of the weir. This would apply more especially to the Cippoletti weir. If correction for contraction is made, then the length should be decreased by one-fifth of the depth of the water. In both these cases, depths are measured in inches, the formulae being given on page 23.

Table V. gives the discharge over rectangular weirs, from 1 to 10 feet long. In this case the discharge with two complete contractions is given and thus, in order to obtain the same result as in Tables III. or IV., the correction in the last column would be added to the results in the previous columns, or it could be subtracted from the result as obtained by the use of Tables III. and IV.

In both Tables III. and IV. the discharge is computed for every one-sixteenth of an inch. In this case the whole inch is given at the left and the sixteenths are given at the head of the page.

Example: What is the discharge over a weir 45 inches long and with a depth of 11¼ inches with two complete contractions?

Find 11 inches at the left of the page, and the column headed one-fourth inch at the head of the page. Follow this column down until it intersects the line of the 11. At the intersection is the discharge, for a portion of the weir one inch long, which is .2519 cubic feet per second. Then for a weir 45 inches long it is 45 times as much, or 11.3345 second feet, if without contraction. The second column gives the allowance for contraction for 11 inches depth; the eleventh column for a depth of 11½ inches. For 11¼ inches we then take a value intermediate between those for 11 inches and 11½ inches, obtaining the correction .567, the amount by which the discharge is reduced. This, then, leaves the total discharge as 11.335—.567 or 10.77 second feet.

Table VI. is for Cippoletti's trapezoidal weir and thus differs from Table V. in not allowing for contraction, as given in the last column of that table. It is also one per cent. greater.

It will be noticed that the discharges in Table VI. are directly proportional to the length of the weir, while in Table V. they are not. The quantities in Table V. were computed with the coefficient 3⅓ instead of 3.33 of the Francis formula.

Table VII. gives the discharge through right angled notches.

Table VIII. is to enable measurements made in inches to be expressed in decimals of feet.

Depth in all cases in the following tables is measured in still water. See page 25.

TABLE I.

Auxiliary Table for Approximating to Velocity of Approach.

Depth of water over weir		Average velocity in section of weir	Depth of water over weir		Average Velocity in section of weir
in ft.	in in.	in feet per sec.	in ft.	in in.	in ft. per sec.
.25	3	1.665	1.75	21	4.400
.50	6	2.354	2.00	24	4.709
.75	9	2.884	2.25	27	4.995
1.00	12	3.330	2.50	30	5.265
1.25	15	3.723	2.75	33	5.510
1.50	18	4.078	3.00	36	5.765

TABLE II.

Corrections in per cent. for velocity of approach, to be applied to values obtained from Tables III to VI.

Veloc-ity	Head*	DEPTH OVER WEIR, IN FEET											
		.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
.25	.0010	00.8	00.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
.50	.0039	03.5	1.8	1.2	0.9	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3
.75	.0087	08.0	4.0	2.6	2.0	1.6	1.3	1.1	1.0	0.9	0.8	0.7	0.7
1.00	.0155	14.3	7.1	4.7	3.5	2.8	2.3	2.0	1.8	1.6	1.4	1.3	1.2
1.25	.0243	22.6	11.1	7.4	5.5	4.4	3.7	3.1	2.7	2.4	2.2	2.0	1.8
1.50	.0350	33.1	16.1	10.7	8.0	6.4	5.3	4.5	4.0	3.5	3.2	2.9	2.6
1.75	.0476	45.7	22.2	14.6	10.9	8.7	7.2	6.2	5.4	4.8	4.3	3.9	3.6
2.00	.0622	60.9	29.2	19.2	14.3	11.4	9.5	8.1	7.1	6.3	5.6	5.1	4.7
2.25	.0787	78.6	37.4	24.5	18.2	14.5	12.0	10.3	9.0	8.0	7.2	6.5	6.0
2.50	.0971	99.1	46.7	30.5	22.6	18.0	14.9	12.7	11.1	9.9	8.9	8.0	7.4
2.75	.1175	121.8	56.9	37.0	27.4	21.8	18.0	15.4	13.4	11.9	10.7	9.7	8.9
3.00	.1398	149.4	69.1	44.8	31.1	26.2	21.7	18.5	16.1	14.3	12.8	11.7	10.7
3.25	.1641	179.6	82.3	53.1	39.1	30.9	25.6	21.8	19.0	16.9	15.1	13.7	12.6
3.50	.1903	213.5	96.9	61.7	45.7	36.1	29.9	25.4	22.2	19.6	17.6	16.0	14.6
3.75	.2185	251.3	113.0	72.3	53.0	41.8	34.5	29.4	25.6	22.6	20.3	18.4	16.8
4.00	.2486	293.1	130.7	82.6	60.9	47.9	39.5	33.6	29.2	25.9	23.2	21.0	19.2

*Head $= \frac{v^2}{64.36}$ v being velocity in feet per second, in first column.

TABLE III.—Discharge Over Weir One Inch Long, in Cubic Feet per Second.

Depth. Inches	Cor'ct'n to be s'btr'ctd for 2 side contr'ct'ns	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	Cor'ct'n to be s'bta'ctd for 2 side contr'ct'ns	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
3	.0208	.0347	.0358	.0369	.0380	.0391	.0402	.0414	.0425	.0306	.0437	.0449	.0461	.0437	.0485	.0497	.0509	.0522
4	.0427	.0534	.0547	.0559	.0572	.0585	.0598	.0611	.0624	.0574	.0637	.0651	.0664	.0677	.0691	.0705	.0719	.0732
5	.0746	.0746	.0760	.0775	.0789	.0803	.0817	.0832	.0846	.0947	.0861	.0876	.0891	.0905	.0920	.0936	.0951	.0966
6	.1177	.0981	.0997	.1012	.1027	.1043	.1059	.1075	.1090	.1438	.1106	.1122	.1138	.1154	.1171	.1187	.1203	.1220
7	.1732	.1236	.1253	.1270	.1286	.1303	.1321	.1337	.1354	.2057	.1371	.1388	.1406	.1423	.1440	.1458	.1475	.1493
8	.2417	.1511	.1528	.1546	.1564	.1582	.1600	.1618	.1636	.2812	.1654	.1673	.1691	.1709	.1728	.1746	.1765	.1784
9	.3244	.1802	.1821	.1840	.1859	.1878	.1897	.1916	.193 5	.3714	.1955	.1974	.1993	.2013	.2032	.2052	.2072	.2091
10	.4222	.2111	.2131	.2151	.2171	.2191	.2211	.2231	.2251	.4770	.2271	.2292	.2312	.2332	.2353	.2373	.2394	.2415
11	.5358	.2435	.2456	.2477	.2498	.2519	.2540	.2561	.2582	.5988	.2603	.2625	.2646	.2667	.2689	.2710	.2732	.2753
12	.6660	.2775	.2797	.2818	.2840	.2862	.2884	.2906	.2928	.7376	.2950	.2972	.2995	.3017	.3039	.3062	.3084	.3106
13	.8135	.3129	.3152	.3174	.3197	.3220	.3243	.3265	.3288	.8940	.3311	.3334	.3357	.3380	.3404	.3427	.3450	.3474
14	.9791	.3497	.3520	.3544	.3567	.3591	.3615	.3638	.3662	1.0689	.3686	.3710	.3734	.3758	.3782	.3806	.3830	.3854
15	1.1634	.3878	.3902	.3927	.3951	.3976	.4000	.4025	.4049	1.2628	.4074	.4098	.4123	.4148	.4173	.4198	.4222	.4247
16	1.3672	.4272	.4297	.4323	.4348	.4373	.4398	.4423	.4449	1.4765	.4474	.4500	.4525	.4551	.4576	.4602	.4628	.4653
17	1.5909	.4679	.4705	.4731	.4757	.4783	.4809	.4835	.4861	1.7105	.4887	.4913	.4940	.4966	.4992	.5019	.5045	.5071
18	1.8353	.5098	.5125	.5151	.5178	.5205	.5231	.5258	.5285	1.9654	.5312	.5339	.5366	.5393	.5420	.5447	.5474	.5501
19	2.1009	.5529	.5556	.5583	.5611	.5638	.5666	.5693	.5721	2.2418	.5748	.5776	.5804	.5831	.5859	.5887	.5915	.5943
20	2.3883	.5971	.5999	.6027	.6055	.6083	.6111	.6140	.6168	2.5404	.6196	.6224	.6253	.6281	.6310	.6338	.6367	.6396
21	2.6982	.6424	.6453	.6482	.6510	.6539	.6568	.6597	.6626	2.8614	.6655	.6684	.6713	.6742	.6771	.6801	.6830	.6859
22	3.0309	.6888	.6918	.6947	.6977	.7006	.7036	.7065	.7095	3.2061	.7125	.7154	.7184	.7214	.7244	.7274	.7304	.7333
23	3.3872	.7363	.7393	.7424	.7454	.7484	.7514	.7544	.7575	3.5743	.7605	.7635	.7666	.7696	.7727	.7757	.7788	.7818
24	3.7675	.7849	.7880	.7910	.7941	.7972	.8003	.8034	.8064	3.9668	.8095	.8126	.8157	.8189	.8220	.8251	.8282	.8313
25	4.1722	.8345	.8376	.8407	.8439	.8470	.8501	.8533	.8564	4.3840	.8659	.8628	.8659	.8691	.8723	.8755	.8786	.8818
26	4.6021	.8850	.8882	.8914	.8946	.8978	.9010	.9042	.9074	4.8265	.9107	.9139	.9171	.9203	.9236	.9268	.9301	.9333
27	5.0574	.9366	.9398	.9431	.9463	.9496	.9529	.9561	.9594	5.2948	.9627	.9660	.9693	.9726	.9759	.9792	.9825	.9858
28	5.5388	.9891	.9924	.9957	.9990	1.0023	1.0057	1.0090	1.0123	5.7894	1.0157	1.0190	1.0224	1.0257	1.0291	1.0324	1.0358	1.0391
29	6.0467	1.0425	1.0459	1.0493	1.0527	1.0560	1.0594	1.0628	1.0662	6.3106	1.0696	1.0730	1.0764	1.0798	1.0832	1.0866	1.0901	1.0935
30	6.5814	1.0969	......	......	......	......	......	.....	.....	......	......	......	......	......	......	......	......	.....

For discharges for depths less than 3 inches, use Tables V or VI. The absolute error will be small.

TABLE IV.—Discharge Over Weir One Foot Long, in Cubic Feet per Second.

Depth. Inches	Cor'ct'n to be s'btr'ctd for 2 side contr'cti'ns	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	Cor'cct,n to be s'bta'ctd for 2 side contr'ct'ns	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
3	.0208	.4163	.4293	.4425	.4559	.4693	.4829	.4967	.5106	.0262	.5245	.5386	.5529	.5672	.5817	.5963	.6110	.6259
4	.0427	.6409	.6559	.6711	.6864	.7019	.7174	.7331	.7488	.0574	.7647	.7807	.7968	.8130	.8233	.8457	.8622	.8789
5	.0746	.8956	.9125	.9294	.9465	.9636	.9809	.9983	1.0157	.0947	1.0333	1.0510	1.0687	1.0866	1.1045	1.1227	1.1407	1.1590
6	.1177	1.1774	1.1958	1.2143	1.2330	1.2517	1.2705	1.2894	1.3084	.1438	1.3275	1.3467	1.3660	1.3853	1.4048	1.4244	1.4440	1.4637
7	.1732	1.4836	1.5035	1.5235	1.5436	1.5638	1.5840	1.6044	1.6221	.2057	1.6454	1.6660	1.6866	1.7074	1.7283	1.7493	1.7703	1.7914
8	.2417	1.8126	1.8339	1.8553	1.8767	1.8982	1.9199	1.9415	1.9633	.2812	1.9852	2.0071	2.0291	2.0512	2.0734	2.0957	2.1180	2.1404
9	.3244	2.1629	2.1855	2.2081	2.2308	2.2536	2.2765	2.2995	2.3225	.3714	2.3456	2.3688	2.3921	2.4154	2.4388	2.4623	2.4859	2.5095
10	.4222	2.5332	2.5570	2.5809	2.6048	2.6288	2.6529	2.6770	2.7013	.4770	2.7256	2.7499	2.7744	2.7989	2.8235	2.8481	2.8729	2.8977
11	.5358	2.9225	2.9475	2.9725	2.9976	3.0227	3.0480	3.0733	3.0986	.5988	3.1240	3.1495	3.1751	3.2008	3.2265	3.2522	3.2781	3.3040
12	.6660	3.3300	3.3560	3.3822	3.4083	3.4346	3.4609	3.4873	3.5137	.7376	3.5403	3.5668	3.5935	3.6202	3.6470	3.6738	3.7008	3.7277
13	.8135	3.7548	3.7819	3.8091	3.8363	3.8636	3.8910	3.9184	3.9459	.8940	3.9735	4.0011	4.0288	4.0565	4.0844	4.1122	4.1402	4.1682
14	.9791	4.1963	4.2244	4.2526	4.2808	4.3092	4.3375	4.3660	4.3945	1.0689	4.4231	4.4517	4.4804	4.5091	4.5379	4.5668	4.5957	4.6247
15	1.1634	4.6538	4.6829	4.7121	4.7413	4.7706	4.8000	4.8294	4.8589	1.2628	4.8884	4.9180	4.9477	4.9774	5.0072	5.0370	5.0669	5.0968
16	1.3672	5.1268	5.1569	5.1870	5.2172	5.2475	5.2778	5.3081	5.3386	1.4765	5.3690	5.3996	5.4302	5.4608	5.4915	5.5223	5.5531	5.5840
17	1.5909	5.6149	5.6459	5.6770	5.7081	5.7392	5.7705	5.8017	5.8331	1.7105	5.8645	5.8959	5.9274	5.9590	5.9906	6.0222	6.0540	6.0857
18	1.8353	6.1176	6.1495	6.1814	6.2134	6.2455	6.2776	6.3097	6.3420	1.9654	6.3742	6.4066	6.4389	6.4714	6.5039	6.5364	6.5690	6.6017
19	2.1009	6.6344	6.6671	6.7000	6.7329	6.7658	6.7987	6.8318	6.8648	2.2418	6.8980	6.9312	6.9644	6.9977	7.0311	7.0645	7.0979	7.1314
20	2.3883	7.1650	7.1986	7.2323	7.2660	7.2997	7.3336	7.3674	7.4014	2.5404	7.4353	7.4694	7.5035	7.5376	7.5718	7.6060	7.6403	7.6746
21	2.6982	7.7090	7.7435	7.7780	7.8125	7.8471	7.8817	7.9164	7.9512	2.8616	7.9860	8.0208	8.0557	8.0907	8.1257	8.1607	8.1958	8.2310
22	3.0309	8.2662	8.3014	8.3367	8.3721	8.4075	8.4429	8.4784	8.5140	3.2061	8.5496	8.5852	8.6209	8.6567	8.6925	8.7283	8.7642	8.8001
23	3.3872	8.8361	8.8722	8.9083	8.9444	8.9806	9.0168	9.0531	9.0894	3.5143	9.1258	9.1623	9.1987	9.2353	9.2718	9.3085	9.3451	9.3818
24	3.7675	9.4186	9.4554	9.4923	9.5292	9.5662	9.6032	9.6402	9.6773	3.9668	9.7145	9.7517	9.7889	9.8262	9.8635	9.9009	9.9384	9.9758
25	4.1722	10.0134	10.0509	10.0886	10.1262	10.1639	10.2017	10.2395	10.2394	4.3840	10.3153	10.3532	10.3912	10.4292	10.4673	10.5055	10.5436	10.5819
26	4.6021	10.6201	10.6584	10.6968	10.7352	10.7737	10.8122	10.8507	10.8893	4.8265	10.9280	10.9666	11.0054	11.0441	11.0830	11.1218	11.1607	11.1997
27	5.0574	11.2387	11.2777	11.3168	11.3560	11.3951	11.4344	11.4736	11.5131	5.2948	11.5523	11.5917	11.6312	11.6707	11.7102	11.7498	11.7894	11.8291
28	5.5388	11.8688	11.9086	11.9484	11.9382	12.0681	12.0681	12.1080	12.1481	5.7894	12.1881	12.2282	12.2684	12.3086	12.3489	12.3891	12.4295	12.4699
29	6.0467	12.5103	12.5507	12.5912	12.6318	12.6724	12.7130	12.7537	12.7944	6.3106	12.8352	12.8760	12.9169	12.9578	12.9987	13.0397	13.0807	13.1218
30	6.5814	13.1629	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

For discharges for depths less than 3 inches, use Tables V or VI. The absolute error will be small.

TABLE V.

Discharge Over Rectangular Weirs, with and without Contraction.

Formula, $D = 3\frac{1}{3}(l - .2\,H)\,H^{3/2}$

For conditions, see page 29.

Depth, H, of Water on crest Measured in Still Water. See Page 24		DISCHARGE IN CUBIC FEET PER SECOND						
		With Two Complete Contractions.						Correction to be ADDED to each of the preceeding to give discharge with no contraction.
In Inches	In Feet	1 Foot Long	1½ Feet Long	2 Feet Long	3 Feet Long	5 Feet Long	10 Feet Long	
0.3	.025	.0133	.0200	.0267	.0400	.0677	.1330	.0000
0.6	.050	.0369	.0556	.0743	.1116	.1863	.3716	.0004
0.9	.075	.0674	.1015	.1350	.2040	.3410	.6830	.0010
1.2	.1	.1033	.1560	.2087	.3132	.5240	1.0519	.0021
1.5	.125	.1438	.2175	.2912	.4385	.7332	1.4695	.0037
1.8	.15	.1879	.2847	.3816	.5753	.9627	1.9312	.0058
2.1	.175	.2355	.3575	.4795	.7235	1.2115	2.4315	.0085
2.4	.2	.2861	.4352	.5843	.8824	1.4787	2.9690	.0119
2.7	.225	.3399	.5177	.6956	1.0513	1.7627	3.5412	.0160
3.0	.25	.3959	.6042	.8126	1.2293	2.0227	4.1462	.0208
3.3	.275	.4543	.6946	.9350	1.4157	2.3771	4.7803	.0264
3.6	.3	.5149	.7888	1.0627	1.6104	2.7059	5.4442	.0328
3.9	.325	.5775	.8863	1.1952	1.8129	3.0482	6.1363	.0401
4.2	.35	.6420	.9871	1.3321	2.0223	3.4032	6.8537	.0483
4.5	.375	.7079	1.0909	1.4732	2.2335	3.7691	7.5976	.0574
4.8	.4	....	1.1974	1.6189	2.4623	4.1485	8.3645	.0675
5.1	.425	....	1.3070	1.7680	2.6926	4.5400	9.1565	.0785
5.4	.45	....	1.4189	1.9221	2.9280	4.9404	9.9775	.0906
5.7	.475	....	1.5333	2.0790	3.1708	5.3523	10.8094	.1037
6.0	.5	....	1.6500	2.2392	3.4177	5.7748	11.6672	.1178
6.3	.525	....	1.7689	2.4029	3.6709	6.2069	12.5469	.1331
6.6	.55	....	1.8890	2.5698	3.9295	6.6489	13.4474	.1496
6.9	.575	....	2.0129	2.7395	4.1928	7.0995	14.3668	.1672
7.2	.6	....	2.1378	2.9123	4.4614	7.5596	15.3052	.1859
7.5	.625	....	2.2646	3.0881	4.7351	8.0291	16.2641	.2059
7.8	.65	....	2.3929	3.2665	5.0133	8.5069	17.2409	.2271
8.1	.675	....	2.5234	3.3478	5.2960	8.9930	18.2354	.2495
8.4	.7	....	....	3.6313	5.5836	9.4832	19.2497	.2733
8.7	.725	....	....	3.8170	5.8747	9.9906	20.2796	.2984
9.0	.75	....	....	4.0052	6.1702	10.5007	21.3262	.3248
9.3	.775	....	....	4.1961	6.4704	11.0190	22.3895	.3524
9.6	.8	....	....	4.3888	6.7734	11.5444	23.4704	.3816
9.9	.825	....	....	4.5833	7.0810	12.0769	24.5659	.4121
10.2	.85	....	....	4.7806	7.3929	12.6169	25.6779	.4440
10.5	.875	....	....	4.9792	7.7075	13.1641	26.8056	.4775
10.8	.9	....	....	....	8.0257	13.7177	27.9477	.5123
11.1	.925	....	....	....	8.3509	14.2839	29.1164	.5486
11.4	.95	....	....	....	8.6731	14.8461	30.2786	.5864
11.7	.975	....	....	....	9.0012	15.4192	31.4652	.6258
12.0	1.0	....	....	....	9.3333	16.0000	32.6667	.6667
12.3	1.025	....	....	....	9.6685	16.5869	33.8829	.7091
12.6	1.05	....	....	....	10.0058	17.1789	35.1109	.7531
12.9	1.075	....	....	....	10.3471	17.7777	36.3552	.7988
13.2	1.1	....	....	....	10.6907	18.3825	37.6100	.8490
13.5	1.125	....	....	....	11.0376	18.9926	38.8801	.8949
13.8	1.150	....	....	....	11.3866	19.6080	40.1625	.9455
14.1	1.175	....	....	....	11.7388	20.2298	41.4573	.9977
14.4	1.2	....	....	....	12.0935	20.8569	42.7664	1.0516
14.7	1.225	....	....	....	12.4507	21.4893	44.0866	1.1073
15.0	1.25	....	....	....	12.8109	22.1279	45.4204	1.1646
15.3	1.275	....	....	....	13.1733	22.7713	46.7653	1.2237
15.6	1.3	....	....	....	13.5375	23.4189	48.1224	1.2846
15.9	1.325	....	....	....	13.9067	24.0727	49.4927	1.3473
16.2	1.35	....	....	....	14.2740	24.7308	50.8733	1.4117
16.5	1.375	....	....	....	14.6450	25.3946	52.2671	1.4780
16.8	1.4	....	....	....	....	26.0625	53.6710	1.5460
17.1	1.425	....	....	....	....	26.7355	55.0870	1.6160
17.4	1.45	....	....	....	....	27.4127	56.5132	1.6878
17.7	1.475	....	....	....	....	28.0950	57.9515	1.7615

Discharge Over Rectangular Weirs.—Concluded.

Depth, H, of Water on Crest Measured in still water		DISCHARGE IN CUBIC FEET PER SECOND			
		With Two Complete Contractions			Correction to be ADDED to each of the preceding to give discharge with NO contraction.
In Inches	In Feet	3 Feet Long.	5 Feet Long.	10 Feet Long.	
18.0	1.5	....	28.7814	59.3999	1.8371
18.3	1.525	....	29.4729	60.8604	1.9146
18.6	1.55	....	30.1680	62.3300	1.9940
18.9	1.575	....	30.8681	63.8116	2.0754
19.2	1.6	....	31.5717	65.3022	2.1588
19.5	1.625	....	32.2809	66.8049	2.2441
19.8	1.650	....	32.9935	68.3175	2.3314
20.1	1.675	....	33.7093	69.8393	2.4207
20.4	1.7	....	34.4299	71.3719	2.5121
20.7	1.725	....	35.1546	72.9146	2.6054
21.0	1.750	....	35.8827	74.4672	2.7009
21.3	1.775	....	36.6151	76.0286	2.7984
21.6	1.8	....	37.3510	77.6002	2.8979
21.9	1.825	....	38.0909	79.1814	2.9996
22.2	1.85	....	38.8346	80.7726	3.1034
22.5	1.875	....	39.5812	82.3717	3.2093
22.8	1.9	....	40.3321	83.9816	3.3173
23.1	1.925	....	41.0860	85.6005	3.4276
23.4	1.95	....	41.8436	87.2271	3.5399
23.7	1.975	....	42.6045	88.8635	3.6545
24.	2.0	....	43.3695	90.5061	3.771
27.	2.25	....	....	107.44	5.06
30.	2.50	....	....	125.17	6.59
36.	3.00	....	....	162.81	10.39

TABLE VI.

Discharge Over Cippoletti's Trapezoidal Weir of Various Lengths and with Various Depths, and Over Rectangular Weirs Without End Contraction.

Formula, $D = 3.3\frac{2}{3} L H^{3/2}$

Depth of Water on Crest		DISCHARGE IN CUBIC FEET PER SECOND						
In Inches	In Feet	1 Foot Long	1½ Feet Long	2 Feet Long	3 Feet Long	4 Feet Long	5 Feet Long	10 Feet Long
.3	.025	.0135	.0202	.0269	.0404	.0539	.0673	.1347
.6	.05	.0367	.0566	.0754	.1131	.1508	.1885	.3771
.9	.075	.0690	.1035	.1380	.2071	.2761	.3451	.6902
1.2	.10	.1064	.1596	.2128	.3192	.4256	.5319	1.0639
1.5	.125	.1488	.2232	.2976	.4464	.5952	.7440	1.4881
1.8	.15	.1956	.2934	.3912	.5868	.7824	.9780	1.9560
2.1	.175	.2464	.3697	.4929	.7393	.9858	1.2322	2.4644
2.4	.20	.3010	.4515	.6020	.9029	1.2039	1.5049	3.0098
2.7	.225	.3592	.5388	.7184	1.0777	1.4369	1.7961	3.5922
3.0	.25	.4208	.6312	.8417	1.2625	1.6833	2.1041	4.2083
3.3	.275	.4855	.7282	.9709	1.4564	1.9419	2.4273	4.8547
3.6	.30	.5531	.8297	1.1063	1.6594	2.2126	2.7657	5.5314
3.9	.325	.6238	.9358	1.2477	1.8715	2.4954	3.1192	6.2384
4.2	.35	.6972	1.0459	1.3945	2.0917	2.7890	3.4862	6.9724
4.5	.375	.7730	1.1595	1.5460	2.3190	3.0820	3.8649	7.7299
4.8	.40	....	1.2777	1.7035	2.5553	3.4071	4.2588	8.5177
5.1	.425	....	1.3993	1.8658	2.7987	3.7316	4.6645	9.3290
5.4	.45	....	1.5246	2.0328	3.0492	4.0656	5.0820	10.1640
5.7	.475	....	1.6534	2.2045	3.3067	4.4089	5.5112	11.0225
6.0	.50	....	1.7854	2.3805	3.5708	4.7610	5.9512	11.9025
6.3	.525	....	1.9210	2.5614	3.8420	5.1227	6.4034	12.8068
6.6	.55	....	2.0599	2.7465	4.1198	5.4930	6.8663	13.7326
6.9	.575	....	2.2018	2.9357	4.4036	5.8715	7.3393	14.6787
7.2	.60	....	2.3472	3.1293	4.6939	6.2585	7.8231	15.6463
7.5	.625	....	2.4955	3.3274	4.9911	6.6548	8.3185	16.6370
7.8	.65	....	2.6462	3.5283	5.2924	7.0565	8.8206	17.6413
8.1	.675	....	2.8007	3.7343	5.6014	7.4686	9.3357	18.6715

Discharge Over Cippoletti Weirs.—Concluded.

Depth of Water on Crest		DISCHARGE IN CUBIC FEET PER SECOND					
In Inches	In Feet	2 Feet Long	3 Feet Long	4 Feet Long	5 Feet Long	7 Feet Long	10 Feet Long
8.4	.7	3.9437	5.9156	7.8874	9.8593	13.8030	19.7186
8.7	.725	4.1565	6.2347	8.2930	10.3912	14.5457	20.7824
9.0	.75	4.3733	6.5599	8.7466	10.9932	15.3065	21.8675
9.3	.775	4.5942	6.8912	9.1883	11.4854	16.0796	22.9708
9.6	.80	4.8177	7.2265	9.6354	12.0442	16.8619	24.0885
9.9	.825	5.0453	7.5679	10.0906	12.6132	17.6585	25.2264
10.2	.85	......	7.9154	10.5538	13.1923	18.4692	26.3846
10.5	.875	......	8.2669	11.0225	13.7781	19.2893	27.5562
10.8	.90	......	8.6234	11.4978	14.3723	20.1212	28.7446
11.1	.925	......	8.9850	11.9800	14.9749	20.9649	29.9499
11.4	.95	......	9.3516	12.4688	15.5860	21.8204	31.1720
11.7	.975	......	9.7233	12.9644	16.2054	22.6876	32.4019
12.0	1.00	......	10.1000	13.5667	16.8333	23.5667	33.6667
12.3	1.025	......	10.4808	13.9744	17.4679	24.4551	34.9359
12.6	1.05	......	10.8666	14.4888	18.1110	25.3554	36.2220
12.9	1.075	......	11.2575	15.0100	18.7624	26.2674	37.5249
13.2	1.10	......	11.6524	15.5365	19.4206	27.1888	38.8412
13.5	1.125	......	12.0513	16.0684	20.0855	28.1198	40.1711
13.8	1.150	......	12.4553	16.6071	20.7588	29.0624	41.5177
14.1	1.175	......	12.8644	17.1525	21.4406	30.0168	42.8812
14.4	1.2	......	13.2764	17.7019	22.1274	30.9784	44.2548
14.7	1.225	......	13.6936	18.2581	22.8226	31.9517	45.6453
15.0	1.25	......	14.1148	18.8197	23.5246	32.9344	47.0492
15.3	1.275	......	14.5410	19.3880	24.2349	33.9289	48.9699
15.6	1.3	......	......	19.9603	24.9503	34.9305	49.9007
15.9	1.325	......	......	20.5394	25.6742	35.9439	51.3484
16.2	1.35	......	......	21.1238	26.4047	36.9666	52.8095
16.4	1.375	......	......	21.7123	26.1404	37.9966	54.2808
16.8	1.4	......	......	22.3075	27.8844	39.0382	55.7688
17.1	1.425	......	......	22.9082	28.6352	40.0893	57.2704
17.4	1.45	......	......	23.5128	29.3910	41.1474	58.7820
17.7	1.475	......	......	24.1242	30.1552	42.2173	60.3105
18.0	1.5	......	......	24.7396	30.9245	43.2943	61.8490
18.3	1.525	......	......	25.3604	31.7005	44.3808	63.4011
18.6	1.55	......	......	25.9866	32.4833	45.4766	64.9666
18.9	1.575	......	......	26.6182	33.2727	46.5818	66.5455
19.2	1.6	......	......	......	34.0685	47.6959	68.1370
19.5	1.625	......	......	......	34.8702	48.8183	69.7405
19.8	1.65	......	......	......	35.6782	49.9495	71.3565
20.1	1.675	......	......	......	36.4913	51.0878	72.9826
20.4	1.7	......	......	......	37.3111	52.2355	74.6222
20.7	1.725	......	......	......	38.1376	53.3926	76.2752
21.0	1.75	......	......	......	38.9691	54.5568	77.9383
21.3	1.775	......	......	......	39.8074	55.7304	79.6149
21.6	1.8	......	......	......	40.6515	56.9121	81.3030
21.9	1.825	......	......	......	41.5009	58.1013	83.0018
22.2	1.85	......	......	......	42.3577	59.3008	84.7154
22.5	1.875	......	......	......	43.2179	60.5031	86.4358
22.8	1.9	......	......	......	......	61.7211	88.1730
23.1	1.925	......	......	......	......	62.9442	89.9203
23.4	1.95	......	......	......	......	64.1720	91.6743
23.7	1.975	......	......	......	......	65.4116	93.4452
24.0	2.0	......	......	......	......	66.6560	95.2228
25.5	2.125	......	......	......	......	72.999	104.289
27.0	2.25	......	......	......	......	79.541	113.63
28.8	2.4	......	......	......	......	87.619	125.18
30.0	2.5	......	......	......	......	93.156	133.07

SOME PHYSICAL CONSTANTS USEFUL IN CONNECTION WITH THE PRECEDING TABLES.

1 cu. ft. water weighs 62.416 lbs. at32 degrees F.
1 cu. ft. water weighs 62.424 lbs. at 39.3 degrees F.
1 cu. ft. water weighs 62.408 lbs. at 50 degrees F.
1 cu. ft. water weighs 62.300 lbs. at 70 degrees F.
1 cu. ft.=7.48052 U. S. gallons.
1 acre ft.=on acre 1 ft. deep=43,560 cu. ft.=325,851.45 gallons.
1,000,000 U. S. gallons=133,680.6 cu. ft. =3.07 acre ft.
1,000,000 cu. ft.=22.9568 acre feet. =11.574 cu. ft. per sec. for 24 hrs.

1 cu. ft. per sec.=448.8312 gals. per min.
=86,400 cu. ft. in 24 hrs. (Nearly 2 acre ft.)
=2 acre ft. in 24 hrs., 12 min.
=1,000,000 cu. ft. in 11.574 days.
=1,000,000 gals. in 1,5472 days.
1 cu. ft. per sec.=38.4 Colorado statute inches.
=50 California statute inches.
1.44 cu. ft. per sec. covers 80 acres 6 in. deep in 14 days.

TABLE VII.

Discharge Over Right Angled Triangular Notches, in Cubic Feet per Second.

$Q = .0051\ h^{5/2}$, h measured in inches.

Depth, Inches	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0	.0001	.0001	.0001	.0002	.0003	.0004	.0006	.0009	.0012	.0016	.0020	.0025	.0030	.0036	.0043
1	.0051	.0059	.0068	.0078	.0089	.0101	.0113	.0126	.0140	.0156	.0172	.0189	.0207	.0226	.0246	.0266
2	.0289	.0312	.0336	.0361	.0387	.0415	.0443	.0473	.0504	.0536	.0569	.0604	.0640	.0677	.0715	.0754
3	.0795	.0837	.0880	.0925	.0971	.1018	.1067	.1117	.1169	.1222	.1276	.1332	.1389	.1448	.1507	.1569
4	.1632	.1696	.1762	.1830	.1899	.1970	.2042	.2115	.2191	.2268	.2346	.2426	.2508	.2591	.2676	.2763
5	.2851	.2941	.3033	.3126	.3221	.3318	.3416	.3516	.3618	.3722	.3827	.3934	.4043	.4154	.4267	.4381
6	.4497	.4615	.4735	.4857	.4980	.5107	.5233	.5362	.5493	.5627	.5762	.5898	.6037	.6178	.6320	.6465
7	.6612	.6760	.6911	.7063	.7218	.7375	.7533	.7694	.7856	.8021	.8188	.8357	.8528	.8701	.8876	.9053
8	.9232	.9413	.9597	.9782	.9970	1.0160	1.0352	1.0546	1.0743	1.0941	1.1142	1.1345	1.1550	1.1758	1.1967	1.2179
9	1.2393	1.2609	1.2828	1.3049	1.3272	1.3497	1.3724	1.3954	1.4187	1.4421	1.4658	1.4897	1.5139	1.5382	1.5628	1.5877
10	1.6128	1.6381	1.6636	1.6894	1.7155	1.7417	1.7682	1.7950	1.8220	1.8492	1.8767	1.9044	1.9324	1.9606	1.9890	2.0177
11	2.0467	2.0759	2.1053	2.1350	2.1650	2.1952	2.2256	2.2563	2.2872	2.3185	2.3499	2.3817	2.4136	2.4458	2.4783	2.5110
12	2.5440	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

TABLE VIII.

Auxiliary Table to Convert Inches into Decimals of a Foot.

Inches	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	.0000	.0052	.0104	.0156	.0208	.0260	.0313	.0365	.0417	.0469	.0521	.0573	.0625	.0677	.0729	.0781
1	.0833	.0885	.0938	.0990	.1042	.1094	.1146	.1198	.1250	.1302	.1354	.1406	.1458	.1510	.1563	.1615
2	.1667	.1719	.1771	.1823	.1875	.1927	.1979	.2031	.2083	.2135	.2188	.2240	.2292	.2344	.2396	.2448
3	.2500	.2552	.2604	.2656	.2708	.2760	.2813	.2865	.2917	.2969	.3021	.3073	.3125	.3177	.3229	.3281
4	.3333	.3385	.3438	.3490	.3542	.3594	.3646	.3698	.3750	.3802	.3854	.3906	.3958	.4010	.4063	.4115
5	.4167	.4219	.4271	.4323	.4375	.4427	.4479	.4531	.4583	.4635	.4688	.4740	.4792	.4844	.4896	.4948
6	.5000	.5052	.5104	.5156	.5208	.5260	.5313	.5365	.5417	.5469	.5521	.5573	.5625	.5677	.5729	.5781
7	.5833	.5885	.5938	.5990	.6042	.6094	.6146	.6198	.6250	.6302	.6354	.6406	.6458	.6510	.6563	.6615
8	.6667	.6719	.6771	.6823	.6875	.6927	.6979	.7031	.7083	.7135	.7188	.7240	.7292	.7344	.7396	.7448
9	.7500	.7552	.7604	.7656	.7708	.7760	.7813	.7865	.7917	.7969	.8021	.8073	.8125	.8177	.8229	.8281
10	.8333	.8385	.8438	.8490	.8542	.8594	.8646	.8698	.8750	.8802	.8854	.8906	.8958	.9010	.9063	.9115
11	.9167	.9219	.9271	.9323	.9375	.9427	.9479	.9531	.9583	.9635	.9688	.9740	.9792	.9844	.9896	.9948
12	1.0000	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Bulletin 151 JANUARY, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

RATION EXPERIMENT WITH LAMBS

1906-07, 1907-08.

SELF FEEDERS FOR HAY

BY

W. L. CARLYLE

AND

G. E. MORTON

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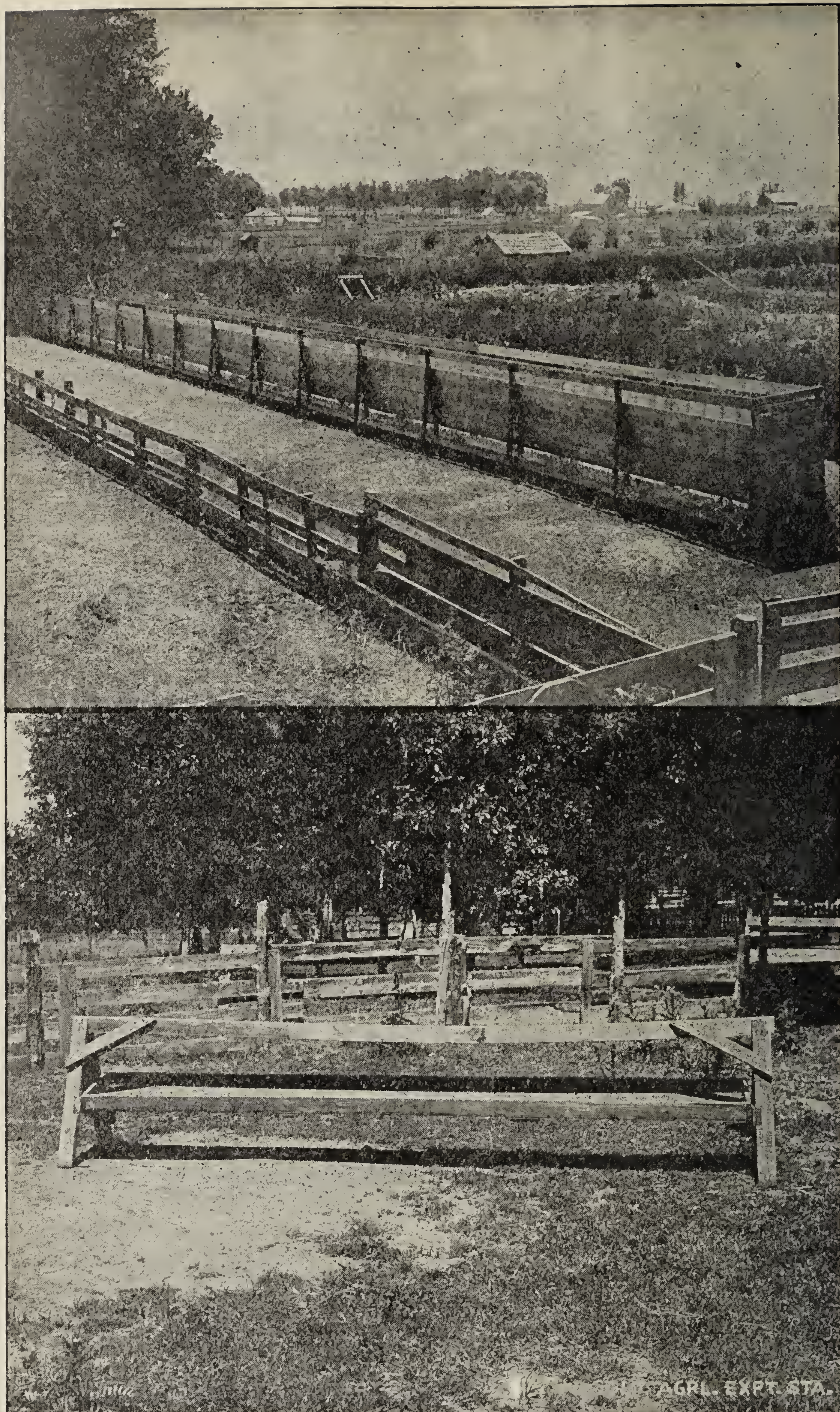

Upper—Self Feeders For Hay.
Lower—A Type of Grain Trough.

RATION EXPERIMENT WITH LAMBS.

1906 1907. 1907-1908.

W. L. CARLYLE and G. E. MORTON.

INTRODUCTION

This bulletin covers two winters' work with lambs done under the direction of W. L. Carlyle. The first winter's work, on Cut Hay versus Whole Hay, was carried out by H. M. Cottrell, and the second winter's work on Cut Hay versus Whole Hay, and on Self Feeders for Hay compared with Old Style Hay Racks, was carried out by the writer, G. E. Morton.

CUT HAY VERSUS WHOLE HAY—ALFALFA—FIRST TRIAL

The Fort Collins district furnishes an excellent field for the study of the lamb feeding industry. Because of the large numbers fed, and the high ranking of the finished lambs on Eastern markets, feeders are unusually alert in their search for means of reducing the cost of production. One of the questions frequently put to live stock men of the College and Station has been concerning the value of cutting alfalfa hay into short lengths. There is considerable waste in feeding whole hay to sheep as they reject quite a large percentage of the stems. There is no doubt that cutting the hay causes sheep to eat it more closely, but the question of interest is whether enough saving is effected by the cutting to reimburse the feeder for the cost of cutting

The trial here reported was made with grade Shropshire lambs from the Idaho range. The lambs were fed whole hay and corn for a period of seven weeks, and were then put upon experiment, one lot being fed whole hay and the other fed hay run through an ordinary feed cutter, and cut to 1/8 of an inch in length.

TABLE I.

TOTAL WEIGHTS AND GAINS—SIX WEEKS

Dec. 1st, 1906, to Jan. 12th, 1907—125 Lambs in Each Lot

Lot No	Weight at Beginning (lbs.)	Weight at Close (lbs.)	Gain in Weight (lbs.)	Total Feed Consumed, (lbs.)		
				Corn	Alfalfa Hay	Oil Meal
A Whole Hay	12,635	14,256	1621	7785	24,592	140
B Cut Hay	12,533	13,948	*1505	7903	10,893	140

*Gain shown by final weight plus 90 lbs., weight of lamb which died.

The weights and gains made by the two lots, as shown in the table, are very closely alike. The amounts of corn and oil meal fed the two lots were also nearly equal. But the hay eaten by the lot fed whole hay was over double that eaten by the lot fed cut hay. Table II shows how this effects the feed required for 100 pounds of gain and the cost of gain. There was only one pound difference in the average gain per head made by the two lots of lambs in six weeks.

TABLE II.

FEED FOR GAIN AND COST OF GAIN—125 LAMBS IN EACH LOT

Lot No.	Ration	Average Gain Per Head, Six Weeks, lbs.	Pounds of Feed For 100 Pounds Gain			Cost of Feed For 100 lbs Gain*
			Corn	Hay		
A	Corn, Alfalfa Hay, Whole, on Ground	13	478	1511	8,6	$8.73
B	Corn, Alfalfa Hay, Cut, on Ground	12	525	724	9.3	7.61

*NOTE—Corn at 1 cent per lb., Alfalfa Hay at $5.00 per ton, Cut Hay at $6.00 per ton, Oil Meal at 2 cents per lb.

FEED FOR GAIN

The lot fed whole hay required 47 pounds less corn for 100 pounds gain than the lot fed cut hay, but ate 1511 pounds of hay for every hundred pounds gain, while the cut hay lot ate only 724 pounds of hay for each 100 pounds gain. This is a marked difference.

COST OF GAIN

The prices, from which the costs given in the above table were computed, are not the exact prices of the feeding stuffs at the time the experiment was carried on; but they are round numbers, and changing the prices of feed stuffs in this instance could not greatly affect the ratio between the figures for the two lots. This experiment shows a considerable saving by using cut hay, although the cost of feed for 100 pounds of gain in either case is so high as to be almost prohibitive. A partial explanation of this may be found in the fact that the fleeces of the lambs were trimmed preparatory to showing at the Western Stock Show, causing a shrinkage in the weight of the lambs during the fourth week. With Lot B this shrinkage amounted to a loss of 252 pounds for the week, or about 2 pounds per head. The most of this shrinkage was regained the following week, however, as shown by the gain of 529 pounds for that week, or over five pounds per head. So we cannot look for an explanation of the high cost in this shrinkage. But considering the feed given the whole hay lot, we find that they ate on an average 4.7 pounds of hay per head each day, an enormous amount. This would indicate very poor hay or an unnecessary waste of good hay, so that in either case, one would not be justified in reaching the conclusion that the economy shown by the table would ordinarily follow the use of cut hay. In view of the unusually heavy consumption of whole hay, a series of experiments along the same line is necessary before a conclusion is warranted. The trial reported below is the second in a series bearing upon the same problem.

CUT HAY VERSUS WHOLE HAY, ALFALFA, SECOND TRIAL

In this trial, self feeders for hay were used, and if there be economy in the use of cut hay, it should appear under these conditions; for the self feeder should protect fine cut hay and leaves from staling and from being blown away by the wind even to a greater degree than they protect whole hay, with the following exception. If there are frequent wet snows, these serve to cause greater waste of cut hay than of whole hay when self feeders are used, because the cut hay dries out less readily than the whole, and so becomes less palatable.

In the following table, Lots I and II are the Lots to be compared:

TABLE A

TOTAL WEIGHTS AND GAINS—14 WEEKS

Nov. 23d, 1907, to Feb. 29, 1908—200 Lambs in Each Lot

	Lot	Weight at Beginning (lbs.)	Weight at Close (lbs.)	Gain in Weight (lbs.)	Total Feed Consumed, (lbs.)	
					Corn	Alfalfa Hay
Hay, Cut, in Self Feeder	I.....	11,675	19,330	7655	20,445	46,329
Hay, Whole, in Self Feeder	II.....	12,240	19,170	6930	20,595	41,615
Hay, Whole, on Ground	III...	11,813	18,555	6742	20,595	49 425

The amount of corn eaten by the two lots was practically equal. There is again a difference in the amount of hay eaten, but in the opposite directions, showing 4700 pounds of hay saved by the whole hay lot. This may be accounted for by too wide an opening in the self feeders where the lambs remove the hay, resulting in some waste of cut hay. The self feeders are in an experimental stage even for whole hay, and little is known concerning their construction for greatest economy with cut hay.

TABLE B

FEED FOR GAIN AND COST OF GAIN—200 LAMBS IN EACH LOT

Lot No.	Ration	Average Gain Per Head, 14 Weeks (lbs.)	Pounds Feed For 100 lbs. Gain		Cost of Feed For 100 lbs. Gain *
			Corn	Alfalfa Hay	
I......	Corn, Alfalfa Hay, Cut, in Self Feeder..	38.3	267	605	$4.48
II....	Corn, Alfalfa Hay, Whole, in Self Feeder	34 7	297	601	4.47
III ...	Corn, Alfalfa Hay, Whole, on Ground..	33.7	306	733	4.89

*NOTE—Corn at 1 cent per lb., Alfalfa Hay at $5.00 per ton, Cut Hay at $6.00 per ton.

ECONOMY

By the table above we see that the cut hay lot gained on the average of 3.6 pounds per head more than those fed whole hay. It required for 100 pounds of gain with the cut hay lot the same amount of hay and 30 pounds less of corn. This resulted in a cost of $4.48 and $4.47 for each hundred pounds gained by the two lots, estimating the cost of cutting hay at $1.00 per ton. The actual cost of cutting amounts to about 50 cents per ton, but counting interest on the capital invested in machinery and depreciation in value of machinery, the cost of cutting will approximate $1.00 per ton. Firms cutting hay for others charge even more than this.

This trial shows no economy in cutting a good quality of alfalfa hay. The hay used was well cured, first and second cutting hay. The only point in favor of the cut hay is that changes in the construction of the hay self feeders may result in a greater saving of the hay, and further trials will be made with this point in mind. In this trial the lambs were made to eat the whole hay about as closely as they do in a commercial feed lot, no unusual amount of stems being cleaned from their racks.

For the present the author feels justified in saying that so far as the experimental work with cut hay has gone at this Station, there is not sufficient evidence in favor of cutting hay to justify sheep feeders in putting in machinery for that purpose. The indications are that it does not pay to cut good alfalfa hay.

SELF FEEDERS FOR HAY.

The trial reported above also included a test of the value of self feeders. Lot II was fed whole hay in a self feeder and Lot III was fed whole hay in racks on the ground such as are in common use in many sections of the state.

From Table B, we find that the average gain of the two lots was 34.7 pounds and 33.7 pounds respectively; and the amount of corn required for 100 pounds gain was 297 pounds for Lot II and 306 pounds for Lot III. When we look at the amount of hay required for 100 pounds gain, we find quite a difference, 601 pounds being required by the self feeder lot, and 733 or over one-fifth more hay required by those fed on the ground. This brings the cost of 100 pounds gain in live weight of the lambs fed on the ground up to $4.89 compared with $4.47 for the self feeder lot. With a higher price than $5.00 for hay the difference would be correspondingly greater.

The self feeder racks shown in the cut of the feed yards, cost $1.00 per running foot completed. They will accommodate about four lambs to the running foot, two on a side, as not so much space is needed at a self feeder as at the ordinary rack, not nearly all the lambs eating at one time. With hay at $5.00 per ton, these racks saved in the present instance 42 cents for each 100 pounds gain, or about 14 cents on each lamb. With four lambs to the running foot of rack this would be a saving of 56 cents against an initial cost for material of $1.00. With hay at $7.00 per ton, a saving of 18 cents per head was effected. This one experiment then indicates considerable advantage for the self feeder when whole hay is fed, as the racks would pay for themselves in two seasons or less. Another trial is contemplated.

SUMMARY.

Two trials of chopped hay do not settle the question of economy in cutting the hay, but the second trial with good hay, where undue waste was not allowed shows no economy. The lambs ate more hay and less corn when the hay was cut, but the cost of 100 pounds gain was practically the same whether the hay was cut or not, with $1.00 per ton charged for cutting.

One trial of self feeders for hay shows a considerable saving. With hay at $7.00 per ton, the self feeders costing $1.00 per running foot for materials, repaid their initial cost in one season, accommodating 6 lambs to the running foot.

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot 1. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Cut, in Self Feeder

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs. Corn	Feed, lbs. Alfalfa Hay
Beginning.......	11675				
2nd Week.......	14270	2595	12.984	1895	
4th Week.......	15037	767	3.832	2800	
6th Week.......	15720	683	3.418	2800	
8th Week.......	16355	635	3.173	2800	
10th Week......	17200	845	4.225	3150	
12th Week.......	18300	1100	5.500	3500	
14th Week.......	19330	1030	5.15	3500	
		7655	38.30	20445	46329

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot II. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Whole, in Self Feeder

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs.	
				Corn	Alfalfa Hay
Beginning.......	12240				
2nd Week......	14695	2455	12 278	2045	
4th Week.......	15340	645	3.223	2800	
6th Week.......	15835	495	2.478	2800	
8th Week........	16195	360	1.80	2800	
10th Week......	17010	815	4.078	3150	
12th Week......	18030	1020	5.10	3500	
14th Week.......	19170	1140	5.70	3500	
		6930	34,67	20595	41615

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot III. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Whole, on the Ground

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs.	
				Corn	Alfalfa Hay
Beginning.......	11813				
2nd Week.......	13935	2122	10.61	2045	
4th Week.......	14715	780	3 90	2800	
6th Week.......	15395	680	3.40	2800	
8th Week.......	15605	210	1.05	2800	
10th Week.......	16195	590	2.95	3150	
12th Week	17140	945	4.723	3500	
14th Week......	18555	1415	7.078	3500	
		6742	33.73	20595	49425

Note.—It will be noticed that the lambs made a large fill the first two weeks. This was in spite of the fact that the experiment was not begun until six days after the lambs were unloaded, the lambs being given all the hay they would eat during this time.

Bulletin 152 October, 1909

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

TWO COMMON ORCHARD MITES

THE BROWN MITE. THE RED SPIDER

BY

GEORGE P. WELDON

PUBLISHED BY THE EXPERIMENT STATION
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TWO COMMON ORCHARD MITES

THE BROWN MITE. THE RED SPIDER

By GEORGE P. WELDON

The dry climate of Colorado favors the multiplication of mites, among the more common and troublesome of which are the two species treated in this bulletin. Throughout the year these two species have been found quite generally distributed in the orchard sections of the Western Slope, and in some localities their injury to fruit trees was quite severe. Very often both species are found on the same tree, and no little confusion exists among the orchardists in separating one from the other.

Because of the prevalence and severity of these pests it was thought best to carry on some experiments to determine how they may best be controlled. The results of these experiments, along with a general discussion of the life histories of the two species of mites, are given in this bulletin.

The mites are not true insects, having 8 legs when adult. They are classified as an order of the Arachnida, to which class the spiders belong.

THE BROWN MITE (*Bryobia pratensis* Garman) Plate I, Fig. 1.

Life History

There are three distinct stages in the life cycle of the brown mite. Beginning with the egg, a short account of each stage follows:

Most orchardists have seen the tiny red, globular eggs on fruit trees during the winter months, and are aware that they are the eggs of the brown mite. The winter is spent principally in the egg stage in Colorado. The over-winter eggs are deposited before the end of the summer season. This year practically no living mites could be found after the first of August, at Grand Junction or Delta, the eggs having been deposited previous to that date. On August 16, an occasional specimen of this mite can be found, but they are very rare and no more damage need be expected of them this season. The eggs are usually deposited on the trunk and limbs of trees, the crotches being favorite places. (See Fig. 7.) Often the bark is covered several layers deep with these eggs. By rubbing one's finger over the egg masses and crushing them, the bark of the tree may be made to assume almost a blood red color. We have found these eggs more numerous on pear, cherry, plum, prune, and almond than on any other orchard trees, the degree of infestation corresponding to the order in which the trees are named. Shortly after the warm weather of spring comes on, the tiny little bright red, six-legged mites may be seen crawling over the leaves and branches. By the first of May they were abundant the past

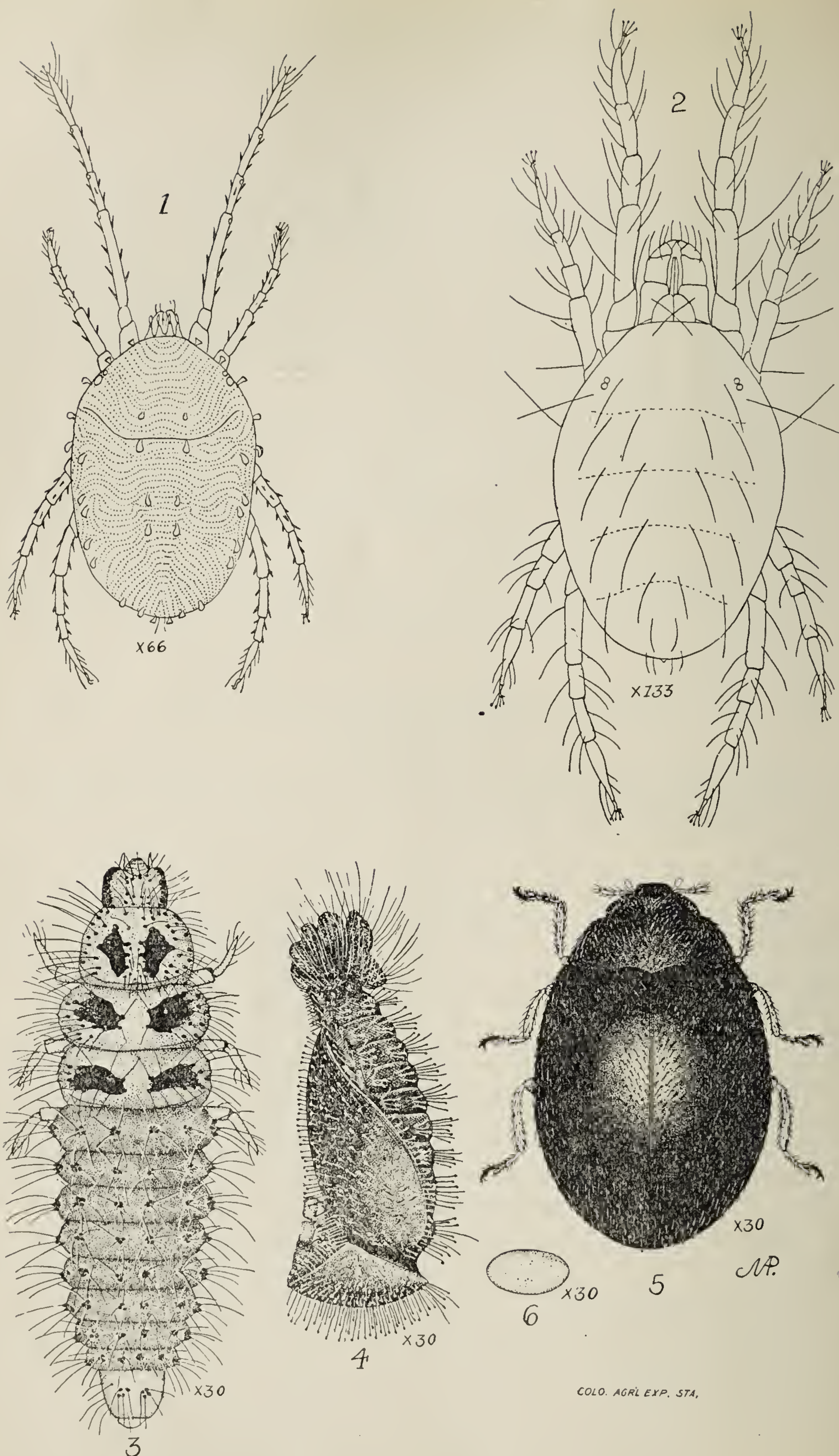

Plate I.—Fig. 1, Brown Mite (*Bryobia pratensis;*) 2, Red Spider (*Tetranychus bimaculatus;*) 3, 4, and 6, larvæ, pupa, adult and egg of (*Scymnus punctum.*) Figure 1, enlarged 66 times; 2, 133 times; 4, 5 and 6, 30 times. Original, Miss M. A. Palmer, delineator.

season at Delta, Colorado. Their color remains red until after they moult for the first time, when they are a brownish, or often an olive green color. After this moult they have 8 legs, instead of 6, which remain with them throughout life. The adult (Plate I, Fig. 1) is brown in color, with the exception of the legs and head, which have a reddish hue. The front pair of legs is very long, and are constantly kept in motion when the mites are feeding, as though they used them to feel their way about on the surface of the leaves. Throughout the months of May, June, and July adult mites are depositing eggs, which may constantly be found on infested trees. If the infestation is severe, not only are their eggs deposited on the bark, but very often a few are deposited on the leaves. They have been noticed principally upon the upper surface, and in the furrow of the mid-rib.

While it is very hard to determine whether or not there is a definite number of broods of this species of mite, observations the past season strongly indicate that there are but three broods.

Nature and Appearance of Injury.—The direct injury from brown mite is confined principally to the foliage. They have been observed feeding upon fruit, and not infrequently have we seen masses of them collected upon the stems where they appeared to be feeding. It is probable that the stems are used mostly as a moulting place. The epidermis of a leaf is pierced by their mandibles and the sap sucked from within. The first sign of infestation of a tree is the pale color of the leaves, not unlike that caused by leaf hoppers; when not abundant there may be only a few leaves affected. They generally attack the lower leaves first, and unless conditions are favorable to their increase, they may confine themselves largely to the water sprouts and tender twigs at the crotch of the tree. When multiplication is uninterrupted, they may cover the foliage of an entire tree, causing it to turn yellow and drop prematurely, thereby materially weakening the vitality of the tree. Little black specks, the droppings of the mites, render the fruit and foliage unsightly, and while there may be no serious consequences from this source, it probably does sometimes interfere with the looks of a fancy pack of early fruit. Often the fruit of a badly infested tree is small and does not mature properly.

Trees and Plants Infested.—The brown mite does not confine its attack to trees, for it was first described as a clover pest. Neither does it confine its attack to orchard trees, for shade trees have been reported infested by them. During our observations of this mite we have not found it on any of our shade trees. Much has been written about it as a household pest, but it seldom, if ever, becomes of any serious consequence in Colorado, where it winters mostly in the egg stage. In the warmer sections of the United States it is said to hibernate as an adult, often migrating into the houses in the fall, where it may trouble the house-wife. During the present season they have been found on apple, plum, prune, cherry, pear, peach and almond in abundance. Probably less were seen on peach than any other of these trees. Only in one section were they observed to be of any serious consequence on peach. So common are they on all other kinds of trees mentioned that it would hardly be safe to say that they are more liable to attack one than another. An infested apricot, or quince tree has not been observed.

Remedies

The following experiments were conducted the past summer to determine which of the insecticides used would best control this pest, the applications being made as a spray, except No. 6:

May 4 and 5, Experiment No. 1.—Sulphate of nicotine, 8 ounces to 50 gallons of water.

May 4 and 5, Experiment No. 2.—Nico-Fume, 9 ounces to 50 gallons of water.

May 4 and 5, Experiment No. 3.—Nico-Fume, 6½ ounces to 50 gallons of water.

May 4 and 5, Experiment No. 4.—Black-leaf, 1 part to 70 parts of water.

June 4, Experiment No. 5.—Flowers of sulfur, 1 pound to 3 gallons of water.

June 4, Experiment No. 6.—Flowers of sulfur as a dust spray.

July 23, Experiment No. 7.—Flowers of sulfur, 65 pounds to 200 gallons of water, and 2 pounds of whale oil soap.

July 27, Experiment No. 8.—Same spray used as in No. 7.

Experiments 1 to 6 inclusive, were conducted by myself. No. 7 was conducted as recommended by me, and No. 8 under my supervision.

Nos. 1 to 6 were in the orchard of Mr. W. E. Obert at Delta, No. 7 in the orchard of Mr. McCarry at Grand Junction, and No. 8 in the orchard of Mr. C. D. Gehman at Grand Junction. Thanks are due these gentlemen for their assistance in the work.

The Sulphate of Nicotine and Nico-Fume are tobacco preparations manufactured by the Kentucky Tobacco Product Co., at Louisville. The Black-leaf is also a tobacco preparation manufactured by the same company. All the tobacco sprays were found to be effective in killing the mites touched by them, but apparently had no effect upon the eggs. An examination of trees 24 hours after spraying showed that many of the adult mites had not been killed. It is next to impossible to do a thorough enough job with any spray which will only kill the mites, to sufficiently hold them in check so that they will not damage the trees, as they hide in cracks of the bark, under bud scales, and in so many other places where it is impossible to reach them. A later examination of the trees showed that the eggs were hatching in abundance, and that the adult mites were also abundant. Any spray that will not kill the eggs, and which will not adhere to the foliage until eggs hatch, is not a practical summer spray for brown mite. If it were possible to do a thorough enough job to kill all mites when the spray is applied and then make a second application later when all the eggs are hatched, that would be effective. Owing to the fact that it is practically impossible to kill all of both eggs and mites, and that the time of hatching of the eggs seems uncertain, the best that could be expected of tobacco sprays would be to keep the mites in check by repeated applications throughout the season. In the use of sulfur the experiments indicate that we have an absolute remedy for this pest.

In experiments Nos. 5 and 6 four small, badly infested cherry trees were treated, two sprayed with a compressed air hand pump, and two dusted with a bee smoker. It was found that by using a small amount of soap in the water sulfur would mix nicely, so that successfully ~~for applying the sulfur in the dry form.~~ The best time to apply the sulfur in the dry form would be in the early morning, or late in the evening, when the dampness would cause it to adhere to the foliage. In experiment 6, sulfur was applied as a dust spray, and enough was used so that every leaf received a coating. An examination of trees was made June 7, and to my surprise, not a single adult mite could be seen; there were, however, many of the newly hatched ones. An examination of these trees again June 9 showed the same conditions. On this date a very careful examination was made of egg masses on check and treated trees. The egg masses (Fig. 7) are favorite places for the mites to moult, and along with those that are depositing eggs there are always many to be found there in abundance. Twenty-five separate egg masses on sprayed trees were examined with a hand lens and not a single adult mite was found. Every

be applied as a liquid spray.

Fig. 7 COLO. AGRL. EXP. STA.

Figure 7, twig with a large cluster of eggs of Brown Mite. Original, Miss M. A. Palmer, delineator.

egg mass examined on check trees in same row had from one to a great many mites crawling about over it. The foliage of sprayed trees recovered its normal green color, and remained so throughout the season, standing out in beautiful contrast to that of the untreated trees, many of the leaves of which turned yellow early in the season. Not only was there a difference in the foliage, but the fruit also showed a marked difference, that from check trees being small and worthless, while that from treated trees matured well and was good.

Experiment No. 7 showed just as conclusive results. The 300 pear trees in this experiment began to pick up immediately after spraying, and an improvement in the fruit was soon apparent. The only trouble in this orchard was that the spraying was neglected until too late, as much damage had already been done. An examination a few days after the spraying showed that treated trees were free from mites, while some plum trees in the orchard, which were left untreated, still had many of the mites on the foliage. As the infestation of mites on the pear trees was serious, it is probable that the spray paid for itself, even though it was late before the applicaton was made. Spraying in this experiment was done with a gasoline power outfit. Previous to the time of spraying this orchard with sulphur, a Black-leaf spray was used with very little success.

In experiment No. 8, twelve cherry and two plum trees were used. The mites were completely exterminated from these trees. One cherry tree was left as a check, and an examination of the trees ten days after spraying failed to reveal the presence of any mites on the treated trees, while on the one check there were still many of them.

I feel that the results of these four experiments with sulphur sprays are conclusive, and that it is perfectly safe to recommend a spray of flowers of sulphur and water for brown mite. While 65 pounds to 200 gallons of water were used in these experiments, it is probable that 50 pounds would be enough. A small amount of soap must be used so that the sulphur will mix with the water. If soap is not used the sulphur will remain on the surface and no amount of agitation will mix it. Two pounds of soap to 200 gallons of water is plenty, and probably less will answer the purpose.

Prof. Gillette has found that a soluble oil spray is more effective in killing the eggs than are the tobacco sprays. In the case of the mites themselves this was reversed, and tobacco prepartions were the more effective. While soluble oil might be successfully used as a dormant spray, it is not a reliable remedy where water is strongly alkaline, and if such water is used a thorough mixture cannot be maintained with any of the different brands of soluble oil that the writer has tried to use. Because of this fact none of the soluble oil sprays were used in the experiments.

It has been determined that lime and sulphur, applied when trees are dormant, will kill mites. Prof. Gillette has experimented with the lime and sulphur sprays upon the eggs of brown mite and has concluded that they are of no value as far as the destruction of the eggs is concerned. Their efficiency seems to depend upon their power to kill the young mites after they hatch from the eggs. Lime and sulphur is very adhesive, and the sulphides of lime will remain on a tree for months after the spraying has been done. Especially is this true in Colorado, where the rainfall is not great.

SUMMARY.

1. The brown mite has been quite a serious pest in Colorado the past season, doing considerable injury to orchard trees, as well as interfering with the maturity of the fruit.

2. The over-winter eggs are deposited in late summer, most of them before the first of August this season; they remain on the trees throughout the winter and hatch shortly after the leaves come out in the spring.

3. Apple, peach, plum, cherry, pear, and almond trees were found infested. Apricot and quince do not seem to be troubled.

4. Mites feed principally upon the foliage where their presence may be detected by the pallid leaves, and the tiny black spots of excreta.

5. Flowers of sulphur, one pound to three gallons of water, and enough soap so that the sulphur will mix with water, is a perfectly effective remedy when used as a summer spray.

6. Tobacco preparations will kill the mites, but not the eggs, and are only effective when repeated applications are made. Oil sprays seem to penetrate the eggs, and destroy them better than the tobacco extracts, but are unsafe to use with water strongly impregnated with alkali.

7. Trees may be treated while dormant with lime and sulphur. This spray has no effect upon the eggs, but probably kills the young mites as they hatch.

THE RED SPIDER (*Tetranychus bimaculatus* Harvey) Plate I, Fig. 2.

Although there are a number of different species of red spiders, or spinning mites, we have found only one species infesting orchard trees in Western Colorado. While in most localities it was probably not responsible for as much damage as the brown mite, still it was of somewhat serious consequence, and is a pest to be watched, and combatted if necessary, to keep it from becoming injurious the coming season.

Life History

Both species of mites treated in this bulletin belong to the same family, but differ from each other in many important respects. The eggs of the red spider are deposited chiefly on the under surface of leaves. An examination of infested trees will reveal the presence of these tiny transparent eggs, resembling minute dew-drops attached to the surface of a leaf, or interwoven among the silvery threads which the mites are capable of spinning. As is the case with the brown mite, these have only six legs when first hatched, the fourth pair developing later. The adult (Fig. 2) is somewhat smaller than the adult brown mite and the fore pair of legs are much shorter, as is shown in the figures. When the mites are seen with the aid of a glass, upon the surface of a leaf, the legs appear much shorter than they do in the drawing, for the reason that they are not extended to their full length while the mites are feeding, or while at rest, while those of the brown mite are nearly always extended to their full length. A glance through any ordinary hand lens is all that is necessary to be able to distinguish the brown mite from the red spider, because of this characteristic. When first hatched this species of red spider is light green, with small dark colored spots on the back. Later the color may change from a light green to a deep brown, or a bright red. Owing to the variability of color this character cannot be depended upon at all in the identification of the species. The spots also vary in size and placing on different individuals. Generation after generation of the mites appear during the summer months, and at all times of the season there may be found eggs, and all other stages of the mites upon the leaves.

The winter is spent in the ground, and here we have an important difference in the life history of the two species treated in this bulletin. On August 9th, myriads of red mites were found in the ground at the crowns of trees upon which they had been feeding. At this time they were all red in color. Although most of them occurred close to the trunks of trees, some were found at a distance of 10 feet away, where they had crawled beneath clods of soil undoubtedly to remain over winter. It is probable that out of the large numbers that leave the foliage and enter hibernation quarters only a very few survive the winter. In the early spring, when the foliage begins to grow, these few crawl out of their winter quarters, ascend the trunks of trees and deposit their eggs for the perpetuation of the species. On last April 7th a number of these mites were found trapped in a "Tree Tanglefoot" band, which had been applied to the trunk of an apple tree to catch the migrating woolly aphids which wintered in the ground.

Nature and Appearance of Their Injury.—The injury from this species is similar to that of the brown mite. The leaves of an infested tree are often yellow in spots, which present a blister-like appearance. This condition has not been observed with brown mite injury, and is due to the red spiders spinning their webs over certain small areas of the leaves, and feeding within those areas. The webs are always found on leaves injured by red spider, and when the orchardist finds these webs he can rest assured that he has red spider to contend with, as the brown mite does not have the power of spinning a web.

Trees and Plants Infested.—In every case, mite injury to shade trees observed the past season, was due to this species of red spider, and not to the brown mite. It has been observed on the same fruit trees as the latter, but in addition it has been commonly found on poplar, ash, and walnut, as well as a great variety of herbaceous plants. In many cases small fruits have been damaged severely. Raspberry, currant, and gooseberry bushes have probably been the greatest sufferers among the small fruits. The injury in this case is the same as to the trees. The leaves are sapped of their vitality, turn yellow and drop early. The fruit is small, often not maturing sufficiently to be salable.

Remedies

Last season the writer tried to kill this pest on some rose bushes at Delta, Colorado, by using a spray of "Black Leaf Extract," using 1 part of the black-leaf to 65 parts of water. A small compressed air spray pump was used, and as thorough an application as it was possible to make was given the bushes. At first it appeared as though the tobacco was thoroughly effective, but an examination of the bushes next day showed that while a great many of the mites had been killed many live ones were still crawling over the leaves, and the eggs did not seem to be affected in the least. In about a week's time the bush was sprayed again, and finally was sprayed a third time by the owner, and even then it seemed impossible to kill enough of the pests so that they would not damage the bushes.

Recently the sulphur spray (sulphur 1 pound, water 3 gallons) recommended for the brown mite, was tried on three small peach trees at Palisade, and the results were highly gratifying. Trees were sprayed on August 12, and on August 17 an examination showed the leaves to be entirely free from red spider, while untreated trees close by, were just as badly infested as upon the day of spraying.

Early in August, Mr. R. B. Cassells, who has an orchard on Fruit Ridge, Grand Junction, complained of a few of his plum trees being infested with the spiders. A sulphur spray was recommended and applied, and again the results were perfect. The trees not only recovered somewhat of their normal color, but the fruit also improved rapidly.

The only objection that might arise to a spray of sulphur so late in the season, would be the odor it would give to the fruit of sprayed trees. It is not probable, however, that any trouble would arise from this source, except possibly in the case of peaches, where the fuzz would cause the sulphur to adhere. Of course, trees should be sprayed as soon as the injury begins, and should not be allowed to remain unsprayed until the end of the season, when practically all of the injury has been done to them. The use of a sulphur spray upon small fruit bushes cannot be too strongly recommended, as these are so often materially injured by red spiders.

Natural Enemies

The principal enemies of the red spider, found during the season's observations, were the lace-winged flies, and a small black species of lady-bird beetle, which Prof. Gillette has determined for me as *Scymnus punctum*.. (See Figs. 3, 4, 5 and 6 of Plate I.)

Several times during the season lace-winged fly larvae have been observed on leaves infested with mites, and no doubt they were feeding upon them. The little lady-bird was found quite abundant on infested peach trees in one orchard at Palisade. It is a tiny black beetle, so small that the orchardist might not become aware of its presence in an orchard even though it should occur in abundance. The larvae are also of a blackish color, and can be readily seen on the leaves when they are feeding upon the mites. The drawings of this lady-bird were made from specimens collected by Prof. C. P. Gillette, at Greeley and Fort Collins, Colorado. Prof. Gillette found them specially common on elm and plum leaves, where they were feeding upon red spiders and working for the most part beneath the webs. He has briefly described the different stages of this beetle as follows:

"The eggs are very small, pale yellow objects, oval in shape, and are deposited singly upon their sides. They are almost too small to be seen by the unaided eye, as they measure barely one-third of a millimeter (one-seventy-fifth of an inch) in length.

"The grubs or larvae are dusky to blackish in color, rather hairy, the hairs being simple and arising in clusters from minute tubercles.

"The pupa is uniform blackish in color and is covered with short golden hairs, most of which terminate in a knob.

"The adult beetles are dull black, with the tibiae and tarsi (lower portion of the legs) pale yellow, and the dorsal surface is set with short golden hairs that are not capitate but pointed; the general form is almost circular, and the length about one and one-third millimeters (one-twentieth of an inch)."

SUMMARY

1. Only one species of red spider has been found injuring orchard trees in Western Colorado.

2. Eggs are deposited in the spring by mites that have hibernated over winter in the soil, or beneath rubbish of any kind in the orchard. Hibernation began as early as August 9th this season, and myriads of the little red pests were found in the ground at Palisade, on that date.

3. Many fruit and shade trees are attacked by the mites. Small fruits are often severly injured Herbaceous plants of all kinds seem to be subject to attack. When fruit trees are badly infested the fruit is usually small and does not mature properly.

4. A sulphur spray, the same as is recommended for the brown mite, is probably better than anything else that could be used during the summer months.

5. The natural enemies of the red spider that were noticed during the season were the lace-winged flies, and a minute black species of lady-bird beetle (*Seymnus punctum*.)

Credit is heartily accorded Miss M. A. Palmer, who made all the drawings for this bulletin.

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H. M. COTTRELL

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FORT COLLINS, COLORADO

INTRODUCTORY

Colorado has not provided means of obtaining statistical information which enables the people and commercial interests of the State to take account of their progress and thus to determine the character of their growth or the conditions which may need improving. In the absence of authentic data of that kind Professor H. M. Cottrell was authorized to obtain information from all sources possible as to the amount of produce actually shipped into the State and especially of a character the state could produce. While the information thus obtained cannot be considered as exact, yet as the sources of information are in close touch with the products in question, the estimates are believed to be close to actual facts. In some cases they may be considered as exact. The railroads and commission men, and in fact all classes have been free to aid, in many cases have opened their books to inspection and have given the advantage of their expert knowledge. The statements therefore represent what is, no doubt, the best summary of such knowledge that is available or has ever been made.

From the standpoint of the State it indicates the large demand for agricultural products that is not met by the growers of this State. This shows only the production shipped into the State, and does not show the amount shipped out of the State. In some cases this is considerable. Thus several times the value of flour is shipped out of the State that is shipped in. Our fruit growers ship out several million dollars worth of fruit annually. Several million dollars worth of potatoes are shipped out annually and shipments of hay and live stock amount to many million dollars each year.

The facts, however, deserve careful consideration, and give a basis for lines of intelligent development.

L. G. CARPENTER, Director.

AGRICULTURAL PRODUCTS SHIPPED INTO COLORADO IN 1909

BY H. M. COTTRELL

According to the most accurate data that could be secured by the Farmers' Institute Department of the Colorado Agricultural College, the following agricultural products were shipped into Colorado in 1909 from other states:

	Estimated Value
Fat Animals for Slaughter	$3,568,380
Fresh Meat	1,094,080
Cured Meats, Lard and Butterine	2,546,680
Canned Meats	1,200,000
Dairy Products	3,986,000
Poultry and Eggs	4,000,000
Wheat	3,750,000
Flour	1,500,000
Millstuffs and Corn Meal	860,000
Corn	2,530,000
Oats, Rye and Barley	310,000
Breakfast Foods and Food Cereals	1,122,000
Crackers, Wafers and Fancy Biscuits	350,000
Broom Corn	96,000
Hay	1,450,000
Field Seeds	240,000
Fresh Fruits, Melons and Vegetables	1,993,000
Canned Fruit and Vegetables	1,345,000
Dried Fruits	500,000
Pickles, Catsup and Pork and Beans	175,000
Total	$32,616,140

FAT ANIMALS SHIPPED IN FOR SLAUGHTER:

Cattle	$1,297,872	
Hogs	2,245,288	
Calves	25,220	$3,568,380

MEAT AND MEAT PRODUCTS:

Fresh Meat:		
Beef	$472,680	
Pork	591,600	
Veal	10,800	
Mutton	19,000	$1,094,080
Smoked Meats	$918,000	
Lard	520,000	
Lard Compounds	93,000	
Butterine	930,000	
Mince Meat	15,680	
Extract of Beef	70,000	$2,546,680
Canned Meats:		
Beef, Veal, Bacon, Ham, Chicken, etc		$1,200,000
Total		$8,409,140

PORK:

Of the 241,570 hogs received at the Denver Stock Yards in 1909, 61,947, or a fraction over one-fourth, were grown in Colorado.

The value of hogs, pork and pork products shipped into Colorado in 1909 were:

Hogs	$2,245,288
Fresh Pork	591,600
Smoked Meats	918,000
Lard	520,000
Total	$4,274,888

Experts estimated that the value of the pork and pork products shipped from the corn belt into the Rocky Mountain and northwestern territory, of which Denver is the gateway, amounts annually to sixteen million dollars.

The three cracker factories of Denver used in 1909 as much lard as was furnished by all the Colorado hogs slaughtered in Denver. Yet every tillable section of Colorado is adapted to the cheap production of pork of the best quality.

Barley fed pork is the highest priced pork in the world, on account of its superior flavor. The irrigated sections of Colorado yield barley at a less cost per acre than the cost of growing corn in Iowa and Illinois, and the production of pork per acre from irrigated barley is greater than that of pork from corn in the corn belt.

The right strains of barley give profitable yields under dry land farming both on the plains and at high altitudes.

Milo is the surest grain crop for dry land farming on the Plains, and produces a choice quality of pork. The Plains farmers alone could produce all the pork and pork products needed in Colorado and adjoining states if they would make a specialty of pork raising, fattening with Milo.

Field peas as grown in the San Luis Valley make a better flavored pork than either corn or barley, and hogs in the San Luis Valley can be fattened on peas at a cost of one and one half cents per pound for the gain in live weight. There are three million acres in the San Luis Valley adapted to pea growing and a much larger area at high altitudes in other sections of Colorado.

Colorado should not only supply all the pork and pork products needed in the State, but should furnish the high priced, choicest pork, and pork products to the rest of the United States. The State needs 50,000 farmers who are expert swine growers and feeders. The majority of Colorado farmers have failed to make hogs profitable because they have neglected the growing pigs through the summer.

Beef.—Colorado beef cattle are better bred than those of most of the range states. The native grasses are not excelled for making growth on young stock and for putting flesh on older cattle. The meat produced from the grass and from the hay made from native grasses is of exceptionally choice flavor. The Colorado Experiment Station and private feeders have demonstrated that our grains, alfalfa, and roots produce, economically, beef of superior flavor with light waste in slaughtering and in cooking.

Fresh beef and veal are shipped weekly from the corn belt into most Colorado towns, and fat cattle were shipped, in 1909, from other states into Colorado, as follows:

	Cattle	Calves
Nebraska	3,778	716
Wyoming	10,299	1,118
Kansas	1,478	402
Utah	5,177	70
Idaho	3,823	151
Nevada	795	19
Oregon	723	46
Montana	343	....
California	623	....
Total	27,039	2,522

If Colorado cattle growers appreciated the value of our feeds, and would make a business of finishing their stock before marketing, we could not only supply our own needs for beef and veal, but on account of the flavor of meats made from Colorado feeds could create a widespread trade outside the state.

Butterine.—There has been such a scarcity of butter in the state and the prices have been so high that during the past year there has been an abnormal increase in the use of butterine, experts estimating that an average of over 10,000 pounds per day is used in Colorado, and that there will be a large increase over this during the coming year. Government officials state that over four times the number of people are selling butterine in Colorado than were in the business eighteen months ago.

Fresh Meats.—Fresh meat is regularly shipped from Omaha to

Denver, and also in carload lots as far west as Grand Junction. It is distributed throughout the mountain sections of Colorado, as well as in the eastern part of the state.

DAIRY PRODUCTS.

Butter and Cream	$3,000,000
Cheese	500,000
Condensed Milk	400,000
Malted Milk	86,000
Total	$3,986,000
Butterine, which is used to take the place of butter	930,000
Total	$4,916,000

There are approximately 160,000 milch cows in Colorado. Many are cows selected from the range and are poorly handled and milked through the summer, producing annually only from $20 to $50 a cow A number of well selected cows are kept in or near towns, and are fed, producing annually from $50 to $150 a cow. The average annual production is probably not over $40 a cow, or a total yearly production for the state, from dairy products, of $6,400,000. If these estimates are correct, Colorado farmers are supplying about 56 per cent. of the dairy products and substitutes for dairy products consumed in the state.

Butter and Cream.—A large amount of butter is shipped into Colorado from Kansas and Nebraska and the larger proportion of the cream churned in the large factories in Denver, Colorado Springs, and Pueblo is shipped in from Kansas and Nebraska. One concern alone in Denver churned, in 1909, over three million pounds of butter, a large per cent. of it from Nebraska cream.

Some of the largest handlers of dairy products in the state estimate that in 1909 an average of over 30,000 pounds of butter were shipped daily into Colorado either as butter or in cream that was churned after arrival. Butter made from Kansas and Nebraska cream is used in Mountain sections of Colorado 450 miles distant from Denver.

Cheese.—The quantity of cheese made in Colorado is so small that it is seldom found in most of the towns of the state. Most of the cheese eaten in the state comes from New York.

Condensed Milk.—The one condensed milk factory in Colorado is situated at Fort Lupton. It has a good trade, puts up a good product, and pays a high price to the farmer for milk.

During 1909 there was a general shortage of milk and cream in most of the towns of the state, and city families were forced to use condensed milk. Many thousand farm families also used condensed milk.

The use in Colorado of condensed milk has been increasing rapidly every year for several years. Wholesale houses report that in 1909 they had a demand for double the quantity of condensed milk that they sold, but they could not secure it from the manufacturers.

More than the usual amount was shipped into the state from the east and several carloads from the Pacific Coast.

The fresh milk from 8,000 average Colorado cows would have been required to produce the condensed milk that was shipped into Colorado in 1909, and the milk from 16,000 cows to fully supply the demand in the state for this food.

Every section of Colorado offers favorable conditions for dairying. The irrigated sections of Colorado offer ideal conditions in every respect:—feed, climate, water, and good markets.

The mountain parks and valleys of Colorado furnish almost the same dairy conditions as the mountain dairy districts of New York, with the advantages of richer feeds and a dry climate. These parks and valleys cover a large area, a single one—the San Luis Valley—having a tillable acreage as great as the entire state of Connecticut.

Good, early cut alfalfa hay will produce as much milk as an equal weight of bran, one of the chief eastern dairy feeds. Alfalfa hay can be produced and fed to dairy cows on the average Colorado farm for $3 to $5 a ton. Bran in eastern dairy sections costs $20 and upwards a ton. A ton of alfalfa hay contains about as much milk producing material as four tons of timothy hay.

Alfalfa grows well in most sections of Colorado up to an altitude of 8,000 feet From 6,500 to 8,000 feet field peas give high yields. Both the hay and grain from this crop are good milk producing feeds, pea hay ranking next to alfalfa for this purpose.

At high altitudes red and alsike clover yield large crops, the latter doing well up to an altitude of 9,500 feet. Both are rich milk producing feeds. The nutritious character of Colorado forage crops makes little grain necessary.

To the many new settlers who are starting dry land farming on the plains of eastern Colorado, dairying offers a sure income. In the past thirty-three years there has never been a year so dry but that a sufficient quantity of feed could have been raised, together with the native grasses, to produce a good yield of milk.

The native grasses are good milk producing feeds, summer and winter. The Sorghums, Milo and Kafir-corn are good drought resisting crops, and in a dry year wheat, oats and beardless barley cut just as they are filling make excellent dairy feeds and often a profitable crop can be secured from these grains by making them into hay, when if left to mature the season would be too dry for them to make marketable grain.

The mild climate of Colorado makes the necessary expense low for shelter. For twenty years the average temperature at Fort Collins for January—the coldest month—has been twenty-six degrees, and for July, the warmest month, sixty-eight degrees, with a few days each year of either extreme heat or cold.

The dry bracing air and high altitude give vitality and health to the cows. Dr. George H. Glover reports that only one-half of one per cent. of the native cattle of Colorado show any trace of tuberculosis, and less than two per cent. of the cows in Colorado cities, where they are closely confined.

The pure air of the high altitude and the intense sunshine—an average of three hundred and twenty days of sunshine each year—make the air much freer from germs which taint milk than the air in low, humid states. For this reason it is much easier and costs less to keep milk and cream sweet in Colorado than it does in states East.

POULTRY AND EGGS.

Eggs	$2,000,000
Poultry	$2,000,000
Total	$4,000,000

Fifty car loads of eggs were taken in a single month from cold storage plants in the East and brought to Denver. Poultry is shipped direct from Omaha to Glenwood Springs and other mountain towns. Even in mountain towns as distant as Telluride, poultry and eggs are shipped direct from Wichita, Kansas. In July, 1909, the hotels in Durango were obliged to furnish their guests Kansas eggs because Colorado eggs could not be secured.

During the past Fall and Winter an average of $1,000 per week has been sent out of Fort Collins for Kansas and Nebraska eggs, and most towns in Colorado have sent out proportionate amounts. One Bank in Denver reports that its customers, alone, send an average of $10,000 a week to Nebraska for poultry.

An investigation made in Pueblo by the Business Mens' Association showed that more money was being sent out of that city to other states for poultry and eggs and butter than was being spent in the city by the 4,000 employes of the great ten million dollar steel plant of the Colorado Fuel & Iron Company, and by the employes of the smelters. Denver dealers handle an average of over $3,000 worth of eggs, daily, and a large part of this is brought from other states.

Two years ago the Farmers' Institute Department of the Colorado Agricultural College made an investigation of egg production in Colorado, having the assistance of a poultry expert from the East as well as Colorado poultry experts.

It was found that in both small and large flocks and in various parts of the state, poultrymen who thoroughly understood the managing of the business under Colorado conditions of feed and climate were making an average of $2.00 a hen a year above the cost of feed. Poultrymen around New York, Boston, and Philadelphia were making but half this amount.

At the same time most of the Colorado farmers, who were consulted, reported that their hens were "eating their heads off" and that keeping poultry was a loss to them.

Colorado needs, at the present time, at least 5,000 men who are experts in egg production, and these men can make much more than they are making in eastern states.

Our average of 320 days of sunshine, the dry climate, high altitude, and bracing air, are as beneficial to poultry as they are to people. Colorado feeds—wheat, barley, field peas, and alfalfa are especially valuable for egg production. The field peas of the San Luis Valley produce a specially choice flavor in the meat from poultry.

GRAIN AND GRAIN PRODUCTS.

Wheat	3,750,000	
Corn	2,530,000	
Oats, rye and barley	310,000	
Flour	1,500,000	
Millstuff and corn meal	860,000	$8,950,000
Breakfast foods and food Cereals	1,122,000	
Crackers, wafers, fancy biscuits, etc.	350,000	$1,472,000
Total		$10,422,000

Wheat.—The U. S. Department of Agriculture reports that there were raised in Colorado in 1908 6,153,000 bushels of wheat, and in 1909 9,467,000 bushels. It requires in the state annually for flour, seeding, and ordinary feeding about 5,600,000 bushels. There was therefore a surplus of wheat above home needs, in 1908, of nearly 10 per cent. and in 1909, of 69 per cent.

A large quantity of soft winter wheat was shipped into Colorado in 1909, from Idaho, and adjoining states. The wheat was shipped with milling in transit privileges through Colorado to southern states. It was ground in Colorado and the flour sent south. Considerable hard winter wheat was shipped into Colorado for grinding from Kansas and Nebraska.

Flour.—Colorado bakers do not use flour made from Colorado wheat for bread making. Practically all the bakers' bread in Colorado is made from Kansas hard winter wheat flour. Experts estimate that over one-half the bread eaten in Denver, and four-fifths the bread eaten in Pueblo, is from Kansas hard winter wheat flour.

Most of the families in Pueblo, particularly those connected with the steel works and with the smelters, use Kansas flour. San Luis Valley Millers buy Kansas flour to supply their bakery trade, and Kansas hard wheat flour is shipped to Durango, Telluride, Grand Junction, and other points, to be used by bakeries and hotels.

Flour to the value of about $190,000 was shipped from Minneapolis to Colorado points in 1909. Most of the flour used by Colorado families is made from Colorado soft wheat with a blend of Kansas or Nebraska hard wheat.

While Colorado produces more wheat than is required to make all the flour needed in the states yet flour, costing at wholesale, $1,-500,000, was shipped in, most of it from Kansas. Some flour was received from Nebraska, and a little from Missouri and other states.

The reason bakers use Kansas flour is that the hard wheat Kansas flour absorbs more water than Colorado soft wheat flour. One hundred pounds of Colorado flour will absorb fifty pounds of water; one hundred pounds of Kansas flour will absorb sixty to sixty-two pounds of water, and make good bread, and can be made to absorb seventy pounds of water if the best quality of bread is not wanted. One hundred pounds of Kansas hard wheat flour will make from ten to fifteen more bakers loaves than one hundred pounds of Colorado soft wheat flour. The Kansas flour contains more gluten. Colorado flour made from Durum wheat contains considerably more gluten than Kansas flour, but is not used by bakers, because it makes a dark colored bread.

Colorado soft wheat alone, or with a blend of hard wheat, makes bread of the best quality. In a bread making contest held by the Denver Gas & Electric Company in 1909 with 1200 loaves competing, the first, second and third prizes for the best loaves were won by loaves made from Colorado wheat. Most Colorado families who bake their own bread use flour made from Colorado wheat. Colorado bakers prefer Colorado flour for cakes and pastry, as it is softer and makes pastry more tender and flaky than hard wheat flour.

The flour made from Colorado wheat, and that from the enormous quantity of soft wheat shipped into Colorado from Idaho and adjoining section, and not used in the state, was shipped to Southern states, where it is preferred, because it makes better biscuits and hot bread than hard wheat flour.

The soft wheat shipped into Colorado should have been produced in the state, and it would have required nearly two-thirds as many additional acres to produce it as were seeded to wheat in Colorado.

Some hard winter wheat is grown in Colorado, particularly on the Plains. Millers have been unable to make a flour from it equal to Kansas hard wheat flour. The largest bakers in Colorado find that the most good loaves of bread can be made from hard wheat flour of certain sections of Kansas only and that the hard wheat flour from other parts of Kansas is not satisfactory.

The Kansas localities named by the bakers as producing desirable flour are those that for several years have paid particular attention to selecting seed and maintaining wheat having hard red berries. The sections of Kansas named as producing unsatisfactory flour are those that have allowed considerable of the yellow berry to show in their wheat.

All hard winter wheat raised on the Plains in eastern Colorado examined by the writer has been badly affected with yellow berries. It would seem that it would pay farmers, farmers' organizations and commercial clubs in eastern Colorado to make a united effort to secure pure seed of hard winter wheat entirely free from yellow berries and to grow wheat from which flour can be made equal to the best Kansas flour. It means the securing for the Plains a market that now amounts to $1,500,000 a year and that is constantly increasing.

Corn.—About 3,700 cars of corn, costing approximately $2,530,000, were shipped into Colorado from Kansas and Nebraska in 1909.

Over 350,000 lambs were fattened on this corn. Most of the hogs slaughtered at home and at packing houses in this state were finished on this corn. A large quantity was fed to beef cattle, to dairy cows, and to horses. We found Kansas corn being fed to fattening hogs in LaPlata county, 450 miles southwest of Denver.

Much of this feeding of imported corn is done from habit, the farmers who feed it having come from corn belt states. Both barley and field peas produce better pork than corn. Barley is as good a feed for horses and dairy cows, and oats is a better feed. Beef produced at the College showed that the choicest flavored beef can be produced without feeding any corn, and many lamb feeders have shown that good results can be secured in fattening lambs on barley, except just at the finish.

Breakfast Foods and Cereal Products.—Over 1,700 tons of cooked cereals, and over 4,200 tons of uncooked breakfast foods, such as oatmeal and cracked wheat, were shipped into Colorado in 1909. These breakfast foods took out of the state over $460,000. Hominy and Grits to the value of $3,200 were shipped in.

About 760 tons of peanuts were shipped into Colorado, costing $114,000. Peanuts do well on sandy soils on the Plains.

Over 430 tons of macaroni were shipped into the state at a cost of $44,000.

About 1100 tons of starch were shipped into the state, costing about $165,000. We shipped in over 3,000 tons of rice that cost us over $300,000. Rice cannot be raised in Colorado, but it is used largely as a substitute for flour products and potatoes.

Less than one pound of cane sugar for each inhabitant was shipped into the state, showing that the greater part of the supposed cane-sugar used by the Colorado housekeeper must be beet-sugar.

About 145 tons of popcorn were shipped into Colorado from East of the Missouri River at a cost of $7,000.

Crackers, wafers and fancy biscuits were shipped into Colorado that cost $350,000. As our home cracker factories use Colorado products chiefly in manufacturing their goods this sum could be kept in the state by buying Colorado made products.

BROOM CORN

Broom Corn **$96,000**

It requires annually from 500 to 600 tons of broom corn to supply home needs in Colorado, and about an equal amount is shipped into the state, made up into brooms and brushes, and then sent to other states.

In 1909 about 150 tons were grown in Colorado, leaving 450 tons to be shipped in for home consumption, and between 500 and 600 tons shipped in that were sent out later in manufactured goods. A considerable portion of the 450 tons needed for home use was shipped into the state in manufactured goods. About two-thirds of the total amount grown in Colorado in 1909 was produced in Baca county.

Normally good broom corn is worth from $60 to $80 a ton. Sometimes it drops as low as $30 a ton, and at present, owing to a severe shortage throughout the United States, the best grade of broom corn is selling at $275 a ton.

The extreme high price for broom corn is exciting many Colorado farmers, particularly in the dry land sections of Eastern Colorado, and many are planning to raise this crop in 1910 for the first time. Some Colorado farmers who have never raised the crop are planning to raise from 200 to 300 acres each.

Most of these beginners will probably make failures. The growing of a good quality of broom corn is the work of an expert of long experience. The differences between strains of broom corn are as many and as great as between varieties of corn. The successful Colorado grower must start with seed adapted to his locality and seed that will produce a tough quick-growing brush, ripening early, and neither brittle nor coarse. He must prepare his soil and keep it through the season in such condition that a rapid growth is maintained. He must have sufficient teams tools and labor to harvest the crop at just the right time to secure the best quality of brush, and he must have proper sheds and racks for curing the crop. Skill, judgment, and experience are needed at every step.

Most of the broom corn grown in Colorado has been of poor quality, considerable of it almost unsalable in years of good supply. A few experienced Illinois growers who have come to Colorado have produced broom corn of high quality.

Colorado broom corn is generally brittle and rough, and much of that raised under irrigation is coarse. These faults come first from the seed. The cool nights tend to make it brittle. Much of the broom corn raised in the state is damaged by not being harvested at the right stage and by being cured without shelter.

The southeastern part of the state is best adapted to the production of broom corn on account of having warmer nights through the growing season than other sections. It is probable that in this territory a quality of broom corn can be produced that will supply most of the demand of the state, if skilled growers give due attention to every detail in producing the crop and are well supplied with the needed equipment.

It is probable that the warmer sections of the fruit belt in western Colorado are adapted to broom corn.

A good yield is one ton to three acres, on irrigated land, and one ton to four acres on dry land. This gives a good profit in years of exceptionally high prices, a little more than pays expenses in average years, and returns less than cost in years of low prices. Broom corn is a fairly good sod crop. It requires about 4,500 acres annually to supply the demand in Colorado.

HAY.

Hay... $1,450,000

About ten thousand cars of hay were shipped into Colorado in 1909, with an estimated wholesale value of $1,450,000. This hay came chiefly from Kansas, Nebraska, Oklahoma and Wyoming. Most of it was shipped in to be fed to horses and was hay made from native grasses.

During this same time a large quantity of alfalfa hay was shipped to southern states for feeding work animals—horses, mules, and oxen. Colorado alfalfa hay is in demand in eleven southern States—planters, contractors and other large users of horses, mules, and oxen considering it the best feed for animals doing hard work. Colorado horsemen do not like alfalfa for this purpose.

Colorado men handling large numbers of horses and mules doing heavy work consider that the best hay for work animals is timothy, grown at an altitude of 7,000 to 8,500 feet. The timothy hay grown at these altitudes in Grand, Routt, and Gunnison Counties sells in the wholesale markets of eastern Colorado at from $4.00 to $5.00 a ton more than the hay that is shipped into the state.

Timothy at these high altitudes yields two tons and upwards an acre, and is a profitable crop. Any one of these three Counties has a sufficient area to supply all the hay of this character needed in Colorado markets, but has not the farmers to produce it. Any considerable increase in the quantity of hay produced in these sections will have to be secured from new settlers.

Eleven southern States want Colorado alfalfa to feed to their work animals, and there is a large and continually increasing demand from all the eastern states for Colorado alfalfa hay, and alfalfa meal. Appreciation of alfalfa hay is growing much faster in the United States than is production, and if Colorado had the farmers to grow it, a good demand would be found for many times the quantity of good alfalfa hay than is now being produced in the state.

FIELD SEEDS.

Alfalfa Seed	$150,000
Seed Potatoes	30,000
Timothy Seed	50,000
Sorghum, Kafir, and Milo	6,000
Millet Seed	4,000
Total	$240,000

Alfalfa Seed.—This season, up to February 1st, 1910, 32 cars of alfalfa seed shipped direct from Germany had been sold in Colorado, and importers expect to sell several more cars of this seed before the end of the seeding season. These 32 cars cost, wholesale, $4,300 per car, a total of $137,600.

German alfalfa seed has a very high germination test, but the adaptability of the various German strains of alfalfa to Colorado conditions, and the quality of hay that they produce, have not been determined.

A few years ago Colorado received large shipments of alfalfa seed from Utah, and the alfalfa from Utah seed was found to be particularly adapted to our conditions. Practically no Utah alfalfa seed is now used in Colorado, for as soon as the trade was established, the Utah shippers began sending seed badly adulterated with sweet clover. Some of the highest priced shipments contained 90% of sweet clover

Some Colorado dealers, after being forced to abandon the Utah seed on account of the sweet clover adulteration, decided to secure seed grown in Arizona; and considerable Arizona alfalfa seed is now on sale in Colorado.

The few tests made of Arizona seed by the Colorado Experiment Station have shown that the plants from it are too delicate for our climate, and begin to rot and die within a year after seeding. Whether this will be true of all alfalfa from Arizona seed we do not know.

Alfalfa seeding in Colorado from seed grown in the western sections of Nebraska and Kansas have shown that seed from these sections is very desirable.

Probably less than half of the alfalfa seed sown annually in Colorado is grown in the state. There is a great opportunity for the development of this industry, as Colorado farmers prefer home grown seed, and if it could be produced there would be great demand for Colorado alfalfa seed in the northern section of the corn belt as well as at home.

Seed Potatoes.—At least 50 cars of seed potatoes are shipped each year into the Greeley district from outside the state, costing wholesale, $20,000. Other parts of Colorado ship in from other states seed potatoes, costing at a low estimate, $10,000, a total of $30,000 per year for seed potatoes shipped into Colorado. Some years nearly twice this amount has been shipped into the Greeley district alone. This seed comes chiefly from Wisconsin, some from Minnesota, and a few cars from Maine.

C. L. Fitch, of the Colorado Experiment Station, has made a careful investigation of the results obtained from this "shipped in" seed. He reports that the average returns in the crop from the seed shipped in is $40 an acre less than that from acclimated seed. The seed shipped into the state is sufficient to plant 4,100 acres, which at $40 an acre, makes a direct loss in the crop each year of at least $164,000. Sometimes double this acreage is planted with seed shipped into Colorado, and the loss is then double the amount given.

On the other hand, for the past two years carefully selected seed potatoes from Greeley sent to the San Luis Valley have produced an average gain in profits of $75 an acre over home grown seed.

About 30,000 acres are planted to potatoes each year in the Greeley district, and the acreage is constantly increasing. If seed could be secured for this district that would give as great an increase in profits an acre as the Greeley seed gives in the San Luis Valley, the additional profits would be enormous.

One of the most promising lines for the potato grower at an altitude of 7,000 feet is the production of seed potatoes grown from seed taken from high yielding hills. When the right seed is developed northern Colorado alone needs 800 cars a year.

Another loss, small to the individual farmer, but large in the aggregate of the state, comes from the common practice of ordering seed potatoes of the new sorts glowingly advertised in eastern seed catalogues. Tests made by the Colorado Experiment Station show that not over one in one hundred of these varieties equals in yield the standard Colorado sorts, and many are worthless.

Timothy Seed.—Most of the large quantity of timothy seed sown in Colorado is shipped into the state. Seedmen state that $50,000 a year is a low estimate of the amount sent out of the state annually for this seed.

Colorado grown seed is heavier and has greater vigor, but Colorado timothy growers perfer to market hay rather than seed. It would seem that there is a good opening for growing timothy seed in Colorado at high altitudes at points too distant from railroads to make the shipping of hay profitable.

Sorghum, Kafir, Milo and Millet.—In a recent examination of sorghum seed from Colorado and from Kansas, Colorado seed averaged in every case heavier per struck bushel than that from Kansas. Colorado grown milo weighed 63 pounds per struck bushel. Colorado farmers should not only supply the demands in the state for these seeds, but should ship large quantities to other states.

FRESH FRUITS, MELONS AND VEGETABLES.

Fruits and Melons not grown in Colorado or shipped in out of season	$1,237,000
Fruits that could have been grown in Colorado	367,500
Potatoes and sweet potatoes	184,000
Green Vegetables	195,500
Total	$1,984,000

FRUITS AND MELONS NOT GROWN IN COLORADO OR SHIPPED IN OUT OF SEASON.

Oranges	$360,400
Bananas	371,000
Lemons	138,000
Strawberries	164,500
Grape Fruit	49,000
Cranberries	42,500
Tomatoes	41,200
Pineapples	35,500
Water Melons	27,900
Figs	7,000
Total	$1,237,000

Oranges, bananas, lemons, grape fruit, pine apples and figs cannot be grown in Colorado, but if there were a sufficient quantity of choice, home grown apples and peaches, the quantity of these subtropical fruits used would be greatly reduced, and the money spent for them kept in the state.

Nearly one-third of the strawberries came in out of our season, and were sent from California, Texas, and Arkansas. Two-thirds of the strawberries shipped into the state came from Missouri, and a large part of these should have been produced in Colorado. Some strawberries came from Oregon, and Utah.

The tomatoes came from Florida, Georgia, Texas, Arkansas, essee, and Mexico, and were received before Colorado tomatoes were marketable.

The watermelons came from Florida, Georgia, Texas, Arkansas, and Oklahoma, and were shipped in out of season.

FRUITS THAT SHOULD HAVE BEEN GROWN IN COLORADO.

Grapes	$208,300
Apples	65,500
Cantaloupes	57,200
Pears	33,500
Prunes	8,300
Peaches	5,800
Cherries	1,300
Total	$379,900

One hundred and thirty cars of Concord grapes were shipped into Colorado in 1909, costing, wholesale, $104,850. Half of these grapes came from New York, over one-third from Michigan, and the remainder from Pennsylvania and Iowa.

The writer has purchased New York grown Concord grapes, at Cortez, Colorado. They were shipped from New York to Denver, and re-shipped to Dolores, 510 miles by rail from Denver, having to be transferred at Alamosa to narrow gauge cars. They were carried by freight wagons from Dolores to Cortez, nearly twenty miles. Yet grapes thrive particularly well in the Montezuma Valley, of which Cortez is the center, and the few vineyards there yield $500 and upwards an acre a year.

California grapes to the value of $91,000, and Imported grapes to the value of $12,450 were shipped into Colorado in 1909. Professor O. B. Whipple, formerly Field Horticulturist for the Colorado Experiment Station, states, in Bulletin No. 141, that California varieties of grapes grow in the fruit section of Colorado will, when mature, give an average annual return of $525 per acre, and Concord grapes an average annual return of over $600 an acre. One of the most successful apple growers in Canon City stated to the writer that grapes planted between rows of bearing apple trees have given him, for twenty years, an average annual return per acre of $100.

The fruit sections of western Colorado are well adapted to grape growing, and it is an industry that offers quick returns. If there were a sufficient number of men to grow them, Colorado could not only fully supply the home market, but the demand in all the other mountain states.

Apples.—About three-fourths of the apples shipped into Colorado in 1909 came from California. They were inferior in flavor, size, and coloring to Colorado apples. Other shipments were made from Oregon, Utah, Montana, and Kansas.

In a trip made by the writer in November and December, 1909, covering the dry land sections of eastern Colorado, it was found that the towns in these sections along the lines of the Burlington, Union Pacific, Rock Island and Missouri Pacific railroads were supplied almost entirely with California apples. The fruit growers of the eastern Slope and of the Arkansas Valley should organize and secure this trade. It is a market that can be greatly increased.

Potatoes and Sweet Potatoes.—Potatoes for the table use to the value of $116,000, and sweet potatoes to the value of $68,000, were shipped into Colorado in 1909.

About half of the potatoes came from Texas, the others from California, Utah, Idaho, Arkansas, and Kansas. Most of the potatoes came in before Colorado potatoes were ready for the market. In February, 1910, a car of new potatoes was received in Denver from Cuba.

Over half the sweet potatoes came from Kansas, one-third from Virginia, and the others from California and New Jersey. From limited trials, it seems probable that the sandy soils in the Arkansas Valley are well adapted to growing sweet potatoes, and that this section should furnish all the sweet potatoes needed in the state, and in other mountain sections.

Green Vegetables.—Cauliflower, cabbage, celery, and onions were shipped into Colorado from California, celery from Florida, cabbage from Tennessee and cabbage and onions from Texas. The growers of these products in Colorado need to pay more attention to the early crops, and to methods of storage that will lengthen the period of home grown supplies.

CANNED GOODS.

California Fruit	$500,000
Corn	310,000
Tomatoes	300,000
Peas	80,000
Beans, Succotash, Sweet Potatoes, Beets, Asparagus and other vegetables and eastern Berries and Fruits	100,000
Grape Juice	35,000
Cider	20,000
Total	$1,345,000

This estimate is conservative. Some of the largest jobbers in the State consider that the actual total is nearly $2,000,000. The most careful estimates place the value of canned goods put up in Colorado, in 1909, at $500,000. The business in the state is increasing every year.

Fruit.—Most of the canned fruit sold in Colorado comes from California, some of it from states east. There is a great opportunity for the fruit growers of western Colorado not only to supply the demand for canned fruit in Colorado, but the demand for the best quality in many other states.

Colorado canned fruit, when properly prepared, is as much superior in flavor to canned fruit from other sections as Colorado fresh apples and peaches surpass those from other states. Only a small proportion of the fruit trees in the fruit sections of Colorado have reached the age of bearing, and in a few years the fruit output of the State will be increased many fold.

As fruit production increases, the canning industry can be gradually established, and the knowledge and skill acquired to produce a canned product uniform and equal in quality to that of our fresh fruits.

Corn.—The best grade of canned sweet corn comes from Maine. The bulk of this product shipped into Colorado comes from Iowa, Missouri and other states in the corn belt.

A few thousand cans were put up at Fort Lupton, Colorado, in 1909. In most of the tillable sections of Colorado the nights in summer are too cool for the best growth of sweet corn. The Arkansas Valley and the warmer sections of the Western Slope have conditions well adapted to the growing of sweet corn for canning, except the damage from boll worms in the ear. In some seasons the worm damages almost every ear, and in other seasons the damage is very slight, but the uncertainty prevents the growth of the sweet corn industry.

Tomatoes.—Experts estimate that 7,200,000 cans of tomatoes were eaten in Colorado in 1909, one-half of which were shipped into the State. Most of the tomatoes shipped into the State came from the corn belt, though large shipments were made from California, and from as far east as New York.

Fifty thousand cases of tomatoes were shipped into Colorado from Utah. These tomatoes were grown under conditions almost identical with those found in the fruit sections of western Colorado.

Tomatoes do well in several sections of Northeastern Colorado and the soil and climate of a large proportion of the Arkansas Valley and of the Western Slope fruit sections are suitable for growing large yields of tomatoes of good quality.

The industry should grow until most of the canned tomatoes used in the State are a home product, and the quality that can be produced in Colorado will find a good market in many other states.

The objection made by retail grocers and by consumers to tomatoes canned in Colorado is that they are not uniform in quality. Several cases may be as uniform in character and of as good quality as the best or the most expensive brands of eastern canned tomatoes, while in the same shipment, from the same factory, will be other cases that contain cans whose contents are watery, often to a serious degree. California canned tomatoes often have the same fault.

Some expert handlers of canned tomatoes believe that this condition is largely caused by over irrigation and that it is made worse by the use of seeds from strains that do not produce firm fleshed tomatoes, by too little cultivation and by a too high temperature in canning.

The best canned Colorado tomatoes are equal to the best produced in any other part of the United States, and the industry needs the intelligent co-operation of the seedsmen, growers and canners to produce a uniform quality of high grade.

Peas.—The peas canned in Colorado by Empson are equal in every respect to the best grades of canned peas produced anywhere else in the world, and if a sufficient supply was produced, they could be sold anywhere on the globe where canned peas are wanted. They are the only canned peas produced in the United States equal to the French peas.

About 90% of the canned peas used in Colorado are from the Empson factories, and most of the peas that are shipped into the state are brought here because jobbers want their own names on the cans and the Empson factories refuse to do this.

Beans, Succotash, Sweet Potatoes, Beets, Asparagus, and Other Vegetables.—These can profitably be canned in Colorado in quantity and of the quality required to supply all the demands of the state.

Canned Goods.—This industry can be developed until a sufficient quantity is produced not only to supply the demands of Colorado, but a much larger market in other states. Before this can be effected a uniform, choice quality must be produced season after season.

The Empson canned peas produced in Colorado are not surpassed by those produced in any other part of the world. Mr. Empson determined the most suitable varieties the best strains of these varieties, and the methods and locations for producing and maintaining seed that will secure high quality in the crop. He ascertained the character of soil that will produce the choicest flavored peas, and he allows peas to be grown on that kind of soil only. The methods of planting, cultivation, irrigation and canning that produce the choicest quality of peas were all discovered and then adopted.

It will require similar methods to give Colorado canned fruits, berries, tomatoes and vegetables the same standing through the United States that is now held by Colorado fresh fruits and potatoes. Many towns in Colorado are planning to establish canning factories. Such factories will be profitable only when methods like those of Mr. Empson are adopted.

DRIED FRUITS.

Dried Fruits $500,000

A large proportion of the dried fruits shipped into Colorado come from the Pacific Coast.

The dried fruit industry has been started in a small way on the Western Slope in Colorado. Apples, peaches and prunes make up the bulk of the product.

Jobbers and grocers complain that Colorado dried fruits fail to be uniform in quality, and state that the production of dried fruit will have to go through the same stages of development through which the production of fresh fruits and potatoes has passed before Colorado dried fruits will have a high standard in the markets of the United States.

PICKLES, CATSUP AND CANNED BEANS.

Pickles (Colorado Sorts)	$50,000
Catsup	50,000
Pork and Beans	75,000
Total	$125,000

Pickles.—The pickle industry is comparatively new in Colorado, and is annually increasing. The pickles put up by those of our manufacturers who are skillful and have had experience are fully equal in every respect to pickles shipped in from other states. Growing material for pickles gives good profits to the farmers who understand the business and the industry is likely to have a continual steady growth.

Catsup.—Some Colorado catsup is equal to the best eastern brands and some is of poor quality. Consumers do not feel certain of the quality and many prefer to buy eastern brands that are good and always uniform. Greater care on the part of all Colorado makers of catsup could overcome this difficulty.

Pork and Beans.—The large demand for eastern brands of pork and beans seems to have been created largely by the expensive advertising given these brands in magazines and ladies' journals.

WHAT THIS INQUIRY SHOULD SHOW COLORADO PEOPLE.

This investigation shows that over *Thirty-one Million Dollars* were sent out of Colorado in 1909 to buy agricultural products that should have been produced in the State. This heavy drain on the State is annually increasing.

The entire output from the metal mines of Colorado, for 1909, is reported by the State Commissioner of Mines, Mr. T. J. Dalzell, to be $33,211,527, as follows:

Gold	$21,946,684
Silver	4,587,643
Lead	2,765,512
Copper	1,220,642
Zinc	2,295,046
Tungsten	396,000
Total	$33,211,527

The gross returns from our metal mines was but little more than sufficient to pay for the agricultural products shipped into the State. The gross product of our silver mines was not quite sufficient to pay for the dairy products shipped into the State. The gross returns from silver, lead and copper were slightly more than enough to pay for the meat and meat products shipped into Colorado. All the zinc mined would a little more than pay our bill for eggs shipped in.

Nearly every agricultural product shipped into Colorado could have been more easily produced in the State, at a greater profit, and under conditions more enjoyable for the producer than in the sections where it originated.

The following figures from the United States Department of Agriculture show the average yearly yields per acre for the past ten years, and indicate the larger yields in Colorado:

	WHEAT Bu.	OATS Bu.	BARLEY Bu.	POTATOES Bu.	HAY Tons
Colorado	24.5	34.2	33	122	2.31
Indiana	....	29.1	25.6	77	1.36
Illinois	....	31.3	28	85	1.33
Iowa	13.8	30.1	26	83	1.52
Kansas	11.6	24.4	19.7	77	1.42
Nebraska	12.6	26.9	24.4	84	1.57
Wisconsin	15.7	33.4	28.8	92	1.56
Minnesota	12.7	31.6	25.8	86	1.66

Although Colorado produces high yields of grain, yet ten million dollars were sent out of the State in 1909 for grain and grain products. The conditions of climate are ideal for growing beef animals, and the feeds produce beef of a choice flavor, yet one million eight hundred thousand dollars were sent out of the State for fat cattle, beef and veal. Pork can be produced at less cost and of better quality than it is being produced in the corn belt. We sent out in 1909 over four million dollars for hogs, pork and pork products. Both climate and feeds are adapted to the economical production of dairy products, still we sent out nearly five million dollars for these products, alone. Four million dollars were sent out for eggs and poultry, while our few expert producers of these products were making nearly double as much, per hen, as was being made in the States from which we made these purchases.

Why, then, with such favorable conditions, did we send out thirty-one million dollars for agricultural products that could have been more profitably produced in the State? Because there was not a sufficient number of farmers in the State. Almost every farmer in Colorado is undertaking more than he can accomplish well, and it will be impossible to increase the present agricultural output of the State to any considerable extent, unless we secure more farmers.

With many products shipped into Colorado, the consumption would be larger could home products be secured. When people are obliged to use cold storage eggs, the consumption drops to a fraction of that when fresh layed eggs are available. More meat, more butter, more cream and milk, and more fruit and vegetables are eaten when strictly fresh, home produced products can be secured.

We need 30,000 more farmers this year in order to produce the agricultural products that will be consumed in the State. We need men who are skillful in the management of beef and dairy cattle, hogs and poultry; grain, fruit and vegetable growers, and men who can produce choice raw material for canning and pickle factories.

The potatoes and fresh fruits grown in Colorado have a National reputation for choice quality and there is every reason to believe that if a surplus above home needs were produced, a large demand could be created in other States for Colorado meats, dairy products, poultry and eggs, seeds, canned goods, and dried fruits. It will require thousands of farmers to produce a sufficient surplus of these products to secure a large outside market.

SECURING ESTIMATES.

The figures given in this bulletin are estimates only. They are based on the most accurate data that could be secured and are conservative estimates, considered in many cases by the largest handlers of the products to be low.

The writer has had charge for over three years of the Farmers' Institute Work of the Agricultural College and during that time has traveled over 60,000 miles in Colorado. During the three years he and his associates from the college in Institute Work, 35 in number, have been collecting data in regard to the agricultural products originating in the State and those shipped in. The data so obtained have been used as the basis for these estimates.

In addition to the above information the railroads furnished us with a statement of the exact number of tons of each agricultural product from the Missouri River, Eastern and Texas points that were shipped in 1908, and in the first four months of 1909, into, but not through, Colorado, to Denver, Colorado Springs, Pueblo, Trinidad and other points by wav of the Santa Fe, Burlington, Rock Island, Missouri Pacific, Union Pacific, Rio Grande and Colorado & Southern Railroads. These figures were used as the basis for estimates where accurate statements for 1909 could not be secured.

The Rock Island and the Denver & Rio Grande furnished statements of the exact tonnage of all agricultural products brought by by these railroads in 1909.

The Burlington and Union Pacific Railroads furnished us the tonnage of grain and grain products brought by them into Colorado in 1909, and the Union Pacific gave us a statement of the tonnage of hay brought into the State by that railroad in 1909. The Santa Fe Railroad furnished us a statement of the tons of grain and grain products brought into Colorado in 1909 by that road.

The Denver Union Stock Yards furnished a statement of the number and value and origin of all fat animals shipped into Colorado in 1909.

The quantity of meat and meat products shipped into Colorado in 1909 was secured from the railroads and the values were furnished by the experts from the Colorado Packing Company.

The estimates on the value of butter and cheese was made after securing figures from all the large handlers of these products.

The estimates on eggs were made from the combined estimates of eight of the largest handlers of these products in the State, together with information obtained during the past year by Professor Vaplon, the Poultryman of the Agricultural College, and myself in most of the towns in Colorado. The estimate on poultry was obtained in the same way, and in addition, information was obtained in regard to the amount being sent out of Colorado through the banks for poultry.

The estimate on condensed milk was secured from the Condensed Milk Factory at Fort Lupton, and from the jobbers of this product at Denver, Colorado Springs and Pueblo.

The estimate on Malted Milk was secured from wholesale and retail druggists.

The information in regard to grain and grain products was obtained from railroad records, from millers, from wholesale dealers in flour and feed and from bakeries.

Seedsmen in Denver and Pueblo and records from railroads furnish the information in regard to seeds.

Data in regard to fresh and dried fruits and vegetables were secured from jobbers and brokers and the records of the railroads. Mr. Geo. Knifton, Denver, was particularly helpful in securing this information. The estimates on canned goods, pickles and condiments are based on information furnished by the largest jobbers in these products in the State, and by canning and pickle factories.

The estimates on hay were based on records of shipments furnished by the railroads and information given by large handlers of this product. The information in regard to broom corn was secured from the chief handlers of this product in Denver and Peublo.

We shall be very glad to receive corrections and additions to these estimates from any reliable source.

Bulletin 154 April, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

ALFALFA STUDIES

THIRD PROGRESS REPORT

BY

P. K. BLINN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

The Agricultural Experiment Station

FORT COLLINS, COLORADO

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REPORT OF ALFALFA INVESTIGATIONS.

By PHILO K. BLINN.

The attempt to improve the hay and seed yielding traits of alfalfa, by systematic seed selection, has had decidedly encouraging results; although it may yet require several years of close observation to fully determine the best types for hay and seed production-

The conclusions from some of the observations, have been rather doubtful, and there are reasons for discounting the value of some of the contrasts that have appeared; for instance, the selections, for ideal leaf, and stem qualities, made the first season, during the seedling growth of the plants in the nursery, have since proven of little value, as there was a decided change in the type of foliage, when the plants took on a more rapid and succulent growth: The same result would follow, as the effect of environment, rather than heredity, for any trait that might appear; hence, the problem is to select plants that have an inherent power for the reproduction of desirable qualities; but, with nearly a hundred strains to consider, and at least a score of points of variation appearing in endless combination, this has not been an easy undertaking.

Several of the varieties tested, show contrasts of decidedly pratical value, such as, *hardiness, habits of stooling, qualities of resistence, to drouth, frost* and *fungus diseases, leafy hay qualities* and *prolific seed yields.* These valuable traits are not found in any one variety, and it is difficult to say which strains, have the points of greatest utility; it is certainly obvious, that marked improvement over most of the ordinary types, of alfalfa is possible, if only seed of some of the strains tested, could be procured, which however, is difficult, as different lots of seed supposed to be the same, often prove entirely different.

It is impossible to identify the seed origin of a field of alfalfa, and it is equally difficult, to make varietal distinction, in the points that are casually observed; for with few exceptions, the same colored flowers, the same shaped leaves, and the same general type of plants, may be found in nearly all varieties, and there is often a greater range of variation in the individual plants of a single strain, than in the contrast of so called varieties.

It is difficult to judge the merits of alfalfa, growing under different conditions of soil, and cultural care; but, in a *comparative test under uniform conditions,* the *contrasts* are *clearly shown,* also in *nearly all varieties* it is *easy* to *recognize* the *superior qualities of some of the individual plants;* which suggests the SINGLE PLANT as the UNIT *for seed selection.*

The results of our nursery work with *individual plant selections* have revealed the facts, that in plants, showing desirable qualities, *some* will reproduce the traits, quite *uniformly true,* while others, will breed *irregularly* the *qualities,* that were *apparently the same;* hence, *heredity* in alfalfa plants *can not be determined, by a cursory view,* but more by the comparison of their *performance records.*

The plan is now, to make individual selections of seed from the *most highly efficient plants,* revealing desirable traits, where ever found, in any of the varieties, and then submit them to a fair comparative test for their reproducing tendency, thus, affording an opportunity to intelligently select and increase seed of alfalfa, with known uniformity, of qualities, for testing in different sections of the state. Some of the principal qualities, that have engaged the attention in this investigation are—*Hardiness,* there are few fields of alfalfa that have not suffered from the lack of this trait, plants dying out, either form frost, drouth, soil conditions, or plant diseases. The superiority in this respect, of the Turkestan and more hardy kinds, over the Arabian, or southern variety is very marked indeed.

PLATE I. CONTRAST OF HARDINESS BETWEEN SOUND TURKESTAN AND UNSOUND ARABIAN PLANTS

The contrast between two, two year old plants, from the nursery, can readily be seen, one perfectly sound, the other with the crown nearly all rotted off, and each having grown under the same conditions, and also representing fairly the condition of the plants, in the plats from which they were taken; showing a lack

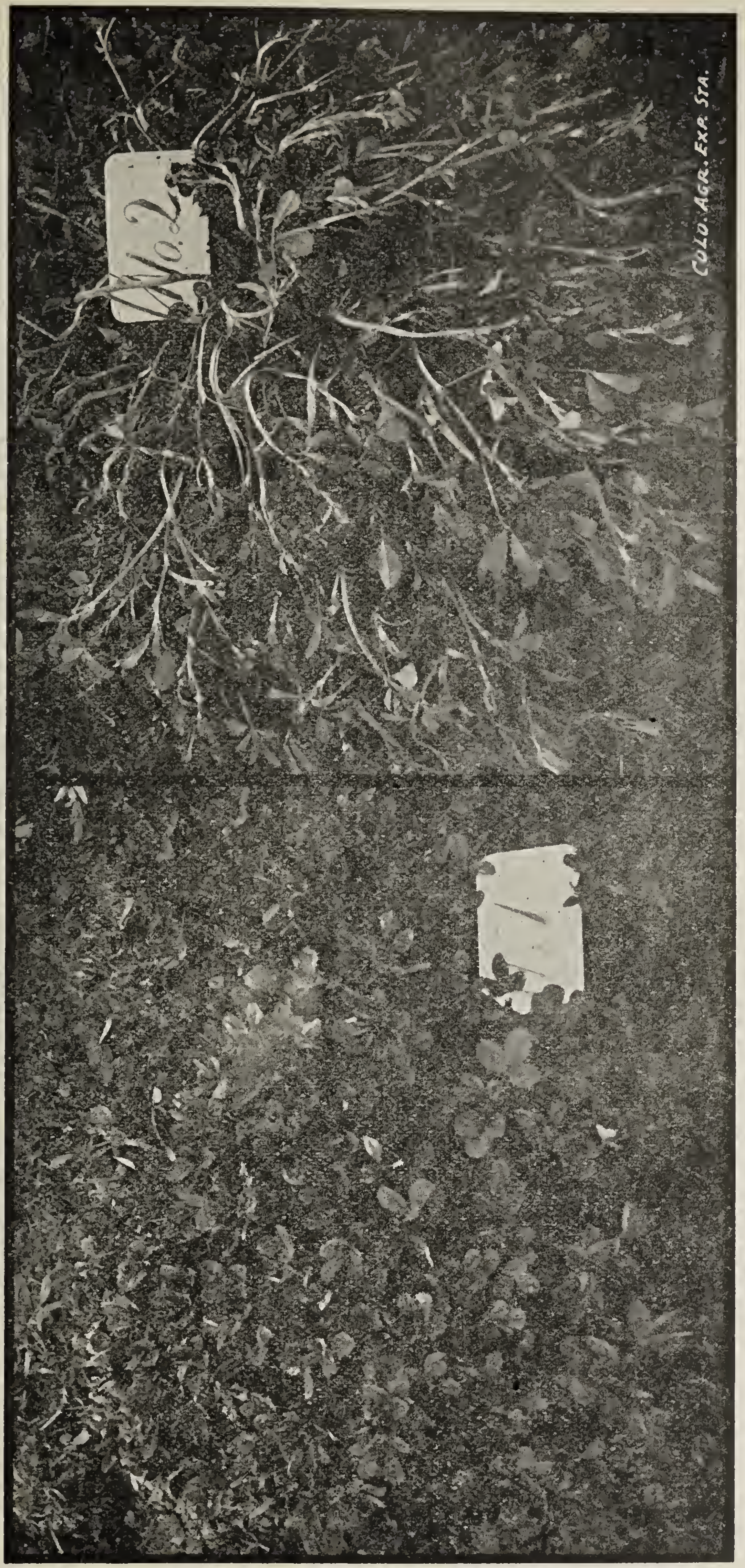

PLATE II. TWO ADJACENT TURKESTAN PLANTS, MAY 3, 1909, TWO DAYS AFTER FREEZE OF 18°

No. 1. Dark green foliage pratically uninjured.

No. 2. Light green foliage; leaves and stems entirely frozen back. Both U. S. P. I. No. 18,425 of vitality. Another contrast along the same line, was in regard to the *frost resistance* of the *green growing plants;* on April 26, 1908, the weather dropped to 22 degrees of temperature.

The alfalfa in the nursery plats, a foot in height, was frozen stiff, but when the sun thawed them out, some plants were exceptionally free from injury; *the light colored foliage,* seemingly to have suffered most.

The past season, the temperature dropped to 18 degrees, on the last of April, and the alfalfa was again severely frozen back, and with the same results, of a contrast in resistence, but not uniformly in the same plants as the year before, but the *dark green colored plants,* were the most frost resistant. As a variety, the Turkestan plats, were the least injured; two plants from a plat of Turkestan

PLATE III. CONTRAST OF STOOLING HABITS

alfalfa, U. S. P. I. No. 18,425, show marked contrast in this trait.

Several plants showing frost resistance have produced seed, which has been secured for future testing for this feature.

One of the most valuable qualities in the alfalfa plant, is its *habit of stooling,* and its power to push out growth for three to four crops of hay a year, almost indefinitely; the nursery plats having been thinned to single plants twenty inches apart each way, gave an excellent chance to observe the stooling habits of the different varieties; here again the Turkestan plats were exceptionally good, better than any other; and in some plants there is a *tendency* to *root down, from* the *crown branches,* which would be a very desirable trait, to thicken a poor stand, or to maintain a stand of alfalfa on poor soil condition, if it could be better developed.

A contrast in stooling habits is shown in Plate No. III, the larger being from the Turkestan plats, compared to common alfalfa, with main roots over an inch in diameter. In each case, the plants are three years old.

The tendency to start growth early in the spring, is a variation that is characteristic of the Turkestan alfalfa, and some others; as early as March 17, in 1908, these strains were showing green shoots three to five inches high, above the ground, while under the same conditions, the native and some other strains, remained dormant full three weeks later. It has now been observed, that a corresponding check in the growth of these very early varieties, takes place late in the fall, and it is doubtful if this variation is of any value, for the crops in the spring, are so often set back, or cut short, by the late spring freezes.

Our observations, and the reports from several other sources, have been to the effect, that horses will prefer the Turkestan alfalfa in a pasture, over the ordinary kinds. This fact seems to be well established, but a comparison of the different varieties, has not been made, nor has the reason for this preference been demonstrated, but it is doubtless due to a better flavor that the horse appreciates.

The contrasts in disease resistant tendencies, in alfalfa are sometimes very marked, but the plats that have been most affected by a disease one season, have not always been the same ones the next; so there seems to be a little question, as to the reliability of these observations. As in the case, of frost resistance, it is the dark green colored leaves that seem to be the least affected by the mildew or "leaf-spot."

The presence of leaf fungus affects seriously the leafiness of hay, and the search for plants that were the least affected, have been carefully sought in our seed selections.

The richest part of alfalfa hay is in the leaves and small stems, hence, a dense foliage, giving *a high per cent* of *"leaf-to-stem" quality* should be a dominant point in the selection for hay type; and selections for this point have been carefully made.

Plate No. IV, shows the contrast in the uniform production of leafy traits, in two rows, sown last May with the seed of apparently equally good selections, for this trait.

All the desirable points previously mentioned, have not been found associated with the most ideal types for hay, but a wider selection may secure the desired end.

The selections for *seed yielding traits,* have been very positive in their results, and the contrast in the production of seed in the different varieties, have been the most marked of all. Most of the Turkestan plats producing practically no seed, while others among the sixty-four plats in the nursery, have produced the phenomenal

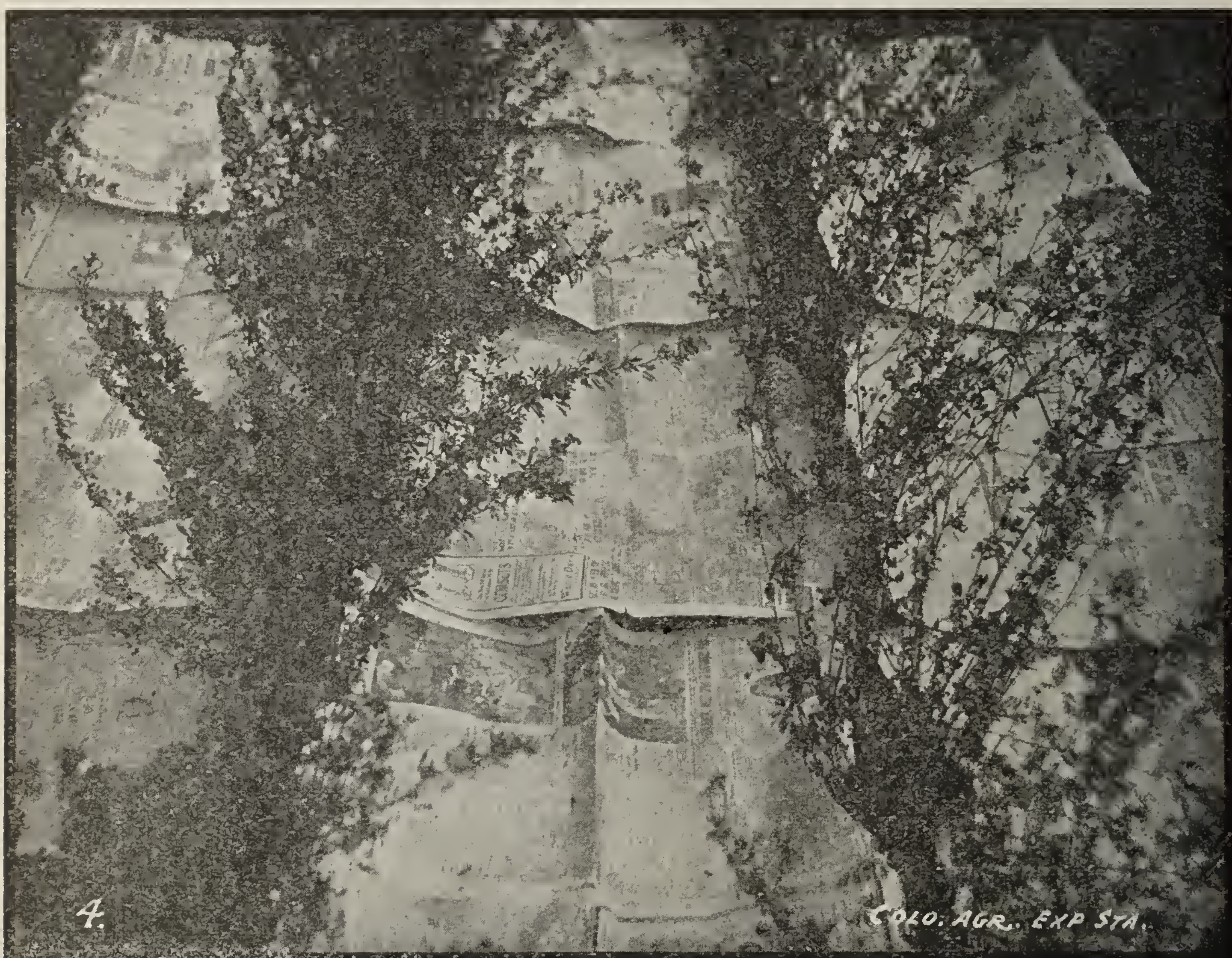

PLATE IV. CONTRAST IN LEAFINESS

yield, of two and one half pounds of clean seed, from a square rod, with less than one hundred plants.

The varieties that have been the heaviest seed yielding ones, one year, have also, been the best the following season; single plants have produced two ounces of clean seed, and the plats sown with the seed of these selections, have in turn been heavy seed producers; so that this trait is to some extent an inherent quality. We have made over a hundred selections of individual plants showing desirable qualities, and Plate No. V, shows the comparison in seed yield of a few of the average plants.

While the seed yielding tendency, may be greatly affected by the hereditary traits, it is doubtless more generally influenced by the *climatic* and *cultural conditions*. All the observations on this point seem to indicate the fact, that outside of insect injuries, the *proper supply* of *moisture,* is the greatest factor in determining the seed yield of alfalfa. The heaviest yield of seed is produced, when the plants make a relatively *slow dwarfed growth.*

Under irrigation, the usual system of flooding supplies too much water, and the alfalfa grows too rank for a seed yield; on the other hand, without irrigation, the seed fails so often, to fill, on account of the lack of water. But where the roots can penetrate to *just* the *proper condition* of *moisture,* or when irrigation is applied, at just the right time and amount, the happy medium is reached, and a good yield of seed is realized.

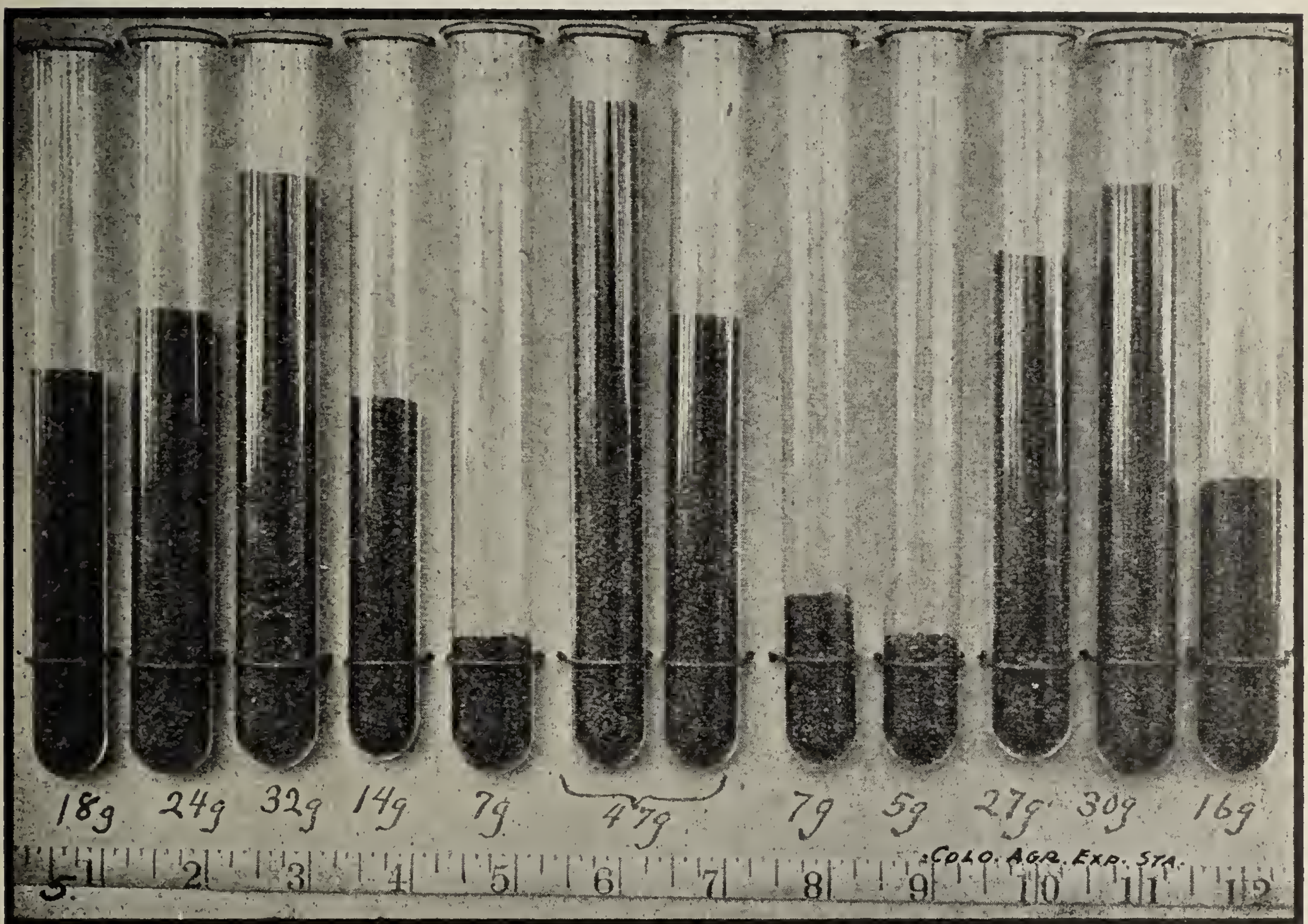

PLATE V. CONTRASTS IN SEED YIELD OF INDIVIDUAL PLANTS

Samples taken at random. Beginning at left, No. 1, Argentine; No. 2, Arizona; No. 3, dry land, Nebraska; No. 4, from Rocky Ford; No. 5, Turkestan; No. 6 and 7, U. S.; No. 8, U. S., No. 17,698, northern Montana, evidently Turkestan, 7 grams; No. 9, dry land, Nebraska; No. 10, Highmore, S. D.; No. 11, Argentine; No. 12, Argentine.

The only practical method to regulate moisture, or to control irrigation for alfalfa seed culture, is to sow the seed *in rows with space,* to permit intertillage to conserve the moisture from rains or winter irrigations, and to enable the rows being "logged" out with clear cut furrows, in about every other row; so that the lightest possible irrigation may be applied quickly and evenly at the proper time, as the needs of the crop may demand.

A *thin stand* of *plants* on the ground, seems also necessary to produce good results in seed yield. The stems growing more stocky, and the plants standing some little space apart, the branches will entwine each other, so as to *brace,* and *prevent lodging from wind* or *heavy storms,* which is disastrous to an alfalfa seed crop.

PLATE VI. A FIVE ACRE FIELD OF ALFALFA IN ROWS TO TEST SEED PRODUCTION

The smooth furrows will also serve to provide good drainage from excessive rains.

This system has been followed in the nursery plat work, and it has been successful apparently. The plan has been reported a success in other states, and it seems practical, to be applied on a large scale for growing seed commercially.

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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

BY

WM. P. HEADDEN

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THE FIXATION OF NITROGEN IN SOME COLORADO SOILS.

By WM. P. HEADDEN.

It has often been claimed that "black alkali" exists in Colorado. This idea has arisen because of the existence of certain black or brown spots which are met with in some localities. The color of these spots is not due, as has been supposed, to the presence of sodic carbonate, to which the name of black alkali has been applied, but to other causes. This salt, sodic carbonate, constitutes a very small percentage of our alkalis and occurs in but one section in such quantities as to be injurious to vegetation. There are several independent occurrences of this salt in the section alluded to, but they are close together and are within an area of a few hundred acres. This occurrence has nothing in common with that of our alkalis, it is not disseminated through the soil but constitutes lakes of sodic carbonate, small ones, it is true, but real lakes having apparently no connection whatever with the surrounding country. The source of this sodic carbonate is without doubt certain underground waters and has no direct relation to the formation of carbonates in semiarid countries. The soils of Colorado do not contain any deleterious quantities of this salt and the so called alkalis seldom contain any large percentage of it. The composition of Colorado alkalis has been a subject of investigation practically all of the time for the past fourteen years or more and it is pretty well established that there is but one type of alkalis in the State and that this is the white alkali, namely, a mixture of sulfates with some chlorids and carbonates, the latter ranging from nothing to 10 or 11 per cent. We have some variations based on the respective bases which may be predominant. The term alkali is used to designate any and all efflorescent salts which form white coatings on the soil or the grass, sticks, etc., which happen to be present and protrude from the surface. The popular term does not take cognizance of the chemical distinction made between alkalis and alkaline earths and the term is here used in its popular and readily understood sense. In some places, due to easily recognized conditions, we have almost pure calcic sulfate, in others, sodic sulfate, and in one rather large section magnesic sulfate is very abundant. We have no type in which either sodic chlorid or sodic carbonate can be said to be really abundant. We have examined some soils with the express purpose of trying to find out whether it would be reasonable and right to attribute their unproductiveness to the presence of salt, sodic chlorid, but no justification for such a conclusion has been found except possibly in two cases. The soil samples chosen were such as were believed to possibly owe their unproductiveness to this cause.

The areas involved varied greatly in size, some of them were very small. This was the case with both of the samples which might be considered as containing salt enough to be detrimental. The data at my command indicates that about 1.5 per cent of the soil is the superior limit which most plants can endure, though 1.8 per cent is given for some. The highest percentage for water soluble chlorin obtained from any soil is 1.025; the highest percentage of total chlorin is 1.887 per cent. As the highest percentages of chlorin are scarcely above the maximum of tolerance for some plants and these have been obtained from two small spots only, the question of chlorin may be neglected in considering the bigger features of the subject even if applicable to these isolated examples.

It is a fact recognized only by a few persons so far that we have in Colorado some very serious problems. On some of our soils the agricultural results, even under the best of practice, present surprises and disappointments. A well trained and experienced agriculturalist made the remark very recently that the results from an agricultural standpoint grew worse instead of better as the practice of the people approached more nearly to those standards which have been and are recognized as the best. This is no exaggeration but represents a real difficulty. Melon growers have noticed for several years that their old grounds have not been producing the same good grade of melons that they produced in former years. In some sections the quality of the sugar beets has shown a falling off. These are general effects the causes of which may or may not be difficult to trace out. It is in specific cases of injury, in exaggerated cases of the operation of such causes that we may best succeed in tracing them and such is the case in this matter. The diffused action over square miles is not intense enough to make definite recognition or a reasonable interpretation of the facts possible. It is only by the aid of extreme cases that we acquire the data whereby to interpret the ordinary manifestation of the cause. In looking over a field in a high state of cultivation, especially a few days after irrigation, the appearance of broad brownish lines just at the outer edge of the irrigation furrows is not a striking feature and usually would be interpreted that the land had been heavily fertilized, or was rich in humus matter, but under no consideration that it might be indicative of danger. My attention was directed to a melon patch last season, 1909, which was sick, this is the term used. There was no rust, no insects, nothing visible to indicate disease. The melon plants were, however, puny and unthrifty. The soil was in fine condition and had been cultivated for several years and fertilized. A melon patch on adjoining land which had been in alfalfa was healthy and vigorous. These plots were separated by the usual wire fence; the soil was the same; the water used for irrigation the same; the cultivation in both cases was excellent; the men were not new hands at growing melons, the only difference was that the one patch was on a piece of recently broken alfalfa ground and the other on ground that had been cropped for several years. There were no features of either soil which would suggest to anyone not conversant with certain facts, that there was any difference in these fields suggestive of any explanation for the difference in the growth of the plants. It was only after having these certain facts forced on my attention for years that they really became suggestive to me.

The brown lines along the edge of the irrigation furrow might mean heavy fertilization with barnyard manure; it might be due to other perfectly harmless if not beneficient causes, but in these cases they are probably significant of the causes producing the difference in the growth of these young plants. We do not hope in the present bulletin to succeed in tracing out general relations, this is a work for the future concerning which we only promise that it will be prosecuted diligently, with the care and conservatism that its importance demands. It is proper that we should meet the questions presenting themselves in our agricultural practices with only one view, to find out the facts as they obtain at the time without predicting results; though they seem to be already certain and only lack verification. For these reasons no attempt or but little attempt, will be made to more than set forth some facts which have been established, reserving much detail work and the extension of this work in bacteriological lines for the future. Work of this kind is already in progress and some results have been attained, but the work is not ready for publication.

No one can foresee what the problem of the fixation of an excessive amount of nitrogen in our soils may develop into, whether it means the introduction of a new practice or a serious difficulty which we may not be able to control. It may for a while present difficulties because we know but little about such a thing. But if it should prove to be a permanent condition in our soils I am certain that we shall be able to find some remedy perhaps not immediately, but quickly.

Fortunately the trouble expressed itself locally with great violence during May and June of 1909. By fortunately it is not meant that it was a good thing that certain persons suffered loss but simply that the loss was so severe that the people of whole neighborhoods have seen with their own eyes, that something is very seriously wrong, for the sudden death of a large portion of an orchard is convincing proof of this. At this time the foliage of many trees, apple trees mostly, showed a burning, beginning at the apices of the leaves, extending rapidly along the margins until the whole leaf had turned brown and was of course killed. Many trees died from this cause. Plate I shows leaves with burned edges. 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 lower lying portions of higher lands and again on 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 deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films.

The preceding gives in a very general way the big features of the question forming the basis of this bulletin. We have certain soils, quite generally distributed throughout the principal sections of the state, which develop what is popularly known as "black alkali" but the popular judgment in regard to the cause of the dark color is wholly wrong because they have adopted the term from California, where it has a fixed and definite meaning, which is not applicable to our case. While it is not advisable to do so we may occasionally use the term because these dark spots are designated by the people as "black alkali." Nitre spots will, however, be used as the equivalent of the popular term "black alkali." We have so far as is now known, no land, unless it is some near a peat bed, to which the term "black alkali" properly applies.

Reports of black spots on which "nothing will grow" have been received at this department quite frequently during the past four years, and occasionally prior to that time. While at work in the San Luis Valley several years ago, my attention was called to what was supposed to be indications of petroleum. We drove through a small section of the country and observed quite a number of round, black spots absolutely devoid of vegetation, the surface was glistening and appeared as though wet. It was frequently the case that these bare areas were occupied by an ant hill but a great many of them were not. I mention this because I thought at first that the ants might have something to do with the color and appearance of these spots, but there were too many spots without ant hills in order that this should hold true.

Samples from the surface of these spots proved to yield 13.4 per cent of their air dried weight to water, and on evaporation this soluble portion proved to be so deliquescent that it could not be evaporated to dryness at 100° C. and was finally dried at 160° C. at which temperature it smelled faintly acid. Incipient decomposition had taken place. This analysis, as all of those given in this bulletin, presented some difficulties, which every chemist will recognize and for this reason moisture, organic matter, etc., have simply been given as loss.

ANALYSIS I.

WATER SOLUBLE PORTION OF SOIL FROM BLACK SPOTS.
Laboratory No. 584.

	Per Cent.
Calcic Sulfate	46.883
Sodic Chlorid	10.032
Calcic Nitrate	12.072
Magnesic Nitrate	17.878
Sodic Nitrate	6.038
Potassic Nitrate	5.871
Silicic Acid	0.365
Loss (water, organic matter, etc.)	0.861
	100.000

The sum of the nitrates is 41.859 or 5.628 per cent of the surface soil.

This analysis represents a spot possibly 12 feet in diameter and almost circular. This is, taken alone, no large area but there were a number of these spots all entirely devoid of vegetation, most of them black and glistening. There were others occurring under different conditions, namely, as round or elliptical, somewhat elevated spots and these, too, were unproductive, but there was a zone about the edges of these spots where oats, barley, and wheat grew luxuriantly. Many other anomalous things were met with in this section of the state. In some places there were no apparent reasons why crops should not, but they did not grow. In others there was some alkali but the amount of it was less than in others where the crops, not necessarily the same crops, were very good. An analysis of this alkali showed it to be essentially sodic sulfate with some sodic chlorid, about 5.5 per cent of the water soluble, and a relatively large amount of potash with some lime and magnesia. Neither the quantity nor the composition of this alkali affords a satisfactory explanation for the very bad condition of the crops. Only the alkali was collected at this place with as little soil as possible, the idea being that it was probably the composition and not the quantity of the alkali that might be producing the trouble. Twenty per cent of it was soluble in water, and ninety per cent of the soluble consisted of sulfates, six per cent of chlorids and about three and a half per cent of silicic acid, etc. The presence of nitrates was not suspected but subsequently it proved that the water soluble portion gave a strong reaction for nitric acid. This is suggestive only and not conclusive that nitrates might have been present in sufficient quantity to have caused the poor growth of the barley.

The explanation for the barren condition of these spots seems plain after the analysis of the surface portion of one of them revealed the presence of a little more than 5.5 per cent of nitrates. The suggestion that nitrates might have injured the barley seemed at first almost absurd but the fact that a few grams of earth taken from the surface of the field contained nitrates enough to give a strong reaction for nitric acid with ferrous sulfate removed the absurdity of the idea and indicated that it might have been the case.

Complaints of brown spots "on which nothing will grow" have been common, more so of late years than formerly. This may mean that the spots are becoming more common or that the land having increased in value more attention is paid to them. The former is probably the case as the complaints are coming from different places and often state that alfalfa, for instance, is dying in spots.

The case of a young orchard of 20 acres presents many interesting points. The trees were first set in 1906, in the spring of 1907 many of them were reset especially in a strip beginning at the N. E. corner and running almost directly southwest through the orchard. These trees likewise died and this strip is in no better condition now than it was then. The surface of the ground was brown, not only had the trees died, but all sorts of vegetation. The ground was bare and has continued in this condition till the present time. The surface presented no other points indicative of any abnormal condition, i. e., than the brown color and its total unproductiveness. Had this soil been plowed and harrowed, no one, however proficient in judging of land, even of alkali lands, would for a moment have suspected that this was other than a very desirable piece of land. I have been on this land and could scarcely believe the things that I knew to be facts. The land had been recently disced and it was only by looking rather closely for the signs which I had recognized as suggestive that I could convince myself that the trouble had not disappeared. The one important fact that remained was the presence of dead trees. The death of these trees was not due to neglect or abuse or the lack of any care that good judgment dictated might be needed to make them grow. There was but little or no efflorescence on the surface. There was in some spots a little incrustation, very slight, but this was brown rather than white. For the sake of convenience the surface soil on which this occurred is designated in my notes as efflorescence on brown spot. This spot was barren. There was no free water at a depth of 2½ feet. But below this point the ground was very wet and one could push an auger down for several feet without turning it. This condition will be described a little later. This sample of surface soil with its incrustation yielded 22.466 per cent soluble in water. We will designate this orchard as No. 1.

ANALYSIS II.

WATER SOLUBLE PORTION OF SURFACE SOIL. Orchard No. 1.

	Per Cent.
Calcic Sulphate	4.462
Potassic Sulphate	2.557
Sodic Sulphate	39.852
Sodic Chlorid	12.626
Sodic Nitrate	29.114
Silicic Acid	0.054
Loss (water, organic matter, etc.)	4.789
	100.000

The sodic nitrate or its equivalent constitutes 6.54 per cent of this surface soil. The first impression, especially in the field, was that salt, sodic chlorid, was the cause of the trouble, but the analysis reveals the presence of another salt which is beyond all question not only more toxic but present in more than double the quantity.

The next sample was taken immediately below the preceding and included the next four inches of soil. The air dried soil yielded 3.4 per cent of salts to water.

ANALYSIS III.

WATER SOLUBLE PORTION OF THE FIRST FOUR INCHES OF SOIL.
Orchard No. 1.

	Per Cent.
Calcic Sulphate	11.769
Magnesic Sulphate	3.748
Sodic Sulfate	21.447
Sodic Chlorid	20.797
Sodic Nitrate	32.552
Loss (water, organic matter, etc.)	9.687
	100.000

The organic matter in this sample was very abundant. The nitrates calculated as sodic nitrate equal 1.107 per cent of the air dried soil.

The next sample was collected in a spot occurring in an alfalfa field, belonging to the same party and west of Orchard No. 1. This spot was quite wet, though it had received no irrigation for about five months. The sample was taken in April, 1908, and to the depth of five inches. The air dried material yielded 7.778 per cent of its weight to water. The residue was quite deliquescent. Dried at 110° it smelled faintly acid.

ANALYSIS IV.

WATER SOLUBLE PORTION SOIL FROM ALFALFA FIELD.
West of Orchard No. 1.

	Per Cent.
Calcic Sulfate	21.448
Calcic Chlorid	17.295
Magnesic Chlorid	12.708
Potassic Chlorid	1.641
Sodic Chlorid	6.612
Sodic Nitrate	33.066
Iron and Aluminic Oxid	0.089
Silicic Acid	0.173
Loss (water, organic matter, etc.)	6.968
	100.000

The amount of calcic and magnesic chlorids in this soil is quite surprising. The presence of these salts in a soil extract is quite rare with us. I have met with a few other instances in which these chlorids constitute a considerable portion of the aqueous extract of the soil; in an extreme case it proved that they constituted a little over 55.0 per cent of the aqueous extract; there was in addition to these 25.5 per cent of sodic and 3.8 per cent of potassic chlorid, or a little over 84.3 per cent of chlorids in all. This sample contained a heavy trace of nitric acid but was not collected in Colorado. We will find in this investigation a few samples which carry even larger percentages of calcic and magnesic chlorids than the one whose analysis is given above. The nitrates in this sample constitute 2.571 per cent of the air dried soil. It is remarkable that the surface soil should contain so large an amount of the very soluble nitrates and chlorids considering its wet condition. The alfalfa was dead but the crowns had not yet entirely rotted, indicating that they had died recently and that the present conditions had not obtained for any very long period. The study of conditions in this alfalfa field was not prosecuted further as the orchard presented better conditions for our purposes and it is impossible to study every instance of these conditions which presents itself.

The next sample was taken 60 feet north and west of the first orchard sample, analysis No. II., to a depth of eight inches.

There was no efflorescence or crust on the surface of the soil at this point and also no vegetation. The water soluble portion equalled 1.87 per cent of air dried soil.

ANALYSIS V.

WATER SOLUBLE PORTION, SURFACE EIGHT INCHES.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	14.319
Calcic Nitrate	26.622
Magnesic Nitrate	6.443
Sodic Nitrate	21.277
Sodic Chlorid	25.224
Loss (water, organic matter, etc.)	6.115
	100.000

The nitrates equalled 1.016 per cent of the air dried soil.

Sometimes there is an incrustation, it may be light or heavy, and underneath this there is a mealy mass of soil particles and minute crystals. At other times the surface soil itself is mealy, a peculiar condition which is often expressed by likening the soil to ashes, not always an apt comparison but sometimes an exact description of the condition, especially if the soil is very dry. A sample of mealy soil was taken from this orchard. The soil was slightly incrusted without efflorescence and was mealy beneath the thin crust. The sample was taken to a depth of four inches. The water soluble equalled 5.372 per cent of the air dried soil. The residue was quite deliquescent and smelled acid when dried at 110° for 1 and 3-4 hours.

ANALYSIS VI.

WATER SOLUBLE PORTION MEALY SOIL, FOUR INCHES DEEP.

Orchard No. 1.

	Per Cent.
Calcic Sulfate	19.756
Calcic Chlorid	2.598
Magnesic Chlorid	8.216
Potassic Chlorid	2.117
Sodic Chlorid	27.466
Sodic Nitrate	33.617
Iron and Aluminic Oxid	0.043
Silicic Acid	0.026
Loss (water, organic matter, etc.)	6.161
	100.000

The nitrates constitute 1.706 per cent of the air dried sample.

The next sample represents the foot of soil succeeding the preceding one or from the 5th to 17th inch inclusive. The water soluble equalled 1.161 per cent of the air dried sample.

ANALYSIS VII.

WATER SOLUBLE, 5TH TO 17TH INCH INCLUSIVE.

Orchard No. 1.

	Per Cent.
Calcic Sulfate	27.456
Magnesic Sulfate	11.245
Potassic Sulfate	2.753
Sodic Sulfate	1.688
Sodic Carbonate	2.255
Sodic Chlorid	29.712
Sodic Nitrate	19.431
Iron and Aluminic Oxid	0.089
Silicic Acid	1.052
Loss (water, organic matter, etc.)	3.319
	100.000

The section of this soil showed alternations of light and dark sandy loam. The nitrates constituted 0.226 per cent of the air dried sample.

The next sample represents the succeeding foot or from the

18th to the 29th inch inclusive. The water soluble was 2.11 per cent.

ANALYSIS VIII.

WATER SOLUBLE, 18TH TO 29TH INCH INCLUSIVE.

Orchard No. 1.

	Per Cent.
Calcic Sulfate	49.413
Magnesic Sulfate	20.202
Potassic Sulfate	0.670
Sodic Sulfate	0.923
Sodic Carbonate	2.556
Sodic Chlorid	12.487
Sodic Nitrate	9.375
Sodic Silicate	1.371
Manganic Oxid (br)	0.141
Loss (water, organic matter, etc.)	2.862
	100.000

The nitrates in this sample which represents the lower 3-4 of the second and the first 1-4 of the third foot from the surface constitute 0.198 per cent of the air dried soil. This is the deepest soil sample taken in the orchard.

The ground water in this orchard cannot be said to present a water plane. The soil is very wet at a depth of two and a half feet and forms a real mud from this point downward, but at a depth of six feet the water came in so slowly that in order to fill a two gallon jug we had to let the hole stand open over night. A little water came in at a depth of five feet but this seemed to be an accident, for the next foot below was the same as above, simply mud. I had never seen anything similar to this condition before I began to study this subject. What the relation may be between these facts I do not know; according to what is generally believed they are more or less incompatible but they are simply facts. It is surprising that soil can be so wet and muddy for 3½ feet and we should be unable to find a proper water table within six feet of the surface, but, as stated, we were compelled to let the opening stand over night in order to obtain the sample of ground water. The ground water as obtained was slightly yellow; the total solids held in solution were 1776.95 grains per imperial gallon; loss on ignition 453.42 grains. A part of this loss is due to the presence of nitrates and is more interesting than important, because on ignition the evolution of the brown oxids of nitrogen was quite copious. This water contained 2.0 parts per million of nitrogen as nitrites, ordinary polluted water contains 0.003 parts per million.

ANALYSIS IX.

RESIDUE FROM GROUND WATER. Orchard No. 1.

	Per Cent.
Calcic Sulfate	15.164
Magnesic Sulfate	9.890
Magnesic Cholrid	11.358
Sodic Chlorid	7.225
Sodic Carbonate	1.825
Sodic Nitrate	53.299
Potassic Oxid	Trace
Iron and Aluminic Oxid	0.372
Silicic Acid	0.061
Loss (water, organic matter, etc.)	0.906
	100.000

This residue containing 53.3 per cent of sodic nitrate gives us 941.0 grains of this salt to each imperial gallon. As iodine compounds sometimes occur associated with the nitrates, I tested this residue, using 30 grams, but obtained negative results.

This gives us an idea of the conditions obtaining in this orchard which may be summarized as follows: The surface soil has a brownish color, efflorescent salts are scarcely present. There is some incrusting of the surface soil, beneath which there is sometimes as much as an inch of mealy material, soil particles and fine crystals. At a depth of two to two and a half feet the ground becomes muddy, but there is no free water to a depth of 5½ to 6 feet. There is no vegetation on parts of this ground and the young trees have failed to live. The country is quite flat but is not particularly low; it probably is not less than 50 feet above the river which flows within four miles of it. We find an abundance of nitrates in the uppermost portion of the soil, the maximum being 6.541 per cent of the soil; this soil was incrusted with some efflorescent salts, commonly called alkalis. The next, a sample of very wet soil taken to a depth of five inches, gave 2.571 per cent of nitrates. These percentages are followed by 1.706, 1.107 and 1.016, for what we may consider the first foot of soil, with 0.226 for the upper portion of the second foot and 0.198 for the rest of the soil to the depth of 29 inches.

In the next orchard which I shall designate as Orchard No. 2, we have the same conditions only greatly intensified. This is an older orchard, what is left of it, and we can see the effects more plainly than in Orchard No. 1. What was once an orchard is now absolutely barren, not so much as a weed growing on several acres of this land. See Plate II. There are a few trees remaining in one corner and a few isolated trees on one edge. These will have a great interest for us. The first samples from this orchard were taken in 1907. The soil was glistening, brown and apparently wet on the surface but was really dry. Mr. Whipple who was with me dug a hole close to a small apple tree which was already so good as dead. No water was met with at a depth of three feet; the soil was wet but not sufficiently so to drown the tree; at this place the soil was somewhat sandy. An excavation had been made, but not recently, for the cellar and foundations of a house, this excavation was over three feet deep but contained no water. This was a surprise to us at the time, especially as we had found the soil only a short distance away so wet. Six months later we found the conditions essentially the same; except worse if anything. There were portions of the ground on which there was a crust about 3-16 of an inch thick and beneath this from 1½ to 3 inches of the mealy mixture of soil and crystals. Below this the soil was practically mud, but, as in Orchard No. 1, we had to dig to a depth of six feet in order to obtain a sample of ground water. The crust in this case was not the ordinary crust of effloresced salts accumulated above and easily separated from the soil, but was the soil particles cemented together by the salts present in it. This crust contained 12.523 per cent soluble in water.

ANALYSIS X.

WATER SOLUBLE PORTION OF CRUST. Orchard No. 2.

	Per Cent.
Calcic Sulfate	8.523
Calcic Chlorid	27.388
Magnesic Chlorid	25.875
Potassic Chlorid	1.581
Sodic Chlorid	16.511
Sodic Nitrate	19.822
Iron and Aluminic Oxid	0.223
Silicic Acid	0.077
	100.000

This analysis has been calculated to 100 because on drying the mass I found that I could not heat it above 110° C. without change and at 110° only a part of the water was driven off. It was therefore necessary to analyze the material as it was and calculate the results to 100 as I have done. The nitrates make up 1.482 per cent of the air dried soil.

The next sample was taken to a depth of 1½ to 3 inches below the crust given above. The water soluble portion equalled 8.44 per cent. The following analysis has been computed to 100 for the same reason given for the preceding analysis.

ANALYSIS XI.

WATER SOLUBLE PORTION OF MEALY SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	15.058
Calcic Carbonate	1.755
Calcic Chlorid	23.158
Magnesic Chlorid	25.532
Potassic Chlorid	1.667
Sodic Chlorid	17.014
Sodic Nitrate	15.421
Iron and Aluminic Oxids	0.130
Silicic Acid	0.265
	100.000

The nitrates constitute approximately 1.301 per cent of the air dried mealy soil.

The next sample was taken from another part of the orchard about six months prior to the taking of the two preceding samples and shows in an unusual measure the variability in the character of the salts present in the soil. The area involved is several acres. I suppose that there are 40 acres at least in this piece of land but I do not know how much of it is involved in this trouble. I estimate the portion that I am familiar with at 10 or 12 acres and very much more in adjoining lands. This sample was taken to a depth of one foot. Water soluble equalled 6.51 per cent. The ground is entirely barren where this sample was taken..

ANALYSIS XII.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	13.072
Magnesic Sulfate	4.928
Sodic Sulfate	7.691
Sodic Chlorid	27.609
Sodic Nitrate	43.578
Loss (water, organic matter, etc.)	3.122
	100.000

The nitrates in this foot of soil amounted to 2.837 per cent of its air dried weight. This indicates the presence of 49.5 tons to the acre foot.

This soil is very wet except the surface portion to a depth of three or four inches, below this point it becomes muddy; even worse if anything than Orchard No. 1. At a depth of about six feet water came into the hole that we dug, very slowly. We were able to get two gallons of water in about an hour. This water contained 2250.01 grains per imperial gallon; the loss on ignition was 375.5 grains.

ANALYSIS XIII.

RESIDUE FROM GROUND WATER. Orchard No. 2.

	Per Cent.
Calcic Sulfate	22.077
Magnesic Sulfate	14.405
Magnesic Chlorid	0.833
Potassic Chlorid	0.441
Sodic Chlorid	44.492
Sodic Carbonate	1.741
Sodic Nitrate	10.545
Iron and Aluminic Oxids	0.256
Silicic Acid	0.067
Loss (water, organic matter, etc.)	5.143
	100.000

Each imperial gallon of this ground water contains 237.0 grains of sodic nitrate. The ground water from Orchard No. 1 contained 941 grains, almost exactly four times as much.

The next place studied included both orchard and non-orchard land, but for the sake of convenience we will designate it as Orchard No. 3.

This is, in some respects, the most interesting case that I have studied because I have been able to obtain its history. The land showed some spots 17 years ago on which there appeared to be too much alkali. Some of the spots grew nothing but at their outer edges things grew well. The owner stated that he had often stood on a barren spot and thrown his hat in the air so that it would fall on the grain at the edge of the spot and lodge on the heads of the grain. This man had tried to wash it off; he had turned a furrow, followed with a subsoil plow and then turned in a hundred inches of water and washed it clean. His farm is beautifully leveled. He had also manured heavily but he has not yet conquered these spots. He states that in the 16 or 17 years past he has set one piece to young trees two or three times and there are no living trees there now. In June, 1908, I took a set of samples from this piece of ground. The top three inches is described as alkali and mealy soil. This three-inch section was removed and taken as one sample. Water soluble equalled 5.04 per cent.

ANALYSIS XIV.

WATER SOLUBLE PORTION OF ALKALI AND MEALY SOIL.
Orchard. No. 3.

	Per Cent.
Calcic Sulfate	14.247
Magnesic Sulfate	4.464
Potassic Sulfate	2.459
Sodic Sulfate	6.849
Sodic Chlorid	33.607
Sodic Nitrate	35.582
Silicic Acid	0.208
Loss (water, organic matter, etc.)	2.584
	100.000

Here the nitrates equalled 1.793 per cent of the air dried weight of the mass.

After removing the three inches of alkali and mealy soil, I took the next 12 inches as a soil sample. The water soluble amounted to 2.97 per cent of the air dried material. This spot had been barren for 16, now 18, years. I saw it a few weeks ago and it is barren still.

ANALYSIS XV.

WATER SOLUBLE, 4TH TO 15TH INCH INCLUSIVE. Orchard No. 3.

	Per Cent.
Calcic Sulfate	15.902
Magnesic Sulfate	2.942
Potassic Sulfate	3.387
Sodic Sulfate	15.264
Sodic Carbonate	4.813
Sodic Chlorid	34.145
Sodic Nitrate	22.781
Silicic Acid	0.252
Loss (water, organic matter, etc.)	0.471
	100.000

The nitrates in this sample equalled 0.676 per cent of the air dried material. I subsequently dug a hole in this piece of ground at the height of the irrigating season, not at this same spot but near it, to see if I could find the water table. I dug to a depth of six feet and found only moist, sandy soil.

The next sample was taken by the owner and sent to me. He stated it was taken from another barren spot and to a depth of one foot. Water soluble equalled 3.33 per cent of air dried soil.

ANALYSIS XVI.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL.
Orchard. No. 3.

	Per Cent.
Calcic Sulfate	5.459
Magnesic Sulfate	1.086
Potassic Sulfate	2.557
Sodic Sulfate	49.260
Sodic Carbonate	2.285
Sodic Chlorid	23.897
Sodic Nitrate	11.762
Silicic Acid	0.111
Loss (water, organic matter, etc.)	3.583
	100.000

The nitrates make up 0.392 per cent of the air dried soil in this case. This is one of the spots in which the owner amused himself by standing and casting his hat in the air to see it fall on the grain so rank and stiff-stemmed that it held up the hat.

The next sample is one taken by myself in an alfalfa field on the same ranch. The spot was quite wet and barren. Sample taken three inches deep. Water soluble equalled 10.572 per cent.

ANALYSIS XVII.

WATER SOLUBLE, FROM ALFALFA FIELD. Orchard No. 3.

	Per Cent.
Calcic Sulfate	6.968
Magnesic Sulfate	6.490
Potassic Sulfate	2.526
Sodic Sulfate	45.168
Sodic Carbonate	1.513
Sodic Chlorid	26.116
Sodic Nitrate	4.056
Silicic Acid	0.458
Loss (water, organic matter, etc.)	6.705
	100.000

The next sample is from another orchard, Orchard No. 4. Had the owner not set this land to apple trees the probabilities are that no notice would have been taken of the fact that there was something wrong with the soil. The care bestowed on a young orchard is greater perhaps than that bestowed on ordinary crops. This accounts for the fact that we find these troubles so frequently in apple orchards; it is not that they do not exist elsewhere, for they do. This young orchard contained, it may be, 20 acres, sloping to the south and west. The land is quite high. Some years ago there was a reservoir in the northeast corner of this piece of ground but it had been abandoned for several years, at least four, before the orchard was set. The soil is a clayey loam, but varies somewhat in different parts of the tract. A shale underlies the whole or the greater portion of it at no considerable depth. There is a little draw running southwest and south through the orchard. It begins near the north side and somewhat east of the middle line and extends almost to the southwest corner of the orchard. The area involved in the spring of 1909 was about four acres. By autumn it had increased to nearly double or about eight acres. The land had previously been in alfalfa which, according to my infromant, had ceased to do well in this portion of the field. Up to this time only preliminary work has been done on this particular orchard and it is given for the reason that it presents entirely different conditions from any presented so far. In March, 1908, I found the surface soil a mealy mass. The conditions at the time did not afford opportunity for me to judge of the color of the soil. There was no incrustation; a scuff with the foot would reveal the fact that the dirt which seemed to be ordinary soil was a mixture of soil and crystals of some sort, for they glistened strongly in the light, and clear sunshine was not necessary. I took a sample to a depth of two inches. The water soluble was 8.23 per cent of the air dried mass.

ANALYSIS XVIII

WATER SOLUBLE FROM SURFACE SOIL. Orchard No. 4.

	Per Cent.
Calcic Sulfate	18.986
Magnesic Sufate	29.771
Potassic Sulfate	1.387
Sodic Sulfate	39.914
Sodic Chlorid	1.474
Sodic Nitrate	8.173
Silicic Acid	0.295
	100.000

The nitrates make up 0.673 per cent of the air dried mass. The results of this analysis were what I expected after I had examined the conditions in the orchard.

The next sample is our Laboratory No. 680, and is not from an orchard but from an oat field. The owner had previously written to me concerning this land. I could not go to inspect it at the time but in February, 1908, I was near this place and went to see it. The chief trouble was seepage, but above the seeped area were other conditions, the surface of the ground was puffed up and mealy. I took a sample of the surface soil to a depth of two inches, water soluble equalled 5.42 per cent. I was compelled to dry the residue obtained on evaporating the aqueous extract to dryness at 140° in order to pulverize it; it puffed up, intumesced, and possibly suffered incipient decomposition.

ANALYSIS XIX.

WATER SOLUBLE PORTION. Laboratory No. 680.

	Per Cent.
Calcic Sulfate	9.919
Calcic Nitrate	10.053
Magnesic Nitrate	17.290
Potassic Nitrate	1.159
Sodic Nitrate	21.719
Sodic Chlorid	38.179
Iron and Aluminic Oxids	0.129
Silicic Acid	0.093
Loss (water, organic matter, etc.)	1.459
	100.000

The nitrates in this surface sample equalled 2.722 per cent of the air dried soil; this is a trifle over 50 per cent of the total soluble salts. It may interest someone to learn that I visited this place in the early spring of 1909 and could see no signs of any trouble whatsoever beyond the fact that a portion of the field was undoubtedly seeped. I visited it again later and the present owner who is a stranger to me, was cultivating it preparatory to planting it to beets and there was nothing suspicious, even to one acquainted with the facts, except the seepage. I visited it again when the beets were almost ready to harvest. There were great bare spots surrounded by beet tops of very luxuriant growth. See Plate V. The bare ground was mealy and excessively rich in nitric acid or nitrates. We must defer further statements concerning this till we have done more work.

Our Laboratory No. 588 is a very alkaline soil collected in an old orchard. The soil is a red mesa soil, grows alfalfa, potatoes, wheat, etc., well. The section is in very bad condition and seeped though the mesa is high above the river. The surface of the mesa makes this possible. The water soluble in this soil was 6.65 per cent.

ANALYSIS XX.

WATER SOLUBLE PORTION. Laboratory No. 588.

	Per Cent.
Calcic Sulfate	20.169
Magnesic Sulfate	6.585
Sodic Sulfate	38.872
Sodic Chlorid	23.751
Sodic Nitrate	4.006
Potassic Nitrate	1.740
Sodic Silicate	0.539
Loss (water, organic matter, etc.)	4.338
	100.000

The nitrates correspond to 0.382 per cent of this soil.

The next sample is Laboratory No. 595, and was gathered as a sample of alkali. The spot was quite destitute of vegetation except for the presence of a few greasewood, sarcobatus plants, and a few surviving alfalfa plants. I have visited this place twice since this sample was collected to observe whether the spot is increasing in size. I found this to be the case. Only so much of the soil was taken as was necessary to get a fair sample of the surface alkali, perhaps an inch. This was a new locality for alkali, so far as my record was concerned and the sample was taken without any regard to the presence or absence of nitrates; it was collected in 1907.

ANALYSIS XXI.

ALKALI. Laboratory No. 595.

	Per Cent.
Calcic Sulfate	9.102
Magnesic Sulfate	8.076
Sodic Sulfate	56.254
Sodic Chlorid	22.609
Sodic Silicate	0.308
Sodic Nitrate	2.771
Loss (water, organic matter, etc.)	0.880
	100.000

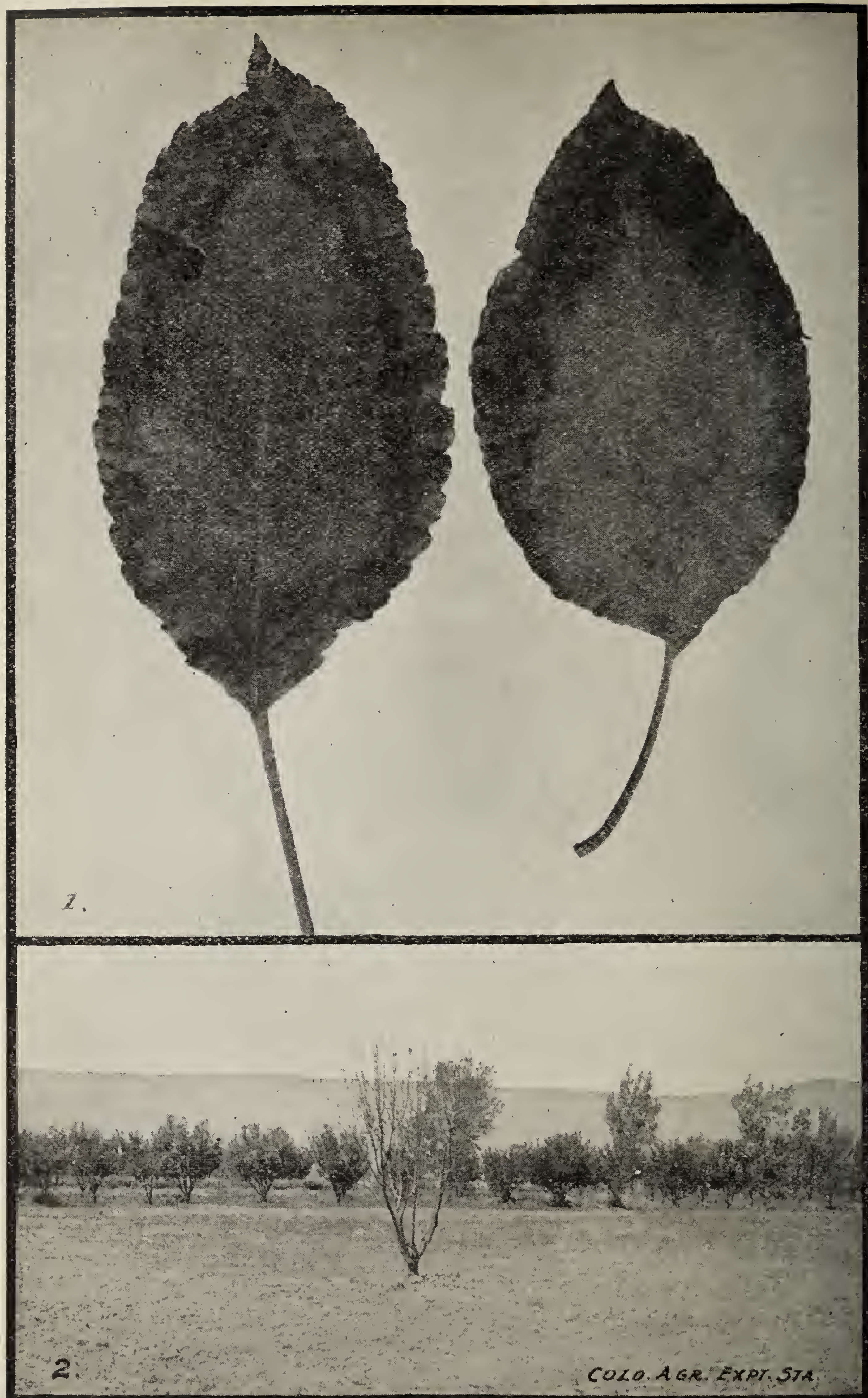
The question of the relation of the greasewood to the alkali question, sodic carbonate in particular, has been discussed somewhat by Prof. Hilgard and others. The association of this plant with the last sample suggests the question whether it might have anything to do with the appearance of the nitric acid in this alkali.

In some cases there is no question about the occurrence of sodic carbonate in dark soils about old clumps of greasewood, but in this case the occurrence of the nitrate in dark, brown soils and the very dark color often noticed in the soil about these old clumps suggests the question whether the greasewood has anything to do with this occurrence. I found a very marked case of a mass of dark soil where such a clump had died and which was evidently very rich in alkali. This was quite near an area where I knew that nitrates occurred in large quantities so I thought it worth while to test the matter. The result was that the soluble salts found to be present were the sulfate 35.248 per cent, carbonate 37.065 per cent, and chlorid of sodium 27.687 per cent, with only a trace of nitric acid. This was the result expected except that the trace of nitric acid was unlooked for under the conditions. Apropos to the occurrence of nitrates in alkalis we have found small quantities of nitrates in others than the one given above but we have not found them always present. Alkalis from these districts may be entirely free from nitrates.

The samples so far given have been of soils or ground waters, the localities of which I have not given and I have purposely avoided giving names. I conceive that the circumstances require that I should do this. I have been requested again and again not to publish the names of owners and places and I believe that it is just that I should not, for while it looks, in many cases, desperate for the future, conditions may change. Some means of remedy may be found whereby what now seems an inevitable result may be avoided.

I have seen instances of these occurrences of nitrates near the southern and within 40 miles of the northern boundary of Colorado and likewise from its eastern to its western boundary. The analyses already given and those to be given, represent many sections, but it is not to be inferred that all or any more than a very small percentage of the agricultural lands of Colorado are in the least endangered. While the matter is serious enough, it by no means amounts to a justification for evil forebodings. I am not at this time prepared to state how we will combat this condition, but I believe that there will be some way. These remedial questions are for the immediate future; the trouble itself has, as yet, only been pointed out.

I will give some cases in a general way but must avoid names and places. A small piece of land, a sandy loam, near and some 12 or 15 feet above the river has a dark brown color and has not been productive for several years. This land has received good cultivation, the application of much barnyard manure, and excessive irrigation in the hope that the "black alkali" would be washed out. This ground is not absolutely barren but some spots in it are nearly



Plates I and II. See Pages 6, 13, 42, 43 and 44.

so. A sample of this soil which was taken by the owner and delivered to me contained 1.262 per cent of water soluble which contained nitric acid equivalent to 11.230 per cent of sodic nitrate, equivalent to 0.142 per cent of the air dried soil. If this sample had been taken to a depth of a foot, which it very probably was, how much would it mean to the average man? Very little so long as it is expressed in tenths of one per cent of the soil. It will mean more to him, perhaps, if we state that this is a piece of very bad land containing 5,680 pounds, 2.84 tons, of sodic nitrate or its equivalent of nitric acid in the top foot of soil. I found on this piece of land an excellent illustration of the mealiness which I have already mentioned several times. The adjoining piece of land on the north is in even worse condition than this, spots in it are barren.

Another case was observed in an alfalfa field under and near a ditch. We are prone to blame seepage for as many of our troubles as possible and I am personally no exception, but I am sometimes conscious that I am trying to give a reason to avoid the labor of finding out a cause. In this spirit I judged the cause of the dead spots in this alfalfa to be due to seepage. The ditch was there; there was water enough; the ditch was higher than the ground. Of course it was simply another case of seepage. I, however, thought it might be well to prove this thing. On examining the ground and digging a hole of some depth my faith in my theory disappeared. I was not at all satisfied about the relation of seepage to the death of the plants. I took a sample of the soil and found that 5.73 per cent of its weight was soluble in water and that this soluble part contained nitric acid corresponding to 27.259 per cent of sodic nitrate or calculated on the air dried soil 1.522 per cent or supposing this soil to have been taken to a depth of four inches it means that there would be 20,290 pounds, 10 1-4 tons, on each acre. If one should spread 10 1-4 tons of Chile-saltpetre on an acre of ground we would not need to appeal to seepage to account for any unproductiveness of the soil which might follow. After a number of such experiences I have concluded that it is not wise to be too certain about the direct and universal effects of seepage. The same remark applies to the effects of alkali. I am quite convinced that I have not seen in Colorado a single instance in which it was even very probable that our ordinary alkali, not this so called "black alkali," has of itself been the cause of the death of any plant. An excess of water in the soil, especially in cases where it continued for a long time, may have been.

These occurrences are not confined to Colorado soils. Two samples of soil received from Brawley, California, were strongly impregnated with alkali and their aqueous extracts reacted for nitric acid with sulfuric acid and ferrous sulfate. Neither the size nor location of the spots relative to the surrounding surface nor the condition of the vegetation was given. The clumps of one of the samples showed distinctly a thin, white incrustation on their upper surfaces. The sample was quite sandy and judging from the clumps of soil had been taken to a depth of from one to two inches. The second sample was quite different in character and described by the sender as being always moist.

The sample numbered one and described as white alkali soil contained 8.886 percent of water soluble salts. The nitric acid in this soluble portion corresponded to 3.939 percent of sodic nitrate or 0.350 percent of sodic nitrate calculated on the air dried soil. This corresponds to 2,333 pounds of sodic nitre in the surface two inches of soil per acre. I do not know anything about the size or location of the areas represented, nor do I know the condition of the vegetation in or about the places where the samples were collected.

One of the samples was a sandy soil and was very probably taken to only a very shallow depth. The sender says that it was scraped up. I would judge from the thickness of the clumps in the sample that from one to two inches of the surface soil had been taken.

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 in 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. Two instances of the occurrence of nitre suggest themselves, one of which is on the side of a hill, and the other on a little reach of rising land at the foot of a hill. It is at least 10 feet higher than land 200 yards away, in short, it is on the gently sloping portion of a hill. These two instances are very far removed from any other occurrences so far mentioned and are nearly 300 miles apart. These occurrences are furthermore very rich in nitrates.

The next sample is an alkali collected from the face of a shale bank from which issued the seep or drainage from an irrigated mesa. The water issuing from this bank contained 176.96 grains total solids per imperial gallon, ignition 21.42 grains. There are no carbonates present. The efflorescent alkalis on this shale bank were white and consisted essentially of magnesic and sodic sulfates, but carried about 2.3 per cent nitrates.

The last sample naturally suggested the examination of other waters issuing from the shales underlying irrigated mesas. The same point had been reached, starting from an entirely different point of departure, i. e., the search for an answer to the question, how much alkali may an irrigation water contain without detriment to the land to which it is applied? No attempt is made to answer this question at this time; it suffices that no one has yet complained with good cause that he has reached the injurious limit. An inspection of the next two analyses will indicate clearly why they are given in this place. The land was planted to corn and rye. It had passed into the hands of a man who had no experience with irrigation; the water was handy and plentiful, the people on the mesa above had only a moderate supply of water or there would have been more. The corn had been rather deeply furrowed for the purposes of irrigation. There was a band of efflorescent alkalis at least two inches wide on the side of each furrow. My curiosity was excited to find some reason why the corn should grow at all and not die. The rye was dying, but the corn was in pretty fair condition, which was a matter of surprise. Inquiry elicited the fact that small stuff had been a failure on this ground. I took a sample of the worst of this surface soil where even the corn, which seemed to have endured better than anything else, had almost failed. The irrigation was very excessive. The sample of soil yielded 4.67 per cent of water soluble, which gave me the following analysis: The determination of NO was made four times, because at the end of the reaction there was a rather copious evolution of CO_2, more than the sodic hydrate in the measuring tube could readily absorb.

ANALYSIS XXII.

WATER SOLUBLE PORTION. Laboratory No. 589.

	Per Cent.
Calcic Sulfate	16.645
Magnesic Sulfate	14.518
Potassic Sulfate	2.360
Sodic Sulfate	35.731
Sodic Chlorid	19.914
Sodic Nitrate	7.352
Sodic Silicate	0.328
Loss (water, organic matter, etc.)	3.152
	100.000

The nitrate according to this analysis is 0.342 per cent in this portion of the soil. This can only be considered as an approximate result. The big fact is that nitrates were present in notable quantities. This land was irrigated with the seepage water which issued from or above the shale underlying the mesa. This water contained 418.2 grains per imperial gallon or 5,975.7 parts per million. No nitrites were present.

Plates III and IV. See Pages 42 and 44.

ANALYSIS XXIII.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 766.

	Per Cent.
Calcic Sulfate	27.397
Magnesic Sulfate	27.697
Potassic Sulfate	1.389
Sodic Sulfate	21.749
Sodic Carbonate	4.026
Sodic Chlorid	5.391
Sodic Nitrate	2.986
Sodic Silicate	0.401
Loss (water, organic matter, etc.)	8.944
	100.000

These two samples are more interesting in connection with this work than in connection with the purpose for which they were collected. Results like the foregoing are very disconcerting when one is seeking the limit of alkalis present in an irrigation water which may be injurious to the land or crops. The same is true in regard to the soil. It is true that this sample represented what I believed to be the worst and what according to the growth of the corn, was the worst, but the whole patch was so bad that it appeared useless to continue that study with great hope of success. The only encouragement that one could find in the case was that some things had died and that the rye was dying, but the question whether this was due to excessive salts or excessive water was impossible to determine. This digression may serve to show that our problems are far from simple and that an acquaintance with a large range of facts pertaining to our conditions does not lead to very firmly fixed convictions concerning what the facts really may be. I will add one more statement relative to this piece of ground and that is, that I saw the wheat grown on it two years later, 1900, and it yielded at the rate of 60 bushels per acre. All of which was extremely perverse from the standpoint of the theorist but very good from that of the owner.

The question of the presence of nitrates in seepage water issuing from the shales seemed to be of sufficient interest to justify further analyses. Another place was selected 80 feet below the top of the bank which was the level of the mesa. The sample was taken in the irrigating season. The water contained 557.9 grains per imperial gallon or 7,970.0 parts per million of total solids; ignition expelled 84.9 grains or 121.3 parts per million. This water was tested for free ammonia and 0.12 part per million was found. The following analysis has been calculated to one hundred.

ANALYSIS XXIV.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 739.

	Per Cent.
Calcic Sulfate	31.102
Magnesic Sulfate	26.487
Potassic Sulfate	1.210
Sodic Sulfate	21.305
Sodic Carbonate	6.101
Sodic Chlorid	8.531
Sodic Nitrate	4.972
Sodic Silicate	0.292
	100.000

The aggregate volume of water issuing from a long stretch of this shale is large and according to this analysis each gallon of 70,000 grains carries 27.75 grains of nitrates.

In looking for a place to take a sample of shale to see whether the shale itself carried nitrates a brick yard offered the best opportunity for here a face, which had been recently opened, was accessible. The overlying strata are thin but the mesa country above and back of this opening is very extensive and quite well watered. It was observed that the brick in the drying sheds were covered with an efflorescence. This consisted essentially of sodic sulfate about 88.0 per cent; nitric acid was present but was not determined. A sample of the shale 1,280 grams was extracted with water and yielded 1.4 per cent of material soluble in water.

ANALYSIS XXV.

WATER SOLUBLE PORTION OF SHALE. Laboratory No. 645.

	Per Cent.
Calcic Sulfate	32.198
Magnesic Sulfate	13.705
Potassic Sulfate	1.930
Sodic Sulfate	42.990
Sodic Carbonate	0.716
Sodic Chlorid	2.477
Sodic Nitrate	1.711
Sodic Silicate	1.081
Loss (water, organic matter, etc.)	3.192
	100.000

The nitrates calculated on the air dried shale gives 0.03 per cent. The shale presents but little of interest. The amount of nitric acid found is so small that it would escape detection in the ordinary course of analysis. Still the analysis of this shale was made and shows that there is nothing in the character of the shale itself to indicate anything unusual.

ANALYSIS XXVI.

ANALYSIS OF SHALE. Laboratory No. 645.

	Per Cent.
Carbon	1.587
Silicic acid	47.292
Sulfuric acid	1.457
Carbonic acid	11.466
Chlorin	0.053
Titanic acid	0.500
Calcic oxid	16.129
Magnesic oxid	2.271
Potassic oxid	2.389
Sodic oxid	2.884
Ferric oxid	4.052
Aluminic oxid	7.957
Water at 108°	1.699
Water at 200°	0.656
	100.392

This shale is fossiliferous, is low in silicic acid and carries a large amount of lime, but no organic matter or other source of nitric acid.

We have presented by a considerable number of samples, the question of the nitrates in the soil, in the ground waters and in some of our seepage waters. There yet remains the question of our drain waters. We have but two of these to present. One is from a water course constituting the natural drainage of the section in which it is located, the second is from a box drain laid 4½ feet deep.

The water course constitutes what is locally called a "wash." The sample was collected in October, 1907, and was made up of a mixture of water from the irrigating canal, of off flow water from irrigated fields, and of seepage or drain water. The total solids were 359.52 grains per imperial gallon or 5,164.5 parts per million; ignition expelled 115.08 grains. This wash runs through the first mesa counting from the river and the mesa back of this has not yet been brought under irrigation. The depth of soil over the shale is not great, in some places it is very shallow.

ANALYSIS XXVII.

RESIDUE FROM WASTE WATER. Laboratory No. 605.

	Per Cent.
Calcic Sulfate	20.283
Magnesic Sulfate	33.573
Sodic Sulfate	20.749
Sodic Carbonate	5.351
Sodic Chlorid	8.528
Sodic Nitrate	4.159
Sodic Silicate	0.631
Sodic oxid (excess)	0.161
Loss (water, organic matter, etc.)	5.346
	100.000

Plates V and VI. See Pages 20, 43, 44 and 45.

I do not know how much water was flowing in this stream at the time the sample was taken. Nor do I know how much the average flow of this stream may amount to. I imagine that the flow varies greatly from time to time.

The next sample is one of a drain water taken in Oct., 1907. This drain was one of the main branches of a system put in 6½ years prior to the taking of the sample for the purpose of improving a piece of ground lying to the east and south and partly to the west of a rather large orchard. In spite of the drain the bad soil conditions have encroached upon the orchard area necessitating the removal of trees till the orchard is much smaller than it was six years ago. The case of this orchard is rather peculiar. There is on the north and west sides of the orchard a wash ranging from 6 to 10 feet deep and on the east, south and part of the west side is this system of drains and yet in June of this year I saw some of the few remaining trees in the extreme southern portion of the orchard very badly burned by nitre. The drain is a box one, seven by six inches laid 4½ feet deep. The land above the orchard was boggy at the time the drain was laid. It has been unwatered to the extent that grain can be grown on the greater portion of the land. The yield on some parts of this land is excellent. The condition of the orchard as suggested is gradually becoming worse and is at this time a promising subject for study. Total solids 637.3 grains per imperial gallon.

The analysis has been calculated to one hundred.

ANALYSIS XXVIII.

RESIDUE FROM DRAIN WATER. Laboratory No. 610.

	Per Cent.
Calcic Sulfate	23.203
Magnesic Sulfate	36.662
Potassic Sulfate	0.705
Sodic Sulfate	29.991
Sodic Chlorid	2.863
Sodic Carbonate	4.093
Sodic Nitrate	2.275
Silicic Acid	0.209
	100.000

The residue gave off water and red fumes when heated in a test tube. A sample of this drain water taken in June, 1909, about 20 months later, showed the presence of 622.65 grains of total solids per imperial gallon. Loss on ignition was 99.26 grains per imperial gallon. The ammonia was found to be 0.56 part per million. The analysis has been calculated to one hundred.

ANALYSIS XXIX.

RESIDUE FROM DRAIN WATER. Laboratory No. 792.

	Per Cent.
Calcic Sulfate	22.352
Magnesic Sulfate	31.586
Potassic Sulfate	1.502
Sodic Sulfate	24.775
Sodic Chlorid	9.050
Sodic Carbonate	4.120
Sodic Nitrate	6.500
Silicic Acid	0.115
	100.000

These results show what is pretty well demonstrated by the other samples, i. e., that the presence of the nitrates in the waters is not an accidental but a regular occurrence.

I have now presented all of the analytical data which I propose to present in this bulletin to show the occurrence of excessive amounts of nitrates in certain of our soils. These occurrences are not confined to one section of the state; the samples given represent widely separated sections.

There are no data that I have been able to find relative to the amount of nitric acid, respectively nitric nitrogen, in soils in general. The most satisfactory statements have been found in the latest edition of Storer's "Agriculture." These statements are largely based on the Rothamsted experiments and give aggregate results which are very difficult to apply to our lands, or to use in answering the questions suggesting themselves. We, therefore, collected a number of samples, representing the surface portion of our soils, because it is only with the upper layers that we are concerned. The percentages of nitrates given in the preceding analyses varying from 0.2 to upwards of 5.0 per cent of the air dried samples will not appeal to some readers as large quantities, therefore we wish to know and present what some other surface soils in Colorado contain. We are aware that the content of nitric nitrogen in a soil varies from time to time and that the nitrates may be carried down to considerable depths by rain water, etc.; all of these things have but little bearing on the object had in view. We wanted to know how much nitric nitrogen we might expect in the soil to a depth of 2½ feet, for our samples have mostly been taken at less depths, in fact the most remarkable quantities have been found practically within the first half inch of soil, though some very large percentages have been found at as great depths as three inches. We determined on sampling different sections of the College farm. The samples were taken in October during a period of fine weather and no irrigation water had been applied for some weeks. Other detailed data of this character are not at my disposal. This study was entrusted to Mr. Douglass and the following is his report:

SAMPLES TAKEN TWO INCHES DEEP.

	Per Cent Nitric Nitrogen Oct. 4	Oct. 6	Oct. 16
S. of Agr'l Hall near N. end of grain field	0.00045	0.00040	0.00035
S. of Agr'l Hall near S. end of grain field	0.00085	0.00120	0.00035
S. of Agr'l Hall near W. side of grain field	0.00050	0.00040	0.00010
Beet field, Experimental Farm	0.00005	0.00005	0.00005
Unused roadway, near beet field	0.00500	0.00350	0.00100
Alfalfa plot, fallow place		0.00225	......
Beet field, fallow place		0.00120	......

SAMPLES TAKEN THREE INCHES DEEP.

October 7, 1909.

	Per Cent Nitric Nitrogen In the row	Between rows
Near a fallow spot	0.000075	0.000100
In the fallow spot		0.002800
In the row nex to the fallow spot	0.000400	....
First full row on north side near west end	0.000150	0.000050
Nineteenth row from N. side near W. end	0.000150	0.000200
Thirty-fifth row from N. side near W. end	0.000300	0.000075
First row on north side near east end	0.000500	0.000100
Forty-seventh row from N. side near E. end	0.000300	0.000150
Midway between ditch and fallow spot	0.000500	0.000150
Fifth row south of fallow strip	0.000200	0.000500
One hundred feet from S. and E. sides	0.000200	0.000100
One hundred feet from west side between ditch and fallow spot	0.000200	0.000300
One hundred feet from W. and S. sides	0.000250	0.000250
The middle of the field	0.000200	0.000075
Twenty feet south and east of fallow spot	0.000100	0.000075
Near the fallow spot	0.000150	0.000100

These samples were taken between the beets in the rows and between the rows to see whether any difference in the percentage of nitric nitrogen could be detected.

SAMPLES TAKEN TO A DEPTH OF 2½ FEET.

October 18, 1909.

	Per Cent of Nitric Nitrogen
South of Agr'l Hall near N. end of grain field	0.000070
South of Agr'l Hall near the S end of grain field	0.000350
South of Agr'l Hall near the W. side, alfalfa 1908	0.000100
Unused roadway next to the beet plot	0.001600
Between plants, alfalfa plot Expt. Farm	0.000800
In the beet plot, among the beets	0.000075

Plates VII and VIII. See Page 43.

SAMPLES TAKEN OCTOBER 18, 1909.

	Per Cent Nitric Nitrogen		
	Top 2 in.	From 2 in. to 6 in.	From 6 in. to 12 in.
South of Agr'l Hall near N. end	0.000350	0.000300	0.000200
South of Agr'l Hall near S. end	0.000250	0.000250	0.000500
South of Agr'l Hall near W. side	0.000300	0.000070	0.000100
S. Agr'l Hall 50 ft. from Col. Ave. E. side	0.000800	0.000800	0.000800
South of Agr'l Hall, middle of field	0.000500	0.000150	0.000250
South of Agr'l Hall S. W. portion of field	trace	none	trace
*Alfalfa plot, Expt. Farm	0.002000	0.000700	0.001000
Alfalfa plots Expt. Farm between plots	0.001000	0.000600	0.000800
Alfalfa plots, Expt. Farm between healthy plants	0.001000	0.000200	0.000300
Alfalfa plots, Expt. Farm stand poor	0.000600	0.000600	0.000600
Cornfield S. of alfalfa plot	0.000800	0.000250	0.000100
Unused roadway next to beet plot	0.001000	0.001000	0.001800
Beet plot, among the beets, between ditch and fallow spot	0.000400	0.000075	0.000050
Beet plot, fallow strip 150 ft. from W side	0.000800	0.000400	0.000400
Beet plot, middle of patch among beets	0.000050	0.000025	0.000025
Beet plot, S. W. corner among beets	0.000175	0.000100	0.000100
Beet field, fallow spot	0.000400	0.000300	0.000200
Beet field, southeast portion among beets	0.000250	0.000025	0.000025
Beet field, fallow strip near east end	0.003500	0.001200	0.000800
Beet field, among beets near east end	0.000150	0.000025	0.000025
Beet field, among beets N. W. corner	0.000300	trace	0.000050
Beet field, among beets middle N. side	0.000100	trace	0.000050
Beet field, among beets W. side	0.000100	0.000025	0.000050
Grain field, south of beet field	0.000500	0.000450	0.000250
Oat field, north of beet field	0.000100	0.000025	0.000050
Virgin soil Sec. 4, T. 6, R. 59 W., top 6 in		0.000800	....
Virgin soil Sec. 34, T 6, R 59 W., top 6 in		0.000800	......
Virgin soil, Yuma County, Colo		0.000120	....
Soil Lab. No. 869, Rocky Ford, Oct. 11, 1909		0.006400	....

According to these results we find rather large amounts of nitric nitrogen in our surface soils. For instance the unused road way at the edge of the beet field gave in the top two inches on October 4, 0.005 per cent nitric nitrogen. This is equivalent to 0.03 per cent of sodic nitrate, 200 pounds per acre in the surface two inches of this soil. The roadway is really only a driveway between two plots of ground and has not been used, so that there was scarcely any more probability of the results having been influenced by the voidings of animals than any spot in the beet plot itself. The sample taken two days later gave nitric nitrogen equivalent to 0.020 per cent of sodic nitrate. This would give 140 pounds in the surface two inches. I am using 6 as the factor for converting nitrogen into sodic nitrate. The more exact factor is 6.0534. On October 16, we obtained much less, 40 pounds in the same depth of soil per acre. The alfalfa plot mentioned in these notes is a young nursery, the plants are small and set, I think 3x3 feet.

*This is a young nursery; the plants are very small and occupy only a small portion of the ground.

It is almost fallow ground. The beet field was a cropped field with the beets well grown and the ground well shaded. Here we find an average of 0.0000975 per cent of nitric nitrogen not including the fallow strip for the depth of from 2 to 6 inches. This is equivalent to 7.8 pounds of sodic nitrate in these four inches of soil per acre. These examples include our extremes but these are small quantities compared with the nitrate content of the first foot of soil of Orchard No. 2, 49.5 tons, or with the soil from the 5th to the 17th inch inclusive from Orchard No. 1, 6.5 tons per acre foot. While the nitric nitrogen in the soil of the College farm is probably normally high, it is simply not comparable to the samples of soils from these orchards. The Rothamsted experiments showed that during a period of from 14 to 15 months nitric acid equivalent to 553 and 572 pounds of commercial sodic nitrate was formed in the first 27 inches of soil per acre. This included the amount removed by drainage. This would give us 0.00625 per cent sodic nitrate counting the weight of an acre foot of soil as 4,000,000 or 0.00726 per cent counting it as 3,500,000 pounds.

The general character of these soils is given by the following analyses.

ANALYSES XXX, XXXI, XXXII AND XXXIII.

	No. 724 per cent.	No. 725 per cent.	No. 697 per cent.	No. 785 per cent.
Insoluble	54.653	57.068	76.500	64.820
Silicic Acid	19.805	12.754		5.650
Sulfuric Acid	0.047	0.049	0.320	0.810
Chlorin	0.032	0.059	3.090	0.890
Phosphoric Acid	0.120	0.127	0.120	0.180
Carbonic Acid	3.048	6.312	3.470	7.040
Lime	6.100	8.465	3.490	7.180
Magnesia	1.355	1.448	2.080	2.190
Sodic Oxid	0.290	0.432	0.840	0.840
Potassic Oxid	0.872	0.742	0.590	0.690
Ferric Oxid	5.601	3.499	3.040	3.110
Aluminic Oxid	3.738	5.397	4.020	2.250
Manganic Oxid (br)	0.118	0.026	.....	.....
Moisture	.....	.....	1.370	1.470
Ignition	5.072	3.887	1.760	2.970
Sum	100.851	100.265	100.690	100.090
O equiv. to Chlorin	0.007	0.013	0.690	0.200
	100.844	100.252	100.000	99.890
Total Nitrogen	0.147	0.069	0.080	0.072
Humus	0.426	.....	.....	0.248

Samples 724 and 725 represent the soil and subsoil of the Experiment Station plots. The surface soil has a depth of one foot and the subsoil was taken to a like depth, so the samples represent the first two feet of the plot. Samples 697 and 785 represent soils of orchards which have suffered severely from the effects of excessive quantities of nitre. These four soils differ principally in the amount of silicic acid set free upon digestion with hydrochloric acid. The carbonic acid may be considered as existing wholly as calcic carbonate which is essentially correct, for the calcic carbonate can be detected in most of the soils by simple physical examination. The humus in our soils is usually low in percentage and though apt to be richer in nitrogen than the humus of states with a higher rainfall it is not always so. The total nitrogen content of our soils as indicated by a fairly large number of analyses is not far from 0.10 per cent. It follows that a great many of them are below this amount. The four samples given illustrate this and show that there is no excessively large quantities of nitrogen present in the soil. The nitrogen determinations were made by the plain Kjeldahl, as it was not supposed that the nitrates were present in sufficient quantities to influence the results, assuming that this is correct it would appear that about one half the nitrogen in number 697 was present in the form of nitrates for we found 0.037 per cent of nitrogen calculated on the air dried soil in the aqueous extract as nitrates. The amount of nitrates present in the soil at a given time seems never to have been made the subject of study, probably because they are very small. The Rothamsted experiments lead to the conclusion that in good agricultural land cultivated as bare fallow about 80 pounds of nitrogen were transformed into nitrates in 14 or 15 months between the removal of the preceding crop and the taking of the samples. This includes the nitrates carried out of the land by drainage. The source of these nitrates is not considered. They may have been and probably were largely formed partly by nitrifying processes, partly by fixation. Storer further states "In three fields at Rothamsted 56.5, 58.8 and 59.9 pounds of nitrogen in the form of nitrates were found in September and October taking the soil to a depth of 27 inches. In one of these fields 49 pounds of nitric nitrogen occurred in the uppermost 18 inches. This result was due to the richness of the soil in nitrifiable matter. The other two fields in less favorable agricultural conditions contained only 33.7 and 36.3 pounds of nitrate nitrogen in the uppermost 18 inches of soil." Lipman states that "The determinations of nitrates, at Rothamsted, in the drainage waters of land that had been kept fallow, showed an annual removal of 40.2 pounds of nitrate nitrogen per acre." The maximum of nitric nitrogen here given, 59.9 pounds, gives only 359.4 pounds of nitrate of soda per acre taken to the depth of 27 inches; while we found in number 697, 9,040 pounds in an acre foot after the rich surface portion had been removed. This surface portion contained in the uppermost four inches of soil 22,747 pounds of sodic nitrate. It is understood that sodic nitrate is used simply as a convenient form of expression and is not intended as a definite statement that there were no magnesic or calcic nitrates present. The fact is that in some samples we have had to combine the nitric acid with these bases because there were no other acids with which to combine them. Another consideration will give an idea of the amount of nitrates in our samples, especially of the surface samples, i. e., that the India saltpetre earth carries a total of nitrates varying from 1.6 to 12 per cent and that the caliche worked in Chile carries from 21 to 51 per cent while these samples carry from about two tenths to more than six per cent of the air dried soils.

It may be thought that the amounts of nitric nitrogen given for our good agricultural soils are exceptional, even for Colorado, in order to answer any such misgiving which some may entertain, I append tables containing 100 determinations representing 64 different fields.

The following 46 samples represent as many different beet patches. The samples were taken to a depth of six inches, October 1-15, 1909.

NITRIC NITROGEN IN FORTY-SIX SAMPLES OF BEET SOILS.

Results Given in Per Cent of Air-Dried Soil.

1.	0.001250	24.	0.000200
2.	0.000050	25.	0.000075
3.	0.006000	26.	0.000100
4.	0.008000	27.	Trace
5.	0.000120	28.	0.000050
6.	0.002000	29.	0.000025
7.	0.000075	30.	0.000800
8.	0.000800	31.	0.000025
9.	0.003500	32.	0.010000
10.	0.000050	33.	0.007000
11.	0.000800	34.	Trace
12.	0.004000	35.	0.000050
13.	0.000600	36.	Trace
14.	0.000600	37.	0.000100
15.	0.000100	38.	0.002500
16.	0.002000	39.	0.000150
17.	0.000075	40.	0.001250
18.	0.000100	41.	0.004000
19.	0.000200	42.	Trace
20.	0.000200	43.	0.001500
21.	0.012000	44.	0.016000
22.	0.003500	45.	0.001500
23.	0.000800	46.	0.000075

The above samples represent a variety of soils on which beets are grown. Some of the land is low and heavy, some of it high, light and well drained. The table shows that the amount of nitrates represented in these soils varies from a trace to 1,920 pounds in the top six inches of soil.

The following 54 samples from 18 different beet fields collected Jan. 26-31, 1910, show the amount of nitric nitrogen in the top six inches of the soil at this date.

NITRIC NITROGEN IN EIGHTEEN BEET FIELDS.
Results Given in Per Cent of Air-Dried Soil.

Number	In the Beet Row	In the Furrow	In the Turning Row
1.	0.000625	0.001375	0.000625
2.	0.001	0.0015	0.003
3.	0.000375	0.0002	0.000375
4.	0.0015	0.003	0.008
5.	0.0002	0.000375	0.0015
6.	0.001125	0.0005	0.00175
7.	0.0004	0.0001	0.0005
8.	0.0005	0.001	0.002
9.	0.000125	0.0005	0.00025
10.	0.005	0.000875	0.0005
11.	0.00075	0.000625	0.0005
12.	0.0001	0.0002	0.000375
13.	0.00025	0.00075	0.000375
14.	0.0015	0.00075	0.0005
15.	0.000875	0.0005	0.014
16.	0.00006	0.00008	0.0002
17.	0.000875	0.00125	0.001
18.	0.001	0.00075	0.001

The preceding table gives us an idea of the amount of nitric nitrogen in our cultivated soils. All of the samples were tkaen to a depth of six inches. The activity of the azotobacter is assumed to have been moderate not only at the time the samples were collected but also for a rather long period before, as the ground had been frozen at least two months prior to this date, and had remained frozen for some time. The rains and snows during the autumn had tended to wash the nitrates deeper into the soil. The amount of rain fall during the months preceding the taking of these samples or practically from September 1st to February 1st, was 3.83 inches of which 3.36 inches fell between September 12th and December 1st.

The samples were taken, as we see, in mid-winter from fields which had been in beets and after a season with heavy rain or snow falls in late autumn and severe freezing. The crops would naturally be supposed to remove considerable quantities of nitrates, the rains and snows would be expected to wash them into the deeper portions of the soil, and the freezing weather should have retarded the activity of the azotobacter. Still the table reveals the presence of nitric acid equivalent to 180 pounds of sodic nitrate in the surface six inches of two of these fields and 600 pounds in another. These samples were taken between beets in the rows. The samples taken in the furrow between the rows give us a maximum corrsponding to 360 pounds of sodic nitrate in the top six inches of soil. The turning row, however, gives us an idea of the amount of nitric acid that may be present and at the same time some idea of the difference in the amount of nitric acid or its corresponding nitrate due to the presence of beets. We have for the fourth farm nitric acid between the beets corresponding to 180 pounds of sodic nitrate, Chile saltpetre, in the upper six inches of the soil, and in the soil of the turning row there is five times as much, 900 pounds. We sometimes find less nitric acid in the middle between the rows than between the beets in the rows, though we usually find more. The presence of larger quantities of nitric acid in the fallow ground of the turning row is a fact which one would expect as the sunshine, air and soil conditions are favorable for its production. The same is true for even small spots within the beet field which for some reason or other may chance to be fallow. The percentages of nitric nitrogen found in the beet plots at this station may be used to show this; in a fallow, i. e., a bare spot 0.002800 per cent; between the beets in the row next to it 0.00040 per cent. Again in the beet field among the beets 0.0001; in an oat field 0.0001; in a fallow strip 0.0035; in another fallow spot in the field, 0.0004 per cent.

The significance of the analytical data may be presented by the following averages representing the College farm at Fort Collins:

	Per Cent of Nitric Nitrogen
71 Samples 2 and 3 inches deep, Oct. 4-18, 1909	0.000626
28 Samples 3 to 6 inches inclusive, Oct. 18, 1909	0.000515
25 Samples 7 to 12 inches inclusive, Oct. 18, 1909	0.000323
6 Samples 2 1-2 feet deep, Oct. 18, 1909	0.000499

The following samples represent other farms, sixty-four in number:

	Per Cent of Nitric Nitrogen
46 Samples 6 inches deep, Oct. 1-15, 1909	0.002005
54 Samples 6 inches deep, Jan. 26-31, 1910	0.001271

The College land contained in October less than one-third as much nitric nitrogen as the other 46 farms sampled at the same time, and about one-half as much as 18 other farms sampled in January, 1910. This is very striking as the samples from the College farm were taken to a maximum depth of three inches while the others were all taken to a depth of six inches.

That there has been a decided deterioration in the quality of our beets within the past six years cannot ,I think, be doubted. Many causes may have attributed to this, but the discussion of these at this time would be out of place. Suffice it, for the present purpose, to state, that there are many fields of good beets every year, but that in spite of this the average quality has been deteriorating. The past few seasons seem to have been especially favorable for the production of nitrates in the soil, and I am of the opinion that there is a direct and intimate relation between these facts.

The amount of nitric acid present in the sugar beet is usually assumed to be small, more in the French beet than in the German, but the amount is always small. Further the nitrates are usually considered as molasses formers. We have examined our beets qualitatively for nitric acid and find it present in quantities, which are easily detected. I have been kindly furnished with samples of Steffens waste water from several factories in this state and find them uniformly rich enough in nitrates to give a strong reaction without one's going to any particular trouble to prepare the waste water. There is nothing new in the occurrence of nitric acid or nitrates in beets. It has been shown that the leaves have contained as much as 0.16 per cent of their green weight, which is stated to be exceptional in plants. Stock beets have been found to contain 0.126 per cent and sugar beets 0.164 per cent of their green weight. The last percentage was found in beets which had been heavily manured with saltpetre or other highly nitrogenous manures. No information is given concerning their deportment in the factory. The nitrates have been considered as exercising a prejudicial influence on the working qualities of the beets if applied alone, in considerable quantities and after the plant has attained to some size. It seems possible that we may have in these facts the explanation for the deterioration of our beets. The nitrates are being continuously formed in our soils. In the turn row of field fifteen, we find nitric acid equivalent to 1,680 pounds of sodic nitrate in the surface six inches per acre whereas we find the equivalent of only 120 pounds in the furrow between the rows. We must be careful about drawing extreme conclusions in regard to the amount of nitrates used by the crop. The quantity was almost certainly materially less than the difference between 1,680 and 120 pounds because the ground had been shaded by the beets during most of the season and this would make some difference; further, the row had been washed out by the irrigation water applied, etc., but the possible supply for the beets grown on this field was as much as 1,680 pounds in the top six inches of soil per acre. This determination was repeated and checked by the determination of the nitric acid in the aqueous extract of the soil by a different method.

The soils here considered are such as were planted to beets last season, 1909. The extreme cases given in other portions of this bulletin are soils in which this process of fixation has proceeded so far that they are now barren, due to the excessive amounts of nitrates.

The past season may have been an exceptionally favorable one for the azotobacter and we may not have the recurrence of such serious results for years; there is, however, no assurance that this may be the case. In fact we have no data relative to the effects of the season upon the activity of the bacteria.

One question has undoubtedly suggested itself in regard to the origin of these nitrates, i. e., whether the popular idea that the irrigation water brings them to the surface may not be correct. Some at least will deem this question as deserving a definite answer especially as I have found that the waters issuing from the shales underlying the mesas carry significant quantities of nitrates. The shales themselves when a sufficient quantity of them, 1,280 grams, were extracted with water actually showed the presence of a trace of nitric acid. There are two samples of waters and one of shale They represent three different localities, two of them within three miles of one another while the third is more than 50 miles from either of the other two. This might mean that the shale area is very large and though it contains but a trace of nitric acid it might suffice to furnish all of the nitric acid which has been found, especially as this water has been issuing from these shales and filling up the lower portions of the country for a very long period. This can all be answered very easily by stating the following facts. The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken. Second, that nitre spots occur in entirely different geological formations where these shales do not occur, in alluvial deposits and under our ordinary prairie conditions, in other words the shales considered as a source of the nitre would not be adequate for the explanation of the greater number of occurrences and independent of any other reason than their insufficiency, we must seek for a more general source or a cause sufficient to account for all of the occurrences assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes.

The occurrence of nitrates in the waters and apparently in the shale is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in the lands above the shales. The water that falls or is put upon these lands washes the nitrates down into the shales. The soil has no power to retain these salts and this seepage water is simply washing the nitrates out of the land. The shale from the brick yard was saturated with this water and the same water was used in making the brick. A trace should be present in the aqueous extract of the shale as we find was the fact.

The effect of the nitre on vegetation has been alluded to; the spots where the soil is rich in nitrates is entirely barren. See Plate II. The most serious manifestation with which we have yet met was the rather sudden death of a large number of apple trees mostly in June 1909. See Plate III. Plate IV is a view of the same rows outside of the affected area. The leaves began turning brown at the apices, then along the margins until the whole leaf was involved. See Plate I. Sometimes it did not affect the whole tree, only a few limbs being attacked. Other trees, beside apple trees were attacked. A number of cottonwoods were affected in this way. As elsewhere stated the condition of the soil in regard to excessive water was immediately investigated but we could not find any reason for attributing the trouble to this cause. One case in particular was instructive, it was in the remnant of the orchard designated Orchard No. 2. See Plates II, VI and VII. Plate VII gives a good idea of the size of this barren area as well as the killing of the remaining trees. The trees in the background are of the same age as those in the foreground. The dead tree in the middle of the background is the same tree that appears in the foreground of Plate II.

There are a few trees on the east side of the orchard which had up to that time remained in very good condition, in fact, were quite thrifty trees. These trees are shown in the background of Plate VI. These trees died suddenly. Plate VIII shows a tree killed late in the summer. The crowns and roots of these trees were apparently healthy. The roots were followed for six or eight feet from the trunk of the tree, nothing could be found to indicate any cause for the deportment of the tree. I had known for three years that this ground was very rich in nitrates and locally in chlorids. This determined me to make some experiments with nitre and salt. The nitre in this soil amounts to many tons per acre foot, 56.7 tons in the surface foot. It was evident that I had to deal with large quantities so I applied nitre to some young trees in an experimental orchard and irrigated them to bring the nitre solution in contact with the feeding roots. The amounts applied were from 5 to 20 pounds per tree. The results were that in those trees, about which I buried five pounds of nitre each, some of the limbs were reached and others were not, in other words in applying the nitre, (Chile saltpetre was used in this experiment), I had reached some of the feeding roots but the others had escaped. With the application of 20 pounds I succeeded in reaching all of the roots, at least I killed the tree in about four days. Judging from the deportment of these trees, I can conceive of ones failing in an experiment of this sort, even though he applied large quantities of nitre or other poison provided the poison was not put within the feeding area of the roots for the effects produced on different trees was by no means proportional to the amounts applied to the soil, the application of five pounds produced just as pronounced results as the application of 10 pounds. This of course depended upon the root system of the tree and the location of the nitre. The effects were in all respects similar to those produced in the other orchards, the beginning and progress of the effects, the killing of the leaves, the deportment of the tree in throwing out a few whitish-yellow leaves and the appearance of the bark and wood after death, were identical. An application of large quantities of salt proved injurious but did not produce these effects. Prof. C. S. Crandall of the University of Illinois, also experimented on the effects of nitre but he introduced the solution under the bark by properly attaching a vessel filled with a solution of nitre to the tree. He wrote me that the result was the same as on the trees which I had shown him. There is no doubt but that the nitre in the soil is capable of producing these effects. The more observant and intelligent orchardists also blame the "black alkali" which in this case is nitre, it may be calcic, magnesic, or sodic nitrate and is probably usually a mixture of the three. A very simple explanation for the death of the trees suggests itself. The nitrates accumulated in the surface soil were probably carried down to the roots by a rain fall or an irrigation at a time when they were very active and enough of the nitre was gathered to do the injury. I am convinced that this simple explanation is the correct one. It matters not that there is arsenic in this soil. These trees are not affected in the least as those are which are injured by arsenic. These may grow thriftily until the time of their being killed. This trouble is not scattered through hundreds of orchards or even through one orchard, a tree here and there, but is confined to areas. See Plates II, IV and V. The orchards designated as Nos. 2 and 3 have been totally destroyed in parts, these parts of the orchards constituting an irregular but continuous area. Other orchards present similar conditions. Both old and young trees have been killed during the past season, nineteen hundred and nine.

This is the only effect of this soil condition that I wish to present at this time though there are other serious agricultural conditions which I believe we will find attributable to this cause, i. e., to an excess of nitre in the soil. Sometimes too much at one time as is attested by the death of apple and also other kinds of trees, sometimes to too great an aggregate supply during the season. The following may illustrate what I mean by the latter statement. It is generally conceded that the application of nitrates to the sugar beet except in the earlier stages of its growth is detrimental to the quality of the beet. The following recommendation has been made in regard to the application of nitrates to this crop. One hundred and seventy pounds per acre applied in conjunction with farmyard manure in the fall and 245 pounds also with manure in the spring, a total of 415 pounds. This is applied either on the surface or near it and the crop is not supposed to receive further application of nitrates during the season. But what will be the condition of the crop if it should receive a continuous supply amounting during the season to, say, 600 or 800 pounds or is planted in soil which already contains several times this amount per acre. If the assumption that nitrates injuriously affect the quality of the beet when present in large quantities, then beets grown in such soils ought to be very poor, not necessarily in crop but in quality. I have seen beets planted in ground so rich in nitrates that when the water soluble residue, amounting to 4.6 per cent of the air dried soil, was treated with ferrous sulfate and sulfuric acid the red brown vapors of NO_2 could be seen filling and even flowing out of the test tube. This sample of soil was taken October 11, 1909. There was only here and there a straggling beet in this portion of the field. Adjoining this was an area of big green tops with medium sized, white, brittle beets. The sugar content and coefficient of purity were not determined. This study has probably only been begun.

Plate V illustrates a beet field, not the one referred to above. The amount of nitric acid in this soil is very high, as high as that of some of our orchard soils in which it is measured by the ton per acre foot of soil. I have tried to give facts enough to place the occurrence of these very large quantities of nitrates in our soils beyond question. I have endeavored to give reasons for believing that the nitrates are not derived from the shales which are often popularly assumed to be the source of this "black alkali" or nitre. I have given one instance of its serious effect upon orchard trees but hold back other features of its influence upon our agriculture for further study.

Unaided by bacteriological investigation, until within the past year, I had to content myself with a theory in regard to the source of these nitrates. I found a few things common to these occurrences. They were all so situated that while the water was not excessive there was an adequate and constant supply of it. The soils are almost uniformly comparatively poor in nitrogenous matter and there is always an abundance of carbonate of lime. We have some occurrences of these nitrates in the northern parts of the state but they are always in places where we have comparatively even, high temperatures for goodly periods at a time. These are favorable conditions for the development of a bacterial flora. I believed that in these places the flora was a nitrogen fixing one. I presented these views to Professor Sackett and have been fortunate enough to obtain his aid in carrying the investigation further on bacteriological lines. Considerable preliminary work has already been done and we purpose to continue the work in the field and in the laboratories even beyond the limits which we now see and there is much work within these limits. Professor Sackett and I have already gathered samples from several sections of the state. All of the samples so far examined are from localities that I have known for several years and in one sense are from promising places, i. e., from sections rich in nitrates. Some of the samples are unfortunately so rich in nitrates that the nitrogen fixing flora has practically perished. One thing is characteristic of them all, i. e., the brown color of the soil, hence the common term "black alkali." This is most striking along the roadsides where we sometimes can observe the dark color continuous for as much as a mile at a time. No samples were taken from such places. The dark color is possibly due to the bacterial flora itself as the azotobacter form yellow brown or dark brown films. The following numbers are simply laboratory numbers for a preliminary series and may not again be presented, this of course is entirely in Professor Sackett's hands. Professor Sackett found that these samples were comparatively rich in nitrogen fixing bacteria of which he finds a considerable variety. It is not time to state any conclusion even tentatively held. Professor Sackett has given me the following results which may suffice for the present purpose, i. e., to place the source of these nitrates beyond a reasonable doubt. The nine samples represent five localities.

Number 1.—A surface soil very rich in nitrates.
Number 2.—This sample is from the same locality taken to a depth of 6 inches.
Number 3.—Same locality 12-14 inches deep.
Number 4.—Taken as normal soil for this locality, 2-6 inches deep, no water at a depth of five feet.
Number 5.—Another locality from 2-6 inches deep.
Number 6.—Another from 2-6 inches deep.
Number 7.—Another locality from 2-6 inches deep.
Number 8.—Normal soil near No. 7.
Number 9.—A normal mesa soil in an alfalfa field with no apparent trouble.

NITROGEN FIXATION.

Milligrams Nitrogen Fixed in 100 CC. Mannite Solution, Infusion of 10 Grams of Soil Added.

	10 Days	20 Days	30 Days
Number 1	0.00000	0.00000	1.05075
Number 2	0 00000	1.19085	0.56040
Number 3	1.78627	3.08220	3.43245
Number 4	3 92780	6.16440	12.46890
Number 5	0.63045	0.84060	3.08220
Number 6	0.07213	0.77055	3.57265
Number 7	1.72130	3.50250	3.01215
Number 8	1.87562	2.38170	2.87205
Number 9	4.13431	13.02930	10.15725

All questions of technique and further detail will be presented by Professor Sackett in due time.

The great variety of soils in which I have observed this trouble and the variety of differences in the appearances of these places make one hopeful of very interesting results.

We may be pardoned for adding the following consideration, possibly of some geological interest. The source of the nitrogen present in the Chile saltpetre beds has been the cause of much speculation. The source of the nitrogen in the India saltpetre earth is considered as evident and the formation of the nitrates is sufficiently accounted for by the action of nitrifying bacteria, which convert the nitrogen of the liquid excreta of the households into nitric acid which may be recovered in the form of potassic nitrate.

In the case of the Chile saltpetre we have no definite evidence regarding the source of the nitrogen and as a result we have a variety of theories to account for its presence in such extremely large quantities in the form of nitrates. Almost every conceivable source, the droppings of great herds of animals, guano or the droppings of birds, marine vegetation, etc., have been suggested. These sources attribute the formation of the nitrates to the action of nitrifying bacteria on nitrogen of animal or vegetable origin. I know that this has not always been stated in just this way. Another source which has been suggested is the atmosphere. It has been claimed that the hydrated oxid of iron has the power to induce the oxidation of ammonia salts and that other basic compounds, the alkaline carbonates, for instance, have the power under certain conditions of inducing the oxidation of atmospheric nitrogen. Again the electric discharge has been suggested as the cause of the union of the oxygen and nitrogen of the atmosphere to form nitric acid, which falling to the earth as a dilute solution of ammonic nitrate in rain water may have reacted with the carbonates of the alkalis or alkaline earths which would then be carried with the waters to natural basins from which the waters have subsequently evaporated leaving the nitrates in their present form and place.

The facts which I have found obtaining in such large districts in Colorado suggest the possibility that the atmosphere is the source of the nitrogen in these nitrates but that the agency which has transferred it from the atmosphere to the fixed form of the nitrates is not the electric discharge nor the action of alkaline carbonates on the nitrogen of the air in the presence of oxidizable matter, but to that of those micro-organisms, the azotobacter, which have the power of converting atmospheric nitrogen into nitric acid, respectively into nitrates, especially if there be enough calcic or other carbonate present to prevent the soil from becoming acid.

We have in miniature a great many analogies to the occurrences of Chile. In the lower parts of small basins we have deposits of sulfate of soda, above this zone we have one rich in nitrates. I have been told that in Chile they sometimes find calcic chlorid but usually sodic chlorid. We find samples in which calcic and magnesic chlorid together constitute 48.5 per cent of the water soluble portion. Others in which sodic chlorid constitutes 44.5 per cent of the water soluble. The amount of nitrates, dealt with in this bulletin, is surprisingly large. We have as the highest percentages of nitrates found, 5.628 and 6.541 per cent of the air dried samples. These samples were gathered from the surface soil and were not taken to any depth, perhaps the one showing 5.628 per cent may have reached a depth of two inches, but the area involved was small. The other sample may have reached a depth of an inch but the area involved was large, some eight or ten acres. In the case of another sample taken to the depth of five inches we find the nitrates equal to 2.571 per cent of the air dried soil. This sample was taken to a medium depth and the area involved is at least eight acres and we would have 344,000 pounds or 172 tons of sodic nitrate in the top five inches of this land. In another sample taken to a depth of four inches we find that 1.706 per cent of the air dried sample is sodic nitrate. The area involved represented by this sample is certainly as large, i. e., eight acres, and we would have 189,971 pounds or practically 95 tons in the top four inches of this land. The largest amount of nitrates indicated by the analysis of any sample taken to a depth greater than four inches was in the case of a sample taken to the depth of one foot which contained 2.837 per cent of sodic nitrate corresponding to 113,480 pounds or 56.74 tons per acre in the surface foot. These figures are given to show the large aggregate amount of nitrogen which is being taken from the air and converted into nitrates in these semi-arid soils usually fairly rich in sulfate of soda and containing large amounts of calcic carbonate.

The aggregate area involved in this active fixation of nitrogen would be difficult to estimate accurately but as stated elsewhere in this bulletin it is present in widely separated sections of the state. In some places only a small area may be involved, in others it is almost continuous for miles.

SUMMARY.

The cause of the barren spots in some sections of Colorado which is popularly, though incorrectly, called "black alkali" is the presence of excessive quantities of nitrates.

These nitrates do not come from the soil nor from the shale as frequently assumed but are formed in the soil.

The death of many apple trees, some poplars and other shade trees during the season of 1909 was caused by excessive amounts of nitrates in the soil.

These nitrates were carried down within the feeding area of the roots by the spring rains and irrigation.

The amount of these nitrates accumulated in some of these soils is already very large, amounting to many tons per acre foot of soil, 100 tons per acre foot having been indicated by some samples.

The agency by which the nitrogen of the air is converted into these nitrates in the soil is a group of micro-organisms possessing the power of converting the nitrogen of the air into nitric acid.

These organisms have a very wide distribution in our soils and are not always hurtful, but when the conditions of the soil, including moisture, temperature, and the presence of much alkaline earth carbonate, become very favorable they develop so vigorously that they produce the effects recorded in this bulletin.

These organisms thrive in some of our best cultivated lands, and some of the anomalies of our agriculture are probably due to them.

The very considerable amounts of nitrates found in some of our soils, together with the large areas so enriched, and their wide distribution suggest the probability that the formation of the nitrates of Chile and Peru may have been due to the agency of these organisms.

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BUTTER MAKING

CLEAN MILK AND COMMERCIAL STARTERS

(Information Bulletin).

BY

WALTER G. SACKETT

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CLEAN MILK AND COMMERCIAL STARTERS AS FACTORS IN BUTTER MAKING

By WALTER G. SACKETT.

It is a fact familiar to all of us, whether we are buying butter or whether we have butter to sell, that farm, ranch and country butter seldom, if ever, commands as high a price on the retail market as creamery butter. There are no doubt cases where precedent, alone, dictates the price of the farmer's product, it having become an established custom in certain towns and at certain stores to pay the countryman from five to ten cents per pound less for his product than for the creamery goods. Injustice is often done the farmer in this way, for some country butter is equal in quality, if not superior, to creamery butter. Why, then, this universal custom of rating the creamery product above that of the ranch? The cold truth of the matter is that the average run of ranch butter is inferior in flavor and keeping qualities to the ordinary creamery output, and the consumer is not willing to pay the factory price for the inferior home article. The question at once arises, why this should be the case, for, most certainly the conditions which enter into good butter making ought to be more easily controlled by the individual farmer, who can give his personal attention to each step in the process, from the milking up to delivery to the consumer, than by the creamery overseer who must take the whole milk or gathered cream from many different sources, some clean, some filthy, and mix it all together. Yet by proper handling from this point, he is able to turn out a first class product. Of course, it goes without saying that no one can make as good butter from dirty, filthy cream as from that which has been produced on a clean farm where some attention is given to the sanitary conditions. Cleanliness is without question the first and foremost consideration in making either good butter or cheese. The word *cleanliness* when used in connection with the dairy and dairy products has a very broad meaning and demands the attention of everyone who has anything at all, no matter how insignificant, to do with the care and handling of the milk and cream. The farmer who does the milking is apt to forget that dirt and filth are intimately associated with his part of the work, and no matter how careless he has been with the milking, he expects the good housewife to turn out a butter of excellent quality, which will score as high or higher than the creamery product. This is absolutely impossible and out of the question.

Those who are engaged in butter making as a profession consider that the two most important factors in good butter making are clean milk and proper ripening of the cream. Both of these can be controlled by the butter maker no matter whether the output is a thousand pounds a day or six pounds a week. Clean milk can be obtained only by the most scrupulous care on the part of those who are entrusted with the handling, and the proper ripening of the cream is best accomplished by the use of what are known as *commercial starters,* which will be discussed fully later on.

To the majority of people who use milk or cream in one form or another, *clean milk* signifies milk free from visible dirt, such as cow hair, hay, straw, etc. As a matter of fact, such forms of dirt are seldom met with in the milk as delivered to the consumer, and of themselves are practically harmless except to the esthetic taste. The milkman has learned to strain his milk and rid it of such debris. It is the filth that we can not see with the unaided eye that does the harm and makes the consumption of dirty milk dangerous. Every particle of dust, every hair, every bit of straw is covered with myriads of bacteria, and when these foreign substances find their way into the milk, the germs are washed off and immediately begin to grow and multiply in the milk. When we know that a single cow hair may harbor from 4,000 to 10,000 germs which can multiply once every half hour, are we not justified in labeling milk which contains such hairs as unfit for use?

When every precaution is taken against contamination, it is possible to obtain milk directly from the cow which contains as few as 200 to 300 germs per cubic centimeter (one-fourth of a teaspoonful); with somewhat less care the numbers will increase to 5,000; when carelessly drawn and handled, it frequently contains in the beginning from 25,000 to 100,000.

Many of our large cities have placed a limit to the number of bacteria which the city milk supply may contain and yet be offered for sale. The city of Boston (1) has set this number at 500,000, Rochester, N. Y., 100,000, and Milwaukee 250,000. In New York City, Park (2) found that during the coldest weather, the milk sold in the shops averaged over 300,000 bacteria per cubic centimeter; during cool weather, about 1,000,000 and during the hot weather, about 5,000,000. In Chicago, Jordan and Heineman (3) found in market milk collected during April, May and June, numbers ranging from 10,000 to 74,000,000. Sedgwick and Batchelder (4) have examined samples of milk from groceries in Boston which contained over 4,500,000. Stevens

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(1). Article 51, Sect. 1. Regulations for the Sale and Care of Milk, Boston Board of Health.

(2) Park: Jour. Hyg., 1, 1901, 1, p. 391.

(3) Jordon and Heinemann: Rept. of Civil Federation of Chicago, 1904.

(4) Sedgewick and Batchelder: Bost. Med. Jour., 1892, 126, p. 25.

(1) has shown the milk supply of Raleigh, N. C., to vary in bacterial content from 1,200 during November to 54,000,000 in May.

A number of the bacteria which fall into milk are harmless in themselves, but during their growth they bring about certain changes which produce disagreeable odors and flavors, and frequently deleterious substances. The natural souring of milk is accomplished by the lactic acid germ. However, Marshall (2) has shown that the lactic bacteria are favorably influenced by the presence of other bacteria, notably by germs of filth, which for the sake of the present illustration, let us call "B." The lactic germ we shall designate "A." By growing the lactic acid germ by itself and also by associating it with the germ B, Dr. Marshall has been able to show the increased number of lactic forms when associated with B in milk. At the time of loppering or curdling of culture A+B, the ratio of the lactic acid bacteria in the two cultures was:

$$A:A+B::27:1614.$$

Again, he has demonstrated that germ B produces stable products which withstand sterilization and exert the same influence over germ A in milk cultures as the living germ. The comparative number of lactic germs in culture A and in culture (A + products of germ B) was expressed by the ratio:

$$A:(A+\text{products of germ B})::27:1007.$$

From this it follows that clean milk will keep sweet much longer than other milk. We see this same thing every day in a practical way when we notice that milk from certain dairies sours so much more quickly than that from other sources, and if we trace down this matter still further, we invariably find that the better milk comes from the cleaner stable.

There are also those forms of microscopic life which produce *bitter milk, ropy milk,* and milk of different colors commonly designated bloody milk, blue milk and yellow milk. If these bacteria are present in the milk, they will be present also in the cream and will impart their disagreeable properties to the butter made from it.

A few suggestions along the line of clean milk may not be out of place at this time. The writer feels that while this topic has been treated upon thoroughly and exhaustively in many publications and by institute speakers, yet, not all of us who are in the dairy business, have understood fully and put into practice the principles and methods advanced by the advocates of sanitary milk.

No dairyman who pretends to produce clean milk should allow his cows to have access to muddy bayous, wading places and irrigating ditches. It is not through any preference, but as a last resort, that cattle in the summer time stand knee deep in mud and water to get

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(1) Market Milk, bacteriological data. Cant. of Bakt, II Abt. Bd. XX. No. 4-5. 1907, p. 114.

(2) Special bulletin No. 33, 1905. Mich. Exp. Station.

away from flies. If some other provisions were made for their comfort, they would not have to seek this refuge. Provide an abundance of shade in the pasture lot and fence off the mud.

See that there is an ample supply of good, clean, drinking water and wholesome food. It is much better to do all of the feeding and bedding after the milking is done, since in handling dry hay or fodder, the air is filled with dust and dirt which will settle into the milk at milking time. If the cows are allowed to eat while being milked, there is always more or less commotion caused by tossing the heads and nosing the feed, and this means a constant supply of dust in the stable. There may be some uneasiness shown at first if they are compelled to wait for their feed, but it is only a question of educating them to it. Those dairymen who are practicing this are getting good results and can testify to the improved quality of the milk.

Some of the cow stables which one sees in traveling through the country are a disgrace to any civilized community. Just because a cow *can* endure such accommodations is no excuse for their existence. Warm, well ventilated, well lighted stables will pay for themselves many times over in increased yield and quality of the milk. Fly screens are a very necessary adjunct to a good stable, and a frequent coat of whitewash will help considerably toward its appearance and sanitary condition. If the stable is properly constructed, the cows can be kept clean and comfortable, and their flanks free from great masses of manure, which, when dried, is apt to fall into the pail during milking. It is to this source that we can trace many of the objectionable "cowy" flavors found in the milk.

Manure must not be allowed to accumulate in the barn lot until the milker is compelled to wear hip boots to get through it on his way to the stable. The udder and flank of the animals should be wiped off with a cloth moistened with some germicide, such as 3 per cent. carbolic acid, or lysol, or 1-1000 mercuric chlorid, just previous to milking; the cows should be brushed frequently to remove any loose hairs or foreign matter.

Very few dairymen stop to consider the importance of cleanliness of their own person when working around milk. It is the usual practice to put on the filthiest pair of overalls available, since milking in the average cow barn is considered a dirty job, which in itself is, indeed, an admission of guilt. The same suit of overalls is used while milking, cleaning out the cow stable, bedding the horses and hauling manure, and it is not until they become so stiff and caked with filth as to make it difficult to get into them, that it is considered at all necessary to have them washed. The dairies of today, which are producing certified milk, furnish their milkers with a clean, white uniform every day. If we could do away with the long standing blue jeans and adopt a white suit we should realize very soon that the cow stables need cleaning up, and that the length of time required for a pair of overalls to become soiled is much shorter than was supposed formerly.

Milkers are not as particular about washing their hands before milking as they should be. It frequently happens that the hired man will be called in from hauling manure or feeding the pigs, or some similar operation, to help with the milking. The chances are that he will never think of washing his hands, but, if, contrary to the usual custom, he should do so, nine times out of ten he will wipe them either on his dirty overalls or on a red bandanna that has escaped the wash tub some three weeks past.

It seems almost unnecessary to have to call attention to the danger of employing persons as milkers who are suffering with any contagious or infectious disease. Tuberculosis, typhoid fever, and diptheria may gain access to the milk through such channels, and epidemics follow as a result. No one who is afflicted with any of these troubles should be allowed any part, no matter how small, in the care and handling of the milk.

While speaking of the spread of disease through milk as the medium, the common house fly must be charged with being the most dangerous agent known to humanity in polluting milk, and the greatest menace to public health by way of spreading disease. The bare statement of this fact should be sufficient to convince any one of average intelligence of the great importance of exterminating this pest,

As a rule, the housewife, to whom is entrusted the cleaning of the pails, pans and cans, does her work more thoroughly than the others associated with her in the dairy work. However, it may not be out of place to mention one or two points in connction with her duties. The mere scalding of a utensil by pouring boiling water over it is not always adequate to sterilize it and render it sweet and clean. It is frequently necessary to allow water to boil in the pails and cans for a half hour or longer in order that the dirt and grease which find their way into the cracks and seams can be soaked up and gotten rid of. Some good washing powder should be used in this operation. The strainer cloths should be boiled thoroughly. After thorough rinsing with boiling water, the different utensils should be placed in the brightest sunshine available, and not on a bench on the shady side of the milk-house. Bright sunshine is one of the worst enemies of germ life, and since it is so effective and so cheap, let us use lots of it, not only in our milk cans, but in our damp, musty cellars, "spare" bed rooms, company parlors, and then turning toward the dark, gloomy barns, give the horses and cattle their share.

The writer has a farmer in mind whose usual custom is to cool off his milk bucket, which has been sterilizing in the bright sunshine for half a day previous to milking, by pumping water into it from a well located in the barn yard at the edge of a hog-wallow. This is certainly a very questionable procedure, since practically all of the good from scalding and sunning is counteracted and more than this there is often danger of introducing undesirable germs into the milk by this means.

It is a matter of common knowledge, that milk absorbs foreign odors very readily and retains them as tenaciously. It follows, naturally, from this that milk must be kept in a clean, cool, well ventilated room, free from all taints and flavors. Anyone who has ever exposed a pan of milk in an ice box along with onions, boiled cabbage, cantaloupes or cucumbers, or who has placed it in a freshly painted or varnished room, or who has allowed the cans of milk to remain in a vile smelling stable for some time, knows the inevitable consequence. The cream from such milk must necessarily give its respective flavor to the butter made from it, and when the consumer complains of an off flavor, the ranchman proclaims his innocence.

Much of the dirt and dust, together with many disagreeable odors, can be obviated by arranging a small milk-room, adjacent to the cow stable and separated from the cows by a tight partitition. Here the straining can be done and the cans kept while they are being filled from the milkers' pails.

The cream should be cooled as soon after separation as possible in order to check the growth of bacteria. This can be accomplished easily by placing the cans, containing the milk or cream, in cold well water by which a temperature of at least 50 degrees F. should be obtained.

Inasmuch as the offensive germs thrive chiefly in the curdy part of the cream, it follows that a thick cream, low in curd, will keep better than a thin cream. For the same reason, poorly worked butter, conttining considerable buttermilk, will not keep as well as butter which is worked thoroughly. Consequently, it is best to separate as heavy a cream as the separator will handle and as is consistent with the time of year, say 35 per cent. in winter and 40 per cent. in summer. Besides obtaining a better grade of cream for butter making, the bulk is reduced, which simplifies the handling, and more skimmed milk is available for feeding purposes.

In closing this chapter upon the production of clean milk, its application to butter making must not be lost sight of. Stated briefly, it is simply this: high class butter can come only from clean cream and clean cream is possible only from clean milk.

The Use of Commercial Starters.

The natural flavor of well made butter from fresh, clean cream is very pleasing to the taste of the average person and it is chiefly this desirable flavor for which the consumer pays. It is obvious, then, that the goal toward which the butter maker must strive is a desirable flavor, accompanied by a pleasing aroma. To be sure, the texture can not be lost sight of, but when the layman buys a pound of butter, he judges it for flavor first of all, and inasmuch as his judgment will determine ultimately the demand for a certain brand of butter, it is important that his verdict be given the weight it deserves.

As noted above, the bacteria which are present in the cream, and which in the end find their way into the butter, are responsible in a large measure for the flavor. On the one hand, if filth germs dominate in the cream, then the butter will have a strong, rancid flavor and odor from the beginning. On the other hand, if the cream has been gathered under sanitary conditions, with cleanliness in mind, all things being equal, a good quality of butter is to be expected. However, this last condition exists so rarely that it can be passed by with mere mention.

Now if it were possible to introduce into the fresh cream immense numbers of desirable bacteria which would give it a good flavor, and which would impart to the butter that "grassy" or "nutty" taste so much sought for, we might be able to control the flavor, in a measure, in spite of the unsanitary condition of the cream. The Starter fills this demand.

The Nature of a Starter.

Hastings (1) has defined a starter as "A quantity of milk in which acid forming bacteria have grown until the milk contains large numbers of them. The addition of the starter seeds the cream with great numbers of bacteria which are in a healthy condition and which, by their growth, cause the acid fermentation to progress rapidly and in a more definite manner than without the addition of the starter." In other words, the starter is the active agent involved in ripening the cream.

Starters are of two kinds, commercial and natural, depending upon the method by which the bacteria are obtained.

The Commercial Starter.

Starters prepared by various commercial firms, where facilities are provided for careful bacteriological work, are known as commercial or pure culture starters. They usually contain but one species of germ and this one selected from many others for its peculiar butter making properties. To be a good starter, the culture must develop at ordinary temperatures, 68 degrees to 70 degrees F.; it must produce acid rapidly and in quantity sufficient to allow of exhaustive churning; and it must be capable of producing substances which will impart to the butter the desired flavor and aroma. The bacteriologist, who prepares these cultures, has all of these points in mind when selecting a specific germ, and for this reason more uniform and satisfactory results are to be obtained with the commercial starter than with the home made or natural starter which is apt to contain germs, good, bad and indifferent.

The cost of these commercial products is so small in comparison with the benefits to be derived that their more general use is to be recommended. The initial cost of a starter is about fifty cents and by careful handling it can be propagated for an indefinite time. They are for sale under trade names such as Butter Culture, Flavorone, Lactic Ferment, etc., and can be procured directly from the manufacturer or through any drug store.

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(1) Hastings: 181, Wisconsin Exp. Station.

Propagation of the Starter.

Commercial starters are put up by the different manufacturers in two forms, one a powder and the other a liquid. Inasmuch as extreme care has been exercised in their preparation to keep them free from contamination, it is important that they shall not be opened until ready to be used. This suggestion is offered since a person with the average curiosity would be tempted to open the bottle and taste or smell the contents, and in so doing expose it to dust and air contamination.

The first step in the propagation of the starter is the preparation of what is known as the "mother starter." One quart milk bottles are very convenient vessels for this part of the work. Some suitable cover or stopper must be provided for the bottles; Bushnell and Wright (1) recommended a cotton batting plug, while Hastings (2) uses an ordinary glass tumbler inverted over the mouth of the bottle. It is also necessary to have some instrument for transferring portions of the mother starter to other bottles in order to perpetuate the culture. For this purpose, Bushnell and Wright recommend a cotton swab attached to a piece of heavy copper wire; Hastings prefers a silver plated teaspoon with a piece of well tinned wire soldered to the handle to give length.

Having procured a number of one quart milk bottles, they should be boiled thoroughly in water for thirty minutes and then allowed to drain in a clean place. Next, several of the bottles are two-thirds to three-fourths filled with fresh, clean, whole or skimmed milk, preferably the former, the spoon or cotton swab inserted, and the bottle finally stoppered with a firm cotton plug covered with a glass tumbler. The bottles and contents are now sterilized in flowing steam for thirty to forty minutes on three consecutive days in order to kill the bacteria present in the milk. This sterilizing may be accomplished in a specially constructed steamer or in an ordinary wash boiler provided with a false bottom or shelf on which to set the bottles. Such a device is described fully by Bushnell and Wright (1). A common kitchen steamer will serve fairly well, provided it is high enough to admit the bottles and still permit the lid to fit down tight. Some authorities believe that better results are obtained when the milk is sterilized on one day only instead of three, their reason being that the prolonged heating injures the milk for starter purposes since the lactic acid germ thrives best in milk which is heated less. The only advantage in heating the milk three days is that it is rendered absolutely sterile, while one day's heating would not destroy the resistant spore forms of the bacteria which might be present, and which, if allowed to develop in the mother starter, would spoil it for that purpose. This would be true especially if several bottles of milk, were steril-

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(1) Bushnell and Wright: Bul. No. 246, Mich. Exp. Sta.
(2) loc. cit.
(1) loc. cit.

ized ahead. If the three day sterilization is employed, the bottles should be kept in a warm room between each sterilization to hasten the development of the spores into the vegetative forms, which are more easily killed by heat. If the one day sterilization is adopted, all the more care must be taken in selecting clean milk since the fewer the bacteria present, the more efficient will be the sterilization.

Add the entire contents of the bottle of culture obtained from the manufacturer to one of the bottles of sterile milk and shake it gently for about five minutes so as to distribute the culture uniformly through the milk. Allow it to develop at a temperature of 75 degrees to 85 degrees F. The milk will become soured and curdled into a solid mass in from 18 to 24 hours and in this condition is known as the "Mother Starter." It is now ready for use in building up the starter proper, to be employed in ripening the cream. But before taking this step, a small portion of it should be transferred to a second bottle of sterile milk either with the teaspoon provided or by simply carrying over the cotton swab to the new bottle and allowing it to remain there for use the next day. In this way a second mother starter is prepared for the following day. In making the transfers from one bottle to another, the bottles should be left open to the air only long enough to make the transfer and then closed at once. If this precaution is not taken, there is great danger of contamination by air bacteria which would result, probably, in the starter going "off flavor." New mother starters should be prepared in this way every day whether they are to be used or not, since the activity of the lactic acid bacteria decreases rather rapidly if this is not done.

A good mother starter should appear smooth, glistening, firm and free from gas holes or free whey. It is always desirable to examine the ripened starter for flavor, odor, and acidity. This should be done by pouring a small quantity from the bottle into a clean cup, rather than by dipping any utensil into it which might be the means of introducing undesirable germs. The starter should have a clean taste, that is, it should be free from any disagreeable flavors; it should have a pleasant odor and should be only slightly acid.

Preparation of the Starter Proper.

The milk for this purpose should be selected for its purity and must be pasteurized by heating it for thirty to forty-five minutes at a temperature of 150 degrees to 160 degrees F. Cool this milk to 75 degrees to 85 degrees F. before adding the mother starter.

To forty or fifty parts of pasteurized whole or skimmed milk, add one part of mother starter. Let this stand for 18 to 24 hours at room temperature, 68 degrees to 70 degrees F., when it will be curdled; stir it thoroughly and it is ready to be added to the cream as a starter. The starter should be used at the time it contains the greatest number of active organisms. If too much acid is developed, the bacteria are killed, and to this fact is due the bad effects of over ripening. The amount of acid which should be developed in a starter is from 0.6 to 0.7 per cent. for at this time it contains the largest number of active bacteria. Another way of judging is by the thickening of the milk which usually takes place at about 0.7 per cent. acid when the temperature is 65 degrees to 70 degrees F.

Ripening the Cream.

For every ten gallons of cream, use from one to two gallons of starter, or, in other words, from ten to twenty per cent. The exact amount can not be stated definitely, as much depends upon the age, acidity, temperature and thickness of the cream, of which the dairyman must be the judge. The cream should be sweet and as fresh as possible when the starter is added, and as much starter should be used as can be handled conveniently. In warm weather either ice or pasteurization must be resorted to to keep the cream sweet from one churning to the next, or else the churnings must be more frequent. Too much must not be expected of a starter, for while it may improve the quality of butter made from old, stale cream that has soured, it gives the best results when used with fresh sweet cream. A temperature of 70 degrees F. should be maintained during the ripening which is completed when the cream has acquired an acidity of 0.5 to 0.6 per cent. Under favorable conditions, this will require from six to eight hours. During this time, the cream should be stirred frequently to insure uniform ripening.

In regard to ripening, Rasmussen (1) says, "It should be considered that too sour cream, as a rule, gives a butter with a strong flavor and with poor keeping qualties and, therefore, the danger of getting the cream too sour before churning is greater than not getting it sour enough." In the absence of any chemical means for determining the per cent. of acid present, the only alternative is experience in judging the ripeness by the taste, aroma and appearance. As a general thing, "cream is ready to churn when it has a mild but distinctly sour taste, not too sharp or bitter, and has a glossy brittle appearance."

Pasteurized Cream.

During recent years, the pasteurization of cream for butter making seems to be gaining favor in our best creameries. In fact this practice has become almost a necessity in those localities where cream of all kinds is gathered from various sources. The butter maker has come to realize that if he is to have control over his finished product, so that he shall have some assurance of the constant and uniform quality of the output, he must resort to means by which he can eliminate the variable factors in his cream, namely, those undesirable bacteria and disagreeable flavors which will develop later on and make their presence manifest in the finished article. By heating the cream

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(1) Bul. 141, New Hampshire Exp. Sta., 1909.

from 170 degrees to 180 degrees F. and *cooling it at once* nearly all of the bacteria are destroyed and many of the objectionable odors are driven off. If a starter is added to pasteurized cream, the lactic acid germs are given a comparatively free field in which to work and exert their beneficial influence. "This (1) method of ripening has a number of advantages over the use of unheated cream. It gives the maker full control over the ripening for by the process of pasteurization most of the bacteria are destroyed, then by the use of the pure culture, the same type of ripening, is assured and a uniform product results, a product that is uniform from month to month."

Kinds of Commercial Starters.

As stated before, commercial starters are put on the market in two forms, liquid and dry. The liquid cultures are usually prepared by inoculating a bottle of sterilized milk with the lactic acid germ, and when received by the purchaser, it has the appearance of sour milk which is exactly what it is, differing, however, from ordinary sour milk or natural starter, in that the curdling in this case has been produced by a pure culture. The liquid cultures are not as long lived as the dry forms and deteriorate more rapidly because of the harmful action of the lactic acid present upon the lactic germs.

The dry starters which are sold in the form of a powder are made by mixing a large quantity of starch, milk sugar or powdered milk with sterilized milk, soured by the lactic culture and the mixture subsequently dried at a low temperature. In this condition, the germs can not grow, but lie dormant, the organism being able to withstand dessication for a considerable period of time. In this state, no lactic acid can be produced, and its injurious effect is eliminated. For this reason the dry starters will keep much longer than the liquid ones.

Most dairy supply houses carry these starters in stock, but starters, like eggs, are better the fresher they are, and for this reason it is usually safer to send directly to the manufacturer, than to depend upon the old stock in the supply house.

A list of some of the manufacturers of commercial starters is given below:

Elov Ericsson,
60-62 E. Fifth St.,
St. Paul, Minn.

Parke, Davis & Co.,
Detroit,
Michigan.

Chr. Hansen's Laboratory,
Little Falls,
New York.

O. Douglas Butter Culture, Co.,
68 Northampton St.,
Boston, Mass.

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(1) Flavorone: Parke, Davis & Co., Detroit, Mich.

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The Agricutural Experiment Station

OF THE

Colorado Agricultural College

ARSENICAL POISONING OF FRUIT TREES

BY

Wm. P. HEADDEN

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The Agricultural Experiment Station

FORT COLLINS, COLORADO

ARSENICAL POISONING OF FRUIT TREES

In Bulletin 131 of this Station, issued in July 1908, were recorded the results of our studies to determine the cause of the death of many of our apple and pear trees. Professors Paddock and Whipple had addressed themselves to this subject for some years, and were unable to satisfy themselves that any of the well known causes usually producing the death of trees could be appealed to as the actual agents in these cases. Mr. Whipple, now professor of horticulture in the Montana Agricultural College, had sought for fungus and bacterial troubles in vain. The results of our observations forced us to the conclusion that the cause was not to be sought in the soil per se for to quote Prof. Whipple's words, "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soils."

While I recognize the fact that it is necessary to control the insects injurious to our crops, I have entertained grave misgivings in regard to the ultimate effects of spraying arsenic on our trees and soils and when the other members of this Station, men thoroughly competent to determine the facts, found none of the causes usually producing disease in trees present in these cases, I became more deeply impressed with the probability that the trouble was primarily due to the action of the arsenic applied to the trees as a spray. I gave in Bulletin 131 a definite experience with a case in which it was charged that arsenic, lead and copper had been the cause of the death of trees, grass and even of animals eating the grass, and I am fully convinced that

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AN EXPLANATION.

In Bulletin 131, Arsenical Poisoning of Fruit Trees, I did not give the location of any orchard or the name of a single owner, nor have I given either in the following pages. My reasons for this are the following: I think that it would be a gross injustice to the owner of an orchard to publish a statement of his misfortunes or unwise practices throughout the state and nation by means of an Experiment Station bulletin. If the statements made are all true, it only makes matters worse rather than ameliorates them. Unscrupulous neighbors might take advantage of such statements to do the party named injury. I have been treated kindly by the orchardists in connection with this work, however, I understand that I have been the innocent cause of injury. The fact that I was interested in the study of an orchard problem, not arsenical poisoning, was made the basis of dishonorable representations which did the owner a serious financial wrong. It would, in my estimation, be wholly unpardonable to name the properties of men who have given me aid in this investigation when I know that it would be doing them an injury and requiting kindness by inconsiderateness and ingratitude. I have not, in any way, concealed or distorted a feature of the problem, but I have purposely used examples from different sections and different orchards in order that I might present the whole case—but by no means all of the different facts—without doing anyone an injury. If I have succeeded I shall be pleased, if I have failed I can only regret it.

W. P. H.

there is great danger of our adding arsenic enough in the form of materials used for spraying to jeopardize not only the life of the trees but bring about other conditions of a most serious character.

I have heretofore been very careful not to condemn the practice of spraying, but simply to call attention to the dangers accompanying the practice and particularly the excessive, even irrational, application of these poisonous preparations to the trees and eventually to the soil. If the soils themselves already contain arsenic enough to pass into the plant system it makes the application of more arsenic only the more ill-advised.

Up to the present time we do not know of any other practical and effective means of protecting our fruit against the codling moth than some form of arsenic, and so far as we now see we must continue to use this means. This, however, does not mean that we cannot improve the practice in several ways. It has been demonstrated that a much smaller amount of arsenic may be used than has heretofore been customary, with most excellent results. Prof. Gillette showed several years ago, that 95 per cent. of the protection given to a crop when three or four sprayings were made was effected by the first spraying. His investigations have shown that a single spraying, thoroughly well done, will produce clean apples unless there is some local source, an adjoining unsprayed orchard, from which moths may migrate and infest the orchard anew. There is another way of improving our practice, namely, by using a form of arsenic more insoluble in water than the forms now used and which will change but slowly into a soluble form in the soil. We have considerable reason for hoping that the sulfid of arsenic may be used with benefit in this direction. A still greater improvement would be to obtain some substance which would furnish our fruit the desired protection, but which would be entirely free from the serious objections which apply to the use of any arsenical preparation. This is not an impossibility, as indicated by the report of experiments with nicotine made by Prof. Gillette to the American Association of Economic Entomologists, at its recent meeting in Boston.

The assumption that the arsenical preparations used for spraying are insoluble in water is not justified, and yet this is a condition which they must fulfill in order that thay may be safely used. Further conditions may, and in some cases certainly do, exist in the soil which makes them more soluble than they are in pure water. I have met with many men to whom it was a matter of some surprise that the arsenic might accumulate in the soil, though they knew that they were spraying a number of times annually and that the amount of soluble arsenic in the soil might increase with the years.

Bulletin 131 states that this line of work was a direct outgrowth of my attempt to study the alkalis of the state. It was then thought that it was rather more than probable that the abundance of these salts in some of our soils had produced an exaggerated effect of the arsenic on our trees. There may be some truth in this view but I am now of the opinion that the effect of the alkali has been nothing more than to increase the action of the arsenic and has not been the cause of it. I am led to modify my views in regard to the importance of the part played by the alkalis because I have found cases of corrosion by arsenic under conditions which preclude their action. This in no way contradicts any facts established in regard to the adequacy of sodic chlorid or carbonate to bring arsenic in solution when present in the form of lead arsenate, calcic arsenite or as Paris green, but simply adds the fact that trees may be attacked in soils practically free from these salts, indicated collectively by the term alkalis.

The result of my study of this subject during the past year has strengthened my conviction that the conclusions presented in Bulletin 131 were not only fully justified by the facts presented, but were very conservative and I do not see any reason to modify any statement by making it less general or in any way milder. I have, furthermore, learned of no fact indicating any reason for altering the previous findings of Professors Paddock and Whipple. These gentlemen did their work thoroughly and with that conservatism demanded of the really scientific worker. In the following pages we shall present some new facts but they will in the main be a re-presentation of the main points set forth in Bulletin 131.

In the bulletin just referred to three phases of the question were set forth: First, the corrosive action of arsenic which had already collected about the crown of the tree, and designated as local irritant poisoning; Second, the action of the arsenic which had been taken into the system of the tree and designated as systemic poisoning; Third, the action of lime, showing that it probably exercised a toxic action either alone or in conjunction with the arsenic. The possible action of both copper and lead is freely admitted, but that of the arsenic is candidly considered as clearly the most important one and these two are scarcely more than mentioned for the purpose of admitting the possibility of their exercising some influence.

The most striking effects upon the trees are produced by the corrosive action of the arsenic on the crown and roots, and this form of the trouble is the one which forces itself mostly upon the average man.

Description of the Trees.

The effect of the arsenic does not express itself in the appearance of the tree till its action has gone so far that the death of the tree is very near. The first general signs of trouble are an early ripening of the foliage the first year followed by heavy blooming and usually an abundant setting of fruit the second. This fruit is seldom matured as the tree usually dies in late summer or early fall, the fruit and leaves remaining on the tree. In the case of pear trees, the foliage is mostly of a deep purple on the badly affected trees while that of healthier trees is still green. An examination of such trees reveals the following conditions, the bark of the crown has been completely disintegrated and almost always that of the roots next to the crown. Its structure has been wholly destroyed and the woody tissue beneath has been stained brown. In bad cases its structure too has been destroyed so that under the rasp it often acts as though thoroughly charred, outwardly it is often blackened. The bark of such trees is usually a reddish yellow frequently showing longitudinal cracks. The woody tissue of the lower portion of the trunk is stained brown though the tree may still be alive. This is shown in Plate 3, Fig. 3, p. 14, Bulletin 131, which is a portion of the lower part of the trunk of a Ben Davis tree dug up when in full bloom. The bark on this portion of the tree was intact and the staining was not due to dead wood exposed to the air.

The Yellowish-Red Bark Not Diagnostic.

The yellowish-red color of the bark of the limbs and twigs of such trees is probably the result of malnutrition rather than of the direct action of the arsenic and while this color is very commonly present in cases of this trouble, I cannot consider it as a diagnostic feature.

The Point of Attack in Cases of Irritant Poisoning.

The attack on the bark is evidently made from the outside because we find patches on some of these trees where the girdling is not yet complete and while the outer portions of the bark may be disintegrated the inner portion may be apparently entirely healthy. There are no signs in such cases that the bark has ever been raised or loosened from the underlying tissues. These facts necessitated the examination of trees in which the trouble had not advanced to this stage. Samples were easily found showing all stages of the progress from the incipient attack in which the disintegrated bark formed only a very thin layer on the outside to those in which it had finally perforated the bark and attacked the underlying wood. In some orchards we find some degree of this girdling on almost every tree. I have in mind at this writing a pear orchard, containing possibly 300 trees, in which I failed to find a single tree which did not show this corrosive action of arsenic in a marked degree and in many cases the bark had already been perforated.

The Roots.

The above remarks apply to the roots especially at their juncture with the trunk; sometimes we find the whole of this portion of the root involved, again only the upper portion, if the attack has not approached very near to the final stages. On the roots we often find a very sharply defined limit to the trouble just as we usually do as we approach the surface of the ground. The distal portion of the roots are as a rule in better or even good condition. This point was well illustrated by the case of a pear tree root which I dug out. The root was entirely dead near the trunk, but was apparently healthy a few feet away and had thrown up sprouts.

The Trunk of the Tree.

The trunk frequently shows no effect of the trouble above the ground, especially is this true of the pear trees. Apple trees sometimes show, in such cases, chocolate brown spots on the trunk of the tree. On removing the bark, its inner side beneath these spots, as well as the underlying tissues, present a mottled appearance. The cambium layer is, in these cases, not darkened or discolored except in these spots; the bark is not loosened or at this time dead but it soon dries down to the wood. These areas often have an offensive odor.

The Varieties Affected.

The varieties of apples and pears in which we have found this trouble are so numerous that it is scarcely feasible to name them. Some varieties appear to be more sensitive in some localities while some other varieties are more generally affected in other localities. Mr. Whipple noted the fact that the Ben Davis and Gano are very sensitive to arsenical sprays. It is apparently a fact that in some localities these two varieties are more generally affected by this trouble than any others, in other localities this is not at all true. This statement can of course be made of the other varieties.

The Influence of the Age of the Tree.

Orchards which had attained a considerable age before any arsenical sprays were applied to them do not seem to show the effects of the arsenic to the same extent as those orchards in which the trees were younger when the first applications were made. I recall an orchard visited in company with Prof. Gillette, in which there were trees of very different ages, the most of the trees being of the first setting, now between 25 and 30 years old, but a few of them were much younger. We found none of the old trees which seemed to be in danger from this trouble, while several of the young trees were about to succumb to it. This by no means proves that old trees are wholly exempt, for I know of trees 30 years old or older that have been killed by this trouble. In one orchard a part of which is 25 to 27 years old, the rest about 14 years old, the older portion contains only a few affected trees, while there is quite a number of such in the younger orchard.

The Influence of the Soil.

We will make some general statements at this time, which while entirely adequate for our present purpose are not intended to cover specific features of the problem. Mr. Whipple's statement "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soil," seems to be wholly justified. I have found it literally "on all kinds of soil." While the character of soil may modify the trouble, it does not determine it. I have found orchards set in most excellent loamy soil, well drained, irrigated with pure water, intelligently cultivated, and well located in respect to protection against severe weather and yet this trouble was exceedingly prevalent, while in other orchards on less desirable, even on bad soil, this trouble, though present, was by no means so prevalent. In other cases the problems presented were so involved that no student of this subject would undertake to unravel them. I am fully convinced that the soil itself does not produce the trouble under discussion.

Do Salts Other Than Arsenic Produce It?

The answer is a negative one. We have very marked cases of trees having been killed by the presence of excessive amounts of nitrates formed in the soils. I described some of these at the meeting of the Society for the Promotion of Agricultural Science in Portland, Oregon in August, 1909,. The action of the nitrates is wholly different from that of the arsenic, neither the crown nor the roots are corroded but the foliage and the tree are killed outright, sometimes within a few days. The attack expresses itself wholly differently, it is not gradual, but as above stated sudden, there is no ripening of the foilage but a strong burning and killing. The bark of the crown and the large roots at the time of the attack is perfecly normal in appearance in cases not complicated by pre-existing troubles.

I have found no conditions under which any trouble can properly be attributed to the presence of any excess of sodic chlorid. I have endeavored to determine the effect of sodic chlorid by direct experiment. It is beyond question that salt, in excessive quantities, is injurious to apple trees, but excessive quantities, according to our results, would mean very many times as much salt as we find in any of our soils. Its action was very moderate and expressed its only visible effect upon the leaves much in the same manner as the nitrate.

There is no carbonate of soda, worthy of mention, in our soils, so the action of this salt is eliminated from the question.

There is in some cases a rather large amount of sulfates (sodic, calcic, and magnesic) present but the action of these is not corrosive. Their action is so mild that seedling plants grew in soils to which I had added as much as two per cent. of the weight of dry soil of sodic sulfate and even the little seedlings were not corroded or injuriously affected. I have made a similar experiment with magnesic sulfate. These experiments were made years ago when the opinion prevailed that the alkalis were prejudicial to our lands. These experiments are in keeping with the fact of common observation in many parts of the state, i. e., the production of good crops on lands so rich in alkalis that a heavy incrustation covers them under conditions favorable to its formation. I know of very healthy orchards on land rich in these salts.

Is the Trouble Produced by Excess of Water?

This question is likewise to be answered in the negative. We know that we can destroy even pear trees by keeping their roots submerged in water but this is a condition nowhere obtaining among all the cases studied. The prevalence of this trouble in orchards on high, well drained lands is a sufficient answer to this.

The Area Involved.

In Bulletin 131 I stated that the principal orchard growing sections of this state were probably involved. It is now certain that the extent is wider than the boundaries of this state. There is no disposition on my part to seek consolation in the fact that I believe many sections of the country to be suffering, in a less degree I hope, from the same ills.

The Number of Trees Affected.

Under this caption in Bulletin 131 I stated that it would be difficult to obtain data on which to base even a rough estimate of the number of trees suffering from this trouble. I have visited many orchards since I wrote the above statement and am now convinced that it is difficult to find a fifteen-year old orchard in the state wholly free from this difficulty. There are probably a few but not many. I know of an orchard, the owner of which said to me: "I must have a thousand sick trees." I think that this was an overestimate, but it serves to convey a definite idea of how very prevalent the trouble is in some orchards. I have seen a pear orchard in worse condition even than this apple orchard. Both of these orchards, though many miles apart and on very different land, are within this state. I have not visited the apple growing sections of the southwestern portion of the state and so do not know the condition of affairs there but in the rest of the state no section is entirely free from this trouble. It is found in Larimer County as well as in Otero, Fremont, Delta and Mesa counties, and this represents a distance of nearly 350 miles from east to west and 200 miles from north to south. I am convinced that the number of trees already seriously affected by this trouble are not numbered by hundreds, but rather by tens of thousands.

This may not be an inappropriate place to state again, as I stated in Bulletin 131, that publication on this matter was not the result of any sudden impulse, nor of any desire to obtain a certain notoriety by creating suspicion and alarm in the minds of any class of orchardists, much less to protest against the general practice of spraying, but the publication was made simply because I was fully convinced of the sufficiency of the proofs that great injury had already resulted from the practice, particularly from the irrationally ultra manner in which the practice has been carried on, and that it was perfectly proper and right that the truth should be made known. The facts were presented conservatively. My colleagues agreed that it was wise to publish the results as simple facts. This is what I did and this is the only purpose that I have in view in the present bulletin.

Present Conditions in Regard to the Presence of Arsenic in the Soil.

Several questions relative to this subject may be raised such as the presence of arsenic in soils in general. Toxicologists have answered this in the affirmative, but the evidence of all is that it is present in minute traces. This is not true of our Colorado virgin soils, for they contain more than mere traces, which question will be discussed in a subsequent paragraph. The bearing of this fact on the question in hand is slight. The arsenic contained in the virgin soils examined, taken approximately to the depth of one foot, is just about one-tenth of the average found in the orchard soils, excluding extremely high ones. The maximum amount found in a virgin soil taken to a depth of one foot is almost exactly one-twenty-eighth of the maximum found in an orchard soil taken to the same depth. The orchardist is not concerned with the source of the arsenic but with its effect upon the trees. If there is already a little arsenic in some of our soils, enough to be taken up by the trees to such an extent that its presence may be shown, it does not argue that we do no damage by increasing this amount from 10 to 28 times.

Another suggestion is that the water used for irrigating purposes may contain arsenic. It is a fact that some spring waters contain minute traces of arsenic, so small, however, that its presence may best be established by examining the deposits from such springs. It is, however, not true of our river waters, so far as my knowledge goes, and if it were true, the quantity usually carried by spring waters, not river water, is so small as to be utterly insignificant in comparison with the quantities which we have been pouring upon our lands.

We have been using arsenical sprays in the various parts of our country for various purposes about 40 years. We have been spraying our apple orchards about 28 years and in Colorado we have been spraying 18 or 20 years. The question is what has been the effect of this in regard to the amount of arsenic in the soil? The answer is given above, i. e., that, even in Colorado, we have increased the arsenic content of our orchard soils at least ten fold and in the older states it must be even worse if they have been nearly as zealous in spraying as we have been. But few people consider the real character of the sprays used and we cannot expect the ordinary orchardist to consider the possible results and there has been an abuse of the practice. The practice in this sense has been a dangerous one. I do not know that any station has ever advised six, eight or even nine sprayings in a season. Three is the maximum recommended by this station, and yet I know of men who have sprayed nine times in one season according to their own statements; four, five and six sprayings are still applied by some. The amount of arsenic used has also been unreasonable in many instances. I have in mind a man who, having been directed to use one pound of arsenious acid to the tank added one and a quarter pounds, and applied 90 gallons or a little over 0.56 pound of white arsenic to each tree during the season. I know another man who used almost exactly the same quantity of spray, 90 gallons to the tree, using

16 pounds of lead arsenate to the tank. This man claimed that this was his custom. Assuming this statement to be literally true, let us see how much arsenic acid he had applied to this orchard per acre in the six years preceding. As stated, he used 16 pounds of arsenate of lead to the tank and applied 90 gallons to each tree during the season. Assuming that the pasty arsenate of lead was one-half water it would give us eight pounds of dry arsenate of lead to the tank,0.04 pound in each gallon of spray and as he used 90 gallons to each tree he applied 3.60 pounds of dry lead arsenate, or if the dry lead arsenate contained 25% of arsenic acid, he added 0.9 of a pound of this acid to each tree or 72.0 pounds per acre each year counting 80 trees per acre. In six years he would add 432 pounds arsenic acid to each acre of his orchard, which if evenly distributed through the first foot of soil would give 108 parts per million. This calculation is much nearer to the facts in the case than such calculations are apt to be, for I found 61.33 and 128.83 parts arsenic acid per million in the upper portions of this soil. The other man who used 1.25 pounds white arsenic to the tank, said to me "you don't realize how heavily I have sprayed. This ground was all white with it." I do realize that he sprayed heavily, but he does not. He was adding arsenic acid to his soil at the rate of 51.84 pounds per acre per annum or taking it for a period of six years, as in the preceding case, he added 310 pounds per acre, or 77.5 parts per million of soil. The latter of these men used 26 times and the former 36 times as much arsenic as we now know would have sufficed to have assured them a crop with not more than 5 per cent. wormy apples. These men have lost a number of trees from this cause.

The Amount of Arsenic Now Present in Our Soils.

Determinations of arsenic in our orchard soils have indicated the following range; 25.5, 26.0, 30.6, 36.8, 38.2, 39.9, 61.3, 128.83, and 137.99 parts arsenic acid per million. The samples were taken, some from about the base of the tree and others out under the heads of the trees and to depths varying from four inches to one foot. The soils here represented are without exception desirable ones, they are free from seepage and alkali, and are well supplied with water. These orchards receive good care, still there is more or less of the trouble described as arsenical poisoning in each of them and some of them are very badly affected.

That the arsenic should accumulate in the soils is what we would expect. The materials used as sprays are not very soluble in water. The amount of water applied to our soils is not excessive, irrigation waters and rainfall together amounting to not more than 24 inches. The materials are not volatile and the evolution of arseniureted hydrogen from the soil has not yet been proven, though a slight elimination of the arsenic in this form, especially under favorable conditions, might take place. The fact, however, is exactly what we would anticipate, i. e., that the soils of orchards which have been sprayed for some years are already rich in arsenic.

Some of This Arsenic is Soluble in Water.

In the application of the sprays it was soon found that the arsenic must be insoluble or it would burn the foliage of the trees and in order to avoid this an endeavor was made to obtain a compound so insoluble that this effect would be avoided. To this end lime was added to the Paris green, and the lime, sal soda and arsenic preparation recommended. I do not know whether any consideration of the final effect of the arsenic on the tree was considered or not. The insolubility of the spray material is the only protection that our trees have had. The term insolubility as here used means nothing more than difficultly soluble and that in a somewhat popular conception of the term. The spray materials used are somewhat soluble in pure water and much more readily so in solutions of sulfate and chlorid of soda. The Kedzie formula was supposed to remove the whole of the arsenic from the solution because of great excess of caustic lime, but this is readily changed into a neutral salt, the carbonate, when its protective action is practically destroyed, besides there remains a considerable amount of arsenic in solution owing to the solubility of the lime salt. Paris green to which the proper amount of lime has been added yields arsenic rapidly to water, and arsenate of lead, $Pb_3(AsO_4)_2$, will yield 0.3% of its dry weight of arsenic acid. Soil, therefore, which contains these spray materials ought to yield arsenic to pure water and it does. I at first assumed that the presence of so much carbonate of lime, as is present in our soils, would wholly prevent any arsenic from going into solution, but this is not the case. Another agent which I thought would also tend to prevent the solution of arsenic is the iron which is fairly abundant in our soils, especially our red soils. A very large number of our soils are marly, namely, contain more than 5% of calcic carbonate, but neither the lime nor the iron nor both together prevent the solution of arsenic in our soils. This is an easily established fact. Sixteen samples of orchard soils from various parts of the state have been tested and found to carry very decided quantities of arsenic which is soluble in water. I have weighed the arsenic in a few instances and obtained the following figures: 0.68, 0.68, 0.84, 1.04, 1.166, 1.265, and 1.345 parts of arsenic acid per million of soil. These quantities corroborated by those obtained with nine other samples are conclusive in regard to the presence of water soluble arsenic in the soil in very decided quantities and that, too, in quantities which competent experimenters have found to be injurious to vegetation when present in nutrient solutions.

When I wrote Bulletin 131 I feared that the presence of water soluble arsenic in our soils might be largely due to the presence of sodic sulfate and sodic chlorid. That these salts are present in our soils in larger quantities than in eastern soils is a well known fact. It has been shown by experiment that lead arsenate, even the tri-plumbic salt, yields arsenic quite freely to dilute solutions of these salts and that calcic arsenite (lime, sal soda and arsenic) acts in a similar manner. It has also been previously stated that the arsenical compounds usually used for spraying are perceptibly soluble in distilled water. The statements made regarding this matter in Bulletin 131 are perfectly correct and I do not wish to change them except to lay less stress on the action of the alkalis, for soils entirely free from alkali contain water-soluble arsenic in weighable quantities. The solubility of the arsenic in the soil is undoubtedly favored by the presence of alkalis, but is not primarily caused by them.

For some years past, since about 1904, we have been losing a number of pear and apple trees by an affection which men, competent to determine the facts, have been unable to establish as due to any other cause than the corroding effects of arsenic. Among the causes considered were bacteria, fungi, King disease, winter killing, alkali, etc. The trouble is independent of the varieties of soil, it expresses itself uniformly in the same manner, attacks the trees at the same point, runs a very uniform course in regard to both manner and duration and is almost uniformly fatal. Here attention should be called to the fact that it has been only the badly affected trees that have been observed until very recently.

In regard to the soil we have shown the extent to which arsenic has accumulated in the soil due to the practice of spraying. Further we have shown that this arsenic in the soil is soluble in water to an extent that exceeds the limit of safety, and that the large quantities of lime and iron salts in our soils do not effectively prevent the solution of the arsenic by pure water. We have shown that the alkalis in our soils may favor, but are not needed, to cause the solution of this arsenic. We have also shown that our virgin soils, a goodly number of them too contain arsenic and will show in the proper place that this arsenic is slightly soluble in water in six out of seven cases.

The amount of arsenic present in our virgin soils, however, is less than one-tenth of that found in our orchard soils, and while it may play a part in some phases of this subject, it does not in any manner enter into the question of corrosive arsenical poisoning because it is associated with the marl and for the most part lies beneath the feeding area of the tree and is not collected about the crown of the tree.

The phase of arsenical poisoning under immediate consideration begins by attacking the outside of the bark at the crown of the tree converting it into a black, friable mass, finally eating its way through the bark, attacking the woody tissues and producing the death of the tree, either by starvation or otherwise, a question which the future may solve. The important fact is that the trees of which we are writing, and there are many thousands of them, are either doomed to die within the next two years or are already dead. That portion of the roots joining onto the base of the trunk is almost invariably involved. The attack may, in a few instances, begin on the roots but the number of these instances is small.

The Effect of Arsenic on Trees.

I have a record of about twenty trees, the greater portion of which I have seen myself, that have been injured or killed by arsenic, either in the form of arsenious acid, sodic arsenite, calcic arsenite or lead arsenate.

In Bulletin 131, page 19, I referred to experiments of others made to establi h the effect of arsenic upon vegetation and gave the results of a few experiments made with greenhouse plants and cited the cases of two trees which I had met with, one of them presenting with great clearness the action of arsenic, particularly in the form of arsenious acid, upon the bark and woody tissues of the tree. I then stated that I gave the case in considerable detail because I believed it to present as conclusive an illustration of the action of arsenic upon trees as could possibly be adduced. I have since then seen several trees injured by the same cause, sodic arsenite, and while they each present an essential reproduction of that case, none of them have been any more marked or presented any feature more forcibly than it. I shall therefore use it again to show that soluble arsenical compounds when present in sufficient quantities will kill trees, secondly to show in some detail what the action of arsenic is on the tissues of the tree, particularly upon the bark and the woody tissues. The condition of this tree in the following April is shown in Plate I, taken from Bulletin 131.

The arsenic used in this accidental experiment was sodic arsenite emptied into an irrigation ditch, twelve feet distant from the tree. This was done in the month of June when the tree was in active growth. Two days later a portion of the tree was sick or dead, the person describing it said dead. I was not present that day. The limb never showed any signs of life afterward, the killing was thorough. Mr. Whipple and I subsequently dug out the poisoned root of this tree tracing it from the trunk to the point in the irrigating ditch where the arsenic had been emptied into it. The other roots of this tree which we encountered were apparently normal. Even those branches of this root which ran parallel to the ditch and whose feeding area had not received any of the arsenic also appeared normal. The rootlets within whose feeding area the arsenic had come were dead, being black and brittle. We could see the course of the arsenical solution from the rootlets to the tip of the twigs as the root lay in the trench which we had dug to expose it. The lateral branches of the root and the two side sections were normal in appearance, the top section and also the bottom section had been very strongly attacked. The bark of the root on the two sections attacked was thoroughly disintegrated and two irregular sections of the woody tissue of the root were killed and stained brown, shown in Plate II, Fig. I. The total

Colo. Ag. Expt. Sta.

PLATE I.


Fig. 3


Fig. 1-A

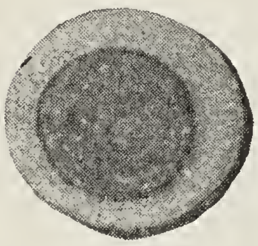


Fig. 2

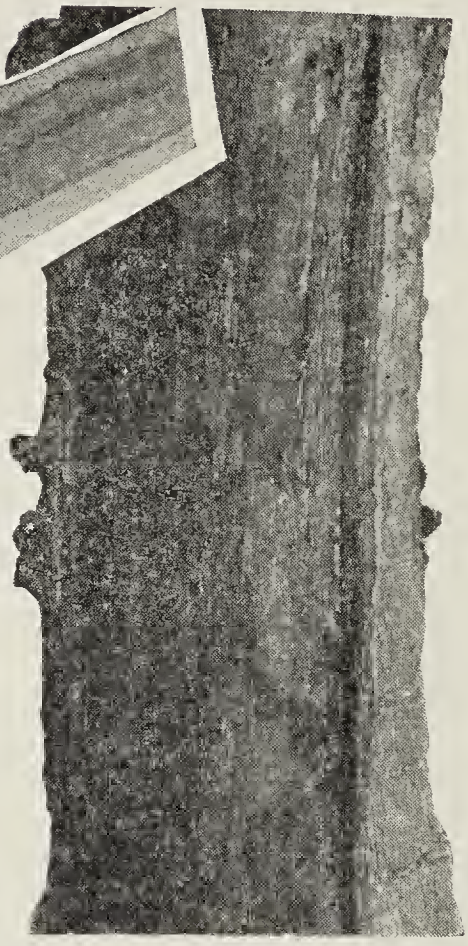


Fig. 4

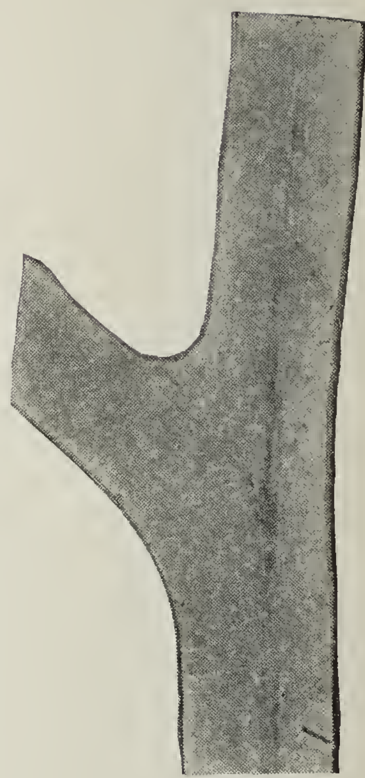


Fig. 1-B


Fig. 1


Fig. 2

Colo. Ag. Expt. Sta.

PLATE II.

disintegration of the bark on the root shown very distinctly in Plate II, Fig. 4, was continuous to the base of the tree. Here the bark became brown and sunken. This particular form of the injury extended some distance up onto the limb. Beneath this bark the wood was stained brown. The sunken part and stained wood is shown in Plate II, Fig. 2. The interior portion of the remoter branches of this limb was stained brown. This is shown on Plate II, Fig. 1-A, in longitudinal section, in Fig. 2 in transverse section. The other portions of this tree were perfectly normal, the bark was healthy, the woody tissues of both roots and branches showed no staining or "black hearted" condition. The healthy condition of the other roots and branches of this tree is also shown on Plate II by Figs. 1-B and 3. The so called black heart is in some cases caused by freezing but this case cannot be explained in this way, for we know its cause and can trace its course and action and the injury was done in the month of June. No one will, I think, suggest that these changes were subsequent to and a result of death and not of the action of the arsenic for all parts of the tree nourished by roots feeding outside of the poisoned area, even sections of this one root, remained apparently healthy and those portions of this tree which I have not cut off are still healthy.

I indicated clearly in Bulletin 131 that I was aware of the fact that this case, and all the cases do the same, raises questions regarding the course of nutrient solutions in the tree. I dismissed this whole subject with the following statements: "The course was direct and the flow of the poisonous solutions was confined to a comparatively narrow channel. * * * I am not concerned about any theory of sap circulation, but am simply tracing the discoloring effect of the arsenic through the roots into this portion of the branches."

I have personal knowledge of four other trees injured by the same agent, sodic arsenite, in a similar manner. The facts in these cases are even more interesting than in the preceding.

There had been fillers planted betwen the rows of apple trees. These fillers, plum trees, had been cut down, the owner poured one half teacupful of the sodic arsenite solution on each of the four stumps to kill them and at the same time get rid of the arsenical solution. No effect was produced for the next two or three days, at the expiration of which time the orchard was irrigated. The statement of the owner and his wife is, that within fifteen minutes after the irrigation water reached these stumps the leaves on one side of the largest of the four trees involved drooped and never recovered. The owner surmising the cause of the trouble dug a trench and cut off the roots of the tree on that side. The odor of the sap exuding from the wounds made on the limbs by the arsenic was very offensive.

The fourth tree in this group presented an interesting case. Two limbs on one side of the tree were injured, portions of them were killed. There was a narrow strip running from the ground up into a big limb of this tree and then divided, following two smaller limbs, breaking out to the surface in an apparently erratic way. The limbs were killed. Not being fully satisfied about the facts connected with this tree, I determined to examine its roots. I found two roots affected, one was still partly alive, the other was entirely dead. Neither of these roots was very large, a scant inch in diameter, but we traced the wholly dead one for twelve feet then we trenched across its course at several points and thus traced its dead rootlets to the stump on which the arsenic had been poured, 22 feet from the trunk of the tree. These roots presented externally the same appearances as the root previously described and is well represented by Plate III, reproduced from Bulletin 131. The other roots of this tree which we encountered were apparently normal. I examined several samples of wood from the first tree and found arsenic abundantly present and determined the quantity of arsenic present in the woody tissue of the root. The amount of arsenic present in the woody portion of the root of the first tree after the bark had been pared off corresponded to 34.5 parts of arsenic acid per million parts of tissue. The arsenic in the root of the second tree described corresponded to 24.02 parts of arsenic acid per million parts of tissue. The disintegration of the root was certainly remarkable.

PLATE III.

I have information of several other instances in which similar results have been produced. According to the statements of the owners it seems probable that the arsenite of lime might have done the damage to their trees.

Mr. A. B. Hoyt, Horticultural Inspector of Mesa County, informs me that he has seen a cottonwood and a willow tree killed by the bursting of a jug of sodic arsenite which had been left beneath them.

I have the record of some other trees killed in a similar manner.

These cases are cited that we may present the effects of arsenic upon the tree and its tissues when it is present in the soil in a soluble form and in sufficient quantities to kill quickly.

We find in these cases the following features: the disintegration of the bark and woody tissues of the roots, the killing of the bark and tissues of the trunk, the production of a black heart, the exudation of ill smelling juices and a stunting in cases where a portion of the limb has survived.

The arsenite of soda mentioned above is the solution of white arsenic in sal soda, and is mixed with lime and water before it is used as a spray. It is mixed with lime to make the arsenic insoluble, though a very marked quantity of arsenic remains in solution in the alkaline liquid. This is contrary to general belief. I have had two lots of this preparation made with very excessive quantities of lime. Two hundred cubic centimeters of the supernatant solution gave a good test for arsenic by Reinsch's test. The sodic arsenite is not itself used for the purpose of spraying the trees but is added to the milk of lime to make the lime, sal soda and white arsenic preparation.

Dr. S. M. Bradbury, Horticultural Inspector of Mesa County for eight years, makes the following statement which is used with his permission. "Bands had been used in a certain orchard and on adopting the lime, sal soda and arsenic spray these bands were left on the trees, some of them for two or three years. Some of these trees died and on examining the bands we found that the bark beneath the bands had been entirely eaten up. The lime and arsenic had collected under the bands and destroyed the bark."

I know of another tree within a few feet of which the owner had mixed his spray material for several years in succession. This tree died and its wood was rich in arsenic. In this case arsenate of lead was used as far back as I have any information—about four years before the death of the tree.

I will cite but one more, though there are a few other instances which might be given. A man emptied his spray tank, containing arsenate of lead, about six feet from an apple tree; that side of the tree died. I did not take and analyze any portion of this tree because the owner did not wish me to deform the tree as he was sure he could cure it. The effects in these cases were in the main the same as in the cases killed by sodic arsenite, disintegration of the bark, the staining of the woody tissue, the production of a "black heart," and the production of a yellowish red bark frequently with longitudinal cracks. It will be remembered that I did not see the trees described by Dr. Bradbury, though I know the orchard very well and can testify that it has been in very bad condition for several years past. His description which I believe to be entirely reliable tallies exactly with what we find in the other instances. It is only through accidents that we have opportunity to observe the effects of sodic arsenite on 16 or 18 year old trees in commercial orchards, but the lime arsenite and the lead arsenate have been applied plentifully to our commercial orchards for years past and the action of these two may be found in almost any commercial orchard from 12 to 18 years old. No distinction can be made so far as I have observed between the action of these two sprays, except that the lime salt being more readily soluble than the lead salt probably has done the greater amount of injury to our orchards.

We have then a fair amount of evidence obtained by direct observation of the effect of arsenic in the three compounds, sodic arsenite, lime, sal soda and white arsenic, and lead arsenate, upon the bark, the woody tissues and the life of the tree. The sodic arsenite acts quickly, causing the death of all parts of the tree to which it may be carried; it causes the disintegration of the bark, especially of the roots, and may also destroy that of the trunk. It stains the woody fibre and causes its disintegration, sometimes producing a punky condition, and produces in the branches not so seriously affected a "black heart" condition. The lime arsenite and the lead arsenate produce essentially the same condition in the tree but their action is very much less intense.

Is Arsenic a Normal Constituent of Any Wood?

I have not examined many woods for arsenic with the object of determining this point, one sample of oak and a few apple trees. The oak contained no arsenic and I have found three apple trees in Colorado which were free from it, two of them were young trees and the third tree was one which had been killed by blight. The presence of arsenic in fodders, vegetables, meats and even in the human body are matters which belong in the province of the toxicologist and have but little bearing on a question dealing with such large quantities of arsenic as we do in studying its effect upon trees. I think that we are justified in assuming that normally arsenic is no more a part of an oak, an elm, or an apple tree than it is of the human body. In these days, however, when arsenic is spread broadcast upon our soils as superphosphates and arsenical sprays it would be rather surprising if it has not become so generally distributed that it might be found in the organs and bones of almost any person. I am certain that should the writer of these lines die suddenly and his body be subjected to a careful analysis, but little trouble would be met with in demonstrating the presence of arsenic in his liver, spleen, and possibly other organs, of which facts I hope to give good proofs in a later paragraph. I think that we may waive the question of traces and assume without any fear of being in error that arsenic is not a normal constituent of apple and pear trees in the quantities with which we are dealing, from one half to upwards of 20 even to 34 parts of arsenic, calculated as arsenic acid per million of the woody tissue.

Arsenic is Taken Up by the Trees.

I have endeavored to convey to the reader a clear notion of the amounts of arsenic which have accumulated in our orchard soils. As much as 138 parts of arsenic, calculated as arsenic acid, having been found per million parts of soil. This does not mean that every man's orchard soil is as rich as this nor does it necessarily follow that I could not have gotten samples from this orchard which would have run less, or perhaps more. This sample was a large one taken to the depth of one foot. I have shown that the water soluble arsenic in these soils in some cases exceeds 1.25 parts per million. The effects of soluble arsenical compounds on apple trees has also been shown. These cases were extreme ones, it is true, but they prove that apple trees may be killed by arsenic and they show the action of arsenic on the bark and wood of the tree. We will now give in some detail what we find in the case of our sick trees. No one can tell how many sick trees we have. I have examined several thousand, however, and in stating this it is to be understood that no trees suffering from neglect or blight or sunscald or nitre or trees in which there was any evident complication of troubles or even mechanical injuries are included.

Plate IV. is a photograph of an Anjou pear tree, taken in September 1909. The trees in the background are already attacked but will live two or possibly three years yet. The soil is a sandy loam free from alkali and seepage. A hole was dug at the base of the tree and there was no water at a depth of four and a half feet. The photograph shows where a large limb was cut off for examination.

The number of individual trees which have been analyzed is eighty-one, sixty-seven in connection with this bulletin and fourteen in connection with Bulletin 131, and of the eighty-one samples examined I have personally taken fifty-five, possibly more. I have not known the history of the trees in more than a few instances. Orchardists do not, except in rare cases, keep a written record of their doings and I find that any other record is of little value; more satisfying than none, it is true, but not to be depended on. This is in no wise a reflection upon the veracity of orchardists or others, but simply the statement of a very well known fact, i. e., that no one remembers their ordinary, every-day doings for more than a very short time, especially when these doings may be repeated quite frequently but at irregular intervals.

I have arrived at the point where I do not consider statements made pertaining to acts done much prior to the current year, and even then I consider a number of things before I place much value on the statements. This is very unfortunate for it necessitates the rejection of much information that might be very valuable and it increases our difficulties when the help that the information would afford is badly needed. I have been told very many times of trees that had never been sprayed; those trees, however, almost uniformly proved to contain arsenic, copper and lead. I admit that this is not absolutely rigid proof that the trees had been sprayed, but in as much as we have been using preparations of copper and arsenic, lime and arsenic and lead and arsenic with which to spray trees and as these substances eventually find their way to the ground from which the tree draws its nourishment, I submit that one is justified in interpreting the presence of these three substances, or even arsenic and either one of the others, in the woody tissue of the tree, as conclusive that the most probable source of the arsenic and lead or arsenic and copper was spray material which had been applied, rather than any original occurrence of these substances in the soil. This would seem the more probable as spraying of fruit trees has been practiced for not less than twenty-eight years and has been general in our section for about fifteen years. As the trees in question are usually from fourteen to thirty or more years of age, I prefer to accept the testimony of the chemical examination as to whether the tree has been sprayed or not rather than the state-

PLATE V.

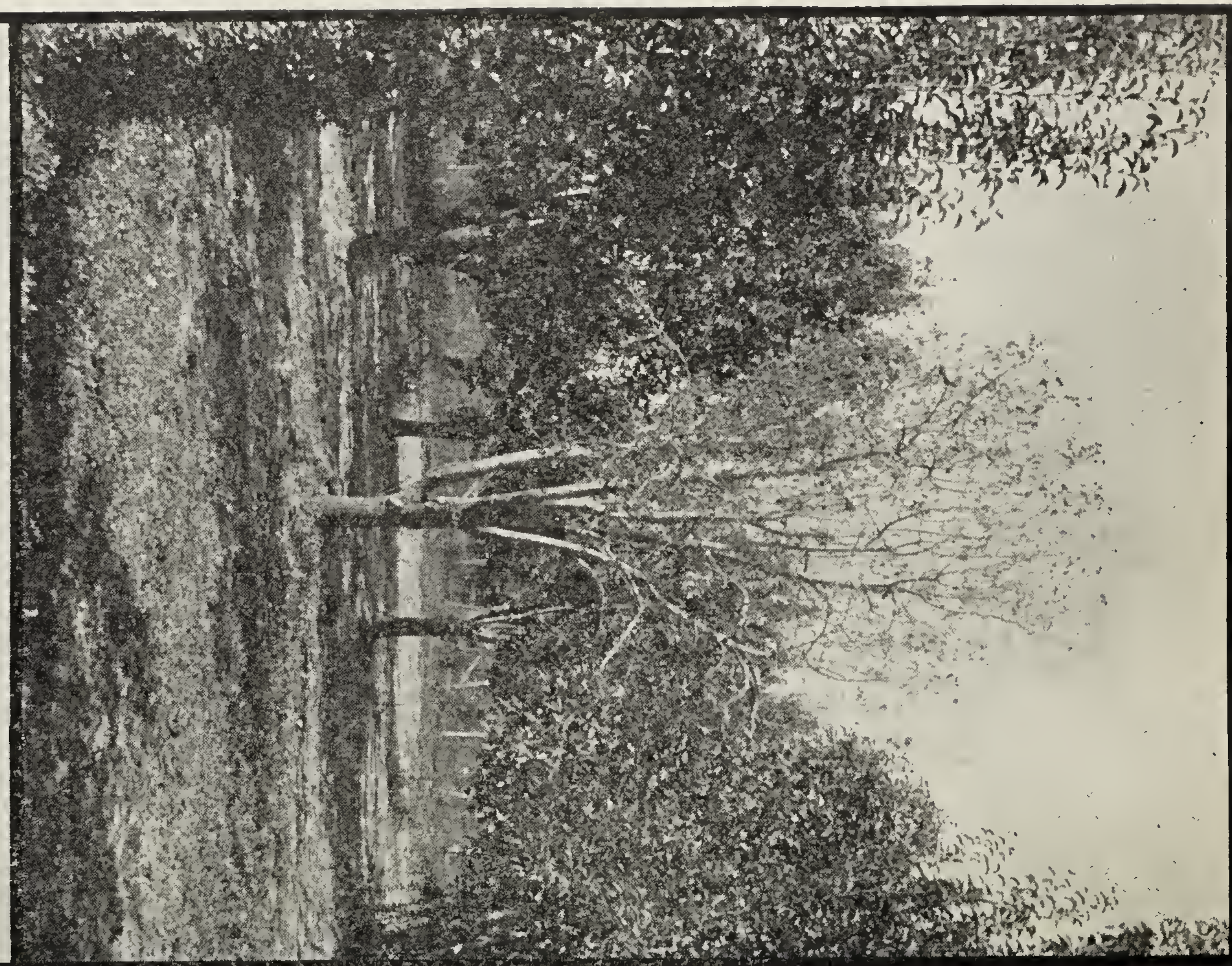


PLATE IV.

ment of the present owner, who in many cases knows nothing about the earlier history of the orchard.

In writing of these trees Mr. Whipple made the following statement:

"Two seasons are required for the disease to kill the tree. The first season the trunk is girdled and the foliage drops early. This early ripening of the foliage is often the most prominent symptom and diseased trees can be easily picked out in the early fall. * * * The second season the tree starts in to leaf as the normal tree, generally setting fruit, and dies in midsummer, the fruit and leaves clinging."

This description is entirely correct, but it applies to trees in which the damage has already proceeded so far that we can, with a great degree of certainty predict how soon the tree will die. This too was the phase of the trouble at which we began to study it. We found a zone beginning just below the ground and extending down on to the roots where the bark had been destroyed and the underlying tissues stained brown. The similarity between these conditions and those produced by the arsenite of soda is perfect. The destruction of the tissue is almost as though it had been charred by dilute sulphuric acid but is more complete than would be accompanied by a like coloration if it had been produced by this acid. I have examined a large number of samples of the woody tissues of such trees, and have uniformly found that arsenic is present. The bark has not been used because the arsenical spray material might be mechanically included in it. For this reason the bark has in all cases been carefully removed. Further no dead wood which has been exposed to contact with spray material has been used, so that the results represent what has taken place in the tree itself.

The first samples examined were roots of a pear tree in which the trouble had not proceeded as far as the phase described by Mr. Whipple, but which were not healthy; these roots contained arsenic in large quantitites. Subsequently other pear trees and apple trees were examined with like results till we have examined in all eighty-one trees, apple, pear and peach. The results may be summed up as follows: in every case in which the death of the tree has been caused by corrosive arsenical poisoning we find the crown of the tree girdled, the bark below the surface of the ground is usually attached to the tree but is brown or black in color and its texture is wholly destroyed, the woody tissue of the root is colored mostly a deep brown and sometimes its texture too is destroyed. The wood of the lower part of the trunk is usually stained, though it may have no other sign of unhealthiness. This is in no manner similar to a spot of dead wood on the trunk of the tree above the crown caused by freezing or by a mechanical injury. The bark above the line of the ground is intact in most of these cases though there are some instances of trees resembling the one shown in Plate 2, Fig. 1, Bulletin 131, which, however, is not similar to cases of winter killing with which any of us are familiar. The heart wood even in the limbs and branches is generally, but not always, of a deep brown color with a decidedly darker brown margin. This coloring is irregular and does not conform to annual rings. The trees that die of this disease, and I believe that they all die, linger two seasons. Further it is safe to predict that every tree that we now find with a corroded crown and some dead roots will perish within the next few years if left to itself. We have many trees which show no sign of the trouble above ground this year, but which we can safely predict will die within the next two years. The signs above ground are those described by Mr. Whipple. The trees first submitted to analysis were naturally trees that were very sick. But few actually dead trees have been examined. No such sick tree has failed to yield a strong reaction for arsenic. This is most abundant at the crown of the tree, less abundant in the upper portion of the stem and still less so in samples of the branches, but is prsent in all parts of the tree.

I wish to emphasize the fact that we have two phases of the action of arsenic, first the local action of that which collects about the crown of the tree and that which has been taken up from the soil by the feeding roots and in this way passed into the tree with the nutrient solutions. It is evident that if the tree has been sprayed often enough to permit so much arsenic to collect at the base of the tree that it corrodes the crown and roots, the tree will also have gathered arsenic from the soil by means of its feeding roots and no one can say how much of that present in the woody tissue has been taken from the soil and how much has been absorbed through the wounds made by the arsenic on the crown and roots of the tree.

I maintain that we have strong reasons for believing that considerable injury has been done by arsenic absorbed with the nutrient solutions when it produces what I have designated as systemic poisoning. This feature was merely touched upon in Bulletin 131 because as there stated the cases of irritant poisoning are more numerous and, I may add, more evident.

It is evidently out of the question to give the details of sixty or more trees suffering from irritant arsenical poisoning. The observed facts are so uniform that it would only be to restate the same thing as many times as we should describe different trees. In every case we find a zone just below the surface of the ground and involving the large roots in which the bark of the tree is converted into a brown or black mass and the texture destroyed, the woody tissue beneath this is in many cases also destroyed, especially of the roots; in the trunk it is usually partially destroyed and always more or less stained of a brown color. As these trees approach death, usually indicated in the early fall of the year preceding this event, the foliage ripens early. The tree usually blooms profusely the next spring, sets fruit and dies early the next fall, the leaves and fruit often remaining on the tree in some instances until far into the winter or even the ensuing spring. In some cases we have a killing of the bark above ground. This occurs in continuous areas extending up so far as to sometimes involve a portion of a limb. This is shown in Plate 2, Fig. 1, Bulletin 131. The bark is not loosened but is killed, the juice that exudes is ill smelling and the area is continuous with the corroded crown. The whole section of a root may be involved or only the upper portion of it. There is frequently as sharp a line showing the limits of the attack on the roots as is shown by these patches on the trunk. This illustrated by Plate VI, rep-

PLATE VI.

resenting the root of an apple tree, the further portion of which was perfectly healthy in appearance, which is also shown in the photograph. It may be of sufficient interest to justify a statement that this root was cut from the tree last May and the tree was practically dead this fall when I last saw it. I have found in such trees from 12.5 parts in the woody tissue to 24.65 parts of arsenic, calculated as arsenic acid, in the disintegrated bark.

Prof. C. S. Crandall, of the University of Illinois, formerly horticulturist of the Colorado Experiment Station, writes me that their chemist, Mr. O. S. Watson, obtained in samples of disintegrated bark which he collected while on a visit to this state 1.8 and 15.8 parts of arsenic per million.

In a sample of disintegrated bark collected from the crown of some pear trees 24.71 parts of arsenic per million, calculated as arsenic acid, were recovered. In the woody tissue of an apple tree root which we know was killed by sodic arsenite, 24.02 parts of arsenic acid were recovered. The inner portion of the bark on the pear tree is for the most part still intact and healthy but the bark is in many places very thin and occasionally we find it eaten entirely through and the underlying sap wood already attacked. The explanation that I offer for this condition is that the spray has been applied heavily enough to run down the trunk and collect around the crown of the tree just as the arsenic collected under the bands described by Dr. Bradbury. It has been soluble enough to saturate the bark to the extent stated, 24.71 parts per million, and to cause its destruction. This sample of disintegrated bark may have contained some arsenic in the form of the spray originally used. We tried to remove all the soil and adhering spray by sifting, this being the only feasible means of removing them.

The Source of the Arsenic.

We have found arsenic present in every sprayed tree which we have examined. I am fully convinced that every sprayed tree contains arsenic enough to permit of its detection in the woody tissue without the use of any very large amount of the wood. I believe that from two to 4 or at most 6 ounces of wood will suffice for the detection of arsenic. The perplexing feature in this work has not been to detect the presence of arsenic but to arrive at a definite conclusion in regard to its source and action. I have already answered both of these questions.

The presence of arsenic alone is not taken as sufficient proof that the arsenic in the trees came from spray material, though such might be the case, but when arsenic and copper or arsenic and lead or when all three are present at the same time I believe it to be sufficient evidence that the tree has taken it up mostly, if not wholly, from the sprays which have been used. If there is arsenic already in the soil the tree might without doubt obtain a trace from this source. This question, however, will be more fully considered under the subject of systemic poisoning, where it properly belongs.

The Cause of Death.

The crowns of trees growing in our neglected orchards are not corroded although the trees may be in bad condition. The trees that have been killed by nitre have perfect crowns. We have described the condition of the bark on trees showing cases of corrosion. We have shown that arsenic destroys the bark in this manner and have cited at least eight instances in which I have seen the trees. We have shown that this bark contains in the case of the pear trees arsenic equivalent to 24.71 parts of arsenic acid per million of the bark. This observation is supported by the findings of Mr. Watson, who obtained 15.8 parts of arsenic per million, which, assuming that Mr. Watson's figures mean metallic arsenic as I suppose they do, would correspond to 24.22 parts arsenic acid per million. These figures are so high that any other source than the spray material is out of the question; besides we know that the spray material does run down the trunk and into the ground at the crown of the tree. That this is a sufficient amount of arsenic to destroy both bark and woody tissue is plainly shown by the amount of arsenic found in the disintegrated tissues of roots which we know were killed by arsenic, in which was found arsenic corresponding to 24.02 parts arsenic acid per million. The maximum amount of arsenic found in any part of a tree, even when the arsenic was known to have been applied in such quantities as to have killed the tree quickly, corresponded to 34.5 parts of arsenic per million. We have stated that we find this corrosion of the bark in all stages of advancement from a mere film on the bark to a point where it has eaten through the bark and attacked the woody tissue and have found this woody tissue to contain arsenic equivalent to 13.20 parts arsenic acid per million. We have then this series of facts showing the progress of the disease till the girdling is complete, or so large a portion of the crown and roots have been destroyed that the tree dies. The amount of arsenic in the bark and in the tissues in extreme cases is as great as is found in tissues known to have been killed by arsenic but we do not know that the amount found in the destroyed root is not very many times the minimum amount necessary to produce this result. I have no hesitancy in concluding that arsenic applied to trees as arsenical sprays, i. e., as Paris green, as arsenite of lime (lime, sal soda and white arsenic), and as arsenate of lead has produced this trouble.

Arsenic in the Trunk and Limbs.

That I am unable to distinguish, in cases of trees which have died of irritant arsenical poisoning, how the arsenic found in the woody tissue was taken up is evident. The trees described were all in a dying condition but not dead, therefore imbibition after death is out of the question, but whether the arsenic found had been taken up by the wood from the injured crown or had been gathered by the feeding roots from the soil I cannot tell. Since this is simply a matter of fact which cannot be directly observed, I will assume that both methods have played a part. That the roots gather arsenic from the soil will be abundantly proven and further that they may gather enough to injure or even kill the tree. On the other hand it is very probable that arsenic is absorbed directly from the corroded crowns and roots, in which case we would expect the tissues in the neighborhood of the wounds to be richer in arsenic than those parts farther removed. This is, I think as much as can be said in regard to this point.

This is the case in these trees. We have in the woody tissue at the crown of a dying tree as much as 13.20 parts of arsenic, as arsenic acid, whereas in the limbs I have not found more than 3.28 parts per million and this was in a Bartlett pear tree which had been heavily sprayed, having received seven or eight sprayings annually for six years. The crown and roots of this tree were badly corroded and the roots contained 4.821 parts of arsenic acid per million. In a tree near which spray material had been mixed and which had killed the tree I found 8.32 parts per million in the roots and 6.35 parts per million in the limb. The roots and crown of this tree were badly corroded. This sample was taken in the month of March. I do not think that the tree would have put out any leaves if it had been allowed to stand. There is not always so marked a difference between the arsenic content of the crown and the limbs though a difference always exists; in the case of a pear tree, the one shown as a badly affected tree in Plate IV, the root showed 3.505 parts per million while the limbs gave 2.19 and 2.64 parts per million.

It is perhaps proper that I should say a word in regard to these determinations. It is a difficult task to manipulate the destruction of 60 or 70 grams of wood without losing some arsenic, again there is some loss in the Marsh-Berzelius method, again it is impossible to weigh such small quantities except on a button balance, which is not always at hand. In this connection I wish to acknowledge my indebtedness to Wm. Ainsworth & Sons who kindly placed one of their balances at my disposal. This balance was claimed by these makers to be accurate to 0.005 milligrams, and the balances are as represented. The weighings are accurate but the difficulties in the recovery of the arsenic will not justify us in claiming the highest degree of accuracy for them. One thing however can be said, i. e., they are all too low, and this without an exception. This I think will be readily acceded by persons competent to judge. The pages of a bulletin are not, in my opinion, the place to discuss analytical methods, therefore this subject will not be mentioned further than to reiterate the statement made in Bulletin 131: "That the reader is assured that the arsenic reported was not contained in any or all of the reagents used. The care taken was in all ways as circumspect, so far as the analytical work was concerned, as though human viscera were in my hands." Trouble was had in obtaining zinc so nearly free from arsenic that one could use it without misgivings.

The Part Played By Alkalis.

I was very explicit in my statements regarding this subject in Bulletin 131. I see no reason to change any statement made therein, namely that lead arsenate yields arsenic quite readily to dilute solutions of sodic sulphate or sodic chlorid and these are our common alkali salts. The other salts always understood, when we use this term, are the sulphates of lime and magnesia. Distilled water dissolved arsenic acid from the arsenate of lead which we used though it, the lead salt, had been previously washed, but water to which sodic sulfate or sodic chlorid, ordinary salt, has been applied will dissolve it more readily. This is true of the neutral lead arsenate and probably in a higher degree of the acid arsenate. Arsenite of lime (lime, sal soda and arsenic) is quite soluble in water but more readily so in water to which sodic chlorid or Glauber's salt has been added. I have, however, met with soils in which there is so good as no alkali and yet a very considerable amount of arsenic can be dissolved out of this soil by distilled water. I have even obtained soils from states in which alkali is not supposed to exist and these soils, too, contain arsenic which is soluble in distilled water and the quantity is so significant that it raises a doubt in my mind as to how big a part our alkalis actually play in the matter. It is evident that they may take some part in bringing the arsenic into solution in water but they are certainly not the primary cause of its solubility. As elsewhere stated, all of the arsenical compounds used as spray materials, Paris green, arsenite of lime and lead arsenate, are perceptibly soluble in water and consequently any soil containing these salts in sufficient quantities ought to yield arsenic to pure water, as they actually do. The alkalis in our soils certainly tend to increase this solubility, but as stated, we find so much water soluble arsenic in soils free from alkali that I am now very much inclined to attribute a rather small part to them, and to take the statement first made by Prof. Whipple, that "soil conditions seem to have no relation to the disease" in the broadest possible sense. I, however, am not willing to say that the alkalis have no influence but simply that I am convinced that they have much less influence on the question than I formerly thought. This view is not only forced upon me by the fact that soils free from alkali contain water soluble arsenic, but also by the fact that I have found so many trees injured by arsenic and yet the soil in which they had grown could not be called an alkali soil without actual disregard of facts.

In order to test this point further and at the same time to determine the difference in the deportment of the orthoarsenate of lead, $Pb_3(AsO_4)_2$ and the acid arsenate, $Pb\,H\,AsO_4$ with dilute solutions of the ordinary "alkali" salts, i. e., sodic sulfate and chlorid, six series of experiments were made which extend those described in Bulletin 131 in that sodic carbonate is included in the solutions and further we have endeavored to determine the arsenic acid that went into solution.

The first solvent considered is sodic sulfate, because this is our common alkali. Three strengthes were used: one, two and three grams per litre. The strongest of these is weaker than many of our soil waters, but is probably as strong as the soil waters in the majority of our orchards. It is very certain that quite a number of orchards can be found in which the soil itself will contain a larger amount of sodic sulfate than 0.1 per cent, or one part per thousand; on the other hand there are a great many that do not contain this much. This statement is made because there are many places where we sometimes meet with saturated solutions of this salt and this condition is supposed to apply to all, or to a very large portion, of the orchard land which is too broad an inference. One and one-quarter gram of the lead arsenate was added for each litre of the solution and the whole shaken frequently.

The solubility of the acid lead arsenate in water was not determined but it has been previously stated that distilled water dissolves about 0.3 per cent. arsenic acid out of the triplumbic or neutral arsenate. According to this each litre of water would dissolve 3.7 milligrams of arsenic out of the 1.25 grams of ordinary arsenate of lead. Portions of the solution were taken at the end of 24 and 72 hours. We had some trouble to obtain perfectly clear solutions. The difference in the amounts of arsenic dissolved being quite small the range being from 3.9 to 7.2 milligrams per litre. I give the average of eight determinations made with the sodic sulfate which is 5.6 milligrams of arsenic acid per litre for the triplumbic arsenate. This includes the thre strengths used, 1, 2, and 3 grams per litre, or parts per thousand. The acid arsenate, $PbH\,AsO_4$, gave higher results from 3.8 milligrams per litre in 24 hours for the solution containing one gram sodic sulfate to 10.5 milligrams in 72 hours for the solution containing three grams sodic sulfate per litre. The average for the eight determinations made is 6.4 milligrams arsenic acid per litre.

The acid arsenate is more readily attacked even by these weak solutions than the ordinary arsenate of lead; but both yield significant quantities.

Previous experiments had inidcated that sodic chlorid (common salt) is much more vigorous in its action on lead arsenate than the sodic sulfate or Glauber's salt. Sodic chlorid is not present in large quantities in our soils and for this reason I used only one-half as much sodic chlorid as sodic sulfate, i. e., one-half, one, and one and a half grams to the litre. As the amounts dissolved and the differences are greater I will state them in tabular form. Ordinary lead arsenate is $Pb_3(AsO_4)_2$, the acid arsenate is $PbHAsO_4$. The results are stated in milligrams of arsenic acid.

		Ordinary	*Acid*
½ gram NaCl per litre	24 hrs.	31.2	68.6
	72 hrs.	——	72.4
1 gram NaCl per litre	24 hrs.	32.3	74.6
	72 hrs.	48.8	95.1
1½ gram NaCl per litre	24 hrs.	36.9	108.4
	72 hrs	47.6	113.4

Sodic carbonate (sal soda) was used in solutions one half as strong as the sodic chlorid, because it is present in our soils in quite small quantities.

		Ordinary	*Acid*
¼ gram Na_2CO_3 per litre	24 hrs.	48.1	114.5
	72 hrs.	56.7	131.1
½ gram Na_2CO_3 per litre	24 hrs.	44.2	157.6
	72 hrs.	56.7	160.9
1 gram Na_2CO_3 per litre	24 hrs.	54.4	157.1
	72 hrs.	55.0	158.7

The ordinary lead arsenate, $Pb_3(AsO_4)_2$, is attacked a little more freely by water containing only a comparitively small quantity of sodic sulfate than by pure water and the amount dissolved increased slightly when we increased the amount of sulfate from one and two to three parts per thousand. Even small amounts of soda chlorid and carbonate decompose the arsenate to a marked extent. The acid arsenate, with thirty per cent or more of arsenic acid, is attacked more vigorously by each of these substances, sodic sulfate, sodic chlorid and sodic carbonate, than the ordinary arsenate with about 26 per cent of arsenic acid. This difference is quite important as the acid arsenate is coming into more general use.

The Part Played By Water.

I know that Prof. Whipple had this condition in mind as much as any other when he made the statement that soil conditions seem to have no relation to the disease and I also had it in mind when I corroborated his statement. This trouble appears on high as well as low ground, on sandy soil as well as in heavy soil. The pear tree shown in Plate IV stands in a light sandy loam with a decidedly sandy subsoil changing to gravel at the depth of four feet. I sunk a hole a little deeper than this at a season when the whole country was being irrigated, namely, at the time of the autumn irrigation and at a depth of a little over four feet this soil was almost dry. I have seen trees drowned but the water in these cases had risen quite to the surface and had remained there for a long time, how long I do not know. These trees do not belong to this class.

In this connection I will again state that trees killed by nitre poisoning present nothing in common with those killed by irritant arsenical poisoning. Trees killed by nitre generally have perfectly healthy crowns and roots. Most of the cases that I have examined have had perfect crowns, in fact I think that they always have unless there is some complication of trouble, as irritant arsenical and nitre poisoning, in which case the tree might die of nitre poisoning though it had a corroded crown.

There is an orchard which I am convinced has suffered several years from a rising water plane and an excessive quantity of nitre. This orchard is drained by a 7x6 inch box drain which discharges a large amount of water but it is not sufficient. The water discharged from this drain carries 637.2 grains of mineral matter in each imperial gallon of which 14.5 grains was sodic nitrate or its equivalent. The crowns of these trees and the roots at the crown are apparently perfect but the trees are in bad condition and many of them have been removed. The distal ends of the roots are killed, rotted off. This I believe, has been done by the high water plane. These trees present an entirely different case from trees killed by irritant arsenical poisoning.

Trees That Have Not Been Sprayed.

I introduce this subject for the simple reason that through this claim for certain trees I found some very instructive and interesting cases. It is a very common thing for persons to state that "those trees have never been sprayed." I have been deceived by this statement so often that I now pay no attention to it at all. I have examined too many trees that "have never been sprayed" and found arsenic, copper and lead present which I consider as establishing a strong presumption that the tree has been sprayed. In this instance, however, I know the owner personally and he was so positive and his statement was corroborated by at least one other member of the family, that when I saw the trees which I thought were surely not sprayed I did not know what to think. I at once saw that I had to examine at least two of the trees, for if these trees had not been injured by arsenic then I had at last found an instance of apple trees with corroded crowns and all the other conditions which I had been attributing to the irritant action of arsenic which were not due to this cause. I took samples of the corroded roots of two trees and found arsenic without any trouble. I knew that my friends had not tried to deceive me and was certain that an explanation was to be had. I suggested to them that potatoes might have been grown between these trees and had been sprayed with Paris green or possibly lead arsenate. This proved to be the case, and while the trees had not been sprayed as apple trees, they had been sprayed with the potatoes. At this time it is impossible to learn whether these trees had ever had the poison applied directly to the body of the tree or not. A few points, however, are established: that the crowns of these trees were girdled, the roots were corroded, arsenic was present in the woody tissues of the trees, the trees have since died. They were never directly sprayed as apple trees but potatoes were grown between these trees and were sprayed with Paris green in the earlier years of the orchard and later with disparine, a trade name for arsenate of lead. I will here mention another case, a little different it is true, but somewhat to the point suggested by the preceding instance. Two young trees were set in the places of two dead trees and stood three years and died. Prof. Whipple was asked to examine the trees, and suspected that they had been killed by arsenic, but these trees had never been sprayed. I visited Grand Junction soon after that and he asked that I go and see these trees, for if the facts were wholly as stated to him I might have to make some exceptions to my general statements. I went and found that the owner had pulled them up and buried them. We dug them up, washed them off and examined them. I, too, felt certain that they had been killed by arsenic. The owner at first insisted that they had never been sprayed, which in one sense was true, but he admitted that the boys had turned the spray on them as they drove past them while spraying the orchard. I asked him for the history of the trees and found that he had a young orchard three years old and these two trees were from the same nursery lot which he had planted in the young orchard. I asked him how many trees had died and he said none but the two trees that he had set in the places of two old sprayed trees and which they had just sprinkled as they drove by with the spray tank. The crowns and roots were corroded and arsenic was present in the woody tissues of the one that I examined. I give the cases of these four trees as suggesting, but nothing more than suggesting, the answer to a question which has frequently been asked: Is it safe to plant young trees in an old, long sprayed orchard? I have uniformly confessed my inability to give an answer to this question. These cases certainly suggest the possibility of danger, especially if the soil filled in around the crown should chance to be rich in arsenic.

This and other serious questions are by no means new to many of our orchardists. One of them rather anxiously asked me in the early spring of 1909. "What are our old orchard lands worth?" This, too, is a suggestive question which I have not ventured to answer.

An elm tree first called to my attention by Mr. H. A. Richardson, Horticultural Inspector for Delta County, presents a most interesting case. Some may feel that the trees previously mentioned had in effect been sprayed; at least the cases need explanation in order that the claim that they had never been sprayed may be understood. There is no doubt but that the first two trees mentioned had not been sprayed, but no one can at this time so much as surmise what may have happened whereby the arsenic may have been applied around the base of the tree. With this elm tree, whose condition in October, 1909, is shown in Plate V the case is different. The bushes in the left hand side of the picture are lilacs; in the background are apple trees of different ages. That portion of the background occupied by young apple trees was formerly a pear orchard. In the spring of 1909 this tree was in such a condition that its owner became anxious about it, especially so as it is a tree the care of which has been a pleasure and whose growth has delighted the owner because it has attached to it memories and a sentiment which none but the owner may share. The conditions found are fairly indicated by the limb on the right; the leaves were dying and this side of the tree was in evident distress; the condition was so bad that the people were glad to have the limb taken for examination. The wound made in removing the limb bled freely and smelled very offensive. The interior portion of the limb was very dark and examination showed the presence of a considerable quantity of arsenic. I have endeavored to find something in the history of this tree which would explain this but I have found nothing.

A roadway passes in front of the tree and on this side of the road is the kitchen garden. The tree has never been sprayed. They did mix a little spray material, lime, sal soda and arsenic, just beyond the lilac bushes once, now seven or more years ago. I have been unable to find any other specific cause for the trouble. This case has been so interesting to me that I have made four visits to the place. The condition of the tree grew steadily worse throughout the past season. Beginning at the point where the limb was cut off one can follow an injured strip running somewhat spirally down the trunk. It is lost at the crown of the tree. I give this fact because I followed this injured strip expecting to find it leading to an injured root which I might follow to the place where they had mixed the arsenite of lime but I was disappointed. So with the aid of Mr. Herrick, our present Field Horticulturist in this section, I traced out the roots of this tree to see if we could find any of them either dead or showing injury. We traced five different roots for a distance varying from twenty to twenty-five feet and found no external injury to the roots except at one place and this I am sure had been done by the ploughshare. We, however, found some roots which were not healthy as they had spots on them and on stripping off the bark we found the inner side of the bark and the tissues of the root colored brown or brownish and livid. The soil at a distance of twenty-five feet from the base of the tree was well filled with fibrous roots of the elm tree. The soil showed by qualitative test that it contained an abundance of arsenic. There remained but one thing for me to do and that was to take more samples. I accordingly cut off one of the roots at a point six feet from the base of the tree and took a section of the root three feet long for a sample. I also took a small limb from the healthy appearing side of the tree. These samples showed the presence of arsenic in considerable quantities. We have in this case a tree which has never had any arsenic applied to it directly. It is not in any way indicated that the tree was injured by the lime arsenite which was mixed at some distance from the tree, but I do not say that it was not. I say only that I failed to find any proof that it was injured, and my judgment is that it is very doubtful whether that operation performed seven or nine years ago had anything to do with the present troubles, except as it has contributed to the general conditions. The root taken started out between the two little bushes near the tree, then turned to the right and ran straight back into the orchard. We find, that some of the roots show a diseased condition quite similar to conditions found occasionally on the trunks of the trees. We find that the woody tissue of the root contains arsenic and also that of the limb taken from the apparently healthy side of the tree. The limb which has been removed was dying; one of the limbs remaining on the right side of the tree is dead. It presented all the signs which accompany the death of trees killed by arsenic and arsenic is present. I have no hesitancy in saying that arsenic is the cause of the trouble and the death of the limb. This tree which has really never been sprayed, and which appears to have escaped accidental poisoning but whose roots were feeding in a soil rich in arsenic, is dying of arsenical poisoning.

The soil in this case is a red mesa soil somewhat clayey and at the same time calcareous, I would say marly, it effervesces freely with acids. I do not know how far it is to water, but judging from the line at which the seepage water breaks out below the edge of the mesa, twenty-five feet is a conservative depth to assume for the water plane.

The ash of the smaller limb which the plate shows as having been cut off shows the presence of copper, but the presence of lead is doubtful. A porcelean lamp was used in incinerating the wood; so that there is no question but that the copper was contained in the wood; besides the quantity present is too big to have come from the flame of a Bunsen burner in the ordinary course of work.

The virgin soil from this mesa was tested for copper, lead and arsenic. One hundred grams of soil failed to give a trace of lead. By careful manipulation we were able to establish the presence of a minute trace of copper, but there is a more decided quantity of arsenic present. The orchard soil is decidedly rich in copper and arsenic. It was not tested for lead and needed not to have been for arsenic, for we know that the arsenate of lead has been put on the soil in spraying the trees. The quantity of arsenic and copper present is much greater than that in the virgin soil and the presence of the two, arsenic and copper, is conclusive proof that this tree has obtained the arsenic which we find in its roots and branches from the spray material applied to the adjacent pear and apple trees, for the tree itself has never been sprayed. In this tree we have no corroded crown, but there is an injured strip running obliquely up the trunk. I could not trace it below the surface of the ground. While some of the roots show signs of disease none of them are corroded. One side of the tree is already dead and the trouble is involving more and more of the tree; arsenic and copper are present in the woody tissues of the limbs. The root was tested for arsenic only. There seems to me no other conclusion to draw from these facts but that the tree has gathered these poisons from the orchard soil.

Lead and Copper in the Trees.

The question whether these metals are playing any part in the troubles which we are discussing or not is certainly germane, but while I am ready to believe that they may have some influence the action of the arsenic seems so clearly to be able to account for all that we have found, that it seems needless to attempt to discuss either lead or copper though we know that the latter can and has injured trees when used in too large quantities.

I have examined a large number of trees for the presence of lead and have always found it. Lead has been determined in but one sample in which 0.003% metallic lead was found. This is practically all that we have done with the lead and copper, i. e., we have examined the woody tissues for them, because I consider their presence as establishing the source of the arsenic with a fair degree of certainty and not because I wished to consider the question of their poisonous character.

The Effect of Lime.

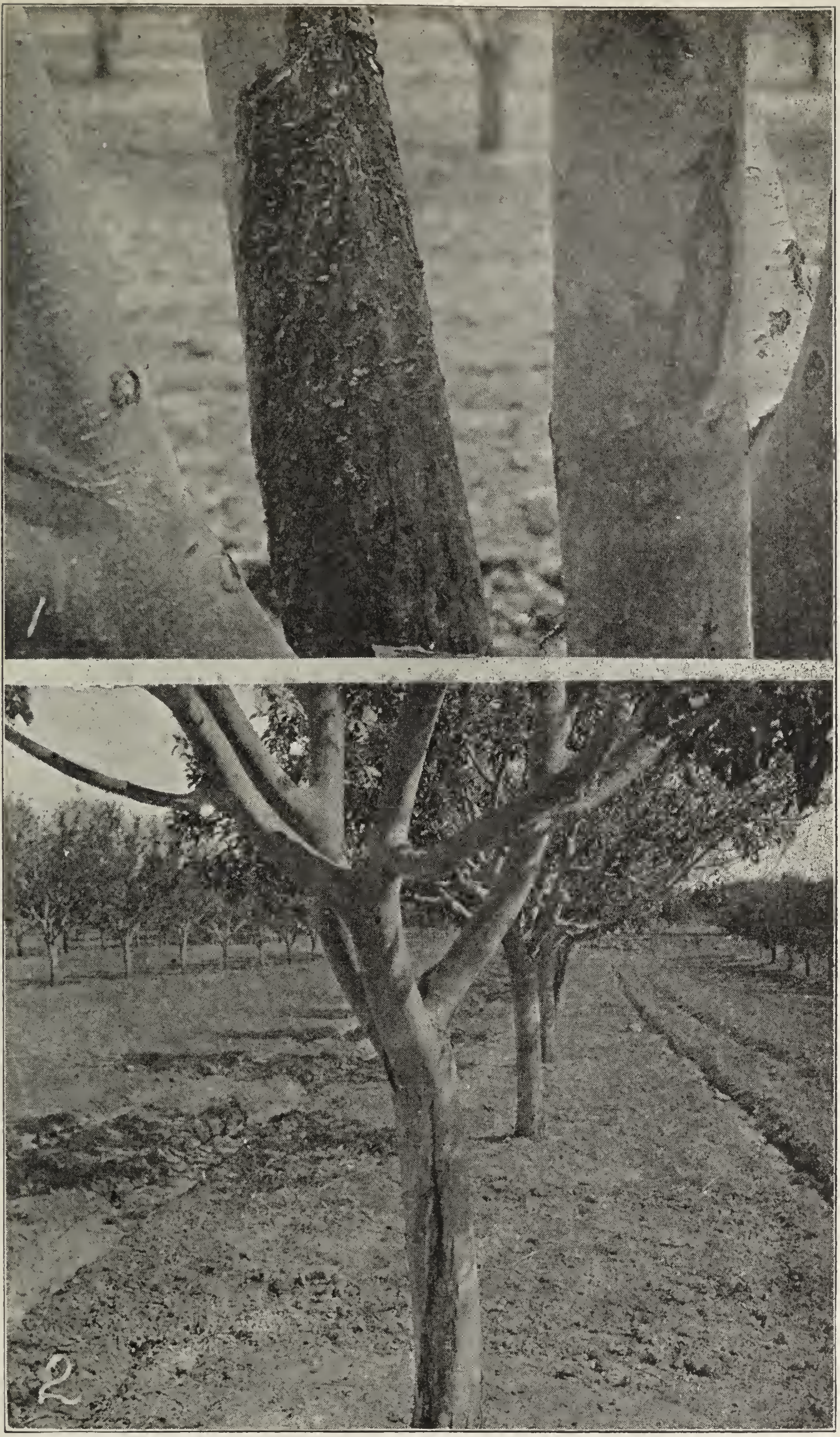
This question is involved in more obscurity than any other that has been met with up to this time. I know of several orchards in which the trees are small for their age and do not show the thriftiness that the care they have received would justify one in expecting. Four of the orchards that I have in mind receive excellent care, but many of the trees are not healthy. There is some irritant arsenical poisoning present but these cases are not numerous and it has nothing to do with the condition here discussed. The one feature that I wish to present in this paragraph is that of bleeding. Namely, the wounds made in trimming last season will bleed badly this season. They sometimes do not bleed the first season but bleed badly the second. In some of these orchards the bark splits and bleeding ensues. The splitting of the bark may take place on the limbs or on the trunk. The bleeding is almost always profuse. This bleeding is so far as I can recall at this time confined to land that is very marly or underlaid by a stratum of marl. Sometimes this stratum is quite thick, two feet or more, at others it may not be more than a few inches in thickness.

The bleeding is sometimes quite profuse, so much so that the outflowing sap may encrust the trunk with a yellowish white deposit for several inches below the split, or if on a limb for a foot or more. I have seen it drip and build little stalactites three inches or more in length and cover the limb with a deposit an eighth of an inch thick. This material seems to be gathered from the soil and is the sap or solution sent up into the tree by the roots and is probably not produced within the limbs or tissues of the tree. This of course cannot be observed, but the following example will make my meaning plain. A limb of a Jonathan apple tree was cut off on the eighth of April. It was cut off close to the trunk of the tree, not more than two feet from the ground. The tree was not healthy, but no more unhealthy than the average tree in the orchard. On the twelfth of May I found that this wound was bleeding and was already covered with the deposit described above. This sap was then exuding through the medulla, as was easily observable. No bleeding could be observed from the sap wood. This bleeding is very marked in some orchards and practically absent in many. The deposit is the same in appearance wherever I have seen it. The soil of these orchards is underlaid by marl and the soil itself is marly. I think that the great majority of our soils carry more than five per cent. of carbonate of lime. This deposit contains 25.00 per cent. of calcic oxid and 49.0 parts per million of arsenic, calculated as arsenic acid. The cracking open of the bark and the bleeding is shown in Plate 5, p. 16 of Bulletin 131, and as it is still representative we will use it again as Plates VII and VIII.

I know nothing about the contents of total solids in normal apple tree sap, but this sap is evidently very rich in total solids which as represented by these deposits are soluble in cold and hot water, but difficultly soluble in alcohol. If to the aqueous solution some alcohol, not enough to precipitate it, be added, fine acicular crystals deposit on standing. Calcium is essentially the only inorganic base present but is accompanied by a small amount of magnesia and the alkalis potassium and sodium.

Lime was not mentioned in the preceding section because it is always present to some extent in the ash of plants and in all soils, and the amount of lime added with the arsenite of lime is extremely small when compared with the lime in our soils for which an estimate of 65 tons per acre foot is very moderate. The soil of one of the orchards referred to carries in the surface foot calcic carbonate equivalent to 224 tons of burnt lime, while the subsoil is still more limey. The supply of lime is excessive, the ability of plant roots to dissolve calcic carbonate is well known, so the appearance of lime in these deposits is no matter for surprise, but the appearance of so large an amount of arsenic, 49 parts per million, is sufficient to raise a question in regard to its source and its relation to the lime.

Some plants are calcifugous but the apple does not seem to belong to this class, for it does well and lives long in limestone soils, not only in other states but also in Colorado. I know of a small or-



Colo. Ag. Expt. Sta.

PLATE VII. (upper), PLATE VIII. (lower)

chard set in a soil so thin that it scarcely covers the underlying calcareous shale and I could find none of this bleeding in these trees. The orchard is young and fairly thrifty. It is further true that this bleeding is not universal throughout the fruit growing sections of the state while the presence of lime in relatively large quantities is certainly the rule with only a few exceptions.

In Bulletin 131 I stated that the question is: Are these trees suffering from systemic arsenical poisoning, lime poisoning, or both? Again I have repeatedly expressed my opinion that it is doubtful whether we can distinguish the part which each plays in the case. There can be no doubt, and there is no doubt in the minds of thoughtful men conversant with the facts, but that something is the matter with these orchards. This does not mean that the trees are dead or that the orchards may not continue to give very handsome returns for years to come, but simply that the trees are not healthy and that the bad condition of some trees is possibly due to this cause. Arsenite of lime was at one time our generally used spray material and it is possible that soil conditions may have been such that this in some cases caused the injury.

The lime and arsenic may have been taken up together, that is, in combination, or taken up at the same time but not in combination and we are not able to distinguish their separate action. I would make no mention of this matter if I did not believe it to be of such importance as to demand mention.

I have studied these marly soils to see if I could find anything indicative of an explanation for this condition. Orchards do quite well on some of these lands, especially if the surface soil is twenty inches or more deep and not too rich in lime. The following analysis will give an idea of their composition:

ANALYSIS OF MARLY SOIL.

Insoluble	48.589
Soluble Silica	17.071
Chlorin	0.008
Phosphoric Acid	0.036
Carbonic Acid	8.532
Lime	11.695
Magnesia	1.674
Sodic oxid	0.374
Potassic oxid	0.589
Ferric oxid	4.890
Aluminic oxid	4.554
Manganic oxide (br)	0.179
Ignition (loss)	(1.776)
Sum	100.002
O Equiv to Cl	.002
Total	100.000
Total Nitrogen	0.386

According to this analysis, the amount of phosphoric acid present is scarcely good but the supply of other plant food is very fair That this soil contains arsenic is assumed as the orchard has been sprayed for years. The carbonic acid, CO_2, present corresponds to about 19.38 per cent. of carbonate of lime. The preceding is a surface soil.

One of these marly subsoils had the following composition:

ANALYSIS OF MARLY SUBSOIL.

Insoluble	55.683
Soluble Silica	2.866
Chlorin	trace
Sulfuric acid	trace
Carbonic acid	12.444
Sodic oxid	0.390
Potassic oxid	0.360
Calcic oxid	16.538
Magnesic oxid	2.438
Ferric oxid	3.428
Aluminic oxid	1.326
Manganic oxid (br)	0.260
	100.033

We have here about 28.28 per cent. of carbonate of lime or marl. This subsoil was taken at a depth of twenty-three inches, and though representing the subsoil of a sprayed orchard I deemed it of sufficient interest to determine the arsenic that it might contain and found 15.33 parts arsenic, calculated as arsenic acid, per million. I scarcely think that the spray applied to the trees would find its way down into this marl. This orchard had been given surface cultivation only, still I acknowledge the question as an open one whether this arsenic is an original constitutent of the marl or an adventitious one arising from the practice of spraying. Personally I believe that the marl itself has always contained the arsenic.

I will give an analysis of a marl from still another place. This sample was not taken in the orchard itself but from an adjoining piece of land belonging to the same owner as the orchard. I will state that this orchard showed a pronounced case of rosette.

ANALYSIS OF A MARL.

Insoluble	24.098
Soluble Silica	8.269
Sulfuric acid	0.350
Carbonic acid	27.115
Calcic oxid	34.525
Magnesic oxid	2.942
Iron and Aluminic oxid	1.960
Manganic oxid (br)	0.180
	99.439

This analysis indicates the presence of about 61.5 per cent. of carbonates, almost wholly lime carbonate and a quantity of decomposable silicates. The most interesting point, however, is that this marl contained 5.21 parts of arsenic, calculated as arsenic acid, per million. These marls open the question of the presence of arsenic in our marly virgin soils. I have stated repeatedly that the greater part of the soils to be considered in this connection are to be considered as marly. I have therefore tested some of our virgin soils from land not yet brought under irrigation. The two already given cannot be considered as virgin soils, i. e., the subsoil twenty-three inches below the surface with 15.33 and a marl with 5.212 parts of arsenic acid per million. I have determined the arsenic in five virgin soils concerning which there can be no mistake about their having never received an application of arsenic, at least not the whole five, which were taken from localities about sixty miles apart. I found in these soils the following quantities of arsenic per million parts of the soil: 2.8, 3.8, 4.2, 4.5, and 4.7 parts. I have further examined six other samples of soils concerning which some doubt might be entertained but I am fully satisfied that two of them have never been sprayed or received the application of any arsenic whatsoever and still it was present.

In connection with this bleeding I have been confronted with the assertion that some of it has been observed in the case of some trees which had never been sprayed. I have not seen such myself but if the observation be correct, it would point rather directly to the arsenical lime, whether native or artificially added, as the cause of this particular trouble, and I believe this to be the case. Those orchards in which I have found this trouble the worst are on such marly soil as I have described, and so far as I know their history, were treated very liberally with arsenite of lime when this preparation of arsenic was exclusively used as a spray material. The samples of virgin soil in which the arsenic is present and cannot be attributed to any known source contain a comparatively small amount of arsenic compared with the orchard soils, in round numbers one tenth as much. This statement does not consider the marly subsoil containing 15 parts arsenic acid per million because some of this arsenic may have been derived from the arsenical spray put on the orchard. No one has, so far as I know, attempted to determine to what depth these sprays may affect the arsenical content of the soil, but as they are decidedly soluble in water it is easy to conceive that the depth to which the arsenic may penetrate is greater than we might think. The sample of soil taken to the depth of one foot and showing 138 parts arsenic acid per million is also excluded from the above statement that the orchard soils contain ten times as much arsenic as the virgin marly soils. As our transplanted apple trees are shallow rooted, seldom feeding to a greater depth than two and one-half feet, it seems probable that they gather their food from the soil proper. I do not think that the marls underlying these lands enter into the question to a great extent, besides only one of them has been found to contain more than five parts arsenic acid per million.

In regard to the solubility of the arsenic in the orchard soils, I have shown that as much as 1.26 and 1.34 parts of arsenic acid per million of soil is soluble in water. The virgin soils on the other hand yield only traces or none. In this connection it is to be remembered that the roots of the trees may be much more effective in bringing the arsenic into solution than distilled water.

This bleeding takes place from cracks in the bark and also from old wounds made in trimming and is especially noticeable in wounds already one year old. I have watched this taking place, when the juices were issuing through the medulla while no other portion of the section seemed to be taking any part in the process. It is common to find this section of a wound surrounded by this deposit which is rich in lime and arsenic. The medullary tract seems to be the easiest channel for these juices to traverse, which may itself be an indication of a diseased condition. Prof. Longyear has suggested that the ducts whose function it is to conduct the sap of the tree upward, may be so clogged and the resistance offered to the upward diffusion of the sap so great, that it follows this unusual course. The Professor kindly consented to examine sections of affected trees and gives me the following statement of his findings:

"Three lengths of affected branches, two inches in diameter, in which an outer layer about one-fourth of an inch thick of healthy sapwood remained, were brought to me in a fresh condition in February, 1910.

"Transverse sections from different portions of these branches under the microscope showed the ducts in the uncolored sapwood free from obstruction and the cells of the medullary rays stored with starch. In the most highly colored zone, just between the healthy and the affected wood, the ducts were found to be filled with a yellowish or brownish gummy substance, insoluble in cold water and dilute solution of caustic potash. Toward the center of the branch this gummy material diminished in quantity quite rapidly but was not entirely lacking. In the colored area the medullary ray cells still contained in some instances a little starch but in most cases they were partly filled with brownish granules and globules of substances remaining or arising from the disorganization of the cell contents. It is evidently from these sells that the gummy matter has found its way into the ducts. This is shown by the fact that this material appears in a duct first on the side next to the nearest medullary ray cells."

In regard to the varieties affected I have seen this bleeding in the Jonathan more often than in any other, but it is not confined to this variety. I have also seen it in the Missouri Pippin, in the Spitzenberg and other varieties.

The facts seem to me to point to the action of arsenic in conjunction with lime rather than to the action of either alone as the cause of this trouble.

Systemic Arsenical Poisoning.

What I have said concerning the action of arsenic and lime might properly, perhaps, have been put under this head, but I have chosen to treat it by itself because it is so pronounced a feature that it is not possible to overlook it and it will be more easily recognized by those familiar with it than if it were included under this caption.

While there is no single feature in the cases of the trees remaining to be described which may be taken, as the destroyed bark of the crowns and roots in the first, or the deposition of an incrustation on the surface of the wounds or on the bark in the second case, as guiding features, we have some which force themselves on our attention, one is a reddish yellow color of the bark, especially of the limbs, another is the lack of thriftiness. The former is not, in my opinion, specifically diagnostic of arsenical poisoning but rather of malnutrition, itself a result possibly of the arsenic.

I have seen this color in an orchard which I am convinced is suffering more from other causes than from arsenic, though it may have contributed some in bringing about the bad condition of the orchard. As I shall not refer to this orchard again, I may describe briefly some of its more marked features. This orchard, in the spring of the year, is a very marked feature of that section of the country because of its abnormal color. There are but few or no signs of corrosion. A large number of these trees were pulled up in the late winter and spring of 1909. The ends of one half of the roots, this is the estimate of the man who pulled them up and not mine, were found to be rotted off. Some of the remaining trees were pulled up and a few of the roots were found to be in this condition. It is my opinion that the color of this orchard is mostly due to starvation but this forms a part of another study, and is mentioned to dissipate any idea that some might get that this reddish color is diagnostic of arsenical poisoning. This color is not due to sunburning. I have considered this, but there are some facts very hard to explain on this theory, for instance this color is only a little more intense on the south side of the limb than on the north side and all of the trees of an orchard may show this color.

Almost any tree in some of these orchards might be used as an example to illustrate and introduce the discussion of systemic arsenical poisoning.

I have stated that the subject of the action of lime and arsenic might have been included under this caption and the first example is a Jonathan; the tree is small for its age, about 14 years old, the bark is somewhat yellowish and it represents a case of moderate bleeding. The deposit formed is rich in arsenic. I cut off a limb of the tree; the interior portion of it was strongly discolored, the discoloration was not confined to the annual rings. An examination of this wood showed the presence of arsenic. Both of the preceding tests were repeated with a confirmation of the results. The crown of this tree is not corroded. We evidently have in this case an instance in which both the lime and arsenic are present and it is difficult to judge whether the arsenic, independent of the lime, is the cause of the bad condition of the tree.

The next case is that of a Spitzenberg. The tree was small for its age, crown was good, bark very yellow, foliage during the preceding season small, scanty and of a bad color throughout the season and ripened too early. This tree was dug up in the spring of 1909 because of its bad condition. The wood from the center of the tree outward for nearly an inch was brown but not deeply colored as the Johathan just described. This tree showed no bleeding. A limb of this tree was taken for examination and the woody tissue showed as strong a mirror as some of the trees which had corroded crowns. The mirror was weighed and corresponded to 2.19 parts arsenic acid per million of wood.

The soil sampled to the depth of one foot at the point where the tree had been pulled up showed the presence of 138 parts of arsenic acid per million of soil. This soil also showed that there was 1.345 parts of arsenic acid per million of soil soluble in cold water.

In investigating further it has been shown that the leaves of apple trees which had, during previous years, been regularly sprayed from two to four times, but had not been sprayed this year, contained arsenic equivalent to 2.628 parts of arsenic acid per million parts of the dried leaves.

I have examined a number of samples of apples and pears from Colorado and other states, namely, from California, Michigan, New York, Pennsylvania, Ohio and Illinois, and found them all to contain arsenic. Some of these samples were bought in market, but for others I am indebted to the officers of the respective Experiment Stations and it is a pleasure to acknowledge my obligations to them. I may state in this connection that the above fact is not the only one indicating that other states where spraying has been diligently practiced are suffering as we are but not to the same extent.

I have stated above that the fruit of seven states, as found upon the market or furnished me by their Experiment Stations, contain arsenic. I have weighed and calculated the arsenic as arsenic acid in a few cases, and the results are per million parts of fresh apples as follows: 0.51, 0.68, 2.30, 0.52, of pears 0.52. The total number of samples of fruit examined is twelve. These were either known to have been grown on sprayed trees or supposed to have been. It is possible that the sample showing 2.3 parts per million ought to be left out of consideration but I know of no reason why it should be except that it is very much higher than the other results. These samples were washed and pared and the calyx cup and ovary cut out; no greater care than this could be exercised to avoid getting any spray material into the sample. I further met this possible error by obtaining fruit from trees not sprayed this year and I found that this, too, contained arsenic.

As the ability of the tree to take up arsenic from the soil is an important factor in systemic poisoning, I have endeavored to ascertain whether trees which had never been sprayed take up arsenic. We have presented several cases in which the application of sodic arsenite to the soil, within the feeding area of the roots, was followed by the almost immediate taking up of the arsenic and death of a portion or the whole of the tree. I have mentioned in all eight instances of this sort, one instance of an apple tree within a few feet of which the spray tank containing arsenate of lead was emptied followed by the death of one limb of the tree, and further the case of the elm tree has been given somewhat fully. It would seem that these cases would suffice to prove that trees will take up enough arsenic from the soil to injure them, even when the arsenic has been applied in a difficultly soluble form, as in the cases of one apple tree and that of the elm tree. To add to the force of these samples, I have examined peach trees which had not been sprayed but which were growing in land already rich in arsenic and these too contained arsenic though two of them were only five years old. The elm tree and the peach trees could not have gotten the arsenic except through the activity of the roots. If further proof is needed the presence of arsenic in the juices forced out of a fresh wound and in the leaves and fruit which had never received any spraying certainly indicate that the arsenic is carried with the sap of the tree. It can certainly make no difference whether the arsenic is originally in the soil or has been added, but the proofs are not wanting that this arsenic comes from the spray materials put upon the soil for it is associated in many cases with both lead and copper, as much as 0.003 per cent of lead having been found in one sample. These facts establish this, i. e., that the trees do take up arsenic from the soil together with lead and copper.

One of the effects of the arsenic on these injured or partially killed trees is to stunt them. This is especially noticeable in those parts which we know to have been affected by sodic arsenite.

Other causes for the unhealthy condition of these trees, their small size, the unnatural color of their bark, the early yellowing of the leaves, the small size and exceedingly high color of the fruit, have suggested themselves. Among these are insect injuries, atmospheric conditions, soils, etc.

We can, I think, dismiss insect injuries, these having been carefully watched for and guarded against, and also atmospheric agencies, including smoke, electricity, etc., and turn our attention to the soil conditions. The average depth of the soil is stated to be from three to three and one-half feet. I think that this is too high for the whole apple orchard, but if the soil is two and one-half feet deep it is quite sufficient for the sustenance of healthy apple trees. There is, however, scarcely a healthy apple tree in the orchard or at most only a few of them.

Whatever our views may be regarding the injurious properties of alkalis we cannot satisfactorily explain the trouble on the theory that they are injuring the trees, for the total water soluble portion of the soil amounts only to 0.22 of one per cent, whereas we have healthy orchards in soil containing a much larger quantity of alkalis than this.

There can be no question of seepage for this is as high as any land in the neighborhood and there is no source from which seepage can come.

There can be no question of ground water for it is necessary to sink wells to a depth of seventy-five feet to obtain water. On the other hand there can be no question regarding the supply of good irrigation water for this is abundant.

This orchard has received intelligent care, neither has labor nor money been spared to make it a good orchard.

These considerations eliminate the questions of neglect, seepage, alkali, the lack of water or the irrational use of it as agencies in producing the present conditions, but they do not eliminate the question of an unfertile soil. If it were not that I know that some very competent persons consider this point seriously as the possible cause in this case I would not discuss it.

Personally I have but little confidence in the results of a soil analysis as criteria whereby to judge of the fertility of our soils. An analysis may have some value, especially if it shows an absolute deficiency in some of those elements which we have found to be essential to the development of plants.

The following analysis, made to answer, if possible, the question in regard to the lack of plant food in this soil, shows its composition:

ANALYSIS OF AN ORCHARD SOIL.

Insoluble	60.966
Silicic acid (sol. in sodic carbonate)	16.228
Sulfuric acid	0.247
Carbonic acid	1.739
Chlorin	none
Phosphoric acid	0.091
Lime	3.176
Magnesia	1.651
Ferric oxid	3.697
Potash	1.240
Soda	0.423
Aluminic oxid	3.746
Manganic oxid (br)	0.644
Moisture	2.070
Ignition (organic matter etc.)	4.412
	100.330

Additional Determinations.

Nitrogen	0.098
Copper	0.0058
Lead	0.0009
Arsenic acid	0.0011

According to this analysis we have an abundant supply of potash, a fair supply of phosphoric acid, more than an average supply of nitrogen for our soils and no possible deficiency except it be of chlorin, which is apparently absent; an aqueous extract of the soil, 25 grams, gives a faint reaction for chlorin, which simply means that it is present in very small quantities. This sample represents the surface foot of soil taken at the place from which a dead tree had been removed. The determination of the water soluble portion, 0.22 per cent. does not indicate an excess of soluble salts. The history of this land shows that it is productive. A portion of it was at one time used as a vegetable or truck garden and produced well. The suggestion that the truck garden might have been heavily fertilized and thus forced into productiveness suggested itself at once and I urged it. The answer was the trees then should show where the truck garden was but they are neither better nor worse than in other portions adjacent to it.

We have no proof that starvation due to the infertility of the soil does in any measure account for the present conditions of the trees.

Another question somewhat more serious than the preceding is in regard to the presence of other poisonous substances besides those of the spray materials. This includes lead and copper. There is only one present which might possibly exercise a deleterious influence and that is lime. I have pointed out elsewhere that apple trees do well in limestone soils, at least they do not show the distress exhibited by the trees under consideration. We have no justification in fact, so far as I know, for assuming that lime as carbonate is injurious to apple trees and still less ground to assume that lime as a silicate is injurious, but a casual inspection of our analysis shows that the lime was probably present in both of these forms and possibly to a slight extent as sulphate.

So far neither the analysis of the soil nor the information received in regard to the garden crops grown give us the least reason for attributing the condition of the orchard to the infertility of the soil nor to any poisonous substances other than the spray materials or possibly to the simultaneous action of arsenic and lime, as has been pointed out under the latter subject.

The depth of the soil has been stated as given to me, but I doubt whether the soil is quite so deep as three to three and a half feet. I dug down to the bottom of the soil at some points and found it about two feet and then a marly subsoil.

I think it safe to assume that there is not lime enough in the soil to do any harm; further, I think it safe to assume that the depth of the soil is amply sufficient to grow healthy trees, provided that the subsoil is not in some way injurious.

I have tried to find out what is probably the greatest depth at which our apple trees feed, and judging by the depth at which I have found the fibrous roots under what I considered the most favorable conditions I would judge that depth not to exceed two and one-half feet. This depth of soil, then, would ordinarily be ample and I believe it is. If this be correct, the character of the subsoil lying below this depth, provided it was pervious to water, would probably not be of as great importance as we, at first glance, might think, for even if it contains arsenic, and I have strong reasons for believing that it does, this arsenic is at best difficulty soluble in water and lies below the feeding ground of the trees. The question is an entirely different one when the subsoil is within 8 or 12 inches of the surface or the material constituting the subsoil is mixed with the soil to such an extent that it constitutes more than an eighth of the soil, as we sometimes find to be the case. We have in the analysis of this soil 1.739 per cent. of carbonic acid (CO_2) enough only to form a little less than 4 per cent. of calcic carbonate. This leaves a slight excess of lime to combine with the other acids. I have assumed this form of lime to exist in the soil as I take it that this is probably the most injurious form of lime, usually met with in soils to which no arsenite of lime has been added or in which this salt does not exist. We do not positively know that carbonate of lime in such quantities is in the least injurious.

The trees in this orchard are sick. A few of the trees have corroded crowns. This feature is on the increase. Some trees have already been killed. There are some cases of bleeding and the deposits, like the others of this kind, are rich in arsenic and lime.

The trees not affected in either of these ways are small for their age and are not thrifty though the crowns are perfect. These trees have not suffered from fungi or insects or blight. There is no excessive water, nor is the soil in such condition as to produce suffocation. Neither Prof. Paddock nor Prof. Whipple was able to detect any cause for the condition of the orchard and tentatively suggested that it might be due to starvation. The small size of the trees, the color of their bark and the small annual growth justify the general conclusion that the trees lack in proper nutrition, but this does not explain whether this lack is due to an insufficient supply of food in the soil or an inability on the part of the tree to take up and assimilate the food. In so far as an analysis gives us any adequate information on this subject, this soil is fairly well provided with the various elements of plant food and if the trees are starving it is not because the supply of food within the reach of their roots is inadequate but because of some other reason. I believe that the trouble is due to the action of arsenic, either alone or in conjunction with the lime. This orchard has been well cared for and diligently sprayed for a number of years, using at first Paris green, next, lime, sal soda and arsenic, and of late years arsenate of lead.

I have shown that the soil, especially about the trees, is very rich in arsenic, as much as 138 parts arsenic acid per million of soil being present; also that distilled water dissolves out of this soil about 1.34 parts of arsenic acid. The rest of the soil is certainly heavily charged with arsenic, the sprayings having been frequent and heavy, placing it within reach of the feeding roots of the trees. That the trees may take up enough arsenic in this manner to do them injury is shown by the case of the elm tree and others which have been cited and there are still others which might have been mentioned. In addition we have two very significant facts, first that the trees are sick, second, that the wood of these trees contains arsenic, the one in which it was determined 2.19 parts per million of woody tissue, as much as is usually found in other dying trees. In cases where arsenic is known to have been the cause of injury one of its effects has been to check the growth of the affected parts, in fact to almost prohibit it. These trees are small for their age, and make but little annual growth. All of the observed difficulties may be caused by arsenic and we find no other causes to which we can with any degree of reasonableness attribute the difficulty. We therefore conclude that systemic arsenical poisoning is very probably the cause of the unhealthy condition of these trees and in some cases of their death.

It is difficult to tell what part, if any, the lime may be playing in producing this specific trouble. I have stated that while it is well known that apple trees do well in limestone soils and that lime in the soil as carbonate of lime, this is the composition of our marls, is not per se injurious to the apple tree, yet the composition of the deposits formed by the bleeding described in Bulletin 131, and again in this, indicates strongly that lime, in some way, participates in producing it. Leaky spots in trees do not ordinarily, so far as my observation goes, give rise to such incrustations or form stalactites as we find on these apple trees. I have been unable to find an analysis of the ash of the apple tree juice and I have been unable to collect the juice in order to make one myself. I have, then, no data pertaining to this subject to serve for comparisons and can only present the facts.

In default of any knowledge concerning the composition of the juice of the apple tree, the best available subject from which to obtain some light would appear to be the ash of the wood on which there seems to be almost no data. I was able to find but one analysis of the ash of this wood and that is an old one, quoted by Adolph Mayer from the compilation of E. Wolf. This analysis shows the presence of over 36 per cent of silicic acid and can scarcely be considered as a typical ash. Dr. E. W. Allen was kind enough to call my attention to the analyses of apple tree ashes published in the report of the Director of the New York Experiment Station for 1891, page 164.

The trees subjected to investigation were young trees. The object in view was to determine the amount and character of the mineral constituents of plant food removed by nursery stock. The trees were probably not more than three or at most four years old. The trees discussed in this bulletin are of various ages, mostly from fourteen to eighteen years old. While I know nothing about the influence of the age of the tree upon the amount of ash in the wood and its composition, I will use these analyses for comparison for I have no others. Again the influence of the soil is a question which must be passed over. Another unavoidable condition which may affect the results is the necessity which compelled me to use small limbs one and a half to two inches in diameter to represent the living trees whereas I cut off a limb fully five inches in diameter at the trunk of the tree to represent the dead one. These are all weaknesses in our data but these data are the only available ones.

The soil in which two of the Colorado trees grew is represented by the analysis given under the caption "Analysis of a Marly

Soil." The third tree grew in a sandy loam, an alluvial soil, along the Gunnison river. The lime dissolved out of this soil by acetic acid was equivalent to 3.547 per cent of calcic carbonate. The subsoil is sandy and there is no marl present in the sense that we speak of its occurring in and beneath the mesa soils. In the former case, that of the soil in which the two trees grew, there is more than nineteen per cent of calcic carbonate and a still more marly subsoil, as against 3.5 per cent calcic carbonate and a sandy subsoil in the latter case. This is as marked a contrast in the character of the soils as is likely to be found in any county in Colorado, waste lands excepted. The localities from which they were taken are about four miles apart, so that the general conditions, climate, etc., are comparable. The trees taken for examination are of the same variety, the Jonathan. This variety was chosen because it seems to be the one which is most subject to these troubles.

The results of an examination of the quantity and composition of apple tree ashes given in the Report of the Director of the New York Station, Geneva, 1891, are as follows, taking the average for three varieties, Haas, Golden Sweet and Hurlburt:

	Branches	Trunks	Roots
Silicic acid	2.30	3.65	26.74
Phosphoric acid	5.89	4.94	7.11
Chlorin	0.68	0.43	0.37
Sulfuric acid	3.18	4.19	4.17
Carbonic acid	28.23	28.65	10.12
Ferric oxid	0.21	0.00	3.36
Calcic oxid (lime)	41.94	43.76	28.39
Magnesic oxid	6.99	6.38	8.17
Sodic oxid	4.86	2.57	5.28
Potassic oxid	5.71	5.43	5.76
	99.99	100.00	100.01

The percentage of ash in these trees was as follows: in the Hulburt 1.6, in the Haas 1.8 and in the Golden Sweet 1.2 per cent.

It was not feasible for us to obtain wood from the trunks of bearing trees. I had to content myself with the heaviest wood removed in pruning. This was branches varying from one and a half to two inches in diameter. In the case of a dead tree I took a large branch, at least five inches in diameter where I cut it from the trunk of the tree. These samples were taken on the 10th of February, 1910. The percentages of ash in the samples as received at the laboratory without drying were as follows. dead tree 0.964 per cent; living trees on marly soil, 2.00 per cent; and living trees on sandy loam on river bottom, 1.17 per cent. The dead tree had died during the early part of the preceding autumn. There were many leaves and nearly if not quite full grown apples still hanging on the tree. There were other trees of the same variety and in the next row presenting the same conditions. These conditions are mentioned because the ash constituents of the wood, such of them as are soluble, may have been used up in the effort of the tree to mature the crop of fruit. There is no way of telling how long the tree had been drawing on this source of supply. The end result is all that we can definitely establish and this shows the presence of 0.926 per cent of ash. The trees growing on the river bottom, sandy loam soil, appear to be perfectly healthy. The growth is vigorous and the bark has a normal color. There are almost no signs of unhealthiness in this orchard that I saw or to which my attention was called. The orchard had been sprayed but not as regularly and persistently as the preceding one. The living trees from the preceding orchard are certainly more nearly comparable to these trees than the dead tree is because they are living trees and because the parts of the trees were of the same size and approximately of the same age. We find that the limbs of the trees growing on marly soil contain 2.00 per cent of ash while those growing on the sandy loam carry only 1.17 per cent. The average percentage of ash in the young trees grown at Geneva, N. Y., is 1.55 while the percentage in Colorado trees assumed to be normal is 1.17 per cent. The dead tree grown on marly soil contains a less percentage and the living tree a larger pencentage of ash than either the New York trees or the Colorado trees grown on a sandy loam soil. The New York trees were taken for examination early in the spring before the buds were well developed. They ought, therefore, to be comparable in this respect.

We see that the living trees on the marly soil contain 1.7 times as much ash as the trees growing on the sandy loam and 1.3 times as much as the young trees grown in New York. I have separated the bark from the wood and the statements of my further results are not directly comparable.

Wood of the dead tree, marly soil, 6464 grams, percentage of ash, 0.453, amount of ash obtained 29.28 grams. Bark from the wood of the dead tree, 624 grams, percentage of ash, 7.854, amount of ash obtained 49.00 grams. The percentage of ash in the bark is 17.3 times as great as in the wood. The percentage of insoluble ash in the bark is 18.35 times and that of the soluble ash 11.6 times as great as in the wood.

Wood of living trees, marly soil, 8760 grams, percentage of ash 0.539, bark 1516 grams, percentage of ash 10.452. Amount of ash obtained from wood, 47.22 grams, from bark 158.45 grams. The percentage of ash in the bark is 19.39 times that in the wood; that of the insoluble ash in the bark is 28.4 times and that of the soluble ash 6.5 times that of the wood.

Wood of healthy trees, sandy loam, 6794 grams, percentage of ash 0.389, amount of ash obtained 26.34 grams, bark 878 grams, percentage of ash 7.21, amount of ash 63.30 grams. The percentage of ash in the bark is 18.53 times that in the wood; that of the insoluble ash 24.93 times, and that of the soluble ash 6.18 times as great as that in the wood.

A comparison between the quantities of ash in the living trees from the marly soil and in those growing in a sandy loam shows a decidedly higher percentage, both in the wood and bark in the former case than in the latter. The composition of these ashes is even more striking than their quantities. The ashes were prepared with great care and yet there was water present in some of them and there is a deficiency of carbonic acid. One of the samples was analyzed four times to be sure that no mistake had been made, the excess of bases and the presence of water could not be altered. The ashes had been treated with a solution of ammonic carbonate and subsequently heated to 210° C. with the addition of dry ammonic carbonate. The carbon, sand, and water have been deducted and the analyses stated on the basis of 100.

	Living tree Sandy Loam		Living tree Marly soil		Dead tree, Marly soil	
	Wood	Bark	Wood	Bark	Wood	Bark
Silicic acid	0.837	0.944	0.807	0.774	0.604	0.552
Phosphoric acid	5.094	3.170	4.524	1.500	3.170	1.234
Chlorin	Trace	0.195	Trace	Trace	0.406	0.135
Sulfuric acid	1.884	0.554	1.821	0.449	1.474	0.396
Carbonic acid	29.549	36.615	33.826	35.467	34.970	39.395
Lime	26.000	49.141	35.920	54.320	41.264	53.697
Magnesia	9.289	3.189	7.574	1.408	8.073	1.125
Ferric oxid	0.105	0.212	0.199	0.184	0.130	0.182
Manganic oxid	0.147	0.101	0.143	0.175	0.149	0.127
Potash	26.621	5.264	14.298	5.200	4.999	1.750
Soda	0.474	0.615	0.888	0.523	4.761	1.407
	100.000	100.000	100.000	100.000	100.000	100.000

As already intimated we do not know whether any of these analyses can justly be considered as representing the quantity and composition of the ash of a perfectly normal apple tree. The New York trees were young and the bark and wood were evidently taken together. The object that that station had in view did not require the examination of these parts separately.

We have seen that the limbs of the Jonathan trees growing on a marly soil contain 2.00 per cent of ash whereas the limbs of trees growing on a sandy loam, the bark included in both cases, contain only 1.17 per cent. We notice further that the wood of the trees growing on the marly soil is high in lime and low in potash compared with that grown on the sandy loam, the ash of the former contains 36 while the latter contained 26 per cent of lime; in regard to the potash the relative quantities are reserved, i. e., the ash of the former contains 14.3, that of the latter 26.6 per cent. The phosphoric acid of these ashes is much more nearly equal, 4.5 per cent in the wood grown on marly soil and 5.00 per cent in that of wood grown on a sandy loam. We find that the ashes of the barks also vary, that of the trees growing on the marly soil being very rich in lime, 54.3 per cent, while that of the trees grown on sandy loam contains 48.2 per cent. The phosphoric acid is twice as great in the ash of the bark from trees grown on sandy loam as on the marly soil. The results obtained for the quantity of ash present in the wood and bark of the dead tree and its composition seem to show mostly the extent to which the tree used up its ash constituents in dying.

The analyses of the ashes given in the New York report are of young trees which may make some difference, but they are similar to ours only in containing a high percentage of lime. The potash in them is only a few tenths of one per cent higher than we find in the ash of our dead tree. I have no analysis of the Geneva soils though some were published in Bulletin 56, old Series.

The effect of the marly soil seems to be to increase the percentage of ash in the wood and bark, to lower the percentage of potash present and to increase that of the lime. This marly soil has been sprayed regularly and heavily. The results give no conclusive answer to the question had in mind when the work was undertaken, but the following facts present themselves. The trees grown on the sandy loam are thrifty and healthy so far as we are able to judge. The trees on the marly soil on the other hand are not thrifty. We find no bleeding in the case of the trees on the sandy loam while it is quite common in the trees on marly soils. The ash of the trees grown on the sandy loam contains much less lime and more potash than that of trees grown on marly soil. The deposits made by exuding juices of the bleeding trees contain 25.0 per cent. of lime and 49 parts of arsenic acid per million. These facts perhaps may not amount to satisfactory proof to some but they certainly point directly to either the lime or the arsenic or to their joint action as the cause of the unhealthy condition of the trees. As lime alone has not been observed to produce these results, confined almost exclusively to these marly soils, we are justified in attributing the trouble to their joint action.

I cut off the limb of a Jonathan tree on the 8th of April and on the 12th of May I removed 2.2 grams of a deposit. The aqueous solution of this deposit gave a very satisfactory test for arsenic. The trunk through which the juice had to pass was very short and the arsenic could scarcely have been gathered from the woody tissues of the tree. The elm root, taken at least six feet from the trunk, was quite rich in arsenic. No doubt can reasonably be entertained but that this arsenic and also the lime had been gathered by the roots. The cases mentioned are by no means isolated ones. In some orchards cases of bleeding are numerous and severe, in others they may be absent. The orchards in which this occurs usually have a marly subsoil at a shallow depth. This bleeding is not confined to wounds made by trimming but frequently takes place from cracks in the bark as previously described. Some instances of this are met with in many of the orchards to which reference has been made.

Healthy trees do not bleed in this manner and their juices do not form such deposits. Trees killed by irritant arsenical poisoning do not bleed in this manner, nor have I seen any deposit of this sort on trees injured by arsenic accidentally applied to them. This condition is not attributable to arsenical poisoning alone. This deposit is, however, rich in arsenic and lime and I infer from these facts that we have in these cases a systemic poisoning by lime and arsenic.

It has been observed by orchardists that certain shallow soils underlaid by marl produce a yellowing of the leaves on apple trees;

this has been attributed to the lime. I have held in these cases that it was starvation rather than poisoning but this cannot be admitted in the case of the soil, an analysis of which has been given on a preceding page, without denying the evidence of this analysis and the actual productiveness of the soil.

I have intentionally permitted these two subjects, the systemic poisoning by arsenic and the effects of lime, to merge into this broader form, because I believe that this form of the trouble is primarily due to arsenical poisoning modified by the presence of lime which exists in the soil in large quantities in the form of calcic carbonate and often forms, beneath the soil proper, a layer from two or three inches to two or more feet in thickness.

I have shown on a previous page that these limey, virgin soils and also these marls contain arsenic, about one-tenth as much as the average orchard soil examined.

To restate the case briefly. We have well cared for trees which are extremely small for their age. Their general condition is bad; some of the trees have died, these trees had no disease of the crown or roots and were not suffering from any recognizable, known disease; the wood is stained a light brown, an effect produced by arsenic; they make but little growth, another effect produced by arsenic; arsenic is present in the woody tissues of these trees and even in their fruit. Some of the trees have corroded crowns, a sufficient cause to account for the death of the particular trees. These cases are not considered in this place. It will be recalled that in discussing irritant arsenical poisoning I pointed out that some of the arsenic found was probably gathered by the roots. Some of the trees show the splitting of the bark and bleeding, forming deposits rich in arsenic and lime.

The arsenic is gathered from the soil by the roots as is shown by the peach trees and also by the elm which were never sprayed. This fact is again shown by the presence of arsenic in the fruit and leaves grown on trees which have not been sprayed this year. This arsenic is evidently carried to the leaves and the fruit from the soil by the solutions passing through the tree. The final question is how much arsenic can a tree tolerate and how long can it endure the amount that the roots gather and pass into the tree. These are questions to be solved. I am convinced that many trees have already reached the limit of their endurance and that this is the cause of their bad condition. I said in Bulletin 131, in reference to this subject of systemic poisoning and the action of lime as distinct from irritant arsenical poisoning, "These trees do not present the symptoms described for arsenical poisoning, though arsenic is very abundant. * * * These soils are marly or have a subsoil of this material and the presence of 25 per cent of lime in the dried sap seems to me to be a very suggestive fact."

I add to this that the presence of arsenic in these soils equivalent to from 26 to 138 parts of arsenic acid per million of soil, and of arsenic equivalent to 49 parts of this acid to each million parts of this dried juice are more suggestive and that the presence of arsenic in leaves which have received no application of spray equivalent to 2.19 parts of arsenic acid per million of dried leaves and in the fruit equivalent to from 0.51 to 2.3 parts of arsenic acid per million of fresh fruit, are still more suggestive, if not satisfactorily conclusive, that systemic arsenical poisoning is really the cause of the small size, the bleeding and the death of some of our fruit trees.

Before I state the conclusions of this bulletin it is proper that I should express my appreciation of the helpful, kindly interest and willing assistance rendered me by the officers and others connected with this station and also to officers of other stations and states.

Throughout Bulletin 131 I tried to make it as plain as language could possibly make it that I fully appreciated the fact that the subject matter of the bulletin was of the most serious character and of very great importance. I told the public that my colleagues had urged me to take up the investigation and used this language: "These statements are not made to devolve any responsibility upon these professors, but to show that this view has not been hidden from the people or my colleagues and the presentation of this bulletin is not a hasty resolve or a thing done without a very keen appreciation of its importance not only to the orchardists of Colorado, but to all orchardists." The same is true in regard to this bulletin.

It is true that the presence of arsenic in apples from California, Michigan, New York, Pennsylvania, Ohio, Illinois, and Colorado show that fruit grown on sprayed trees contains arsenic and further that this is a general fact, but there is no reason at all for alarm for either the health or life of persons eating such pears or apples. Two of my assistants and I have tried it, one of us eating nearly eight pounds of apples by weight, in twelve hours. The apples from Illinois, Ohio, and New York were just as rich in arsenic as those from California or Colorado. I repeat that so far as the public is concerned there is no reason at all for the least concern. At present it seems possible that we may use the sulfid of arsenic with less danger than accompanies the use of lead arsenate and we will certainly use very much less arsenic than in the past. It has been demonstrated that if everybody will give his orchard one thorough spray at the time now recommended, using one or one and one-fourth pounds of pasty lead arsenate to fifty gallons of water, four to four and one-half pounds to the 200 gallon tank, we will have fairly clean apples. The preceding statement applies only under favorabe conditions. There can be no doubt but that excellent results have been and may be obtained from one spray but there are conditions under which one spray will not suffice to supress the injury by the codling moth even to a reasonable limit. It seems that the first brood may be so long in making its appearance that one may find unhatched eggs and pupated specimens representing the first brood on the same date.

The growing apples present a comparatively large amount of surface entirely free from the arsenate of lead and consequently not protected against the attack of late hatching individuals. These are not theoretical considerations but facts as they have been observed in the orchard were may be found, in some sections, many apples which the worms of the first brood have entered from the side. In such cases one spraying would mean a wormy crop. On the other hand the results obtained with one spraying have been excellent, especially in cases where the orchard was not subjected to subsequent infection from adjacent, unsprayed, or very poorly sprayed orchards.

Summary

While many trees, both apple and pear, have been damaged, even killed, by the action of arsenic collected about the crown or collar of the tree, other causes of death are not excluded. It is shown in Bulletin 155 that nitre in the soil may kill apple trees, but the crowns and roots are not attacked by this agent as they are by arsenic.

The total number of trees affected is large. It is seldom that more than a few affected trees occur together, usually they occur singly, scattered throughout the orchard.

Trees killed by nitre usually occur in blocks, sometimes only a few trees, 12 to 20, but in other instances they occur by the acre.

The arsenical preparations used for spraying are supposed to be insoluble in water, this is not correct. Well washed arsenate of lead will yield arsenic acid to pure water, about, 0.3 per cent. of its dry weight.

The addition of sodic sulfate, sodic chlorid or sodic carbonate, even in small quantities, to the water materially increases the amount dissolved. This is especially true of the sodic chlorid and sodic carbonate .

In Bulletin 131, I attached considerable weight to the action of these alkali salts which are present in all of the soils of the semi-arid regions in a greater measure than in the soils of some other sections. I do not doubt but that they have some influence upon the solubility of the arsenical compounds, but as much as 1.38 parts of arsenic acid per million soluble in water has been found when the total water-soluble portion amounted to only 0.22 per cent. of the air dried soil. Again I have found weighable quantities of water soluble arsenic in soils which were free from alkali. The alkalis in our soils may increase but they are not the only cause of the solubility of the arsenic.

Three forms of this trouble are recognized, corrosive arsenical poisoning, systemic arsenical poisoning and arsenic-lime poisoning. The last form is consdered as being produced by the joint action of lime and arsenic, because we do not find this trouble present on limestone soils in general nor is it characterstic of arsenical poisoning produced by soluble arsenic preparations, sodic arsenite for example.

Corrosive arsenical poisoning attacks the tree at the crown, below the surface of the soil and usually involves the large roots also. The attack is from the outside and causes the disintegration of the bark, the cambium is not destroyed until the corrosion has perforated the bark which is not loosened. Pear and apple trees are affected; the pear tree is, at least, as susceptible to the action of the arsenic as the apple tree. Some varieties of pears, as well as apples, seem more susceptible than others, but this is true only in a general way. The age of the tree at the time the first applications were made seems to have some effect upon the resisting power of the bark. The variety of soil may have some influence but it is not pronounced enough to be recognized with certainty. Very many, if not the greater part of our soils, contain arsenic. This is true of our virgin soils as well as of our cultivated soils. Our orchard soils now contain from 10 to 28 times as much arsenic as our virgin soils.

No other agency known to us produces the observed results, but arsenic when applied in soluble form produces similar effects quickly.

The first sign of trouble in the apple tree is an early ripening of the leaves, at least, one year before the death of the tree; in pear trees the foilage ripens early and assume a deep purple color.

The amount of arsenic present in the destroyed bark and in the woody tissues of such trees is as great as in cases in which it is known that arsenic was the cause of death.

The trouble is very general throughout the state and occurs in all kinds of soils which fact eliminates the question of seepage and, to a large extent, that of alkalis.

While the alkalis may in some instances be present in the soil in sufficient quantities to produce a perceptible effect, we cannot, owing to the wide range of localities and the great variety of soils in which we meet the trouble attribute very great importance to their action. Their presence, however, in soils undoubtedly tends to make the arsenic more readily soluble.

In the case of trees which have not been sprayed but which have been grown as fillers in sprayed orchards, the wood contained arsenic. This is true, too, of young trees grown in soil which contains arsenic. This shows that the arsenic may be and is taken up with the nitrient solutions. The fruit grown on such trees, apples and pears, contain arsenic and also the leaves. The fruit and leaves grow and are shed each season this is not the case with the woody portions of the tree.

Systemic poisoning is produced by this arsenic distributed throughout the tree, interfering with nutrition and growth of the tree and in some cases causing its death.

The bleeding met with in trees on marly soils is probably due to the combined action of lime and arsenc. A study of the ash constituents contained in the wood of trees grown in marly soil and in a sandy loam shows a remarkable difference in the amount of ash, 2.00 per cent. against 1.17 per cent. of the wood and a very much lower percentage of potash, 14.-298 per cent. against 26.621 per cent. of ash. The deposit produced by this bleeding is very rich in arsenic as it contains 49 parts of arsenic acid per million of the dried deposit.

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A BACTERIAL DISEASE OF ALFALFA

BY

WALTER G. SACKETT

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A BACTERIAL DISEASE OF ALFALFA.

By WALTER G. SACKETT.

HISTORY AND DISTRIBUTION.

In May of 1904, Hon. J. L. Chatfield, who resides at Gypsum, Eagle County, Colorado, observed that while the stand of alfalfa on his ranch was good, much of it was shorter than it should be at that time of the year, and that here and there plants were dying. He reported this condition to the Experiment Station at Fort Collins, and in response to his request, Professor Paddock and Professor Gillette visited his fields. They examined a number of plants, but they were unable to give any decisive answer as to the exact cause. Occasionally, worms were found in the crowns and in the roots, and by splitting the latter lengthwise, numerous dark streaks could be traced through the tissue. A few crowns were blackened, as well as some of the stems, but this discoloration was looked upon as due, possibly, to insect work, although no specific insects could be found at that time.

The following year, there was practically none of the trouble to be seen in the whole valley, which has an area of at least five thousand acres, more than one half of which is in alfalfa.

The next year, however, 1906, the conditions were worse than ever before and the universal complaint among the farmers was that there was "something wrong with the alfalfa." Professor Paddock again visited Gypsum, and at this time the blackened stems were very abundant and much more conspicuous than when he was there before. He brought back specimens of this material to the college and a microscopic examination satisfied him that, in all probability, the trouble was of bacterial origin. As a result of these findings, in November, 1906. Professor Paddock (1) called attention to a new alfalfa disease occurring in certain parts of Colorado, which was different from any previously described malady and which, from all appearances, was not related to either leaf spot or mildew.

The disease has spread with increasing severity until at the present time it is a very difficult matter to find one acre of alfalfa land in the whole valley which is entirely free from the trouble. The loss in tonnage for the first cutting is estimated at eighty per cent, or the crop is only one-fifth of what it was in former years. The disease became so serious in 1907 that it was thought advisable to make the study of this malady a theme for special research. Accordingly, May 1, 1908, the writer began an intensive investigation of the trouble and during the past year has been occupied with laboratory, greenhouse and field experiments bearing upon the cause and possible remedies for the disease. The results of this

(1) Press Bulletin No. 28, Colo. Exp. Sta.

work are given in the pages which follow.

DISTRIBUTION.

Within the state of Colorado, the disease occurs generally throughout the Gypsum Valley in Eagle county, and to a somewhat less extent in Garfield county, and at Rocky Ford in the Arkansas Valley. Prof. W. Paddock has noted it in the Plateau Valley, Mesa county, and between Hotchkiss and Paonia in Delta county.

So far as our present knowledge goes, it has not been seen in the San Luis Valley, or in the Boulder, Longmont, Loveland, Fort Collins and Greeley districts.

In our neighboring states, what appears to be a similar bacterial disease has been observed by Professor Northrop in Utah, by Professor Wooten in New Mexico, by Professor Wilcox in Nebraska, and by Professor Roberts in Kansas. Its occurrence is reported as negative by Professor Nelson for Wyoming, by Professor Kennedy for Nevada, by Professor Lewis for Oklahoma, and by Professor Ball for Texas.

DESCRIPTION OF THE DISEASE.

When a field suffering with this bacterial trouble is viewed as a whole, about the only comment which could be made is that the growth is short and the alfalfa is a little off color. The rich, dark green color in the leaves is absent and the juicy, succulent appearance of the stem, so characteristic of a thrifty stand, is wanting. The plants tend to grow more spindling; the leaves often appear dwarfed, narrow, light green and have a tendency all along the stem and in the growing tip to remain partly closed just as they do in cold or dry weather.

The disease is primarily a stem infection and it is here that we find the most valuable characters for diagnosis. In the earliest stages, the stem has a watery, semi-transparent, yellowish to olive green appearance along one side. This extends down the stem from below the point of attachment of a leaf for one to three internodes. Again, on another side of the stem, the infection may cover two or three different internodes or parts of the same ones. Most commonly the first three to five internodes are the worst infected. Such stems are usually healthy and normal below the ground. Soon after they take on this dark, olive green, watery appearance, there oozes out from the diseased tissue a thick, clear, viscid liquid which spreads over the stem and collects here and there in little bead-like droplets. This exudate dries in a short time with a glistening finish, and gives the stem very much the appearance of having been varnished, and where the liquid has collected in little amber colored scales and has hardened, it looks as if the varnish had run and dried. Stems in this condition have a dry, slightly rough feel to the touch. The exudate also dries uniformly over the surface or just beneath it, and there produces a dark brown, resinous surface which blackens with age. Such stems are very brittle and easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

If the epidermis is scraped from an infected stem, the tissue underneath has the same yellowish, watery appearance. This pathological condition extends to the center of the stem and if it is split lengthwise, the interior cavity presents a brownish, mealy aspect. Such stems will collapse much more readily when pressed between the fingers than healthy ones. A shoot in this condition is virtually girdled; its circulation is impaired and its food supply is practically cut off as is evident from the poor growth it makes. Some stems remain in this inactive state and struggle along until the mowing machine puts an end to their existence; others turn black, shrivel and die six weeks before time for the first cutting. During the past season, the disease appeared about May 15th, and up until June 10, twenty-six days later, there were no blackened stems to be found. During this period, the trouble was manifested by the characteristic yellowish green, watery look.

The leaves attached to the diseased part of the stem usually show a watery, pale yellow color at the base, along the mid rib of the leaflets, and especially in the tiny petioles. Those on the parts of the stem which are blackened are always dried up, yellow and extremely brittle. The stipules at the base of the petioles are yellow and brittle and usually show the disease before their corresponding leaves.

Sometimes the leaves exhibit the infection independently of the stem. In this case the petioles become watery, pale yellow and droop. The malady may be confined to the petiole and base of the leaflet or it may involve the whole of the blade. Occasionally leaves are found where the inoculation has been made, apparently, in the margin of the leaflet, and the infection has proceeded toward the middle. In such instances, the tender tissue has a watery look, as if it had been bruised. These leaf infections have been observed to occur a little earlier than the stem troubles, although it may be merely a matter of being able to detect the pathological condition there first.

One year old plants may exhibit blackened areas in the crown, and black streaks which run down into the tap root. As the plant grows older, this blackening increases until the whole crown becomes involved and either the crown buds are destroyed or the root is no longer able to perform its functions, and the plant dies.

So far as our present observations go, the disease appears to run its course with the first cutting, and those plants which have sufficient vitality, throw out a good growth for the second and third cuttings. Strange as it may seem, there is little or no trace of the blight during the remainder of the season, but in the following spring, a renewed outbreak may be looked for. The severity of the attack seems to vary from season to season. As has been noted before, the trouble was moderate in 1904; in 1905 it was practically unseen; in 1906 and 1907 it was extremely bad; in 1908 the attack was mild and during the past year there was but little to be found. This season the crop was the best that has been harvested for four years. This variation in the degree of the attack would seem to indicate that there may be some relation between the prevalence of the disease and the weather conditions, especially late frosts and late freezing, intermingled with warm, pleasant days as compared with a late, cold spring. Not many plants are killed the first year, but they begin to die after the blight has been prevalent more than one season, and after three or four years so many of them may be missing that the stand is practically worthless.

CAUSE OF THE DISEASE.

If a small piece of the yellowish green, watery tissue from a diseased plant, it matters not whether it be stem or leaf, is placed in a drop of clean water on a glass slide, there will appear on all sides of it, after half a minute, a dense, milky cloud, which can be seen readily with the naked eye, and which slowly diffuses out into the drop. When this preparation is examined under the low power of the microscope (Leitz Objective No. 3, Eye Piece IV.) this milky zone easily resolves itself into swarms of bacteria, which under the high power (Leitz Objective No. 7, Eye Piece IV.) can be distinguished as actively motile rods, relatively short and thick, with rounded ends and occurring for the most part singly and in twos.

If the surface tissue is removed and a portion of the deeper layers is examined, identically the same results will be obtained. If a fragment of the dried exudate is likewise placed in a drop of water, the whole gradually disintegrates and becomes a milky cloud, which under the microscope is a mass of motile bacteria.

Now, if stained films are made from the milky cloud of any of the above preparations, using aqueous fuchsin, one invariably finds a practically pure culture of a short, medium thick bacillus with rounded ends, and with a tendency to stain darker at the poles than in the middle.

Nutrient agar plates, prepared from any of this diseased tissue or from the dried exudate, and incubated for 72 hours at 28° C., will give, almost invariably, a pure culture of a smooth, glistening, grayish white colony, slightly raised, round, margins entire or undulating, and concentrically ringed.

Out of twenty-one infected stems examined and plated at different stages of the disease, thirteen gave pure cultures of this colony in the Petri dishes. In seventeen plates, it was the dominant colony. Platings from five different leaves gave pure cultures in three cases and in four out of five the above colony was the most abundant. In other words, pure cultures were obtained in 62 per cent of the original isolations and in 81 per cent this white colony was dominant. In two out of twenty-six isolations or in seven per cent, it was absent. Plates made from the moist or freshly dried exudate, as a rule, gave pure cultures of the same organism.

An examination of the following notes, made in connection with some of the isolations, may be of interest in showing with what degree of purity the organism can be isolated from field material.

Plates made from material collected at Gypsum, Colorado, May 25, 1909. Plated in Nutrient Agar May 27, 1909.

I. **Petiole.**—Culture pure; growth after 72 hours; culture picked up 6-1-09. Colony round, smooth, grayish white, glistening, slightly raised. Stained film preparation from four day old colony; short rods, medium thick, mostly single, occasionally in twos, slightly curved and wedge shaped; stain readily with ordinary aqueous fuchsin.

II. **Leaf.**—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above.

III. **Stem Tissue—New Infection.**—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above.

IV. **Stem Tissue.**—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above. Orange colonies appeared on June 5th; picked these up.

V. **Stem Tissue—Black.**—Culture mixed; growth after 48 hours; cultures picked up 6-1-09. Yellow colonies dominant; few white colonies which resemble those described from petiole.

VI. **Exudate Scale No. 1.**—Culture pure; growth after 72 hours; culture picked up 6-1-09. Characteristic white colonies same as petiole but germs themselves seem shorter, less curved and wedge shaped. Later observations have shown this germ to be the same as the petiole culture.

VII. **Exudate Scale No. 2.**—Culture pure; growth after 72 hours; culture picked up 6-1-09. Characteristic white colonies; germ same as that described from Exudate No. 1.

In all probability, all of the above characteristic white colonies were the same. Slight differences in staining seemed to make some difference in the size and shape of the organism itself. In every case the germ is a short, medium thick, motile rod with rounded ends and with a tendency to produce slightly curved forms which show granules on staining.

Plates made from material collected from the Experimental Plats at Gypsum, Colorado, June 11, 1909, and plated June 14, in nutrient agar. Notes taken June 19, 1909.

I. Stem Yellow—Typical.—Plate pure; growth just visible after 48 hours, good after 72 hours; culture picked up 6-19-09. Colony round, smooth, grayish white, glistening, slightly raised, margin entire to undulate. Stain: rods, short, moderately thick, rounded ends, many wedge shape and curved.

II. Stem Advanced.—Plate pure; white colony same as "stem yellow" above. Growth just visible after 48 hours, good after 72 hours. Stain: same as "stem yellow." Culture picked up 6-19-09.

III. Stem Brown.—Plate pure; white colony same as above; growth and stain same; culture picked up 6-19-09.

IV. Stem Green.—Plate contained the same white colony, but an orange colored colony dominated; this orange colony (1) previously shown not to be the cause of the trouble. No cultures picked up.

V. Stem Yellow No. 2.—Plate mixed; the same white colony dominated; there was also the above mentioned orange colony and a large yellow one found once before in earlier plates (2). No cultures picked up.

VI. Stem Watery.—Plate pure; white colony same as above; growth visible after 48 hours, good after 72 hours. Stain: same as "stem yellow" above; short, curved rods, wedge shape and irregular. Cultures picked up 6-19-09.

VII. Single Stoma—Old Infection.—Plate pure; white colony and stain same as "stem yellow" above. Growth visible after 48 hours, good after 72 hours. Culture picked up 6-19-09.

(1) Stem tissue—plates of May 27, 1909.

(2) Stem tissue black—plates of May 27, 1909.

VIII. Stomata—New Infection.—Plate pure; white colony and stain same as "stem yellow" above. Culture picked up 6-19-09.

IX. Stomata—Black.—Plate pure; white colony and stain same as "stem yellow" above. Culture picked up 6-19-09.

All of the cultures picked up from the dominant white colonies, present in all of the plates, have been shown to be one and the same organism and when inoculated onto alfalfa plants, all are capable of producing the disease.

Inoculations have been made upon alfalfa plants, grown under greenhouse conditions, with the three different cultures which have been isolated during this investigation, namely, the characteristic white one, the yellow and the orange, and the only one which has produced typical symptoms of the disease, in fact the only one which has produced any pathological condition whatever, is the dominant white colony referred to so frequently above. Cultures obtained from stem, leaf, petiole, or exudate, were equally pathogenic. Detailed descriptions of this part of the work are given on page 24 under "Greenhouse Experiments."

In order to establish further the fact, that this germ was the unmistakable cause of the trouble, an alfalfa plant was inoculated June 7, 1909 with our present stock culture of the causal organism, to which the name *Pseudomonas medicaginis*, n. sp. has been given, which was isolated from an infected stem May 27, 1909. By June 19, typical symptoms had developed, and plates were made from the yellowish green, watery tissue. On June 21, the Petri dishes showed a pure culture of the same white colony and the organism

5
4
3
2
1
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was reisolated on an agar slant. When compared with the original culture, the recovered organism was identical both in the hanging drop and when stained with aqueous fuchsin. The reisolated culture was again inoculated, June 25, by needle pricks into three different stems, and all of the inoculations gave positive results; the needle pricks showed a yellow, watery zone around the point of infection after nine days, and later turned black. When material from these diseased areas was examined microscopically, August 16, the same milky cloud appeared in the mount as has been described for field material, and swarms of motile rods were visible.

In all, one hundred and two inoculations have been made with this culture, introduced either by scraping the stem or by needle pricks, and positive results have been secured with one hundred per cent of the infections. Control inoculations with a sterile needle have been carried along with all of the experiments, and in no case have any of the check plants developed symptoms of the disease.

METHOD OF INFECTION.

In an effort to secure a satisfactory explanation of the method of infection, the writer spent over a month in the field where the disease is most prevalent. As a result of the daily observations and the gross and microscopic examination of more than three hundred plants, collected at all stages of the disease, before it made its appearance and until it was flourishing, he believes the following to be the most tenable and satisfactory solution of the question.

This phase of the investigation was carried on at Gypsum, Colorado, where our first observations were taken May 4, 1909; this was early in the spring for this locality and altitude (over 6,000 feet above sea level). The season was considered cold and backward, and a moderately heavy snow had fallen one week before; traces of this were still to be seen in the valleys, and the surrounding hills and mountains were heavily covered.

The alfalfa was just beginning to grow, the average height in the diseased fields being from 1½ to 2 inches. Most of the plants had a yellowish green color due, presumably, to the cold. An examination of the young, succulent shoots showed that the epidermis of practically every one of them was wrinkled just below the point of attachment of the first four or five leaves, and often this wrinkling extended half way to the next leaf below. The epidermis was loose from the tissue beneath and appeared to be too large for the stem. When this was peeled off, the underlying tissue had a yellowish, green color much like the diseased plants, but a microscopic examination of such material failed to show any micro-organisms present. In those parts of the stem where this wrinkling was absent, the tissue beneath the epidermis was not yellow, but a whitish green. In many plants, the loosened epidermis had the appearance of partially collapsed blisters, while around and underneath these blisters the tissue seemed darker than normal and watery, with a suggestion of its having been frozen. Numerous lenticular breaks occurred in the epidermis of some stems. These might have been due to insect work although rather early in the season for this. Occasionally stems were found where the wrinkled epidermis had split open for a distance of one centimeter, exposing the moist pyrenchyma beneath.

Ten days later, May 14, the epidermis of practically every stem in the field was split wide open from node to node over the first six internodes, the third to the fifth internodes being the most common. This splitting appeared to have begun with the wrinkled epidermis mentioned above, and had extended the whole length of the internode thereby exposing the succulent, moist tissue beneath to infection. It is the concensus of opinion of those who have observed this phenomenon, that both the breaking away of the epidermis from the underlying tissue and the wrinkling and subsequent splitting are caused by freezing. A similar trouble ascribed to freezing has been observed in cherry trees and less frequently in the apple. Here the bark cracks and later splits open, exposing the green wood beneath just as in the alfalfa stems.

Anyone who has ever lived in Colorado is familiar with the soil carrying capacity of our winds, and with this in mind, it is easy to understand how germ laden soil might be blown into these cracks, where it would adhere to the moist, exposed surface, and bring about a fatal inoculation. As a matter of fact, soil was always found adhering to these surfaces, and, already, typical cases of the disease were developing. A microscopic examination of the tissues from the injured areas usually showed the germs to be present in great numbers, while ten days previous, that is before the splitting had occurred, there was no indication of any infection. Invariably, the disease appeared first and was worst on those parts of the stem where the epidermis had split and where soil had been caught in the open wound. A striking example of this was seen in an alfalfa field adjacent to a field which had been cultivated recently and sown to oats. The oat field was on the windward side, and with every gust, quantities of fine soil were carried over into the alfalfa. All along this side of the field, there was an aggravated attack of the disease, extending twenty to thirty feet into the alfalfa and the whole length of the field. Every plant was gray with soil and it is only reasonable to suppose that the disease was more severe here than in the more remote parts of the field because of the heavier soil inoculation.

This explanation satisfies one of the most difficult questions which has arisen in connection with the problem, namely, why does the first cutting, alone, suffer from the attack? There are never any frosts after the first crop is out of the way, and consequently there are no split stems in which to start the infection.

In a preliminary report (1), the writer has suggested that possibly the constant tramping of cattle and horses, pastured on the alfalfa fields during the winter, might have split open the crowns and bruised the young, tender shoots so that during the first irrigation, soil containing the disease germs was washed into the injured tissue and started the trouble on the first cutting. Our observations during the past season do not warrant such a conclusion in the majority of cases at least, since, in the first place, the disease was active at least two weeks before the first irrigation, and in the second place, our experimental plats, to which stock had no access, suffered just as severely as the fields which were pastured.

Not infrequently, we find the disease at work on stems where there has been no apparent previous injury to the epidermis; sometimes this assumes the form of a continuous, unbroken infection of the whole internode, and again it occurs as separate, punctiform lesions giving the stem a speckled appearance. This last condition would seem to indicate an infection through the stomata, and inasmuch as we have been able to secure successful inoculations in the greenhouse by applying the culture to the unbroken epidermis, it is altogether possible that stomatal infections take place under field conditions. The leaflets often exhibit yellowish, watery areas along the margin and the larger veins when there is no evidence of the trouble in any other part of the plant; again, the tiny petioles succumb to the disease independently of either the stem or the attached leaflets. Water pore and stomatal infection similar to that described for the black rot of cabbage may explain these cases.

There are doubtless other ways in which infection can take place, but the methods described above, especially the inoculation through the split epidermis, seem to be the most common. It is possible that added observations of another season will give us more light upon this point and so rather than draw any final conclusion as to the *one way* in which inoculation takes place in the field, we prefer to leave the question open.

DESCRIPTION OF THE CAUSAL ORGANISM.

Pseudomonas medicaginis, n. sp. (Sackett.)

I. MORPHOLOGY

1. Vegetative Cells.

When grown upon nutrient agar for 24 hours at 28° C., and

(1) Bulletin 138, Colo. Exp. Sta., Jan. 1909.

stained with aqueous fuchsin, the organism is found to be a short rod with rounded ends, for the most part single, more rarely in short chains of four to six elements, and occasionally in long filaments. Many of the rods appear slightly curved and wedge shaped; the rods taken directly from diseased stems are usually shorter, and when stained with aqueous fuchsin, appear to take the stain more deeply at the poles.

The individual rods usually measure about 1.2 to 2.4μ x .5 to .8μ; the majority are about 2.1μ x .7μ; the filaments vary in length from 20.2μ to 37.2μ.

2. Sporangia.

No sporangia have been observed.

3. Endospores.

No endospores have been observed in agar cultures four months old.

4. Flagella.

When stained by Loeffler's (1) method, it was possible to demonstrate from 1 to 4 flagella attached to each pole. Following Migula's classification, this bi-polar attachment of the flagella places the organism in the genus **Pseudomonas.** A 24 hour agar culture, examined in the hanging drop, exhibits very actively motile rods with rounded ends, from two to four times as long as broad, and which occur, for the most part, singly and occasionally in short chains and filaments.

(1) Centralbl. f. Bakt., 1889, 6, p. 209; 1890, 7, p. 625.

5. Capsules.

No capsules have been observed when stained by Welch's method. (2)

6. Zoogloea.

No zoogloea have been observed.

7. Involution Forms.

Films made from an agar culture four months old and stained with carbol fuchsin show many degenerative forms. Long irregular rods which stain unevenly, giving a granular appearance, and usually darker at the poles, are among the most common. No unusual or strikingly characteristic forms have been observed.

8. Staining Reactions.

The organism stains readily with the ordinary aqueous stains, anilin gentian violet, and carbol fuchsin.

Gram's Stain.

The results from repeated efforts at staining by Gram's method were not sufficiently sharp and decisive to warrant any positive conclusions; the stain was neither entirely lost nor was it retained in its original depth and brilliancy. Both the anilin gentian violet and the iodine solution were used for one and one half minutes and the preparations were left in absolute alcohol for five minutes. When examined, the germs were distinctly stained, but not as intensely as those which had not been treated with the alcohol and for this reason, alone, the organism is here reported as Gram negative, while in reality it is neither positive nor negative.

Loeffler's Methylene Blue.

Stained with Loeffler's methylene blue, the protoplasm of the organism appears very coarsely granular, so much so, in fact, as to give the rods almost a striated appearance.

Neisser's Stain.

Neisser's stain brings out a more or less granular structure to

(2) Bull. Johns Hopkins Hosp., 1892, 3, p. 128.

the protoplasm, but no definite meta-chromatic or polar granules are demonstrable.

II. CULTURAL FEATURES

1. Agar Stroke. Nutrient Agar.

GROWTH, at 27°-28° C., moderate in 24 hours, abundant after 72 hours; no growth at 37° C.
FORM OF GROWTH, filiform becoming more or less echinulate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, translucent.
CHROMOGENESIS, § grayish white, Engine color No. 12.
ODOR, absent.
CONSISTENCY, butyrous.
MEDIUM, light fluorescent green on the third day.

2. Potato.

GROWTH, scanty in 48 hours, moderate after 6 days.
FORM OF GROWTH, filiform becoming more or less echinulate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
CHROMOGENESIS, cream; best described as the color of light manilla paper; color lies between Orange Yellow Tint No. 2 and Engine Color No. 1. After 8 days, the color deepens to Orange Yellow Tint No. 2, and after 12 days, resembles most nearly Engine Color No. 7.
ODOR, absent.
CONSISTENCY, butyrous and slightly viscid.
MEDIUM, grayed and darkened.

3. Loeffler's Blood Serum.

STROKE. moderate in 3 days at 28° C.
FORM OF GROWTH, filiform.
ELEVATION, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
CHROMOGENESIS, grayish white.

4. Agar Stab.

GROWTH, best at top; surface growth moderate in 48 hours, abundant after 4 days; surface growth restricted.
LINE OF PUNCTURE, papillate; no liquefaction.
CHROMOGENESIS, grayish white, Engine Color No. 12.
MEDIUM, fluorescent at the surface on the third day.

5. Gelatin Stab.

GROWTH, best at top, no growth in the lower half of the stab.
LINE OF PUNCTURE, filiform to papillate.
LIQUEFACTION, none.
MEDIUM, unchanged.

6. Nutrient Broth.

SURFACE GROWTH, pellicle on the third day.
CLOUDING, slight in 24 hours, moderate in 48 hours, never strong; persistent; fluid slightly turbid.
ODOR, absent.
SEDIMENT, compact, slightly viscid on agitation, scant.

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§ Color terms refer to Standard Colored Papers made by Milton Bradley Co., Springfield, Mass.

7. Plain Milk.

No visible change takes place in the milk in 30 days; there is no peptonization, no coagulation; the reaction becomes neutral to phenolphthalein after 40 days. Reaction after 1 day, +12, after 2 days, +10, after 4 days, +8, after 10 days, +5, after 20 days, +2. The medium is unchanged in color; there is no curd formation and no peptonization at the expiration of 30 days.

8. Litmus Milk.

No change observed until the sixth day when the litmus appears somewhat lighter in color; by the seventh day it becomes bluer and by the fourteenth day it is intense blue. At the end of twenty days, it has the same deep blue color; there is no curd formation and no peptonization at the expiration of 30 days. There is no reduction of the litmus at any time.

9. Gelatin Colonies. Eight days old.

GROWTH, slow, 20° C.
FORM, round.
ELEVATION, slightly convex.
EDGE, undulating.
LIQUEFACTION, none after twenty days.

10. Agar Colonies. Five days old.

GROWTH, slow at 25° C. Fine white colonies visible to the eye after 48 hours.
FORM, round.
SURFACE, smooth, glistening, concentrically ringed.
ELEVATION, convex.
EDGE, entire to undulate; flattened sides.
INTERNAL STRUCTURE, more coarsely granular and denser at the center becoming more finely granular and less dense at the margin.
CHROMOGENESIS, grayish white, Engine Color No. 12.
SIZE, medium, average 1.5 m.m.

11. Glycerine Agar. Agar stroke.

GROWTH, at 27°-28° C., slight in 24 hours; moderate in 48 hours.
FORM OF GROWTH, filiform becoming more or less papillate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, translucent.
CHROMOGENESIS, grayish white, Engine Color No. 12.
ODOR, none.
CONSISTENCY, butyrous.
MEDIUM, very light fluorescent green on the third day; not as deep a green as nutrient agar.

12. Alfalfa Agar. Agar stroke.

GROWTH, slight growth in water of condensation at base of stroke atfer 5 days; slight along line of inoculation in 12 days.
FORM OF GROWTH, filiform.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, nearly opaque.
CHROMOGENESIS, Green Yellow Tint No. 2. Growth studded with fine black particles as if sprinkled with pepper.

ODOR, none.
CONSISTENCY, butyrous.
MEDIUM, surface becomes clouded as if a very fine precipitate had been formed in the medium as a result of the growth.

13. Synthetic Agar Low in Nitrogen. Agar stroke.

GROWTH, at 27°-28° C., moderate in 24 hours; very abundant after 3 days.
FORM OF GROWTH, filiform.
ELEVATION OF GROWTH, decidedly convex.
LUSTER, glistening, watery.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, transparent; resembles boiled starch.
CHROMOGENESIS, watery white.
ODOR, none.
CONSISTENCY, butyrous or more exactly the consistency of starch jelly.
MEDIUM, no change.

14. Cohn's Solution. 28° C.

GROWTH, absent.
FLUID, no growth.

15. Uschinsky's Solution, 28° C.

GROWTH, slight in 24 hours, moderate in 3 days, abundant in 10 days.
FLUID, viscid sediment after 4 days; clouding, strong, persistent, fluid turbid. Light green after 21 days.

16. Dunham's Solution, 28° C.

GROWTH, moderate.
CLOUDING, moderate, persistent, fluid slightly turbid.

17. Asparagin Solution, 28° C.

GROWTH, abundant.
CLOUDING, moderate, persistent, fluid turbid.

18. Nitrate Broth, 28° C.

GROWTH, moderate.
CLOUDING, moderate, persistent, fluid slightly turbid.

19. Dextrose Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

20. Saccharose Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

21. Lactose Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

22. Maltose Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

23. Glycerine Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

24. Mannite Bouillon, 28° C.

GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

25. Growth in Bouillon Over Chloroform.

GROWTH, absent. 1 c.c. of chloroform was added with a sterile pipette to 10 c.c. of sterile bouillon in a test tube and after the chloroform had collected at the bottom of the tube, the broth was inoculated with two loops of a 24 hour broth culture.

26. Sodium Chloride in Bouillon.

The effect of sodium chloride upon growth has been determined by inoculating tubes of nutrient broth (+15° Fuller's Scale), containing different amount of chemically pure sodium chloride, with two loopfuls of a 24 hour broth culture. A preliminary test in which the broth contained from 0 to 12 per cent of salt, each tube differing by 1%, showed that the toxic strength lay somewhere between 3 and 4 per cent. In the next determinations, the tubes contained 3.0, 3.25, 3.5, 3.75 and 4 per cent of NaCl respectively. This same series was repeated three times with the result that growth took place in the presence of 3.75 per cent of NaCl, but **4 per cent was sufficient to inhibit it.**

27. Nitrogen.

Nitrogen has been obtained from **peptone, asparagin, glycerine, and beef broth,** but not from ammonium tartrate. No determinations have been made with other ammonium salts, urea or free nitrogen. An abundant growth has been obtained on a synthetic agar low in nitrogen, such as is used for growing the nodule forming bacteria; this would seem to indicate the possibility of the organism being able to utilize atmospheric nitrogen. Determinations of this particular feature are in progress at the present time.

28. Best Media for Long Continued Growth.

Standard nutrient agar with a reaction of +15° Fuller's scale has proved entirely satisfactory.

29. Quick Tests for Differential Purposes.

Fluorescent green color produced in the nutrient agar streak; no growth at 37½° C.; non liquefaction of gelatin; surface pellicle on nutrient broth; luxurient and characteristic growth on synthetic agar low in nitrogen (q. v.).

III. PHYSICAL AND BIOCHEMICAL FEATURES

1. Gas Production.

Four fermentation tubes, each, of dextrose, saccharose, lactose, maltose, glycerine and mannite broth were inoculated with a 48 hour culture; two of each were kept at 28° C. and two at 37½° C. Those held at 28° C. gave growth in the open arm after 24 hours, but none in the closed arm and no gas; those at 37½° C. showed no growth whatever. The turbidity in the open arm of those kept at 28° C. increased with age, extending over half way into the U, but at the end of ten days there was **no growth in the closed arm** and **no gas.** There was a well defined line between the growth in the bulb and the clear liquid in the closed arm, which seemed to point strongly toward the aerobic nature of the organism.

2. Production of Acid and Alkali.

60 c.c. portions of dextrose broth, saccharose broth, lactose broth, maltose broth, glycerine broth and mannite broth in 200 c.c. Erlenmeyer flasks were inoculated with two loopfuls of a 24 hour broth culture of **Ps. medicaginis, n. sp.** Five cubic centimeters were taken from each flask for titration every twenty-four hours for a period of ten days. This was diluted with 45 c.c. of distilled water in a porcelain evaporating dish and titrated cold with N/10 NaOH or N/10 HCl as the case required. Phenolphthalein was used as the indicator. An examination of Table No. 1 will show that in no instance has there been any acid produced, while on the other hand, after the third day, there has been a gradual production of alkali until after

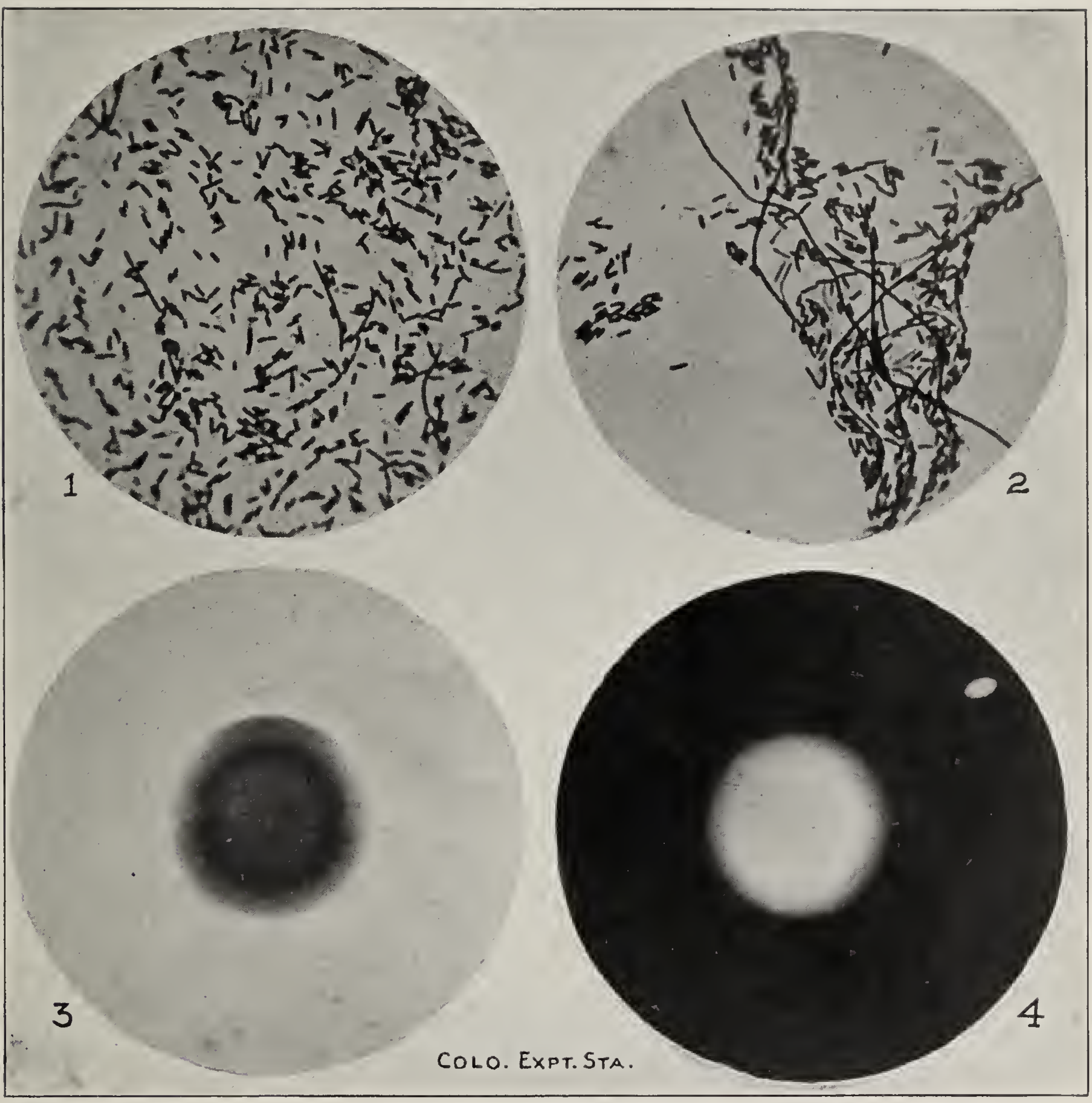

Plate I.

ten days growth the cultures were decidedly alkaline. The dextrose broth fell from +10 to —3, the saccharose broth from +8 to —5, the lactose broth from +8 to —6, the maltose broth from +8 to —5, the glycerine broth from +8 to —4, the mannite broth from +8 to —7. The results of the daily titrations are given in Table No. 1.

TABLE NO. 1—PRODUCTION OF ACID AND ALKALI.

Sugar Free Broth plus 1%	Degree of Reaction After										
	No ds	1 d	2 ds	3 ds	4 ds	5 ds	6 ds	7 ds	8 ds	9 ds	10 ds
Dextrose	10	10	10	10	9	6	4	2	1	0	—3
Saccharose	8	8	8	8	8	6	3	1	0	—4	—5
Lactose	8	8	8	8	6	4	2	0	—1	—4	—5
Maltose	8	8	8	8	7	7	5	1	0	—4	—5
Glycerine	8	8	8	8	7	5	2	1	0	—3	—4
Mannite	8	8	8	8	7	4	2	1	—1	—5	—7

3. Production of Ammonia.

The production of ammonia has been determined in nutrient broth, Dunham's peptone solution, Jordan's asparagin solution and nitrate broth. 100 c.c. portions of nutrient broth and Dunham's solution were placed in 500 c.c. Erlenmeyer flasks, sterilized, and inoculated with a 48 hour agar culture. Similar portions of each of these media were kept as sterile controls. After ten days, both the cultures and the uninoculated checks were analyzed for ammonia by distillation with magnesium oxid. The distillates were collected in N/10 H_2SO_4 and subsequently titrated with N/10 NaOH. Ammonia was produced by the culture both in the nutrient broth and in the peptone solution, the larger amount being present in the former. The results are given in Table No. 2 below.

TABLE NO. 2—PRODUCTION OF AMMONIA.

Medium	Milligrams NH_3 in 100 c c. of culture	Milligrams NH_3 in 100 c. c. uninoculated control	Milligrams NH_3 produced by the bacteria
Nutrient Broth....	21.63318	18.39672	3.23646
Dunham's Solution	4.00279	2.81060	1.19219

Large quantities of ammonia were produced in the asparagin solution after ten days. This was easily demonstrated by adding one cubic centimeter of Nessler's solution to inoculated tubes of this medium.

No ammonia was produced in nitrate broth by the reduction of the nitrates.

4. Nitrates in Nitrate Broth.

Nitrates are not reduced. Tubes of nitrate broth inoculated with **Ps. medicaginis, n. sp.** were tested after five days and ten days for nitrites and ammonia, and both were found absent. A subsequent test for nitrates showed the original nitrate to be present as such.

5. Indol Production.

There is no indol produced in Dunham's peptone solution.

6. Relation to Acid and Alkali.

The organism exhibits much more latitude in the reaction of its food stuffs on the acid side of the neutral point than on the alkaline, the limits of growth being from —4° to +32° Fuller's scale. The optimum reaction appears to be between +15 and +18. Growth is retarded by a neutral reaction, on the one side, and by +32 on the other, and is prevented entirely by —6 and +34.

To tubes containing exactly 5 c.c. of sterile broth, sufficient standard NaOH or HCl was added, with aseptic precautions, to give them reactions ranging from —40 to +40, each tube differing by 2° from the others, thus: —40°....—8°, —6°, —4°, —2°, 0°, +2°, +4°, +6°, +8°............+40°. Six tubes were prepared for each reaction, one of which was titrated to verify the degree of acidity or alkalinity. Without further sterilization, these tubes were inoculated with two loopfuls of a 48 hour broth culture and allowed to develop at 28° C. We found by trial that if the broth was sterilized after the acid or alkali had been added, the reaction might change considerably, especially in the case of the alkali, due, presumably, to certain chemical combinations which took place between the NaOH and the broth constituents at the sterilizing temperature (95.5° C. Altitude 4,981 feet above sea level). This was borne out by the fact that if the medium was not sterilized after adding the NaOH, —6° was sufficient to inhibit growth, but if sterilized, broth reacting —10° before being heated was required to accomplish the same result.

Detailed results of the experiment are given in Tables Nos. 3 and 4.

TABLE NO. 3—RELATION TO ACID.

Degree of Acid	Growth Resulting After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
0	−	−	−	+	+	+	+	+	+	+
2	−	+	+	+	+	+	+	+	+	+
4	−	+	+	+	+	+	+	+	+	+
6	+	+	+	+	+	+	+	+	+	+
8	+	+	+	+	+	+	+	+	+	+
10	+	+	+	+	+	+	+	+	+	+
12	+	+	+	+	+	+	+	+	+	+
14	(+)	+	+	+	+	+	+	+	+	+
16	(+)	+	+	+	+	+	+	+	+	+
18	(+)	+	+	+	+	+	+	+	+	+
20	+	+	+	+	+	+	+	+	+	+
22	+	+	+	+	+	+	+	+	+	+
24	−	+	+	+	+	+	+	+	+	+
26	−	+	+	+	+	+	+	+	+	+
28	−	+	+	+	+	+	+	+	+	+
30	−	+	+	+	+	+	+	+	+	+
32	−	−	−	−	−	+	+	+	+	+
34	−	−	−	−	−	−	−	−	−	−
36	−	−	−	−	−	−	−	−	−	−
38	−	−	−	−	−	−	−	−	−	−

TABLE NO. 4—RELATION TO ALKALI.

Degree of Alkali	Growth Resulting After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
0	—	—	—	+	+	+	+	+	+	+
−2	—	—	—	—	+	+	+	+	+	+
−4	—	—	—	—	—	+	+	+	+	+
−6	—	—	—	—	—	—	—	—	—	—
−8	—	—	—	—	—	—	—	—	—	—
−10	—	—	—	—	—	—	—	—	—	—
−12	—	—	—	—	—	—	—	—	—	—
−14	—	—	—	—	—	—	—	—	—	—
−16	—	—	—	—	—	—	—	—	—	—
−18	—	—	—	—	—	—	—	—	—	—
−20	—	—	—	—	—	—	—	—	—	—
−22	—	—	—	—	—	—	—	—	—	—
−24	—	—	—	—	—	—	—	—	—	—
−26	—	—	—	—	—	—	—	—	—	—
−28	—	—	—	—	—	—	—	—	—	—
−30	—	—	—	—	—	—	—	—	—	—
−32	—	—	—	—	—	—	—	—	—	—
−34	—	—	—	—	—	—	—	—	—	—
−36	—	—	—	—	—	—	—	—	—	—
−38	—	—	—	—	—	—	—	—	—	—

(+) Best growth.

7. Optimum Reaction.

The optimum reaction for growth in bouillon is +15° to +18° Fuller's scale.

8. Vitality on Culture Media.

Vitality on culture media is only moderate. Transfers made from a stab culture in nutrient agar which was four months old failed to give any growth; however, growth has been obtained from cultures on agar which were six weeks old. No difficulty has been experienced in carrying the culture upon nutrient agar if it transferred as often as once in ten days.

9. Temperature Relations.

THERMAL DEATH-POINT.—The thermal death-point lies between 49° and 50° C. 10 c.c. portions of nutrient broth, +15 Fuller's scale, in thin walled test tubes of resistance glass, having a uniform diameter of 16 to 17 m.m., were inoculated with two loopfuls of a 24 hour broth culture grown at 28° C. As soon as inoculated, the tubes were plunged into water of the desired temperature up to the cotton plugs, and kept there for exactly ten minutes. In order to insure a uniform temperature, the water in the water bath in which the exposures were made, was kept in constant motion by a horizontal paddle attached to a stirring machine and operated by a water motor. The different temperatures were maintained by hand regulations with a Bunsen burner. At the end of the ten minutes exposure, the tubes were immediately cooled in cold water and subsequently allowed to develop at 28° C. Twelve tubes of broth were used for each temperature and determinations were made for each degree of temperature from 40° to 60° C. If turbidity appeared in any of the tubes within ten days, this was taken as an indication that the temperature to which the tubes were exposed was not fatal.

OPTIMUM TEMPERATURE.—The optimum temperature lies between 28° and 30° C.

37½° C., no growth occurs on nutrient agar, in nutrient broth or in the various sugar broths.

28° C., abundant growth on agar and moderate in broth after 48 hours.

20° C., moderate growth on agar and slight in broth after 48 hours.

10° C., slight growth on agar and none in broth in 48 hours.

6.5° C., slight growth on agar and none in broth in 48 hours; moderate growth on agar and slight in broth in 6 days.

10. Relation to Oxygen.

Ps. medicaginis, n. sp. appears to be an obligative aerobe. Stab cultures were made in glucose litmus gelatin and placed in an atmosphere of hydrogen in a Novy jar. No growth whatever took place in 120 days. Again, in our studies upon gas production from the different sugars, glycerine and mannite, we have observed that no growth occurred in the closed arm of the fermentation tubes and that there was a sharp line of demarcation between the growth in the open arm and the clear liquid in the closed arm. This would seem to point strongly toward the aerobic nature of the germ. The total absence of any deep growth in the gelatin stab serves to emphasize further this feature.

11. Effect of Dessication.

The organism is relatively resistant to drying, being able to withstand dessication for eleven days when spread on cover glasses and dried in sterile Petri dishes. A suspension of the 24 hour growth on agar was made in sterile water, and one loopful of this was spread over each of a number of one-half cover glasses, sterilized by flaming. These smears were placed in sterile Petri dishes at once and allowed to dry. Every twenty-four hours for a period of twenty-two days, two of these inoculated cover glasses were taken out and dropped into tubes of sterile broth; if growth resulted, this was taken as evidence that the germs had not been killed by drying. Detailed observations are given in Table No. 5 below.

TABLE NO. 5—EFFECT OF DESSICATION.

Number of Days Dried	Growth Resulting in Broth After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
1	0	0	+	+	+	+	+	+	+	+
2	0	0	+	+	+	+	+	+	+	+
3	0	0	+	+	+	+	+	+	+	+
4	0	0	+	+	+	+	+	+	+	+
5	0	0	0	0	+	+	+	+	+	+
6	0	0	0	0	0	0	0	0	0	0
7	0	0	+	+	+	+	+	+	+	+
8	0	0	0	+	+	+	+	+	+	+
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	+	+	+
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
0	0	0	+	+	+	+	+	+	+	+

12. Relation to Freezing.

1/100 c.c. and 1/10,000 c.c. portions of a 24 hour broth culture grown at 28° C., were plated in nutrient agar as controls. This culture was then frozen in a mixture of snow and salt, and kept in this condition for 24 hours, at the end of which time it was thawed out by placing it in an incubator at 28° C. As soon as melted, dilution plates were made using the same amounts as before freezing. After four days, colony counts were made which showed the culture to have contained 470,000 germs per c.c. before freezing and 5,100 after freezing, or 98.9 % had been killed.

13. Relation to Light.

DIRECT SUNLIGHT.—Three tubes of liquefied agar were sown thinly with different amounts of a 24 hour broth culture and poured into sterile Petri dishes. As soon as the agar had solidified, one half of each plate was covered with one thickness of heavy, black, glazed paper. They were then placed on a bed of firmly packed snow in a large crystalizing dish and the whole was exposed for fifteen minutes to the bright sunshine of Fort Collins, Colorado (altitude 4,981 feet above sea level), Nov. 20, 1909, 11:30-11:45 A. M.

100 % of the germs were killed in the exposed portions of the plates, while 25, 9, and 5 colonies, respectively, developed in the protected parts.

DIFFUSED LIGHT.—Our cultures have been kept in diffused light in a culture room supplied with light from a north window, which was perhaps eight feet from the table on which the cultures were kept. We have never noticed any detrimental effect from this light upon either the vigor or the virulence of the cultures. Other cultures have been kept next to the window for a week at a time, and when subcultures were made from these, no difficulty has been experienced in getting good growths.

14. Production of Hydrogen Sulphide.

Nutrient broth in tubes was inoculated with a 48 hour agar culture, and at the same time narrow strips of filter paper, moistened with lead acetate, were suspended in the upper part of the tubes and held in place by the cotton plugs. These strips of paper were remoistened with lead acetate every twenty-four hours for a period of ten days but there was no blackening to indicate the production of hydrogen sulphide.

A second method of demonstrating H_2S was to make stab cultures in nutrient gelatin to which .5% of iron potassium tartrate had been added. If hydrogen sulphide had been produced, the line of puncture should have been marked by a well defined black line due to the formation of iron sulphide. Tubes of this medium inocualted with **Ps. medicaginis, n. sp.** failed to show the production of any H_2S.

15. Production of Ferments.

Determinations have been made for the presence of diastase, invertase, zymase, rennet, pepsin and glucase. Tests were made for these enzymes after five, seven and thirty days, and the only one which we have been able to demonstrate was invertase. A trace of this was evident on the seventh day, and was abundant at the end of thirty days. A 48 hour agar culture has been employed in all of the inoculations.

DIASTASE.—100 c.c. of sugar free beef broth containing.1% soluble starch were inoculated with the organism under study. After five, seven and thirty days, portions were removed from the flask with a sterile pipette and tested for starch with iodine solution, and for maltose with Fehling's solution. Starch was present at all times, and at no time was there any reduction of the Fehling's solution; therefore no diastase was formed.

INVERTASE.—Saccharose broth, prepared by adding 1% of saccharose to sugar free broth, was used in the determination of invertase. 100 c.c. of this medium were inoculated and after five, seven and thirty days tests were made for invert sugar with Fehling's solution. There was no reduction at the end of five days, a slight one after seven days and at the end of thirty days, a good test for glucose was obtained from the inoculated flask, while the sterile control gave no reduction of the Fehling's solution; therefore invertase was formed.

ZYMASE.—Glucose broth, prepared by adding 1% of glucose to sugar free broth, was used in our study of zymase. Observations covering a period of thirty days failed to show at any time the evolution of CO_2 gas, or the presence of alcohol in the inoculated tubes, and consequently, we have concluded that there was no zymase produced.

RENNET.—Plain milk was employed as the medium in the study of rennet production. At no time during the thirty day period of examination, did the inoculated milk tubes show any evidence of curd formation, which fact has been interpreted as indicating the absence of rennet.

PEPSIN.—Plain milk and nutrient gelatin, contained in test tubes, were epmloyed as the media in the study of pepsin formation. Stab cultures were made in the gelatin and the milk was inoculated in the usual way. There was neither any liquefaction of the gelatin nor any digestion of the casein of the milk during the period of observation, which was sixty days for the gelatin and forty days for the milk.

GLUCASE.—Beer wort, and sugar free broth to which 1% of maltose was added, furnished the media for the study of glucase, but owing to the difficulty in distinguishing maltose from glucase when present in the same solution, no satisfactory conclusions could be reached regarding the presence of glucase, and hence concerning the production of glucase.

16. Crystals Formed.

No crystals have been observed to form in any of the media employed.

IV. PATHOGENICITY

1. Pathogenic to Animals.

Inasmuch as the organism does not grow at 37½° C. it has been considered unnecessary to carry on any animal inoculations.

2. Pathogenic to Plants.

Pathogenic for alfalfa (**Medicago sativa**); not pathogenic under field conditions for sweet clover (**Melilotus alba**), white clover (**Trifolium repens**), or winter vetch (**Vicia sativa**).

V. NUMERICAL CLASSIFICATION

According to the numerical system of recording the salient characters of an organism, **Ps. medicaginis, n. sp.** (Sackett) becomes Ps. 212.3332133.

MEDIA EMPLOYED.

The *nutrient broth, nutrient gelatin, nutrient agar* and *sugar free broth,* employed in this work, have been prepared according to the Standard Methods of Water Analysis (1). Reaction +15° Fuller's scale.

Sugar Broths.—These were prepared by adding one per cent of the different sugars, as well as glycerine and mannite, to sugar free broth.

Glycerine Agar.—Prepared by adding four to six per cent glycerine to nutrient agar.

Dunham's Solution.—

Distilled water	1000.0 c. c.
Witte's Peptone	10.0 grams
NaCl	5.0 grams

Nitrate Broth.—

Distilled water	1000.0 c. c.
Witte's Peptone	1.0 gram
KNO_3 (nitrite free)	.2 gram

Asparagin Solution.—(Jordan). (2)

Redistilled water	1000.0 c. c.
Asparagin	2 0 grams
$MgSO_4$	1.0 grams
K_2HPO_4	1.0 grams

(1) Supplement Journal Infect. Diseases, May, 1905, p. 104.
(2) Jordan. Bot. Gaz., 1899, 27, p. 9; Jour. Expt. Med., 1899, 4, p. 627.

Uschinsky's Solution.—(1)

Distilled water	1000.0 c. c.
Glycerine	30–40 grams
NaCl	5– 7 grams
$CaCl_2$	.1 grams
$MgSO_4$	.2–.4 grams
K_2HPO_4	2.–2.5 grams
Ammonium lactate	6 –7 grams
Sodium asparaginate	3 –4 grams

Cohn's Solution.—(2)

Distilled water	1000.0 c. c.
KH_2PO_4	5.0 grams
$MgSO_4$	6.0 grams
Ammonium tartrate	10.0 grams
KCl	.5 grams

Synthetic Agar, Low in Nitrogen.—

Distilled water	1000.0 c. c.
Cane sugar	50.0 grams
KH_2PO_4	1.0 gram
$MgSO_4$	.2 gram
Shredded agar	15.0 grams

Reaction +3° Fuller's scale.

(1) Cent. f. Bakt., Erste Abt., Bd. XIV., 1893, p. 316.
(2) DeBarry, p. 86, Vorles. u. Bact., 2 Auflage.

Potato.—Cylinders of raw potato were washed in running water over night, rinsed in a very dilute solution of NaOH, and sterilized in the autoclave for five minutes at 120° C.

Alfalfa Agar.—Prepared by adding 15 grams of finely shredded agar to 1,000 c.c. alfalfa infusion made by steeping 500 grams finely chopped green alfalfa in 1,000.0 c.c. tap water for one hour. Reaction not changed.

Litmus Milk.—Prepared by adding to plain milk one per cent of a solution of azolitmin made by dissolving 1 gram of azolitmin in 40 c.c. of distilled water and kept at 37.5° C. for 12 to 18 hours.

GREENHOUSE EXPERIMENTS.

The constant occurrence of characteristic white colonies, in such a large percentage of our plates, was sufficient to make us suspicious that the micro-organisms making up such colonies were the immediate cause of the disease. However, the crucial test of a pathogenic organism is its power to reproduce the given disease when introduced in pure culture into its normal host. Accordingly, we have fulfilled this requirement by making a large number of inoculations upon alfalfa plants under greenhouse conditions, and by this means we have been able to establish *Ps. medicaginis, n. sp.* beyond the remotest shade of possible doubt, as the unquestionable cause of the trouble. We have reproduced the infection in from five to seven days with practically its characteristic field symptoms, and we have been able to follow its progress through the different changes up to the blackening and complete destruction of the stem after six weeks.

In the plant inoculations, which are described below, we have employed three different germs. These are the only ones which we have met with in our isolations, and for convenience they are here referred to as "Yellow Colony," "Orange Colony" and "White Colony," the last, *Ps. medicaginis, n. sp.,* having been shown to be alone responsible for the disease.

Successful inoculations have been obtained by scarifying the epidermis of the stems with a sterile scalpel, and then immediately smearing the freshly exposed, moist surface with a 48 to 72 hour agar culture of the organism. Another method has been to prick the stem at intervals of about one centimeter with a needle previously dipped into the growth of a 48 to 72 hour agar streak. Again, we have rubbed the culture over the surface without any previous injury to the epidermis.

No precautions have been taken against the drying out of the inoculated areas other than to spray the plants once just after inoculation, and once a day thereafter for the next three days with sterile water. A water bottle with a fine rose nozzle has been used for this work. The spray would collect in large drops, and ultimately run down the stems, and in this way moisten the inoculated regions. This treatment together with the moist atmosphere of the greenhouse seemed adequate.

Plant Inoculations of June 3, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 1.—The epidermis of each of four stems was scarified for a space of 10 cm. and smeared with a 48 hour agar culture of **Ps. medi-**

PLATE II.

ginis, n. sp. obtained from an infected stem. For comparison with inoculations not specially protected against dessication, this pot was covered with a bell jar, the opening in the top being stoppered with a cotton plug. Circulation of air was possible yet there was a moist, if not saturated, atmosphere surrounding the plant all the time. By June 18th., the scraped areas were blackened and a microscopic examination of this tissue showed the characteristic milky cloud and swarms of bacteria.

Pot No. 2.—Each of four stems was inoculated by ten needle pricks with a 48 hour agar culture of **Ps. medicaginis, n. sp.** This pot was also covered with a bell jar as described above. By June 18th, each needle prick showed a dark brown zone 1 mm. wide surrounding the point of infection. A microscopic examination of the tissue from this zone showed clouds of motile bacteria.

Pot No. 3.—Four stems were inoculated in the same manner as those of Pot No. 1, but they were not covered with a bell jar. The plant was sprayed with sterile water once a day for the first three days after inoculation. By June 18th., the stems were blackened and exhibited the characteristic phenomena under the microscope. The diseased condition of the stems was much more typical than in those which were covered with the bell jar.

Pot No. 4.—Four stems were inoculated in the same manner as those of Pot No. 2, but they were not covered with a bell jar. They were sprayed with sterile water once a day for the first three days after inoculation. On June 18th., there was a brown area surrounding each needle prick and a microscopic examination of the discolored tissue showed swarms of motile bacteria. The gross appearance of the diseased parts was more typical than in the plant covered with a bell jar.

Pot No. 5.—Four stems were scarified and inoculated with a 48 hour culture of **Ps. medicaginis, n. sp.** isolated from a diseased leaf. The plant was covered with a bell jar. The stems were blackened by June 18th., but they were not as typical as those which were left uncovered.

Pot No. 6.—Four stems were inoculated by needle pricks with a 48 hour culture of **Ps. medicaginis, n. sp.** isolated from a diseased leaf. The plant was covered with a bell jar. June 18th., the disease was evident from the blackened areas around each needle prick, but it was not as typical as in those stems which were not covered.

Pot No. 7.—Four stems were inoculated in the same manner as Pot No. 5, but were exposed to the air and sprayed with sterile water. By June 18th the disease was apparent by the blackened stems and a microscopic examination showed swarms of bacteria coming from the tissue and a milky cloud surrounding the whole; more typical than stems under bell jar.

Pot No. 8.—Four stems were inoculated in the same manner as Pot No. 6, but were exposed to air and sprayed with sterile water. June 18th. there were dark brown areas surrounding each puncture; very typical; microscopic examinations characteristic.

Plant Inoculations of June 7, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 9.—Each of four stems was scarified and inoculated with a 48 hour culture from a yellow colony isolated from a black stem. By June 18th. the stem was slightly yellow and shiny but probably nothing more than the result of the scraping; nothing typical had developed; there was no sign of any growth of the germ and no evidence of any discolored or diseased tissue. Microscopic examination failed to show the presence of bacteria and consequently this germ was considered as not responsible for the trouble.

Pot No. 10.—Each of four stems was scarified and inoculated with a 48 hour culture from an orange colony, isolated from a diseased stem.

By June 18th. there was no change whatever in the inoculated stems, and on June 25th. they were in all respects the same as the uninoculated controls; therefore, this germ was eliminated as a possible cause of the disease.

Plant Inoculations of June 21, 1909.

The cultures used were isolated June 19, 1909.

Pot No. 11.—Five stems were inoculated by spreading a 48 hour agar culture of **Ps. medicaginis, n. sp.** upon the unbroken epidermis, the object being to determine whether stomatal infection could be produced in this way. After twenty days, isolated brownish spots appeared on the inoculated portions of all the plants, and after thirty days these brownish areas were black. A microscopic examination of the tissue showed the true infection.

The object of the following inoculations was to determine whether **Ps. medicaginis, n. sp.** was equally pathogenic when isolated from different stages in the progress of the disease.

Pot No. 12.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a stem which had reached the brown stage of the disease. The infection developed in both stems after seven days and by August 1st. both were black.

Pot No 13.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a stem in the earliest stage of the infection when it showed the light green, yellow, watery tissue. Both of the stems developed the disease in seven days and were black after five weeks.

Pot No. 14.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a black stem in the advanced stage of the disease. Both stems developed the trouble in five to seven days and were black August 1.

Pot No. 15.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from what appeared to be a very recent stomatal infection on the stem; there was no indication of the epidermis being broken, and the disease occurred in isolated spots around the stomata. Both stems developed typical symptoms in five to seven days and were black by August 1st.

Pot No. 16.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from an advanced, black stomatal infection of the stem. Both stems developed the disease in five days, and the inoculated areas were black August 1st.

Pot No. 17.—One stem was scarified and smeared while another was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a single infected stoma of the stem. Both stems developed very good symptoms in four days and were black by August 1st.

Plant Inoculations of August 25, 1909.

Cultures used isolated June 1, 1909.

Pot No. 18.—Stem scraped over the whole internode and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem; Sept. 3rd. inoculated area yellowish green color, watery and darker along the edge; Sept. 7th. dark brown; Sept. 30th. black.

Pot No. 19.—Stem scraped in patches and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem. Sept. 3rd. inoculated spots plainly visible by the watery, yellowish green patches; Sept. 7th. spots dark brown; Sept. 30th. spots black.

Pot No. 20.—Stem inoculated by needle pricks with culture of **Ps. medicaginis, n. sp.** isolated from diseased stem. Sept. 3rd. watery areas for 1 to 2 mm. around each needle prick and yellowish; Sept. 7th. dark brown; Sept. 30th. black.

Pot No. 21.—Controls. One stem scarified with a sterile scalpel and a second pricked with a sterile needle. No change visible at any time in either stem.

Plant Inoculations of November 2, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 22.—Three stems were scarified and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from an infected stem. On Nov. 7th, two of them were watery, shiny and yellow, while a liquid had been oozing from one and had dried on the stem. The third stem showed almost no change from the check. By Nov. 18th. all of the scraped areas were dark, watery green and turning brown; by Nov. 20th, they were a dark brown; a microscopic examination on Nov. 23rd. showed a typical infection. (See colored plate.)

Pot No. 23.—Two stems were inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem; Nov. 7th, yellowish, watery appearance around each one of the stabs; Nov. 18th, needle pricks all taking well; very well defined brownish green areas one to two mm. around each; infection spreads slowly; Nov. 20th. the diseased spots dark brown and slightly sunken; Nov. 23rd. an examination of the diseased tissue gave milky cloud in the mount and swarms of germs under the microscope. (See colored plate.)

Pot No. 24.—Stem inoculated by smearing culture of **Ps. medicaginis, n. sp.** upon the unbroken epidermis. The object, here, was to attempt to secure a successful infection through the stomata. Nov. 10th, two yellowish, watery spots developed on the part of the stem smeared; Nov. 18th. these spots were dark brown and by Nov. 24th. they were almost black. A subsequent microscopic examination showed a true bacterial infection.

In order to eliminate the germicidal action of the direct rays of the sun, the plants were shaded by one thickness of canvas, placed next to the glass roof.

In order to determine whether the infection was communicated to the plants through the roots, twelve pots were prepared with sick soil containing quantities of the diseased stems. Fifteen germinated alfalfa seeds, which had been sterilized previously in a 1-500 mercuric chloride solution, were planted in each of the above pots. A good, vigorous stand was obtained. The possibility of frozen stems was eliminated by growing the alfalfa in the greenhouse and the danger from dust infection was reduced to a minimum by keeping the surface soil in the pots moist. These plants are now sixteen months old and up to the present time not a single stem in any of the twelve pots has shown any sign of the disease. From these results, we can say with a reasonable degree of certainty, that the disease is not, primarily, a root trouble, and if the roots do become diseased. the infection must start from the crown and work downward.

SUMMARY OF GREENHOUSE EXPERIMENTS.

From these experiments it will be seen, first, that we have been able to produce the disease successfully in 100 per cent of the plants inoculated with pure cultures of *Ps. medicaginis, n. sp.*; second, that cultures of this organism produce identically the same symptoms irrespective of their origin, i. e., whether they were originally isolated from stem, leaf or exudate; third, that it has been possible to produce the disease by introducing the germs through needle pricks and by smearing them upon scarified areas, as well as by spreading them upon the unbroken epidermis; however, inoculations by the last method develop more slowly and are not as typical of field lesions; fourth, that after cultivation upon nutrient agar for five months, *Ps. medicaginis, n. sp.* seems to have retained its initial virulence practically undiminished; fifth, that neither of the other two cultures which have been found associated with the trouble are able to produce the disease; sixth, that the infection is not communicated to the plants through the roots.

FIELD EXPERIMENTS.

Inasmuch as the disease seems to be directly tracable to soil infection, and consequently may be considered a soil trouble, the only practical method of controling it is by the introduction of resistant varieties. To this end we have planted twenty-six varieties of alfalfa on sick land with the hope of obtaining one or more blight resistant strains. The seed for this work was procured from the United States Department of Agriculture through Mr. W. J. Brand, and planted April 16 and 17, 1907. The ground upon which the plats are located is owned by Hon. J. L. Chatfield, and had been in alfalfa a number of years, was plowed in the spring of 1905 and planted to oats and potatoes; in 1906 again planted to oats and produced 100 bushels per acre. The rows of the plot are about fifteen rods long and run from east to west. Two rows of each variety were planted through the plot, then the series was repeated in the same order but only one row of a kind was used. The variety designated as Gypsum No. 1 was grown from cuttings which were taken from land that had been in alfalfa, and was plowed up because of the prevalence of the disease, and planted in oats. These plants were very vigorous at the time the cuttings were made. This part of the work was begun by Professor Paddock over two years ago.

The following is a list of the varieties which we have used in our field tests.

No. 9451, Sairam.
No. 11275, first quality commercial.
No. 12398, from Colorado.
No. 12409, Utah, non-irrigated.
No. 12671, from Kansas.
No. 12702, from Sherman, Texas.
No. 12747, from Billings, Mont.
No. 12748, from Germany.
No. 12784, Utah, irrigated.

No. 12801, from Texas Panhandle.
No. 12816, from Chinook, Mont.
No. 12820, from Nebraska.
No. 12846, from Kebilli Oasis, Tunis.
No. 13291, from New York.
No. 13259, from Nebraska.
No. 13857, from Simbirsk, Russia.
No. 17698, from Chinook, Mont.
No. 18751, from Turkestan.
No. 19508, from Kansas.
No. P. L. H. 3251, grown in South Dakota, from Baltic seed.
No. P. L. H. 3252, also grown in South Dakota.
No. 9322, from Tougourt.
No. 12694, from Provence, France.
No. 9453, from Bokhara.
No. 13437, from Arizona.
No. 1, Gypsum, Colorado, from cuttings.

A very satisfactory stand was secured with all varieties except No. 12,846 and No. 9,322. When the plants were one year old, they were examined very carefully for the presence of the disease with the result that all varieties but one, P. L. H. 3,251, were affected to a greater or less degree. While not all of the plants in each variety were suffering, some from each, with the exception of the one mentioned above, were diseased. Table No. 6, below, gives the results of these observations which were made June 20, 1908.

TABLE NO. 6

Showing Condition of the Different Varieties of Alfalfa When One Year Old. June 20, 1908.

Variety	Stand	Vigor	Prevalence of Disease	Size of Plants
9451	Fair	Fair	Present	Medium and small
11275	Good	Good	Present	Variable
12398	Fair	Fair	"	Variable
12409	Good	Good	"	Large
12671	Fair	Good	"	Variable
12702	"	Fair	"	Variable
12747	"	Good	"	Large
12748	"	Very good	"	Large
12801	"	Fair	"	Small
12816	"	Good	"	Variable
12820	"	Good	"	Variable
12846	Very poor	Very poor	"	Almost no plants
13291	Poor	Fair	"	Large
13259	Fair	Fair	"	Small
13857	Poor	Good	"	Large, varieties mixed
17698	Very good	Good	"	Low and large
18751	Good	Good	"	Variable
19508	"	Fair	"	Small
P. L. H. 3251	"	Very good	Absent	Large
P. L. H. 3252	Fair	Fair	Present	Small
12694	"	Poor	"	Frost bitten, varieties mixed
9453	"	Fair	"	Large spreading
13437	Poor	"	"	Small
12784	Fair	"	"	Variable
9322	......	....	......	No plants
Gypsum 1	Very good	Very good	Present	Small

Similar observations, made June 11, 1909, when the plants were two years old, showed that all varieties were affected, including P. L. H. No. 3,251, which had promised immunity the previous season. At this time of the year, the alfalfa was from ten to twenty inches high; the majority of it had a good color, and while the blight was present in all varieties, it was not abundant enough to do any serious damage to the crop. Only a few stems of each plant were suffering and only the lower internodes of these. Such stems had the characteristic watery, yellow green color, very little blackening having occurred up to this time. Occasionally plants were found on which the attack had been so acute that they were entirely destroyed. Their location was marked only by patches of dwarfed, shriveled stems, now dried and prostrate. Four of the twenty-six varieties were noticibly freer from the infection than the rest, namely, No. 12,398, No. 12,671, No. 12,784, and P. L. H. 3,251. It is a matter of considerable practical interest, that the first three of these are from seed which we may consider as home grown; the first is from Colorado, the second, Kansas; the third, Utah. If we are so fortunate as to find high resistance in plants from local seed, the question of obtaining resistant varieties will be much more easily solved than if we are compelled to breed up a strain from foreign seed. Table No. 7 gives the detailed observations on the variety plats, made June 11, 1909.

TABLE NO. 7

Showing Condition of the Different Varieties of Alfalfa when Two Years Old. June 11, 1909.

Variety	Vigor	Prevalence of the Disease
9451.......	Fair	Present
11275.......	Fair	Present
12398.......	Good	Present, but not serious
12409.......	Fair	Present
12671.......	Good	Present, but not serious
12702.......	Good	Present
12747.......	Good	Present
12748.......	Fair	Present
12784	Good	Present, but not serious
12801.......	Poor	Present
12816.......	Fair	Present
12820......	Good	Present
12846.......	No plants	No plants
13291.......	Fair	" "
13259.... ..	Fair	" "
13857.......	Poor	" "
17698......	Good	" "
18751.......	Fair	" "
19508	Good	" "
3251.	Very good	Present, but not serious
3252.......	Fair	Present
9322.......	No plants	No plants
12694.	Very good	Present, but not serious
9453.......	Poor	Present
13437.......	Fair	Present, but not serious
GypsumNo.1	Good	Present, but not serious

We shall continue this part of the investigation with the same, as well as additional varieties, since the only practical way of testing out the disease resistance of these different kinds of alfalfa is to grow them under actual field conditions on infected soil, where natural agents are at work. We shall introduce, also, legumes other than alfalfa, in order to determine the susceptibility of these to the disease, so that we may be in a position to recommend other crops as substitutes where the land is so badly infected as to make profitable alfalfa growing no longer possible.

PREVENTION AND TREATMENT.

Where the areas under cultivation reach such tremendous proportions as the alfalfa fields on the mountain ranches, all schemes for soil sterilization are obviously impracticable at the outset. The same may be said of the use of germicides to be applied to the plants either in the form of sprays or otherwise, for even though some such means should be discovered by which the infection could be prevented, the cost would undoubtedly make it prohibitive. Obviously, then, as stated before, the only practical way of combating and controlling the blight is by the introduction of resistant varieties. What is being done in this direction has been mentioned before.

Our field observations during the past year seem to indicate that immunity to the disease is closely related to resistance to late spring freezing. On the one hand, those plants which were severely injured by the late spring frost were, without exception, the first to show the disease and were the worst infected later in the season; on the other hand, those varieties which grew from hardy stock and which suffered only slightly from the frost, were more nearly free from the blight. This coming year we shall endeavor to determine whether the relation between disease resistance and frost resistance is a constant one, and if it proves to be such, then we shall attempt to stamp out the trouble by securing frost resistant varieties.

In the meantime, we recommend, as a means of control, that the frosted alfalfa be clipped as soon as one is reasonably certain that there is no more danger from frost. By this means, the frost split stems, in which the disease appears to originate, will be gotten rid of, thus affording an opportunity for the early growth of a new cutting. Prof. P. K. Blinn, who has charge of the Experiment Station work at Rocky Ford, informs the writer that this practice of early clipping to remove the frost bitten shoots, which retard growth, is rapidly growing in favor among the farmers in his locality.

ACKNOWLEDGMENT.

The writer wishes to thank Prof. B. O. Longyear and Miss M. A. Palmer for the preparation of the colored plate.

EXPLANATION OF PLATES.

PLATE I.—Fig. 1, Ps. medicaginis, n. sp.; 24 hour agar culture stained with aqueous fuchsin; original x 1,000, reduced by engraver 6:5.

Fig. 2, Ps. medicaginis, n. sp.; 48 hour agar culture stained with aqueous fuchsin to show the formation of filaments; original x 1,000, reduced by engarver 6:5.

Fig. 3, Ps. medicaginis, n. sp.; surface agar colony 7 days old, photographed by transmitted light to show concentric rings of growth; original x 20, reduced by engraver 6:5.

Fig. 4, Ps. medicaginis, n. sp.; surface agar colony 7 days old, photographed by reflected light; original x 20, reduced by engraver 6:5.

PLATE II.—Fig. 1, Ps. medicaginis, n. sp.; agar colonies 7 days old showing deep and surface colonies by transmitted light; original x 20, reduced by engraver 3:2.

Fig. 2, Ps. medicaginis, n. sp.; agar colonies 7 days old showing deep and surface colonies by reflected light; original x 20, reduced by engraver 3:2.

Fig. 3, Petri dish showing pure culture of Ps. medicaginis colonies 2/3 natural size; original x 1, reduced by engraver 3:2.

PLATE III.—Fig. 1, Alfalfa stem, inoculated by smearing the freshly scraped stem with a 48 hour agar culture of Ps. medicaginis, x 2; 40 days after inoculation.

Fig. 2, Diseased alfalfa stem showing the yellowish, olive green color, characteristic in the early stages, x 2. Field specimen, natural inoculation.

Fig. 3, Diseased alfalfa stem showing the blackened condition in the late stages of the blight, x 2. Field specimen, natural inoculation.

Fig. 4, Alfalfa stem, inoculated with a 48 hour agar culture of Ps. medicaginis by means of needle pricks, x 2; 15 days after inoculation.

Fig. 5, Alfalfa leaf showing diseased, yellow areas, apparently of water pore or stomatal infection, x 2. Field specimen, natural inoculation.

NOTE.—Figs. 1 and 2, Plate I, were made by the writer with a Leitz Photomicrographic apparatus in connection with the Leitz microscope, 1/12 oil immersion objective, eyepiece I; Welsbach gas light; Cramer's Medium Isochromatic Plates. Figs. 3 and 4, Plate I, and Figs. 1 and 2, Plate II, were made by the writer with the Leitz Photomicrographic apparatus in connection with a Leitz Microsummar, 35 mm., f:4, 5. Plate III. was prepared by Miss M. A. Palmer and Prof. B. O. Longyear from fresh material.

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A NEW ALFALFA DISEASE

STEM BLIGHT

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BY

WALTER G. SACKETT

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STEM BLIGHT

*A New Bacterial Disease of Alfalfa**

By WALTER G. SACKETT.

HISTORY AND DISTRIBUTION.

In May of 1904, Hon. J. L. Chatfield, who resides at Gypsum, Eagle County, Colorado, observed that while the stand of alfalfa on his ranch was good, much of it was shorter than it should be at that time of the year, and that here and there plants were dying. He reported this condition to the Experiment Station at Fort Collins, and in response to his request, Professor Paddock and Professor Gillette visited his fields. They examined a number of plants. but they were unable to give any decisive answer as to the exact cause. Occasionally, worms were found in the crowns and in the roots, and by splitting the latter lengthwise, numerous dark streaks could be traced through the tissue. A few crowns were blackened, as well as some of the stems, but this discoloration was looked upon as due, possibly, to insect work, although no specific insects could be found at that time.

The following year, there was practically none of the trouble to be seen in the whole valley, which has an area of at least five thousand acres, more than one half of which is in alfalfa.

The next year, however, 1906, the conditions were worse than ever before and the universal complaint among the farmers was that there was "something wrong with the alfalfa." Professor Paddock again visited Gypsum, and at this time the blackened stems were very abundant and much more conspicuous than when he was there before. He brought back specimens of this material to the college and a microscopic examination satisfied him that, in all probability, the trouble was of bacterial origin. As a result of these findings, in November, 1906. Professor Paddock (1) called attention to a new alfalfa disease occurring in certain parts of Colorado, which was different from any previously described malady and which, from all appearances, was not related to either leaf spot or mildew.

The disease has spread with increasing severity until at the present time it is a very difficult matter to find one acre of alfalfa land in the whole valley which is entirely free from the trouble. The loss in tonnage for the first cutting is estimated at eighty per cent, or the crop is only one-fifth of what it was in former years. The disease became so serious in 1907 that it was thought advis-

* This is an abbreviated edition of Bulletin No. 158, entitled A Bacterial Disease of Alfalfa. The former includes detailed description of the causal bacterium and inoculation experiments. Bulletin No. 158 will be sent on request.

(1) Press Bulletin No. 28, Colo. Exp. Sta.

able to make the study of this malady a theme for special research. Accordingly, May 1, 1908, the writer began an intensive investigation of the trouble and during the past year has been occupied with laboratory, greenhouse and field experiments bearing upon the cause and possible remedies for the disease. The results of this work are given in the pages which follow.

DISTRIBUTION.

Within the state of Colorado, the disease occurs generally throughout the Gypsum Valley in Eagle county, to a somewhat less extent in Garfield county, and at Rocky Ford in the Arkansas Valley. Prof. W. Paddock has noted it in the Plateau Valley, Mesa county, and between Hotchkiss and Paonia in Delta county.

So far as our present knowledge goes, it has not been seen in the San Luis Valley, or in the Boulder, Longmont, Loveland, Fort Collins and Greeley districts.

In our neighboring states, what appears to be a similar bacterial disease has been observed by Professor Northrop in Utah, by Professor Wooten in New Mexico, by Professor Wilcox in Nebraska, and by Professor Roberts in Kansas. Its occurrence is reported as negative by Professor Nelson for Wyoming, by Professor Kennedy for Nevada, by Professor Lewis for Oklahoma, and by Professor Ball for Texas.

DESCRIPTION OF THE DISEASE.

When a field suffering with this bacterial trouble is viewed as a whole, about the only comment which could be made is that the growth is short and the alfalfa is a little off color. The rich, dark green color in the leaves is absent and the juicy, succulent appearance of the stem, so characteristic of a thrifty stand, is wanting. The plants tend to grow more spindling; the leaves often appear dwarfed, narrow, light green and have a tendency all along the stem and in the growing tip to remain partly closed just as they do in cold or dry weather.

The disease is primarily a stem infection and it is here that we find the most valuable characters for diagnosis. In the earliest stages, the stem has a watery, semi-transparent, yellowish to olive green appearance along one side. This extends down the stem from below the point of attachment of a leaf for one to three internodes. Again, on another side of the stem, the infection may cover two or three different internodes or parts of the same ones. Most commonly the first three to five internodes are the worst infected. Such stems are usually healthy and normal below the ground. Soon after they take on this dark, olive green, watery appearance, there oozes out from the diseased tissue a thick, clear, viscid liquid which spreads over the stem and collects here and there in little bead-like droplets. This exudate dries in a short time with a glistening finish, and gives the stem very much the appearance of having been varnished, and where the liquid has collected in little amber colored scales and has hardened, it looks as if the varnish had run and dried. Stems in this condition have a dry, slightly rough feel to the touch. The exudate also dries uniformly over the surface or just beneath it, and there produces a dark brown, resinous surface which blackens with age. Such stems are very brittle and easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

If the epidermis is scraped from an infected stem, the tissue underneath has the same yellowish, watery appearance. This pathological condition extends to the center of the stem and if it is split lengthwise, the interior cavity presents a brownish, mealy aspect. Such stems will collapse much more readily when pressed between the fingers than healthy ones. A shoot in this condition is virtually girdled; its circulation is impaired and its food supply is practically cut off as is evident from the poor growth it makes. Some stems remain in this inactive state and struggle along until the mowing machine puts an end to their existence; others turn black, shrivel and die six weeks before time for the first cutting. During the past season, the disease appeared about May 15th, and up until June 10, twenty-six days later, there were no blackened stems to be found. During this period, the trouble was manifested by the characteristic yellowish green, watery look.

The leaves attached to the diseased part of the stem usually show a watery, pale yellow color at the base, along the mid rib of the leaflets, and especially in the tiny petioles. Those on the parts of the stem which are blackened are always dried up, yellow and extremely brittle. The stipules at the base of the petioles are yellow and brittle and usually show the disease before their corresponding leaves.

Sometimes the leaves exhibit the infection independently of the stem. In this case the petioles become watery, pale yellow and droop. The malady may be confined to the petiole and base of the leaflet or it may involve the whole of the blade. Occasionally leaves are found where the inoculation has been made, apparently, in the margin of the leaflet, and the infection has proceeded toward the middle. In such instances, the tender tissue has a watery look, as if it had been bruised. These leaf infections have been observed to occur a little earlier than the stem troubles, although it may be merely a matter of being able to detect the pathological condition there first.

One year old plants may exhibit blackened areas in the crown, and black streaks which run down into the tap root. As the plant grows older, this blackening increases until the whole crown becomes involved and either the crown buds are destroyed or the root is no longer able to perform its functions, and the plant dies.

So far as our present observations go, the disease appears to run its course with the first cutting, and those plants which have sufficient vitality, throw out a good growth for the second and third cuttings. Strange as it may seem, there is little or no trace of the blight during the remainder of the season, but in the following spring, a renewed outbreak may be looked for. The severity of the attack seems to vary from season to season. As has been noted before, the trouble was moderate in 1904; in 1905 it was practically unseen; in 1906 and 1907 it was extremely bad; in 1908 the attack was mild and during the past year there was but little to be found. This season the crop was the best that has been harvested for four years. This variation in the degree of the attack would seem to indicate that there may be some relation between the prevalence of the disease and the weather conditions, especially late frosts and late freezing, intermingled with warm, pleasant days as compared with a late, cold spring. Not many plants are killed the first year, but they begin to die after the blight has been prevalent more than one season, and after three or four years so many of them may be missing that the stand is practically worthless.

CAUSE OF THE DISEASE.

If a small piece of the yellowish green, watery tissue from a diseased plant, it matters not whether it be stem or leaf, is placed in a drop of clean water on a glass slide, there will appear on all sides of it, after half a minute, a dense, milky cloud, which can be seen readily with the naked eye, and which slowly diffuses out into the drop. When this preparation is examined under the low power of the microscope (Leitz Objective No. 3, Eye Piece IV.) this milky zone easily resolves itself into swarms of bacteria, which under the high power (Leitz Objective No. 7, Eye Piece IV.) can be distinguished as actively motile rods, relatively short and thick, with rounded ends and occurring for the most part singly and in twos.

If the surface tissue is removed and a portion of the deeper layers is examined, identically the same results will be obtained. If a fragment of the dried exudate is likewise placed in a drop of water, the whole gradually disintegrates and becomes a milky cloud, which under the microscope is a mass of motile bacteria.

Out of twenty-one infected stems examined and plated at different stages of the disease, thirteen gave pure cultures of this colony in the Petri dishes. In seventeen plates, it was the dominant colony. Platings from five different leaves gave pure cultures in three cases and in four out of five the above colony was the most abundant. In other words, pure cultures were obtained in 62 per cent of the original isolations and in 81 per cent this white colony was dominant. In two out of twenty-six isolations or in seven per cent, it was absent. Plates made from the moist or freshly dried exudate, as a rule, gave pure cultures of the same organism.

Inoculations have been made upon alfalfa plants, grown under greenhouse conditions, with the three different cultures which have been isolated during this investigation, namely, the characteristic white one, the yellow and the orange, and the only one which has produced typical symptoms of the disease, in fact the only one which has produced any pathological condition whatever, is the dominant white colony referred to so frequently above. Cultures obtained from stem, leaf, petiole, or exudate, were equally pathogenic.

In order to establish further the fact, that this germ was the unmistakable cause of the trouble, an alfalfa plant was inoculated June 7, 1909 with our present stock culture of the causal organism, to which the name *Pseudomonas medicaginis*, n. sp. has been given, which was isolated from an infected stem May 27, 1909. By June 19, typical symptoms had developed, and plates were made from the yellowish green, watery tissue. On June 21, the Petri dishes showed a pure culture of the same white colony and the organism was reisolated on an agar slant. When compared with the original culture, the recovered organism was identical both in the hanging drop and when stained with aqueous fuchsin. The reisolated culture was again inoculated, June 25, by needle pricks into three different stems, and all of the inoculations gave positive results; the needle pricks showed a yellow, watery zone around the point of infection after nine days, and later turned black. When material from these diseased areas was examined microscopically, August 16, the same milky cloud appeared in the mount as has been described for field material, and swarms of motile rods were visible.

In all, one hundred and two inoculations have been made with this culture, introduced either by scraping the stem or by needle pricks, and positive results have been secured with one hundred per cent of the infections. Control inoculations with a sterile needle have been carried along with all of the experiments, and in no case have any of the check plants developed symptoms of the disease.

METHOD OF INFECTION.

In an effort to secure a satisfactory explanation of the method of infection, the writer spent over a month in the field where the disease is most prevalent. As a result of the daily observations and the gross and microscopic examination of more than three hundred plants, collected at all stages of the disease, before it made its appearance and until it was flourishing, he believes the following to be the most tenable and satisfactory soluti . of the question.

This phase of the investigation was carried on at Gypsum, Colorado, where our first observations were taken May 4, 1909; this was early in the spring for this locality and altitude (over 6,000 feet above sea level). The season was considered cold and backward, and a moderately heavy snow had fallen one week before; traces of this were still to be seen in the valleys, and the surrounding hills and mountains were heavily covered.

The alfalfa was just beginning to grow, the average height in the diseased fields being from 1½ to 2 inches. Most of the plants had a yellowish green color due, presumably, to the cold. An examination of the young, succulent shoots showed that the epidermis of practically every one of them was wrinkled just below the point of attachment of the first four or five leaves, and often this wrinkling extended half way to the next leaf below. The epidermis was loose from the tissue beneath and appeared to be too large for the stem. When this was peeled off, the underlying tissue had a yellowish, green color much like the diseased plants, but a microscopic examination of such material failed to show any micro-organisms present. In those parts of the stem where this wrinkling was absent, the tissue beneath the epidermis was not yellow, but a whitish green. In many plants, the loosened epidermis had the appearance of partially collapsed blisters, while around and underneath these blisters the tissue seemed darker than normal and watery, with a suggestion of its having been frozen. Numerous lenticular breaks occurred in the epidermis of some stems. These might have been due to insect work although rather early in the season for this. Occasionally stems were found where the wrinkled epidermis had split open for a distance of one centimeter, exposing the moist pyrenchyma beneath.

Ten days later, May 14, the epidermis of practically every stem in the field was split wide open from node to node over the first six internodes, the third to the fifth internodes being the most common. This splitting appeared to have begun with the wrinkled epidermis mentioned above, and had extended the whole length of the internode thereby exposing the succulent, moist tissue beneath to infection. It is the concensus of opinion of those who have observed this phenomenon, that both the breaking away of the epidermis from the underlying tissue and the wrinkling and subsequent splitting are caused by freezing. A similar trouble ascribed to freezing has been observed in cherry trees and less frequently in the apple. Here the bark cracks and later splits open, exposing the green wood beneath just as in the alfalfa stems.

Anyone who has ever lived in Colorado is familiar with the

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M.A.Palmer

soil carrying capacity of our winds, and with this in mind, it is easy to understand how germ laden soil might be blown into these cracks, where it would adhere to the moist, exposed surface, and bring about a fatal inoculation. As a matter of fact, soil was always found adhering to these surfaces, and, already, typical cases of the disease were developing. A microscopic examination of the tissues from the injured areas usually showed the germs to be present in great numbers, while ten days previous, that is before the splitting had occurred, there was no indication of any infection. Invariably, the disease appeared first and was worst on those parts of the stem where the epidermis had split and where soil had been caught in the open wound. A striking example of this was seen in an alfalfa field adjacent to a field which had been cultivated recently and sown to oats. The oat field was on the windward side, and with every gust, quantities of fine soil were carried over into the alfalfa. All along this side of the field, there was an aggravated attack of the disease, extending twenty to thirty feet into the alfalfa and the whole length of the field. Every plant was gray with soil and it is only reasonable to suppose that the disease was more severe here than in the more remote parts of the field because of the heavier soil inoculation.

This explanation satisfies one of the most difficult questions which has arisen in connection with the problem, namely, why does the first cutting, alone, suffer from the attack? There are never any frosts after the first crop is out of the way, and consequently there are no split stems in which to start the infection.

In a preliminary report (1), the writer has suggested that possibly the constant tramping of cattle and horses, pastured on the alfalfa fields during the winter, might have split open the crowns and bruised the young, tender shoots so that during the first irrigation, soil containing the disease germs was washed into the injured tissue and started the trouble on the first cutting. Our observations during the past season do not warrant such a conclusion in the majority of cases at least, since, in the first place, the disease was active at least two weeks before the first irrigation, and in the second place, our experimental plats, to which stock had no access, suffered just as severely as the fields which were pastured.

Not infrequently, we find the disease at work on stems where there has been no apparent previous injury to the epidermis; sometimes this assumes the form of a continuous, unbroken infection of the whole internode, and again it occurs as separate, punctiform lesions giving the stem a speckled appearance. This last condition would seem to indicate an infection through the stomata, and inasmuch as we have been able to secure successful inoculations in the

(1) Bulletin 138, Colo. Exp. Sta., Jan. 1909.

greenhouse by applying the culture to the unbroken epidermis, it is altogether possible that stomatal infections take place under field conditions. The leaflets often exhibit yellowish, watery areas along the margin and the larger veins when there is no evidence of the trouble in any other part of the plant; again, the tiny petioles succumb to the disease independently of either the stem or the attached leaflets. Water pore and stomatal infection similar to that described for the black rot of cabbage may explain these cases.

There are doubtless other ways in which infection can take place, but the methods described above, especially the inoculation through the split epidermis, seem to be the most common. It is possible that added observations of another season will give us more light upon this point and so rather than draw any final conclusion as to the *one way* in which inoculation takes place in the field, we prefer to leave the question open.

GREENHOUSE EXPERIMENTS.

The constant occurrence of characteristic white colonies, in such a large percentage of our plates, was sufficient to make us suspicious that the micro-organisms making up such colonies were the immediate cause of the disease. However, the crucial test of a pathogenic organism is its power to reproduce the given disease when introduced in pure culture into its normal host. Accordingly, we have fulfilled this requirement by making a large number of inoculations upon alfalfa plants under greenhouse conditions, and by this means we have been able to establish *Ps. medicaginis, n. sp.* beyond the remotest shade of possible doubt, as the unquestionable cause of the trouble. We have reproduced the infection in from five to seven days with practically its characteristic field symptoms, and we have been able to follow its progress through the different changes up to the blackening and complete destruction of the stem after six weeks.

In order to determine whether the infection was communicated to the plants through the roots, twelve pots were prepared with sick soil containing quantities of the diseased stems. Fifteen germinated alfalfa seeds, which had been sterilized previously in a 1-500 mercuric chloride solution, were planted in each of the above pots. A good, vigorous stand was obtained. The possibility of frozen stems was eliminated by growing the alfalfa in the greenhouse and the danger from dust infection was reduced to a minimum by keeping the surface soil in the pots moist. These plants are now sixteen months old and up to the present time not a single stem in any of the twelve pots has shown any sign of the disease. From these results, we can say with a reasonable degree of certainty, that the disease is not, primarily, a root trouble, and if the roots do become diseased. the infection must start from the crown and work downward.

FIELD EXPERIMENTS.

Inasmuch as the disease seems to be directly tracable to soil infection, and consequently may be considered a soil trouble, the only practical method of controling it is by the introduction of resistant varieties. To this end we have planted twenty-six varieties of alfalfa on sick land with the hope of obtaining one or more blight resistant strains. The seed for this work was procured from the United States Department of Agriculture through Mr. W. J. Brand, and planted April 16 and 17, 1907. The ground upon which the plats are located is owned by Hon. J. L. Chatfield, and had been in alfalfa a number of years, was plowed in the spring of 1905 and planted to oats and potatoes; in 1906 again planted to oats and produced 100 bushels per acre. The rows of the plot are about fifteen rods long and run from east to west. Two rows of each variety were planted through the plot, then the series was repeated in the same order but only one row of a kind was used. The variety designated as Gypsum No. 1 was grown from cuttings which were taken from land that had been in alfalfa, and was plowed up because of the prevalence of the disease, and planted in oats. These plants were very vigorous at the time the cuttings were made. This part of the work was begun by Professor Paddock over two years ago.

The following is a list of the varieties which we have used in our field tests.

No. 9451, Sairam.
No. 11275, first quality commercial.
No. 12398, from Colorado.
No. 12409, Utah, non-irrigated.
No. 12671, from Kansas.
No. 12702, from Sherman, Texas.
No. 12747, from Billings, Mont.
No. 12748, from Germany.
No. 12784, Utah, irrigated.
No. 12801, from Texas Panhandle.
No. 12816, from Chinook, Mont.
No. 12820, from Nebraska.
No. 12846, from Kebilli Oasis, Tunis.
No. 13291, from New York.
No. 13259, from Nebraska.
No. 13857, from Simbirsk, Russia.
No. 17698, from Chinook, Mont.
No. 18751, from Turkestan.
No. 19508, from Kansas.
No. P. L. H. 3251, grown in South Dakota, from Baltic seed.
No. P. L. H. 3252, also grown in South Dakota.
No. 9322, from Touggourt.
No. 12694, from Provence, France.
No. 9453, from Bokhara.
No. 13437, from Arizona.
No. 1, Gypsum, Colorado, from cuttings.

A very satisfactory stand was secured with all varieties except No. 12,846 and No. 9,322. When the plants were one year old, they were examined very carefully for the presence of the disease with the result that all varieties but one, P. L. H. 3,251, were affected to a greater or less degree. While not all of the plants in each variety were suffering, some from each, with the exception of the one mentioned above, were diseased. Table No. 6, below, gives the results of these observations which were made June 20, 1908.

TABLE NO. 6

Showing Condition of the Different Varieties of Alfalfa When One Year Old. June 20, 1908.

Variety	Stand	Vigor	Prevalence of Disease	Size of Plants
9451	Fair	Fair	Present	Medium and small
11275	Good	Good	Present	Variable
12398	Fair	Fair	"	Variable
12409	Good	Good	"	Large
12671	Fair	Good	"	Variable
12702	"	Fair	"	Variable
12747	"	Good	"	Large
12748	"	Very good	"	Large
12801	"	Fair	"	Small
12816	"	Good	"	Variable
12820	"	Good	"	Variable
12846	Very poor	Very poor	"	Almost no plants
13291	Poor	Fair	"	Large
13259	Fair	Fair	"	Small
13857	Poor	Good	"	Large, varieties mixed
17698	Very good	Good	"	Low and large
18751	Good	Good	"	Variable
19508	"	Fair	"	Small
P. L. H. 3251	"	Very good	Absent	Large
P. L. H. 3252	Fair	Fair	Present	Small
12694	"	Poor	"	Frost bitten, varieties mixed
9453	"	Fair	"	Large spreading
13437	Poor	"	"	Small
12784	Fair	"	"	Variable
9322	......	.....	......	No plants
Gypsum 1	Very good	Very good	Present	Small

Similar observations, made June 11, 1909, when the plants were two years old, showed that all varieties were affected, including P. L. H. No. 3,251, which had promised immunity the previous season. At this time of the year, the alfalfa was from ten to twenty inches high; the majority of it had a good color, and while the blight was present in all varieties, it was not abundant enough to do any serious damage to the crop. Only a few stems of each plant were suffering and only the lower internodes of these. Such stems had the characteristic watery, yellow green color, very little blackening having occurred up to this time. Occasionally plants were found on which the attack had been so acute that they were entirely destroyed. Their location was marked only by patches of dwarfed, shriveled stems, now dried and prostrate. Four of the twenty-six varieties were noticibly freer from the infection than the rest, namely, No. 12,398, No. 12,671, No. 12,784, and P. L. H. 3,251. It is a matter of considerable practical interest, that the first three of these are from seed which we may consider as home grown; the first is from Colorado, the second, Kansas; the third, Utah. If we are so fortunate as to find high resistance in plants from local seed, the question of obtaining resistant varieties will be much more easily solved than if we are compelled to breed up a strain from foreign seed. Table No. 7 gives the detailed observations on the variety plats, made June 11, 1909.

TABLE NO. 7

Showing Condition of the Different Varieties of Alfalfa when Two Years Old. June 11, 1909.

Variety	Vigor	Prevalence of the Disease
9451.......	Fair	Present
11275......	Fair	Present
12398.......	Good	Present, but not serious
12409.......	Fair	Present
12671.......	Good	Present, but not serious
12702	Good	Present
12747.......	Good	Present
12748......	Fair	Present
12784	Good	Present, but not serious
12801.......	Poor	Present
12816.......	Fair	Present
12820.	Good	Present
12846.......	No plants	No plants
13291.......	Fair	" "
13259.... ..	Fair	" "
13857.......	Poor	" "
17698......	Good	" "
18751......	Fair	" "
19508	Good	" "
3251.	Very good	Present, but not serious
3252.......	Fair	Present
9322.......	No plants	No plants
12694.	Very good	Present, but not serious
9453.......	Poor	Present
13437.	Fair	Present, but not serious
GypsumNo.1	Good	Present, but not serious

We shall continue this part of the investigation with the same, as well as additional varieties, since the only practical way of testing out the disease resistance of these different kinds of alfalfa is to grow them under actual field conditions on infected soil, where natural agents are at work. We shall introduce, also, legumes other than alfalfa, in order to determine the susceptibility of these to the disease, so that we may be in a position to recommend other crops as substitutes where the land is so badly infected as to make profitable alfalfa growing no longer possible.

PREVENTION AND TREATMENT.

Where the areas under cultivation reach such tremendous proportions as the alfalfa fields on the mountain ranches, all schemes for soil sterilization are obviously impracticable at the outset. The same may be said of the use of germicides to be applied to the plants either in the form of sprays or otherwise, for even though some such means should be discovered by which the infection could be prevented, the cost would undoubtedly make it prohibitive. Obviously, then, as stated before, the only practical way of combating and controlling the blight is by the introduction of resistant varieties. What is being done in this direction has been mentioned before.

Our field observations during the past year seem to indicate that immunity to the disease is closely related to resistance to late spring freezing. On the one hand, those plants which were severely injured by the late spring frost were, without exception, the first to show the disease and were the worst infected later in the season; on the other hand, those varieties which grew from hardy stock and which suffered only slightly from the frost, were more nearly free from the blight. This coming year we shall endeavor to determine whether the relation between disease resistance and frost resistance is a constant one, and if it proves to be such, then we shall attempt to stamp out the trouble by securing frost resistant varieties.

In the meantime, we recommend, as a means of control, that the frosted alfalfa be clipped as soon as one is reasonably certain that there is no more danger from frost. By this means, the frost split stems, in which the disease appears to originate, will be gotten rid of, thus affording an opportunity for the early growth of a new cutting. Prof. P. K. Blinn, who has charge of the Experiment Station work at Rocky Ford, informs the writer that this practice of early clipping to remove the frost bitten shoots, which retard growth, is rapidly growing in favor among the farmers in his locality.

ACKNOWLEDGMENT.

The writer wishes to thank Prof. B. O. Longyear and Miss M. A. Palmer for the preparation of the colored plate.

EXPLANATION OF PLATE.

Fig. 1, Alfalfa stem, inoculated by smearing the freshly scraped stem with a 48 hour culture of Ps. medicaginis, x 2; 40 days after inoculation.

Fig. 2, Diseased alfalfa stem showing the yellowish, olive green color, characteristic in the early stages, x 2. Field specimen, natural inoculation.

Fig. 3, Diseased alfalfa stem showing the blackened condition in the late stages of the blight, x 2. Field specimen, natural inoculation.

Fig. 4, Alfalfa stem, inoculated with a 48 hour agar culture of Ps. medicaginis by means of needle pricks, x 2; 15 days after inoculation.

Fig. 5, Alfalfa leaf showing diseased, yellow areas, apparently of water pore or stomatal infection, x 2. Field specimen, natural inoculation.

SUMMARY.

The disease has been known in Colorado since 1904, where, in some localities, it has caused the loss of practically eighty per cent of the first cutting.

Within the state, it is known to occur in Eagle, Garfield, Mesa, Delta and Otero counties.

The blight makes its first appearance from the first to the fifteenth of May, depending somewhat upon the locality.

The stems appear watery, semi-transparent in the early stages, and have a yellowish, olive-green color which soon changes to amber, due to the appearance and subsequent drying of a thick, clear exudate. This dried excretion gives the stems a shiny, varnished appearance, and a slightly rough feel to the touch. These stems blacken in six to eight weeks, become very brittle and are easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

The disease seems to run its course with the first cutting, and is not seen again until the next year.

The cause of the blight is a germ, **Pseudomonas medicaginis, n. sp.**, which, presumably, lives in the soil and enters the plants with soil through stems which are cracked and split by late freezing.

No varieties of alfalfa entirely resistant have been obtained up to the present time.

As a means of control, we recommend that the frosted alfalfa be clipped, with the mower set low, as soon as it is reasonably certain that the danger from late frosts is past. This will rid the plants of the diseased portions, and afford an opportunity for the early growth of a new cutting. If this is done in time, the regular number of cuttings should be secured with little or no loss in tonnage.

Bulletin 160 May, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

NITRATES IN THE SOIL

An Explanation of so-called "Black Alkali" or "Brown Spots"

BY

WM. P. HEADDEN

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NITRATES IN THE SOIL

By WM. P. HEADDEN

Bulletin No. 155 of this Station, entitled "The Fixation of Nitrogen in Some Colorado Soils," gives the results of our field observations on this subject up to the latter part of the year 1909, together with those obtained in the laboratories in more detail than is absolutely necessary for a general understanding of the subject.

The people in many sections of this State understand perfectly well what is meant by the expression "brown spots." This expression was more appropriate a few years ago than at the present time, for then the term spot described quite accurately the area involved, as it does in some instances today. There are, at this time, however, areas measured by acres, which the term does not describe. What was five or six years ago a spot has now grown to involve as much, perhaps, as six, eight or more acres, and the use of the term spot is justified only on the ground that it was at first used to describe a condition as well as an area.

The condition which it describes is well known to the people of some sections of the State where it appeared a long while ago as barren places, or spots, the surface of which had a brown color. Sometimes they were shining and looked as though they were wet or perhaps oily. Some of the worst spots to which my attention has been directed appeared as though they had been wetted with a thick, black oil. The fact that nothing grew on these spots has been used by many correspondents as descriptive of them. These spots occur in a great variety of soils, from heavy adobe to light, sandy loams and silts. The spots are only local and exaggerated expressions of a condition which is becoming quite general. I have met persons who really knew but little about the matter, though they assumed to know a great deal, and who have insisted that these were seepage spots. It is true that a regular and fairly abundant supply of moisture seems to be a very favorable factor in the development of this condition, but I have not observed it anywhere, where there is an excess of moisture, especially at the surface. In some extremely bad places, I have found a very peculiar condition of the ground, beginning at depths varying from a few inches to two and a half feet below the surface which I cannot describe in any other way than as muddy. This ground is very soft and wet but retains the water so persistently that the water runs out of it very slowly, or so good as not at all. On the surface of such lands we often find a thin crust and just beneath this a mealy mass, sometimes as much as three inches thick. This brown color is by no means always associated with this wetness of the soil but is generally, though not always, associated with this mealy, or, as the people often describe it, ashy condition. We sometimes find it, the brown color, on sandy soils in which we can find no unusual amount of moisture until we get down to a depth of six or seven feet or strike gravel.

It might be inferred from what has been stated, that these brown spots, or the condition expressed by this term, occur only or mostly in low ground. While they do occur very frequently in such ground they are not at all uncommon on high ground. I have recently found excellent examples of this brown color on the College farm at Fort Collins in land which it would scarcely be possible to seep, and I know of a number of such occurrences on high mesas from 80 to 150 feet above the river bottoms, which lie immediately below them.

Persons acquainted with our soils know that we have some conditions which make drainage very difficult if not impossible. In some places, it is necessary to run a drain to almost every wet spot in a field or meadow in order to drain it. It is not an uncommon experience to find a drain within a few feet of a mud hole which has no effect on the latter. I recall opening a partially filled underdrain, laid at a depth of about four feet. I found it open and some water flowing in it, and yet water was standing on the surface of the ground ten feet away. This water was not due to recent rains or irrigation but came from the ground below. A gentleman once asked me why his alfalfa was dying, and what he should do. I answered: "Drain your land," to which he responded that it was so good as impossible, because one spot in this field might be too wet, and the alfalfa perish for the want of water within fifteen or twenty feet of it. This man told the truth, improbable as it may seem. Some may think that these brown spots are associated with bad drainage. This is not true, for while the ground is in some cases muddy, as previously stated, the soil in which this trouble is met with is more often well drained. I recall three instances in which the soil is sandy or silty and underlaid by gravel at from five to eight feet. The brown surface soil in each of these cases occurs within three hundred feet of the river which is from eight to twelve feet below the level of the land; one could scarcely find better drainage than this. In two other cases we dug holes, in one of which we struck gravel with water at five and a half feet; in the other we struck neither gravel nor water at a depth of seven feet; both soils were sandy. This condition then is not restricted to low land; is not dependent upon the variety of the soil, unless it be within very wide limits, and is not due to bad drainage though it is often observed in low, moist places.

The brown spots have often been considered as indicating the presence of black alkali. This is not to be wondered at; in the first place the color of the surface soil is suggestive of the name and in the second place the bad effects upon vegetation which are associated with this color, lead the average man to attribute the cause of this to the only agent with which he is familiar, and which is believed to be adequate to produce this effect, namely, black alkali or sodic carbonate. Another reason which has apparently justified this inference in regard to the presence of sodic carbonate is the fact that the soil when moistened with an acid effervesces; this is due to the presence of calcic carbonate or marl, a form of limestone, and is not a proof of the presence of sodic carbonate.

The appearance of a white coating or efflorescence on the surface of the soil indicates, with us, the presence of the sulfates of lime, magnesia, and soda in the soil and usually an excess of water. The excess of water may be very injurious but these alkalis do not do any serious damage. These brown spots may or may not occur in association with the white alkalis. The intimate association of the two is so rare that we may state that they present distinct occurrences. When they occur in the same piece of land, they usually occupy distinct areas, the brown being on higher ground than the white where there is a less abundant supply of water.

Concerning the effects of the brown spots there is but one testimony, i. e., that nothing will grow. It is common to hear the expression that the white alkali is not bad but that the black is ruinous. We have had occasion to see the effects of it in many places, especially about Grand Junction, during the past season, the summer of 1909, when many apple trees and some shade trees succumbed to its influence. The effect that it produced was a burning of the leaves beginning at the tips, then extending along the edges till the whole leaf was brown. Sometimes only a few limbs on the tree were attacked in this way but very often all of the leaves were attacked and the tree was killed. I saw a great many apple trees killed during the summer of 1909 in this manner. I know of one orchard from which 110 trees have been removed this—the spring of 1910—from another 200; and in another more than 200 have been removed or are dead. There are many orchards in which a few trees, from one to twenty or more, have died. Further, there are young orchards in which the trees have refused to live. I recall several pieces of land which have been reset to orchard, peach, apple and pear several times, as many as eight according to my information, and many of the trees are dead at this time. The condition indicated by the brown color affects both young and old trees. None of the trees alluded to above, as having been pulled up, were less than 14 and some of them were 27 years old. Some of these trees were nearly two feet in diameter and had yielded as many as fifty boxes of apples at a picking. The young orchards alluded to are not confined to one section of the State, and I recall at this time nine such orchards.

The only reason for writing of orchards rather than of other crops is that the injury is more obvious in the case of trees than of some other crops, alfalfa for instance. Complaint has been received very often that alfalfa is dying in spots. It does not follow that every spot of dead alfalfa has been killed by this so-called black alkali,but many of those that the writer has seen, have been. The same may be said of sugar beets. Sometimes large spots of bare ground occur surrounded by a very large growth of tops, with a few plants scattered throughout the area, showing a similar luxuriance in the growth of the leaves. This condition is, as a rule, associated with the brown color of the surface with a slightly incrusted, and under this a mealy condition of the surface soil. These are not the only questions which have to be considered in regard to the effects of this condition on the crops, but they are visible effects which can be easily recognized; the effects upon the quality of the crops grown cannot be seen by the eye but must be studied and determined in other ways.

Inasmuch as the injury to the trees observed during the season of 1909 did not seem to affect the roots of the trees, I hoped that there would be, at least, some recovery in the case of those trees which did not die outright at the time of the attack, but observations of such trees this spring, 1910, give but little reason to expect any recovery. Whether this is due to the fatal effects of the poison present last year, or to an injurious supply of it in the soil at the present time, I do not know. I cannot candidly state that I have seen a single case of recovery but I have, on the other hand, seen a number of cases in which there is no reason to expect the trees to live.

We have now stated something about the occurrence and distribution of these brown spots, their appearance and visible effects upon vegetation. We do not know when they began to appear but some of them have been observed for several years past. This condition is rapidly becoming more prevalent. The land occupied by the orchards referred to as having been seriously injured in 1909, had evidently not been in such bad condition before during the time that they had occupied the land, from 14 to 27 years in the different cases.

The people very generally refer to the spots as "black alkali spots," but there is no sodic carbonate or only a very little of it in such spots and the color is not due to dissolved humus as would be the case if black alkali were present. These black spots, moreover, are only very extreme cases of a condition which is very widely distributed throughout the cultivated sections of the State. The brown streaks often seen around the edge of a wet place in some lawns, or along the margins of an irrigation furrow, are in very many instances due to the same cause. The writer has found very marked examples of this on the College farm this season, and has seen it occurring abundantly in other parts of the State.

Many people imagine that this black alkali is brought to the surface by water rising from below, such is not the fact as follows from the consideration of the general distribution of this same color in places where there is no rising water plane, others think that it is alkali dissolved out of other lands and brought into these places by seepage water, but this notion is refuted by the occurrence of just such brown spots on mesas which are themselves the highest cultivated lands in the section.

The most of us think of the soil as a mass of very small particles of rocks and some moisture which furnishes physical support and sustenance to the plants that grow in it, and nothing more. We do not think of it as teeming with life, but it is. Some of this life is beneficial to the growth of the cultural plants which furnish us our food and pleasure, but some of it is indifferent or perhaps prejudicial. Most of us have, during the past few years, heard of the part played by certain germs, which acting in succession effect the conversion of organic nitrogen, vegetable or animal, into nitric acid forming nitrates in the soil, in which form the nitrogen is taken up by the plants. This change of organic nitrogen, either of vegetable or animal origin, into nitric acid or nitrates, is called nitrification, and consists, as intimated, of several separate processes. This is not the only process going on in the soil which is dependent upon the presence of germ life, or micro-organisms. Among others is one which has to do with the building up of nitric acid or the formation of nitrates. The preceding process, nitrification, depends upon the vegetable or animal matter in the soil for its supply of nitrogen and there are three steps in the process of converting it into nitric acid, but in this one the source of the nitrogen is the atmosphere and the agent which takes the nitrogen from the atmosphere and converts it into nitric acid, respectively nitrates, is also a germ that lives in the soil. There is a number of species of this germ, one of which produces a brown pigment. This germ is abundant in our soils and apparently grows with great luxuriance. The brown color, whether in spots in a field or on the side of an irrigation furrow, or as a broad zone about the edge of a moist spot, is of itself not injurious but it is usually conclusive testimony of the presence of this germ, and a sample of soil taken from such a place will readily react for nitric acid. These germs are not necessarily detrimental to our trees and crops. If they would produce only just enough nitric acid or nitrates, they would do us a great service, but they have built up too much of these compounds in many places. The brown color is not due to the presence of the nitrates, for they are colorless, but to a coloring matter formed by these germs. This coloring matter is soluble in water and may be partially, or at times possibly wholly, washed into the soil with the nitrates. The brown spots and soils scattered throughout our valleys and irrigated sections have been the cause of many inquiries during recent years. There are some instances in which the color may not be due to these germs but they are the cause of almost all of it. This is not the only germ which converts the atmospheric nitrogen into nitric acid or effects the fixation of nitrogen, as it is designated, but it is a common one in our soils.

It is not the brown color that does the damage, but it is the nitrates which are formed by the same agent in quantities large enough to kill the trees and other vegetation. It is the nitrates that produce the mealiness of the soil, at least nitrate or soda applied to the soil produces the same condition. Nitrate of soda applied to apple trees in excessive quantities, produces a burning of the leaves and the death of the tree in a manner similar to that shown by the trees in the orchards.

The amounts of nitrates found in the various samples of soils taken from affected areas strike one as almost incredible. We found in a sample of surface soil 6.54 per cent of sodic nitrate. This is the largest amount found in any sample and indicates the presence of nearly eleven tons in an acre of ground taken to a depth of one inch. Many samples indicate the presence of extremely large amounts of nitrates in these soils.

While these nitrates in small quantities are beneficial to vegetation they are poisonous when applied in larger quantities. The death of trees, for instance, was due to excessive quantities of nitrates formed in the soil.

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CEMENT AND CONCRETE FENCE POSTS

BY

H. M. BAINER
H. B. BONEBRIGHT

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MATERIALS USED IN CONSTRUCTING CEMENT AND CONCRETE FENCE POSTS*

By H. M. BAINER and H. B. BONEBRIGHT

PART I.

GENERAL STATEMENTS

Cement.—In cement fence post construction, it is desirable that the post be made as light and as strong as possible, and thus it is practical to use nothing but the best grade of Portland cement.

Sand.—Clean, sharp sand with grains varying in size from small to large makes the best mixture. Sharp sand is composed of sharp, angular grains of all sizes and makes a better mixture than that which is smooth and round, or "river-worn."

A sand composed of fine and coarse grains mixed, is to be preferred, because less cement will be required to fill the voids than either used by itself.

Leaves, sticks, stones or gravel should be removed by screening.

Gravel.— The same general rules used in the selection of a good grade of sand will apply to gravel. It should be composed of clean, sharp pebbles of all sizes. For post construction, the pebbles must not be too large, as they will interfere with the proper placement of reinforcement.

Broken Stone.—Broken stone used for post construction must contain no large pieces as they will interfere with the placement of the reinforcement. It is necessary to use some sand with the stone to fill voids and thus save cement. It is not desirable to use soft sandstone, soft limestone, slates, or shales. Granites, hard limestones, and coarse gravel, which has been crushed, is considered best.

Water.—The water used in making a cement or concrete mixture should be clean and free from alkali or acids.

Proportions.—On account of the difference in the total open space or voids in sands or gravel composed of different sized particles and also that more cement is required in some conditions than in others, it is often necessary to make a rough determination of the percentage of voids to the total aggregate. Where maximum strength is required about 10 per cent. more cement should be used than the total voids.

The determination may be made as follows: Secure a water-tight box or pail of known capacity, fill it with the aggregate to be used so that when it has been well shaken it will smooth off even

* This bulletin is an abbreviated edition of Bulletin No. 148 of June, 1909. A large part of the details of the tests have been omitted, but all the important results are summed up in the tables here presented.

at the top. Pour water of known amount into this until full. The volume of water used in proportion to the total volume of the receptacle determines the total voids.

The proportions used in the constructions of the fence posts in this bulletin varied from 1 part cement and 3 parts of sand to 1 part of cement and 5 parts sand. In others, gravel was used in the proportion of 1 part cement, 3 parts sand, and 3 parts gravel. It is a difficult matter to use broken stone or gravel in large quantity and place the reinforcement properly.

Measure all materials in correct proportions. This may be done with a shovel, a pail, wheelbarrow, or barrel. It will usually be advantageous to measure the water, especially where small quantities are mixed or where the same amount of mixture is made several times.

Mixing.—Where the mixing is done by hand, a flat, watertight platform, or shallow box is convenient. Measure the sand and place it in a uniform layer and over this spread the proper amount of cement. Mix this thoroughly before adding water until it shows a uniform color. The rule is to shovel it over at least three times. Now spread out the mixture, making a sort of basin in the middle into which the greater part of the water may be poured. Work in the dry edges until the water disappears, then add enough more water in small amounts to make the mixture of the desired consistency. Do not mix more material than can be used in twenty minutes.

Poured Posts.—There are two general classes of mixtures which may be used in the construction of posts; the poured and the tamped. In the poured mixture, enough water is used in mixing to make it thin enough to pour from a pail or scoop almost like water. The mixture is poured into a mold and allowed to remain in it until it has set, which is from one to five days, depending upon the time of year and the weather. In drying summer weather, from one to two days is usually sufficient. In cool or damp weather, they must be left in the molds much longer.

In order to make several posts of the poured type at once, it is necessary to have several molds ready for use. With 6 molds only 6 posts could be made at once, and it would be necessary to wait until the cement was set before 6 more could be made.

It was found that to make a good poured post, the mixture should be stirred or shaken immediately after placing in the mold. This should be done carefully to prevent displacement of reinforcement wires. This helps to remove the air from the mixture and makes a post of smooth finish.

The experiment showed that a poured post of a certain mixture was stronger than a tamped post of the same mixture. It is enough stronger to justify anyone in constructing it in preference to the tamped one at the necessary additional expense for molds. The poured post is smoother, more nearly impervious to water, not so hard to cure, stronger, somewhat more expensive, and can be better recommended than the tamped one.

Tamped Posts.—The tamped post is one in which the mixture contains very much less water than the poured one. It contains just enough water to make it hold together well when tamped. In the manufacturing of this type of post, only one mold is necessary. The mixture is tamped into it, and the sides of the mold can be removed immediately, the post remaining on the bottom piece until the cement has set. Thus the same mold can be continuously used for making as many posts as are desired. The necessity for but one mold makes this type of post less expensive than the poured one. The results of the test made, show that the tamped post is inferior to the poured one and cannot be placed in an equal class with it.

On account of less water being used in the mixture for a tamped post than in the mixture for a poured one, the tamped post requires more water and attention in curing. It is of more open texture, less impervious to water, not as strong, and not as desirable as the post of the poured type.

Molds For Tamped Posts.—In this class of molds we find mostly the heavy cast-iron forms which are built of strong and heavy material. The most of these molds are designed to be laid upon pallettes or upon a smooth floor. The mixture is first tamped into the mold to a depth of about one inch. The reinforcement is then placed and the mold is next filled, and the mixture tamped, so that only about one inch of material remains to be filled in. The second set of reinforcement wires is put in place next and the mold is tamped full to overflowing. The last step consists in smoothing off the top of the post with a trowel and removing the mold. This is done by unfastening some form of hook or clasp, slipping the sides of the mold a little distance away from the post, and then removing the molds to the position chosen for the next post.

The principal advantage of these molds lies in the fact that they being made of heavy iron need no center stays. This gives greater speed in operation, due to the fact that there are no cross pieces to interfere with the placing of the reinforcement, the tamping of the mixture, and the smoothing off of the top of the post at the finish.

Molds For Poured Posts.—The more common forms are made of sheet iron, either galvanized or plain. For posts having a continual taper from top to bottom, sheet iron molds prove very satisfactory, providing sufficiently heavy material is used in their construction.

The advantages of the sheet iron mold are many. They are light to handle and easy to keep clean. If properly made they are nearly water tight. This insures the user against the possible loss of cement by leakage. Another marked advantage of the sheet-iron mold is that the surface being smooth, imparts a very smooth,

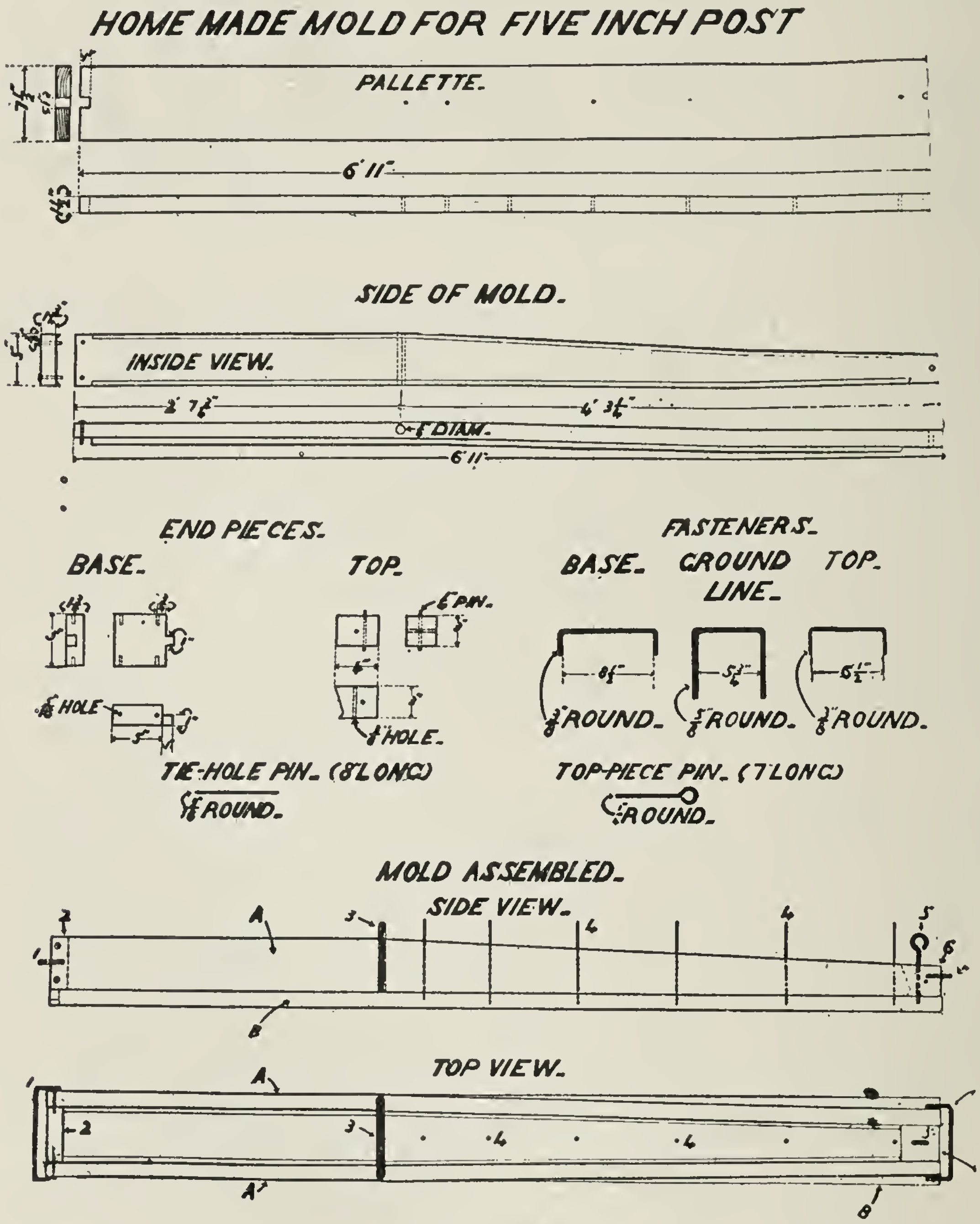

Figure I.

A Home Made Mold Giving the Proper Shape to the Post.—1. Base fastener. 2. Base end piece. 3. Ground line fastener. 4. 4, etc. Tie hole pins. 5. Top piece pin. 6. Top end piece. 7. Top fastener. A. Side of mold. B. Pallette.

glossy finish to the surface of the post. This not only adds beauty to the post, but aids in keeping out water, which might otherwise enter the cured post.

As the sheet-iron molds are made in one piece, no pallette is necessary. In hot weather the post may be removed after 48 hours, but in cold weather a much longer time is required.

In making poured posts in these molds exactly the same process is followed as with tamped posts in molds of the first class just described; with the exception that the mixture is not tamped and greater care must be exercised in preventing the reinforcement from being misplaced.

Some forms of wood molds are made and used for the purpose of making poured posts only. Any desired form may be given to the post by properly shaping the mold. This point, in favor of the wood mold, is an extremely important one, as it permits the post to be made of uniform size from the bottom to the ground line, but with a rapid taper from this point to the top. Then too, the sides of the mold may be removed after 24 hours and used again in connection with other pallettes; while the post which has not yet become sufficiently strong to be removed from the pallette lies unmolested in its original place until it is ready to move.

Molds which may be used for making either the tamped or the poured posts are much the same as the wooden molds for poured posts, except that they are stronger. The heavy, cast-iron molds could be used in making the poured posts as well as the tamped ones, but their original cost make them impracticable. The wooden molds serve the purpose equally well and are much cheaper.

Selecting the Mold.—The most important point to be considered in selecting the mold is the *shape and size* of it. Next to the shape and size we should look for ease of operation. The simple mold almost always proves to be the best, providing it has sufficient strength.

Care of Molds.—Before the molds are used they should be well coated with some kind of heavy oil. Crude petroleum is perhaps the best and cheapest material for this purpose. In case the petroleum cannot be obtained, a good oily mixture may be made by stirring about two pounds of axle grease into a gallon of gasoline. This mixture is applied to the molds with a brush. The gasoline evaporates, leaving a thin coat of axle grease spread over the entire surface of the mold. This oily mixture should be applied to the outside as well as the inside of the mold, which makes it impossible for any of the material to cling to it. With the iron molds, the oil prevents rusting. In case the molds are made of wood, the oil helps to keep out the moisture, thus preventing shrinking and swelling, and also making them easier to keep clean.

As soon as the mold is removed from the post all material sticking to it should be scraped off and the inside surface covered with a thin coating of oil. Great care should be taken not to allow the molds to become bruised or dented. If the molds are not to be used for a time, they should be thoroughly scraped and oiled, inside and out, and carefully laid away.

Reinforcement.—Cement and concrete work has the property of resisting great, crushing stresses, but when subjected to tensile stress the best of it breaks very easily. For this reason it becomes necessary to put some material possessing great tensile strength into the post, in order that the full crushing strength of the cement or concrete may be utilized. Iron is the most satisfactory material from which to make reinforcement. The reinforcement should be placed in the post as near the corner as possible. This places it as far as possible from the neutral axis thus giving it the greatest advantage in strengthening the post. In order that the reinforcements may be properly held and protected by the cement, it is a good plan to place it from ⅜ to ¾ inch in from each side.

The material used for reinforcement should be strong, light and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch. The experiments showed that ordinary iron or steel wire was cheapest, strongest and easiest to procure. In order to provide a means by which the cement may cling firmly to the wire, it is best to twist two small wires together instead of using one large one.

Curing the Posts.—In order for the cement to become thoroughly cured or "set" water must be supplied to aid in the action. For the first thirty days the posts should be kept wet if the best results are to be expected.

The most favorable conditions for conserving the moisture consists in curing the posts in a shed where the wind does not strike them. Under these conditions neither the sun's rays nor the wind have a chance to dry out the posts too rapidly. The posts should be thoroughly sprinkled every day for at least thirty days.

Wire Fasteners.—An inventor has devised a cast-iron socket which is placed in the post. Later the wire is fastened to the post by driving a staple into the socket or staple holder. The staples pull out easily and the sockets add greatly to the cost of the post.

Another system consists of two staples which have the prongs bent to the side. The staples are placed about one-quarter inch apart, with the prongs projecting to the side. The line wire is placed between the two staples and a nail or a piece of wire is driven down through the staples, outside of the line wire. As the tips of the staple touch the reinforcement wires, direct electric connections are established between the line wire and the ground at the bottom of the post. This, it is claimed by the patentee, insures the user against loss of stock by lightning. The system is called the "Double Staple." (See Fig. 2.)

A "single staple" may also be used, but the wire is fastened to the staple by a small "cold shut link," or wire ring. The latter system is not a very strong method of fastening, owing to the ease with which the cold shut links open. (See Fig. 2.)

Perhaps the most common method of fastening wires to cement or concrete posts consists of tying in the line wire to the post by means of a piece of smaller wire called a "tie wire" (usually No. 14 or No. 15 wire). The single tie consists of wrapping one end of the tie wire three or four times around the line wire, then passing the long end through a hole in the post and bringing it around to the face of the post where it is also wrapped around the line wire. (See Fig. 2.)

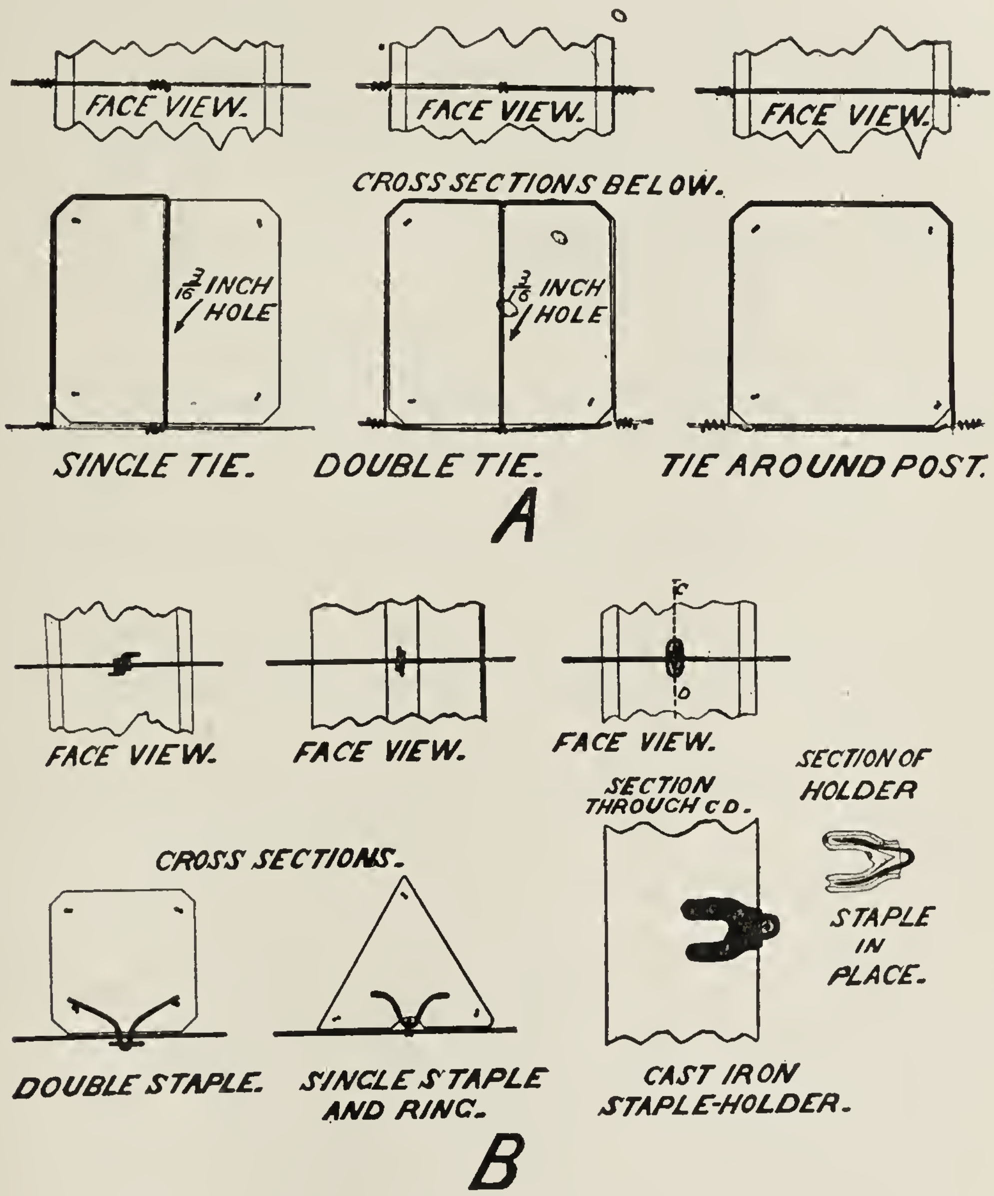

Figure II.

Different Types of Wire Fasteners.—A. Home made fasteners. B. Commercial fasteners.

The tie around post is much the same as the single tie, except that the tie wire passes around the post instead of through the hole. (See Fig. 2.) Neither the single tie or the tie around post are very strong unless the tips of the tie wire are hooked over the body of the tie wire after the wraps have been made. This is known as the "special tie."

The strongest and perhaps the most satisfactory system of tying in the wire is the "double tie." The tie wire is bent into the form of a long staple, straddled over the line wire and both ends passed through a hole in the post. One end is brought to either side and wrapped about the line wire at the face of the post. This system insures a solid fastening and is equal in strength to any ordinary wood post fastening.

The holes in the posts are formed by No. 6 wires being placed in the post while it is soft. These wires are called "Tie Hole Pins." (See Fig. 1.) They are removed from the poured post after the cement has set for 24 hours. The pins are removed from the tamped posts immediately before the molds are removed.

The following table shows the comparative holding strength of various wire fasteners, as determined by the tests:

WIRE FASTENERS (See description of same)	KIND OF POST	No. Lbs. Required to Pull Fastener	REMARKS
Ordinary 1¾ inch staple	New Cedar	425	Average of 3 pulls. Staple was well driven into post.
Single special tie	Cement	520	Average of 2 pulls. Fence wire broke.
Double tie	Cement	510	Average of 2 pulls. Fence wire broke.
Double staple	Cement	245	Average of 3 pulls. Staples pulled.
No. 14 wire plain single tie	Cement	115	Average of 2 pulls. The wire untwisted.
No. 14 wire around post	Cement	110	Average of 3 pulls. The wire untwisted.
Cast staple holder with ordinary 1¾ inch staple driven into it	Cement	85	Ave. of 2 pulls. Staple pulled out of holder.
Cold shut-link in single staple	Cement	83	Link opened in every case. Ave. of 3 pulls.

Taper of Posts.—To obtain the maximum strength with the least amount of material, the cement post must be so shaped as to have its greatest strength at the ground line.

By making the post of uniform size from the base to the ground line, no material is wasted. The post may then be tapered from the ground line to the top. It has been found that in a 5-inch post which projects 4 feet above the ground, a taper of one inch on each side from the ground line to the top, insures almost equal strength throughout. This design gives more strength with less material than those with the continuous taper.

PART II.

THE EXPERIMENTS

These experiments were conducted for the purpose of determining the method of building the best posts at the least cost.

Apparatus.—Various commercial molds of different shapes and construction were secured. In each of these molds several posts were made in order to determine the practicability of the mold; also the best combination of mixtures and reinforcements.

The Farm Mechanics Department designed, built and used a simple home made mold which makes a post of uniform size from the base to the ground line with a rapid taper from the ground line to the top. (See Fig. 1.)

A shed which was closed on all sides with a sliding door on the east was used as the work and curing room.

Materials—The sand and gravel used was clean and sharp, with all sizes of grains varying from small to large. There was a very small percentage of mica in the sand, which was objectionable. One brand of Portland cement was used for making all posts.

A total of 238 line posts and 8 corner posts were built and tested during the experiment, the records of which are found in the following tables:

Cost of Materials.—In figuring cost of materials the following prices were used:

Sand and gravel, $1.00 per cubic yard.
Cement, 60 cents per sack.
New reinforcement, 4 cents per pound.
Old barbed wire, 2 cents per pound.

The Test.—In making the test, the posts were placed under as near fence conditions as possible. All line posts were set and firmly tamped into the ground so that 4 feet and one inch projected above the surface. By means of a wire, a dynamometer was attached to the post exactly 4 feet from the surface of the ground. A steadily increasing force was applied to the dynamometer by means of a block and tackle, until the first visible crack appeared in the post when a reading was made. The force was then increased until the post gave away completely when the final reading was made.

In making the posts enough of the mixture was provided for the construction of three posts at once. The three were cured alike for 60 days and were tested at the same time. The tables show the average results of the test on the three posts as one.

In the reinforcement the short wires mentioned are two feet long and are placed in the post so the top extends about 12 inches above the ground line and the bottom about 12 inches below. One of these extra wires is placed in the face side of the post and the other in the back, so that they help to bear the strains on the post. In case of four extra wires, one is placed in each corner of the post with the other reinforcement wires.

TABLE NO. 1.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement and 3 parts sand by measure. Cost for cement for posts, 16.2 cents; sand, 3.7 cents. For cost of reinforcement, see table.

REINFORCEMENT			COST	FINAL BREAK			
				Poured Posts		Tamped Posts	
Kind of Wire	Weight per post	Cost per post	Cost of Material in each Post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10, 4 twisted strands of 2 wires	2½	10.0c	29.9c	307	Wires broke	240	Mixture broke, wires did not break
No. 10, 8 strands crimped	2½	10.0c	29.9c	254	Wires slipped and finally broke	263	Wires slipped, did not break
No. 6, 4 long wires hooked at ends	2¾	10.6c	30.5c	232	All wires slipped	184	All wires slipped
New barbed, 4 long strands	1⅔	6.6c	26.5c	188	Wires broke (Post was 130 days old)	123	Wires broke
Old barbed, 4 long strands	1⅔	3.3c	23.2c	158	Wires broke	128	Wires broke
New barbed, 4 long and 2 short	2	8.0c	27.9c			198	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	23.9c	200	Mixture broke above extra wires		
Old barbed, 4 long and 4 short	2¾	5.5c	25.4c	229	Long wires broke above extra wires		
No. 10, twisted 4 long and 2 short	3	12.0c	31.9c	290	Extra wires did no good	160	Extra wires did no good

* This table is a summary of Tables 1 and 2, Bulletin 148, Colo. Exp. Sta.

Amount of Labor Required for Making Posts.—No definite statements can be made as to the amount of time required to make a cement or concrete fence post. The amount of time will vary with conditions, handiness of materials, methods of mixing, etc. According to data obtained in the experiment, two men mixing by hand, with everything reasonably handy, can make from three to five 5-inch poured line posts per hour. Figuring labor at $2.00 per day, ten hours for each man, the cost for making a post would amount to about 10 cents each. Three men with a small home made mixer and a two horse-power gasoline engine for driving it, would be able to make at least twice as many posts as two men working by hand and the cost for making would be very much less.

The Effect of Alkali on Cement and Concrete Posts.—It has been found that some soils contain an excessive amount of alkali, which has a tendency to destroy concrete work. While no experimental work has been done to test the effect of such soils upon cement or concrete posts, it has been conclusively proven that cement drain and sewer tiles which come in contact with water which has percolated through these alkali soils are soon destroyed.

While it might be possible that the action on cement or concrete posts would be slower than in case of the tiles, it is probable that the post would eventually be destroyed.

For further information in regard to the effect of alkali on cement construction see Bulletin No. 69, of the Montana Agricultural Experiment Station, and Bulletin No. 132, Agricultural Experiment Station of the Colorado Agricultural College.

TABLE NO. 2.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost for cement per post, 16.2 cents; sand, 3.7 cents. For cost of reinforcement, see table.

REINFORCEMENT			COST	FINAL BREAK			
				Poured Posts		Tamped Posts	
Kind of Wire	Weight per Post	Cost per post	Cost of material in each post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10, 4 twisted strands of 2 wires	2½	10.0c	26.9c	222	Mixture broke, wires not well placed	192	Wires broke
No. 6, 4 long wires hooked at ends	2⅔	10.6c	27.5c	222	Wires slipped	162	Wires slipped
No. 10, twisted 4 long and 2 short	3	12.0c	28.9c	322	Mixtures and wires about equal		
Old barbed 4 long strands	1⅔	3.3c	20.2c	95	Wires broke, poorly placed	137	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	20.9c	127	Poor wire. Wires broke	142	Wires broke
New barbed, 4 long and 2 short	2	8.0c	24.9c	172	Wires well placed, cement broke	170	Wires not well placed
Old barbed, 4 long and 4 short	2¾	5.5c	22.4c			196	Wires broke
New barbed, 4 long strands	1⅔	6.6c	23.5c			160	Wires broke

* This table is a summary of Tables 3 and 4, Bulletin 148, Colo. Exp. Sta.

TABLE NO. 3.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 110 to 112 pounds. Mixture, 1 part cement and 5 parts sand, by measure. Cost for cement per post, 17 pounds, 10.2 cents; sand, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			COST	FINAL BREAK			
				POURED POSTS		TAMPED POSTS	
Kinds of Wire	Weight per Post	Cost per Post	Cost of material in each post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10,4 twisted strands of 2 wires	2½	10.0c	23.9c	235	Mixture broke (poor)	97	Mixture not strong enough
No. 10, twisted 4 long and 2 short	3	12.0c	25.9c	220	Extra wires did no good	98	Posts split. Mixture weak
Old barbed, 4 long strands	1⅔	3.3c	17.2c	113	Wires broke	117	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	17.9c	137	Mixture and wires about equal	113	Mixture and wires about equal
New barbed, 4 long strands	1⅔	6.6c	20.5c	123	Mixture and wires about equal	108	Mixture and wires about equal
New barbed, 4 long and 2 short	2	8.0c	21.9c	140	Wires broke	103	Wires poorly placed
No. 14, 4 twisted strands of 3 wires each	1⅔	6.6c	20.5c	130	Wires broke		
No. 14, 4 long and 2 short, 3 twisted strands each	2	8.0c	21.9c	175	Wires and mixture about equal		

* This table is a summary of Tables 5 and 7, Bulletin 148, Colo. Exp Sta.

TABLE NO. 4.—Poured Posts.*

Size, 4x4 inches at base, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 80 pounds.

REINFORCEMENT			COST OF MATERIAL AND FINAL BREAK			
			Mixture, 1 part cement and 3 parts sand.		Mixture, 1 part cement and 4 parts sand.	
Kind of Wire	Weight per post in lbs.	Cost per Post	Cost of Material in Post	Pounds to break post	Cost of Material in Post	Pounds to break post
No. 10, 4 twisted strands of 2 wires	2½	10.0c	23.3c	183	20.6c	168
Old barbed, 4 long strands	1⅔	3.3c	16.6c	108	13.9c	65
New barbed, 4 long strands	1⅔	6.6c	19.9c	105	17.2c	88
No. 14, 4 strands of 3 twisted	1⅔	6.6c	19.9c	102	17.2c	62
No. 14, 4 long and 2 short strands of 3 twisted	2	8.0c	21.3c	185		

* This table is a summary of Tables 6 and 8, Bulletin 148, Colo. Exp. Sta.

The Three Cornered Post.—The following conclusions are drawn after testing 23 triangular posts. Size, 7 inches on each side at the bottom, tapering to 5 inches on each side at the top. Mixture, 1 part cement and 3 parts sand, by measure. Cost of material varying from 14 cents to 19 cents each.

The three cornered post which is advocated to some extent, does not have as many points in its favor as it may seem. In the first place an equal amount of reinforcement in each corner of the post cannot make a post of equal strength from two opposite directions. If a force is brought to bear against one of the flat sides of the post towards the opposite corner, the material in the corner will crush long before the wires will break on the side from which the force is exerted. On the other hand, if a force is brought to bear against one corner of the post towards the opposite flat side, the single reinforcement in the corner will break before the mixture has begun to crush on the flat side.

An extra reinforcement in the corner on which the force is exerted towards the opposite flat side will make it practically as strong as the flat side. But when the force is again applied to the flat side towards the single corner which is doubly reinforced, the mixture in the corner gives away too soon and it is no better than with but a single reinforcement.

TABLE NO. 5.—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x4 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement, 3 parts sand, and 3 parts gravel, by measure. Cost of cement per post, 14 pounds, 8.4 cents; sand and gravel, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST		COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 wires twisted No. 10	2½	10.0c	218	Ground line Ground line 4 in. below	22.1c	Wires broke on 2 and mixture broke on one
4 long and 2 short twisted strands No. 10	3	12.0c	330	4 in. above 12 in. above 4 in. below	24.1c	Wires broke
4 long strands old barbed wire	1⅔	3.3c	110	Ground line Ground line Ground line	15.4c	Wires broke
4 long and 2 short old barbed wire	2	4.0c	118	20 in. above 24 in. above 15 in. above	16.1c	Wires broke, not well placed
4 long strands new barbed wire	1⅔	6.6c	143	4 in. below Ground line Ground line	18.7c	Wires broke
4 long and 2 short new barbed wire	2	8.0c	123	Ground line 3 in. above 10 in. above	20.1c	Wires broke
4 long strands of 3 twisted wires, No. 14	1⅔	6.6c	123	Ground line 27 in. above Ground line	18.7c	Wires broke
4 long, 2 short strands of 3 twisted No. 14	2	8.0c	143	Ground line 7 in. below 4 in. below	20.1c	Mixture broke on two and wires broke on one

TABLE NO. 6.—Corner Posts.

Size, 8x8 inches from base to ground line, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 360 pounds. Mixture, 1 part cement, 2 parts sand, and 3 parts of gravel, by measure. Cured 90 days. Cost for cement per post, 51 pounds, 30.6 cents; sand and gravel, 3 cubic feet, 11.1 cents. For cost of reinforcement, see table below. Test shows pull exerted in pounds as by each of two fences pulling at right angles.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs.	Location of Break	Cost of Material per Post	All reinforcements figured at 4c pound excepting old barbed wire at 2c.
2-8 ft. and 2-5 ft. pieces ½ in. rod on tension side	16	64c	poured	7200	8500	at brace	$1.057	Short wires extended from below ground line to above brace line
Same as above	16	64c	tamped	5050	5600	at brace	1.057	Short wires extended from below ground line to above brace line
14 strands old barbed wire on tension side.	8	16c	tamped	6300	7300	at brace	.577	Mixture broke
Same as above	8	16c	poured	5900	7400	at brace	.577	Mixture broke
10 twisted strands No. 10. on tension side	8	32c	tamped	5400	7300	4 in. below brace	.737	Mixture broke
Same as above	8	32c	poured	6300	6650	4 in. above brace	.737	Mixture broke

Size, 7x7 inches at base, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 250 pounds. Mixture, 1 part cement, 2 parts sand, and 3 parts gravel, by measure. Cured 90 days. Cost of cement per post, 36 pounds, 21.6 cents; sand and gravel, 2 cubic feet, 7.4 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs,	Location of Break	Cost of Material Per Post	All reinforcements figured at 4c pound excepting old barbed wire at 2c.
8 strands old barbed wire 2 in each corner	4½	9c 2c lb.	poured	2700	3600	at braces	$0.38	Mixture broke
8 strands new barbed wire 2 in each corner	4½	18c 4c lb.	poured	3225	4050	at braces	.47	Mixture broke

HOLLOW POSTS.

It has been suggested that the cement and concrete posts should be made hollow. The hollow post would require less mixture and it would also be lighter. As the material in the center of the post does not have a good opportunity to act to the best advantage in compression, it is argued that the strength of the hollow post would be nearly as great as that of the solid post.

In case time is of little value it would probably prove more economical to build hollow posts. As the amount of reinforcement is not affected by the change from the solid to the hollow post, only the saving in cement, sand and gravel need be considered. It is an easy matter to compute the saving accomplished by the making of hollow posts, and then by knowing the cost of labor, the economy of building them may soon be calculated. With cement at 55 cents per sack and sand at $1.00 per yard, one cubic foot of 1 to 4 mixture costs 18 cents. If a 1½ inch hole were to be left in the center of a post 7 feet long about 1½ cents' worth of material would be saved. With labor at 15 cents per hour, 6 minutes might be given to the extra work of making the post with the hollow core.

In case of alkali soils the hollow center gives additional exposed surface upon which the alkali may act. In a 4-inch square post with a 1½ inch core, the extra surface amounts to about 28 per cent. of the original lateral surface.

Finally there is a serious question as to the relative strength and durability of the hollow post as compared with the solid one.

CORNER POSTS AND GATE POSTS.

In the building of a fence with cement or concrete posts, the corner and gate posts must be especially strong, so as to prevent the pull of the wires coming upon the line posts. All the pull of the wires should be borne by the corner or gate posts. With this in mind the designer should aim not only to build a very strong post, but the system of bracing should receive special attention.

As the cement posts are not as strong as wood posts, we cannot use the same bracing systems, which are so commonly in use in wood post fence construction. It has been found advisable to place the brace so that it supports the post at a point very little, if any, above the middle of the post. For the reason that the posts are strong in compression, but do not stand as much pull as wood posts, it proves advisable to place the brace against the brace post at least one foot below the ground line; thus the post distributes the pressure at the end of the brace against an area of ground equal to the surface covered on the opposite side of the post.

There should be several wires connecting the brace post and the corner or gate post together. These wires should be placed under the ground at a depth of about one foot. By having these wires tight the corner post cannot move unless the brace post moves, and as this is securely fastened to it, the whole becomes a unit, offering a rigid resistance to the pull of the fence.

In case of a corner post, the wires may be fastened by wrapping them around it, but the most satisfactory way is to cast wire staples in the post. These staples should extend into the post far enough to be wrapped around one or more of the reinforcement wires.

The hinges for gates may also be cast in the posts when it is desired to do so.

Corner and gate posts are usually reinforced in the same way as line posts. It is unnecessary, however, to place reinforcement wires on the inner sides of the corner posts, as the outer sides bear almost all of the tension.

With the tapered posts, it is desirable to construct the face sides straight; this brings all of the taper on the other two sides. Small lugs or shoulders should be cast on each brace side of the post, against which the brace is placed.

The ordinary five-inch line post proves to be strong enough to act as a brace post for an eight-inch corner post.

The following table gives a summary of breaking strength and cost of materials of some of the best poured posts, which were made and tested in this experiment.

MIXTURE	DESCRIPTION	REINFORCEMENT								
		4 Long No. 10 Twisted	4 long 2 short No. 10 twisted	4 long New Barbed Wire	4 long Old Barbed Wire	4 long 2 short new barbed	4 long 2 short old barbed	3 long No. 19 5/8 in. band iron	4 long 4 short old barbed	6 long old barbed
1 to 3	Ground line 5x5 top 3x3	307 lbs. 29.9c	290 lbs. 31.9c	188 lbs. 26.5c	158 lbs. 23.2c	none none	200 lbs. 23.9c			
1 to 4	Ground line 5x5 top 3x3	222 lbs. 26.9c	322 lbs. 28.9c	none none	95 lbs. 20.2c	172 lbs. 24.9c	127 lbs. 20.9c			
1 to 5	Ground line 5x5 top 3x3	235 lbs. 23.9c	220 lbs. 25.9c	123 lbs. 20.5c	113 lbs. 17.2c	140 lbs. 21.9c	137 lbs. 17.9c			
1 to 3	Base 4x4 top 3x3	183 lbs. 23.3c	none none	105 lbs. 19.9c	108 lbs. 16.6c					
1 to 4	Base 4x4 top 3x3	168 lbs. 20.6c	none none	88 lbs. 17.2c	65 lbs. 13.9c					
1 to 3 3	Ground line 5x5 top 3x3	218 lbs. 22 1c	230 lbs. 24.1c	143 lbs. 18.7c	110 lbs. 15.4c	123 lbs. 20.1c	118 lbs. 16.1c			
1 to 3	Base 5x5 top 3x3 horse shoe shape	202 lbs. 23.3c			133 lbs. 16.6c			157 lbs. 22 3c	148 lbs. 18.8c	
1 to 3	Triangular Base 7x7 top 5x5			110 lbs. 18.0c						147 lbs. 15.9c

Strength of cement posts compared to new wood posts tested under like conditions.

KIND OF POST	SIZE OF POST	BREAKING STRENGTH	REMARKS
(1) Best cement post tested	5x5 in. at ground line tapering to 3x3 in. at top	322 lbs.	
(2) Cement	Same as above	307 lbs.	
(3) Cement	4x4 in. at base tapering to 3x3 in. at top	185 lbs.	The post was 3.6x 3.6 in. at ground
(4) Split cedar (new)	3.6x3.6 in. at ground line	613 lbs.	Same size at ground as No. 3 above
White pine (new)	4x4 in. at ground line	2000 lbs.	
Red spruce (new)	4½x4½ in. at ground line	2400 lbs.	
Red spruce (new)	5x5 in. at ground line	3350 lbs.	

CONCLUSIONS.

Poured posts are easier to make than tamped ones. They are somewhat more expensive because one mold will make but one poured post per day, while the same mold may be used for making as many tamped posts as the builder can mix and tamp in the same time.

According to the tests made poured posts are a little over 25 per cent stronger than tamped ones of the same size, mixture and reinforcement.

Poured posts are not so porous as the tamped ones and are therefore more nearly water proof, thus making them better able to withstand the action of frost and alkali.

The poured post is enough better in every respect to justify its construction and use in preference to the tamped one.

Most commercial molds make a post which tapers from the base to the top, but the most economical mold is one which casts a post as large at the ground line as at the base, tapering from the ground line to the top. For a description of this form of mold, see Fig. 4.

The best form of post is one which is equally strong from all directions. The square, or round post, fulfills this requirement. The triangular post does not meet the requirements because it cannot be economically constructed so as to be equally strong from all directions.

To be economical, the amount of reinforcement should be in proportion to the size of the post and strength of the mixture. See tables.

The material used for reinforcement should be strong, light and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch.

The smooth reinforcement tends to slip even if hooked at the ends.

Two or more wires twisted together make as satisfactory a reinforcement as can be obtained.

Crimped wire tends to straighten and thereby breaks pieces out of the post at the point of greatest stress.

The reinforcement should be placed in each corner of the post at a depth of from ⅜ to ¾ of an inch from the surface.

There are several commercial wire fasteners now found on the market, the most of which are either cumbersome or expensive. For a simple and satisfactory fastener, see cut of fasteners. (Fig. 5, A.)

The posts should be cured in the shade for at least 60 days, the first 30 days of which they should be sprinkled daily.

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The Agricutural Experiment Station

OF THE

Colorado Agricultural College

RABIES

BY

GEO. H. GLOVER

AND

B. F. KAUPP

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Fig. 1.

FIG. 1.—A case of dumb rabies.. Note the peculiar attitude and the dropped jaw. Reproduced from K. C. V. C. Bul.—Kinsley & Kaupp.

Fig. 2.

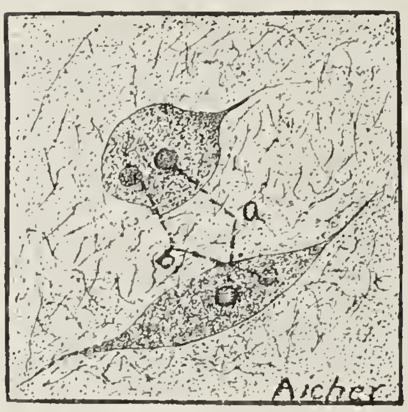

Fig. 3.

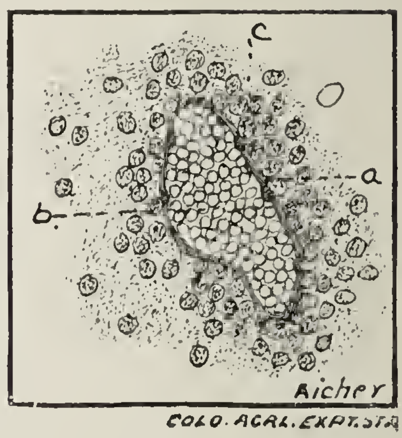

Fig. 4.

FIG. 2.—Section from plexiform ganglion showing degenerative changes; with round cell infiltration. Babes' corpuscles.

FIG. 3.—Nerve cells from Hippocampus showing granular condition of cytoplasm.

a.—Nuclei.

b.—Negri bodies.

FIG. 4.—Section from Medulla.

a.—Blood vessel wall.
b.—Red blood cells.
c.—Perivascular Infiltration.

RABIES

By DR. GEO. H. GLOVER, Head of Veterin.ry Dept. and DR. B. F. KAUPP, Pathologist, Veterinary Dept.

DEFINITION: Rabies is an acute infectious disease, usually transmitted by the bite of a rabid animal. It effects the cerebro-spinal system, and is accompanied by extreme nervous excitability.

History of Rabies in Other Countries.

Rabies was recognized as a distinct disease by the Israelites and Egyptians as far back as 322 B. C. We find descriptions of it by Horace, Celsus, Virgil, and other writers of those times.

Rabies is most common in the north temperate zone, although it may be found in nearly every part of the world, and from the sea levels to the high altitudes. It is usually found most prevalent in the most densly populated districts, where the conditions are most favorable for its spread.

New Zealand, Tasmania and Australia are reported not to be infected with rabies. All animals, and especially dogs, are kept under strict quarantine for a period which is calculated to exclude the possibility of its introduction into these countries. St. Helena and the Azores are said never to have suffered from the disease. In many German cities, including Berlin, muzzling ordinances have done most to stamp out the disease. Through strict enforcement of the muzzling ordinances in England no case of rabies has been reported since 1901, and in Ireland since 1903. It is interesting to note that at one time rabies was so common in London that many people were afraid to venture on the streets at night. In France 1892 cases of rabies were reported during the year 1907, and in Belgium 226 cases with 179 suspected ones were reported the same year. During this same year 254 cases were reported in Austria, 55 in India (British), 1825 in Hungary, 701 in Italy and 36 in the Netherlands.

The Prevalence of Rabies in the United States.

This disease was quite rare in this country till about 30 years ago. Since that time new centers of infection have been constantly appearing.

The presence of rabies has been positively proven in twenty-two states and probably exists in all.

In the District of Columbia, during 1907, rabies was identified in 37 dogs, 4 dingoes, 1 cow, 1 sheep and 1 cat. During 1905, from one pathological laboratory in Kansas City, 31 cases were reported as follows, 1 cat, 1 hog, 1 sheep, and the balance dogs. From this it will be seen that most cases occur in dogs.

History of Rabies in Colorado.

The recent outbreak of rabies in Colorado is said to have started in Greeley about two years ago, when a dog which had just been brought to that place from the east, developed the disease. The infected area at this time seems to be confined to the eastern portion of Colorado and extends from about 50 to 75 miles north of Denver to as far south as Pueblo. The most thickly populated districts of this territory, as Denver and its vicinity, have the most cases.

The beginning of this investigation was on August 31, 1908, when a call came from Greeley, where several cases had been diagnosed as rabies among dogs, cattle, etc., In this investigation the disease was studied in one horse, two cattle, and eight dogs. This covered a period of less than six months. Laboratory findings were confirmed by repeated animal inoculations. Several people bitten by rabid dogs were advised to proceed to a Pasteur Institute and take anti-rabic treatment. The mayor and city council upon receipt of an official report that rabies existed in that city, enforced a muzzling ordinance. All dogs on the highways not muzzled were destroyed. The result of this proceedure was that rabies was stamped out of Greeley.

Later a typical case was received from Loveland. In a few weeks two cases came from Longmont, and about ten months later a third case. This last, a dog, had bitten another and in thirty-five days the dog bitten developed rabies. One case has been received from Fort Lupton, one from Platteville, and three from Castle Rock. Two serious outbreaks of rabies, due to stray rabid dogs, have occurred within the past few months near Denver.

Since September, 1909, forty-three animals or their heads have been received at this laboratory from Denver. All but one head were from suspected cases of rabies. Of these heads two were from cattle, one cat, one wolf and the balance from dogs. Of these heads the brain of one was in a state of puterfaction and could not be examined and six did not show lesions of rabies. The balance, including two heads of cattle, showed lesions of rabies.

Animals Affected.

All animals may develop rabies when bitten by one that is rabid. This includes horses, cattle, sheep, hogs, dogs, cats, pole cats, mice, wolves, man, etc.

Transmissibility.

So far as has been proven the disease is only transmitted by the bite of a rabid animal or by inoculation.

Virulency of the Saliva.

The virus may be introduced into an already existing wound through holding an autopsy, or by the animal licking a wound. It is usually done by the bite of a rabid animal. By careful experiment it has been found that the saliva of a dog may contain the virus for seven or eight days before developing symptoms of the disease. As the virus is contained in the saliva, the teeth inflicting the wound carry the infection and deposit it in the wound.

It is a mistake to hasten to kill a suspected dog. The symptoms, if any, should be noted, and later, if rabies is diagnosed, the dog may be killed, and if desired, the head sent to the laboratory for microscopic examination.

Persons or Animals Bitten.

The wound should be cauterized at once, before the virus has had time to find its way beyond the point of reach of the cautery. This can best be done by the use of a red hot iron or by the use of dilute nitric or sulphuric acid applied deep into the wound with a stick, if nothing better is at hand. Nothing short of reaching the entire depth of the wound will be effective and this must be done at once. Lyssophobia, or fear of rabies, is common in nervous persons, who have been bitten by a dog rabid or normal. Should the dog biting a person be found free from rabies after keeping him confined for ten days, or a microscopic examination or by rabbit inoculation, the mind of the person should be set at ease. Should the dog be found to be rabid, the Pasteur Treatment, being a sure preventative when the person goes early, should also set the mind at rest.

Period of Incubation.

The period from the time the bite is inflicted until the symptoms of the disease appear, varies from three or four weeks to several months. It is doubtful if any authentic cases have developed after eighteen to twenty-four months.

The length of time that elapses from the bite until the animal developes the disease depends largely on two factors: first, the location of the wound, and second, the severity of the lacerations. The fact has long been established that the virus travels the course of the nerves. Thus if the wounds are in the facial regions the course from the inoculated point to the brain is short and the disease develops quicker. The deeper and more severe the lacerations, the greater the quantity of saliva introduced into the wound and the more dangerous it is. Thus in scratches the danger is not so great as when the tooth penetrates the flesh. Bleeding has a tendency to wash out some of the virus and lessen the danger.

In dogs, street rabies usually develops in from 23 to 35 days, in horses and cattle in from 4 to 6 weeks, in hogs and cats the time is about the same as in dogs. Street rabies is that form found from natural infection. The virus from one animal may be more or less virulent than from another.

The disease develops in pups quicker than in adult dogs, and in children in less time than in adults. In mature people the period of incubation is from 40 days to three months. While the mortality is considered to be 100 per cent., yet, conservative estimates place the number of those bitten that develop the disease at 16 to 20 per cent. Under certain conditions the percentage runs higher. The clothing or the thick coat of hair, in animals, has a tendency to clean the teeth of saliva and lessens the probability of infection.

Dumb Rabies.

The form known as dumb rabies may characterize the disease from the first or may develop in the later stages of the furious type. This form of disease runs a more rapid course, and by some is considered to be due to a greater degree of infection. There is a greater toxemia. Dogs with this type usually die in from 3 to 4 days after the symptoms have fully developed.

Symptoms.

The first symptoms noted will be a change in the disposition. The kind playful dog will become morose, fretful, and easily excited. In these earlier stages, if running at large, he may pick up and swallow sticks, hair, and even stones. There is a tendency to lick and gnaw the point at which he was bitten. This part may itch and possibly cause pain. He is prone to crawl under the porch or other place and hide a part of the time, coming out to eat and again seeking seclusion. At this stage he may leave home and bite men and animals that chance to come his way. He may return home after several hours in an exhausted state or he may never return. The jaw drops from paralysis and the owner thinks the dog has a bone in his throat. He eats and drinks with difficulty or not at all, owing to the partial or complete paralysis of the throat. He may bark but his bark is drawn out into a long howl. This howl, if once heard, will never be forgotten. The dog may still know his master but has a tendency to try and bite or attack any one he does not know. Later he does not even recognize his master. If in a cage he will bite or snap at any stick poked at him. If tied he will try to chew the rope and free himself. The ears may be erect and trembly. The dog is ever alert to any noise, and is always disturbed by it. He stares, his eyes at first moist later become dry. This is due to the cessation of the tear secretion. Finally he becomes paralized, first in the hind quarters, then in the fore, and death ends his suffering. Oftentimes the tongue is protruded and more or less paralized and as a result of exposure to the atmosphere is oftimes dry and black. Figure 1, shows a photograph of a dog with dumb rabies.

Furious Rabies.

In furious rabies the animal is more irritable than in the dumb form. There is a greater tendency to bite. The jaw is not dropped or paralized until the very last stages. In the furious type the dog may live from six to eight days after the symptoms are well developed. Horses and cattle more often develop the furious type. The writer has seen a case in the horse, in which an ordinary box stall was not strong enough to hold the animal, so furious was he in his spasms. The horse makes violent efforts to bite or attack, the cow more often tries to butt any animal or person that comes near.

Post Mortem Findings.

The dog, or any animal, to be sent to the laboratory should not be shot through the brain, as that lacerates the brain and causes hemorrhages into its substances. This greatly interferes with a detailed examination. The proper, and one of the most humane ways, is to shoot the dog or other animal through the heart. The head should be cut off in such manner that three or four inches of the neck remains with the head. This enables the securing of the nerve centers for microscopic study. A sectioned surface of the brain is usually dark in appearance. Occasionally a bloody spot, small in size, can be seen under the coverings of the cord. This is especially noticeable from the cords of the experimental rabbit inoculations, otherwise the cord and brain has a normal appearance. The changes are so slight in their appearance that nothing definite can be told short of a microscopic examination. In the stomach may be found sticks, straws, shavings, etc, picked up while running at large. Aside from these substances, the stomach is empty. There should be observed an absence of all acute diseased lesions, at the autopsy.

Microscopical Examination.

For microscopical examination, the brain must be in good condition. Brains that are in a state of putrefaction cannot be satisfactorily examined. The first definite microscopic lesions of rabies to be pointed out, was by V. Babes in 1892. He found degeneration of the nerve cells in the medulla and the plexiform ganglion. The degeneration in the medulla was particularly noticeable near the central part of the ganglionic portion. There was observed an invasion of small round cells in the spaces occupied by the cytoplasm of the cells. These he called rabic tubercles which are now sometimes called Babes tubercles or corpuscles. Figure 2 shows one of these tubercles from the plexiform ganglion.

In 1893, A. Negri called attention to certain bodies always found in the nerve cells of a dog or other animal dead of rabies. To these was given the name Negri bodies. Since that time these bodies have been studied in more detail by many scientists and are now believed by the foremost workers to be protozoan in nature. Different stages of their development have been studied which corresponds to the different stages of the disease. These bodies stain characteristically. They contain eosinophilic granules. Figure 3 shows nerve cells containing Negri bodies.

Delafield & Prudden call special attention to the peri-vascular infiltration which usually accompaines this condition. Figure 4 gives an illustration of this phase.

Animal Experiment.

When a person is bitten by a dog suspected of being rabid and the laboratory findings are not satisfactory the laboratory worker can, if the brain is still fresh and is not contaminated, inoculate an animal. In doing this an emulsion is made from a small part of a certain part of the brain. The rabbits skull is trephined and a small part of the emulsion is injected under the coverings of the brain. If care in technique is taken the animal will appear healthy, and eat and drink until the symptoms develop, which is usually about the 14th to the 16th day. If the technique has been at fault and infection taken place the rabbit will die of septic infection long before the time for rabies to develop. Freezing does not destroy the virus and it will resist putrefaction for a long time. Drying will soon destroy it.

Control and Eradication of Rabies.

This most terrible disease is the most easily eradicated of all contagious diseases as shown by the results in England, where rabies once prevalent, is now practically unknown. As the spread of the disease is by the bite of a dog in practically every instance, the muzzling of all dogs with the destruction of those not kept muzzled, is the easy solution of the problem. This muzzling must be universal throughout the infected district.

Pasteur Treatment.

Soon after Pasteur had perfected the vaccine for Anthrax, which was about 1880, his attention was called to a little girl in a ward of a hospital dying of rabies. As a result of the study that followed, Pasteur by experimenting on the lower animals perfected the vaccination method which is still used to vaccinate and protect the lives of people when bitten by a rabid dog. As early as 1880 it was a recognized fact that drying practically destroyed the virus of rabies. Pasteur took advantage of this fact by drying the cord of rabbits dead of rabies, over potassium hydrate thus attenuating it, and making a vaccine. By injecting a certain portion of the cord, so treated for 14 days, under the skin, in the form of an emulsion, followed once a day with a like injection, gradually using cord less attenuated, in 21 days the person is immune from the disease and the treatment is complete.

Danger of Milk and Meat.

In regard to the infectiousness of milk from rabid animals it must be considered at all times dangerous, as some experiments have proven that the milk is infectious. Some experiments conducted along this line have given entirely negative results. The young should be taken away from the mother as soon as rabies is found to have developed. The milk should never be used for human consumption. So far, all attempts to produce rabies in experimental animals by feeding them the meat of animals dead of rabies have failed. The virus from the brain mixed with food has in some instances produced rabies experimentally. Rabies has been produced in mice by feeding them rabic brain mixed with their food.

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FARM BUTTER MAKING

BY

H. M. BAINER

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The Agricultural Experiment Station

FORT COLLINS, COLORADO

FARM BUTTER MAKING

By H. M. BAINER

Looking at farm butter making from a business standpoint, every farmer or dairyman who keeps cows for the butter product, desires to make as much and as good butter as possible. There are many factors which are likely to produce a second or third grade of butter, these must all be taken care of as they come. The majority of dairymen are beginning to realize that good butter is made only from good cream. The churned butter cannot be better than the cream from which it is made. This bulletin is written with the idea of giving general information or directions for making a better grade of farm or ranch butter.

THE DAIRY.

It is generally understood that the kitchen is not a good room in which to ripen and churn the cream.

A good clean cellar, which is well drained, properly lighted

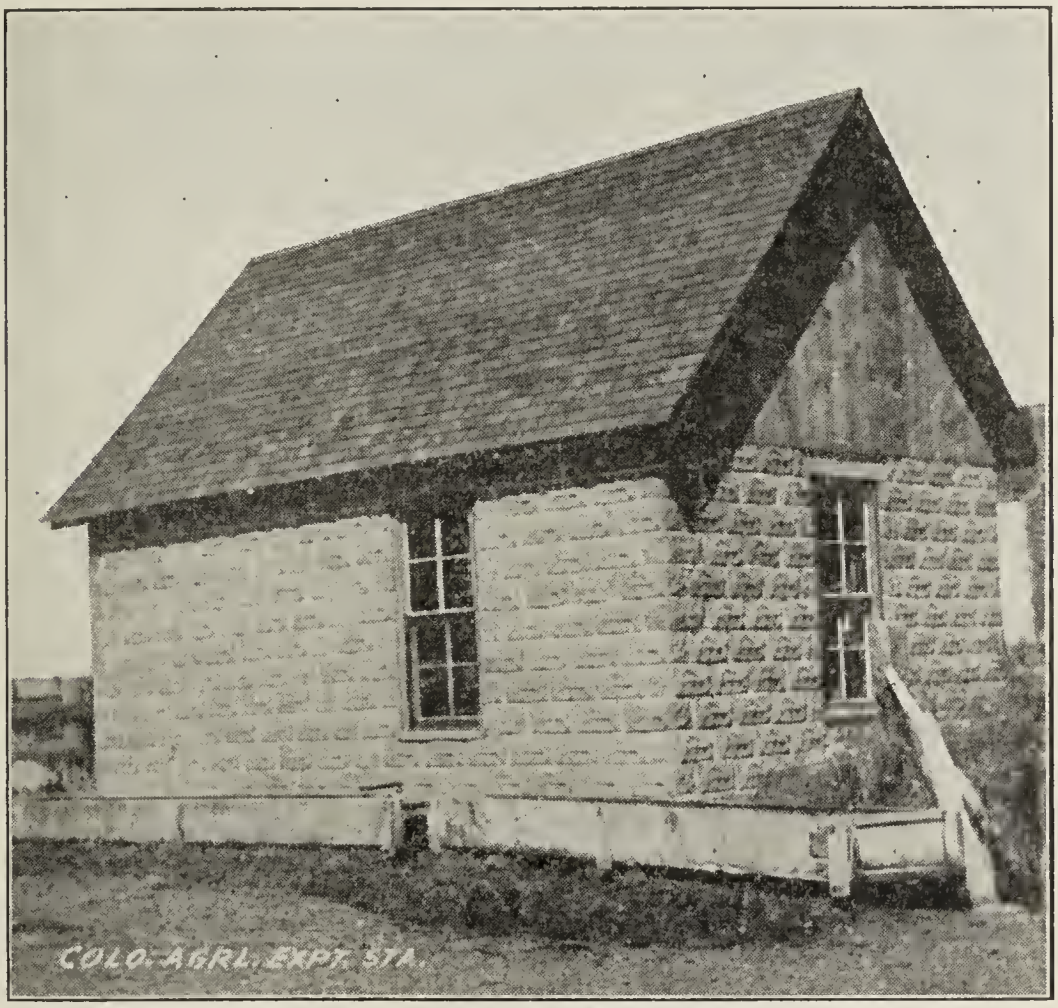

Fig 1—Cement Block Dairy.

and well ventilated is far superior to the kitchen. A separate room, next to the kitchen, with an outside as well as an inside entrance is desirable, if used for dairy work only. There are very few farmers or small dairymen who feel able to construct a separate dairy, although it is desirable.

Such a building can be easily and cheaply constructed of solid concrete walls or cement blocks, as shown in Fig. 1. Any farmer who understands handling cement and can make good forms or molds for construction can make a good solid wall concrete dairy very cheaply. The walls can be made of solid concrete, 4 to 6 inches thick and plastered on the inside with a cement plaster. An excellent wall can be made out of a mixture of 1 part Portland cement, 3 parts sand and 3 parts of gravel, plastered on the inside with a mixture of 1 part cement to 2 parts of sand. The mixture should be placed in the forms in a very wet or sloppy condition. Old barbed wire, or wire of any kind, placed in the walls as they are being constructed, will strengthen them very much, especially at the corners. The floor in the dairy room should be constructed out of concrete, with a cement surface.

The separate dairy should be located so that it is handy to both the house and the barn, so that hot and cold water can be easily secured, and so that it can be well drained. It is advisable to place it near the well so that cold water can be easily secured for cooling the milk or cream. It is a good plan to arrange the dairy so that all water which is pumped for live stock has to pass through a cement tank in the dairy and out through an overflow pipe into the watering trough or supply tank.

Usually a building 10x12 feet, clear on the inside, will be large enough for the average farm dairy.

CLEANLINESS A NECESSITY.

If good butter is to be produced, the milk and cream must be properly handled. The milk cannot be produced under unsanitary conditions and at the same time furnish the raw material for a good quality of butter. The reasons for a poor grade of butter are more frequently found before the milk has been skimmed than after.

The cows should be kept in a healthy condition. The stable should be well lighted, properly drained and thoroughly ventilated. The milker should remember that milk takes on odors very readily and that undesirable bacteria and filth which are allowed to get into it during the milking period, even in apparently small quantities are likely to spoil the product. Some of the greatest sources of contamination are the cows, the milker, the stable, the flies, the pails, strainer, and the stable air. The dark, unventilated, damp stable is the home of disease and germs. On the other hand, plenty of sunlight and fresh air is conducive to health and sure death to most germs. Everything that falls into the milk, flies, hair, particles of dirt, etc., carries with it thousands of bacteria, the majority of these being detrimental. Every possible precaution should be exercised to keep the milk clean and pure. All dirt should be brushed from the cow before starting to milk and it is often advisable to wipe the udder with a damp cloth. The milker should be clean. The cows should not be fed before milking as it will raise a dust which will help carry bacteria into the milk. The milk should not be allowed to stand in the stable any longer than is absolutely necessary, it should be removed to the dairy room as soon as possible and there strained for the creaming process.

Poor feed, such as musty hay, damaged grain, rotten silage, fermented feeds, etc., will give the milk and butter a bad flavor. Again, certain weeds in the pasture, such as wild onions, ragweeds, etc., will produce bad flavors. Poor water for the cows also has its effect.

THE DAIRY UTENSILS.

All pails and cans should be made of a good grade of tin. They should be made of pressed tin or should have the seams smoothly soldered over, so there will be no places for dirt to lodge. Galvanized and wooden pails are not advisable. The tinware should not be allowed to rust and, above all, it should not be used for any other purpose.

All dairy utensils, including pails, cans, separators, churns, etc., should be thoroughly washed every time after using. They should be first washed or rinsed in cold or luke warm water, not hot, as it will cook the milk onto the tin. After rinsing, wash them in hot water, then thoroughly scald with boiling water or steam and place in the direct rays of the sun. It is not advisable to dry them with a cloth, as they will remain cleaner, if scalded and allowed to drain in the sunlight. Do not use laundry soap in washing the dairy utensils but rather a good washing powder or sal-soda which contains no grease.

SKIMMING THE MILK.

There are two general systems of separating the cream from the skim milk: The centrifugal or hand separator method and the gravity or setting method. The gravity method being again divided into three divisions; namely, deep setting, shallow pan and water dilution. Taking these all together there are four general methods.

Briefly summarized we give the following statements concerning each method:

Hand Separator.—This method is, by far, the best. The relative skimming efficiency of the hand separator and gravity systems as determined by experiments at the Purdue Agricultural Experiment Station showing the per cent. of butter fat in the skim milk are as follows:

Hand separator .02%.

Deep setting .17%, 8½ times the hand separator.

Shallow pan .44%, 22 times the hand separator.

Water dilution .68%, 34 times the hand separator.

Not only does the hand separator secure practically all of the butter fat, but it delivers the skim milk in a sweet, warm and undiluted condition ready to be fed to the calves or pigs. Fewer dairy utensils are needed, as the milk is separated as soon as it comes from the cow and the skim milk is fed at once.

Less work is required to handle the milk in this method than in others.

The cream delivered from the separator is of uniform richness with much of the fibrous and foreign matter removed. About 50%

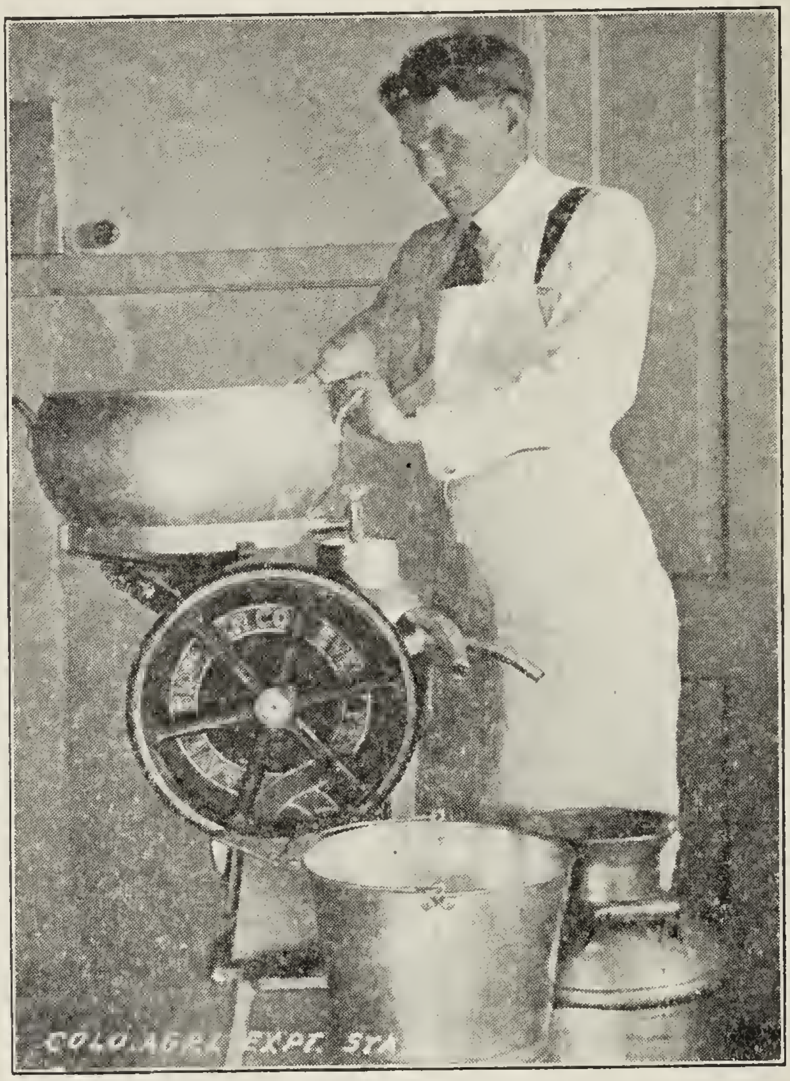

Fig. 2—Hand Separator Ready for Skimming.

of the total number of germs found in the milk are thrown out by the separator into the bowl slime.

The milk has had less chance to absorp bad flavors and odors from standing around and the cream is produced in excellent condition. By using the hand separator, there is a gain in the quality as well as the quantity of butter obtained.

Deep Setting.—In this method, the warm milk is strained into a can, usually of the shot gun type, which is tall and of small diameter. This is set into a tub or trough and is surrounded with cold water. The milk is usually allowed to set for 24 hours, at the end of which time the skim milk is drawn off through a faucet at the bottom, leaving the cream in the bottom of the can. Often the can is not provided with a faucet and the cream is removed from the surface with a saucer or hand skimmer. Generally, the deep setting system produces a better grade of cream than either the shallow pan or water dilution systems. The cream is usually removed in a sweet condition, less surface is exposed to the drying action of the air and the skim milk is in better condition for feeding, although it is cold and sometimes sour. The cream is not of uniform richness and is often not rich enough to churn well.

Shallow Pan.—The milk is strained into pans or crocks and is set in a cool place to cream out. It is sometimes set in cold water. It requires about 36 hours setting and is then skimmed from the surface. Usually the cream and skim milk is sour. The cream is not of uniform richness, and is often leathery and of a poor quality.

Water Dilution.—The milk is strained into a special can and is usually diluted with equal parts of cold water. It is set for 12 hours and then skimmed by drawing off through a faucet at the bottom. This method is poorest of all. Often as high as one-fourth of all the butter fat is lost. The skim milk is very poor. The calf has to drink two gallons to get one gallon of milk. The cream is thin, it has a watery flavor and is often very much contaminated with the impurities of the water.

The water dilution separator must be considered as a failure.

The farmer who handles the milk from 10 cows which produce 80,000 pounds of milk per year, should not lose over 30 pounds of butter fat in hand separator skim milk. By good use of the gravity methods he would lose from 275 to 600 pounds of butter fat in the skim milk. To be sure this is not all lost, especially when fed to calves or hogs, but the same food element can be much more cheaply supplied, in corn, kafir, or milo.

SELECTING THE SEPARATOR.

There are many makes of good separators now found on the market which are sold as cheaply as many of the poorer makes.

Select a "Standard" machine, one that has a good recommendation and is known to be durable and reliable. Buy a well known machine, one that is guaranteed in construction, material and clean skimming.

Size of Separator.—Hand separators may be procured in sizes varying in capacity from 150 pounds of milk per hour (18 gallons), to 1,200 pounds per hour (144 gallons). The prices vary from about $35.00 for the smaller size to $165.00 for the larger size.

Select a separator with a capacity of not less than 50 pounds per hour for each cow milked. A 10-cow herd would then require a 500 pound capacity machine and an 18-cow herd a 900 pound capacity one. Don't make the mistake of getting a machine that is too small, as it will take too much time to skim the milk.

COLLECTING THE CHURNING.

Cream should be churned at least twice a week during cold weather and three times a week during warm weather. The frequency of churning will depend largely upon the conditions under which the cream is collected and kept. Enough has been said to show that the kitchen is not the proper place in which to collect and keep cream, although it may be necessary, at times, to take it there for ripening.

As soon as the milk has been skimmed, the cream should be cooled by setting it in a cold place or by running cold water around it. It should be kept in as nearly sweet condition as possible until enough has been gathered for churning. After thoroughly cooling each skimming of cream, it can be added to the previous skimming. In no case should warm cream be added to cold cream, both should be equally cold and then they may be put together and thoroughly mixed. Every time a new skimming of cream is added to that already gathered it should be thoroughly stirred into the cream below. None of the cream should be allowed to stick to the sides of the cream can or jar above the surface.

Do not add fresh cream to a batch of older gathered cream later than twelve or sixteen hours before churning, as it will not ripen or churn uniformly.

A refrigerator is a poor place in which to keep cream which is being collected for a churning. In the first place, it is usually used for keeping a little of everything and a mixture of odors are found in it, which will flavor the butter and at the same time give it a characteristic refrigerator aroma. Again, the refrigerator does not contain enough pure air for cream. About as good a method as any, is to place the cream can in a tank of cold water and give it plenty of pure fresh air. Keep the cream as cold as your well water until within about 12 hours of churning time when it may have to be warmed somewhat for ripening.

RIPENING THE CREAM.

In order to ripen cream, the temperature must be made favorable to the development of the lactic acid bacteria (those that produce the lactic acid or sour the cream). This temperature is usually somewhat above 60° F. The object of ripening or souring the cream is to produce the flavor and aroma in the the butter, to make the cream churn easier and to improve the keeping qualities of the butter. The process of ripening largely controls the quality of the butter, therefore it must be considered as the most important step in farm butter making.

Cream that has been gathered by the gravity methods, instead of the hand separator will need but very little ripening, and will usually not need a starter as it will be sour enough by the time a churning has been collected. It must be frequently stirred, however, during the gathering period to insure its ripening uniformly throughout.

Separator cream, properly collected and cared for will in most cases be practically sweet at the time when enough has been gathered for a churning.

Under creamery conditions, in order to quickly ripen cream and to be sure that the right kind of bacteria are in it, what is known as a starter is added. This starter is nothing more than milk which has been properly soured and kept in good condition and is added to the sweet cream in small quantity. This not only adds the right kind of bacteria for souring the cream but also gives the butter maker control of the fermentation process and he is able to make a uniform grade of butter out of several batches of cream.

Under farm conditions, where the milk is under the control of the butter maker from the beginning, starters are seldom necessary. In fact, to keep a good starter under farm conditions of churning two and three times a week, is a difficult proposition. For farm conditions, the starter cannot be generally recommended, although there may be times when they are necessary. For example, it may be necessary in winter months to add a starter in order to hurry up the ripening process, or to head off the action of numerous undesirable bacteria.

The starter may be good skim milk or whole milk which has been soured under favorable conditions, or it may be ripened cream or butter milk from the previous churning. The starter must be kept in a cool place after it has been properly soured, until used. It should not be allowed to get old or stale, or it will be worse than none. One quart of starter thoroughly mixed with six or eight gallons of cream which has been warmed to from 65° to 75° F. should cause it to properly ripen in 12 hours.

As soon as the cream has become properly ripened, it should be cooled to the churning temperature. The farm butter maker must judge the degree of ripeness by the taste, aroma and appearance. Too sour cream makes a strong flavored butter with poor keeping qualities, in fact, it produces a poorer butter than cream that is not sour enough.

THE CHURNING PROCESS.

The Churn.—One of the best types of farm churns is that with no inside fixtures, such as the barrel churn. Those churns with inside fixtures, agitate the cream in a different way and have more of a tendency to spoil the grain of the butter, they are also harder to keep clean.

At present, there are several churns on the market that are guaranteed to get the butter out of the cream in from three to eight minutes, these must be considered as frauds. They always spoil the grain of the butter and at the same time partly emulsify or mix the butter fat and milk in such a way as to make them inseparable, thus producing a salvy or grainless butter of very poor keeping quality.

For dairies, making 75 pounds or more of butter per week, there is no doubt but that the small combined churn and worker

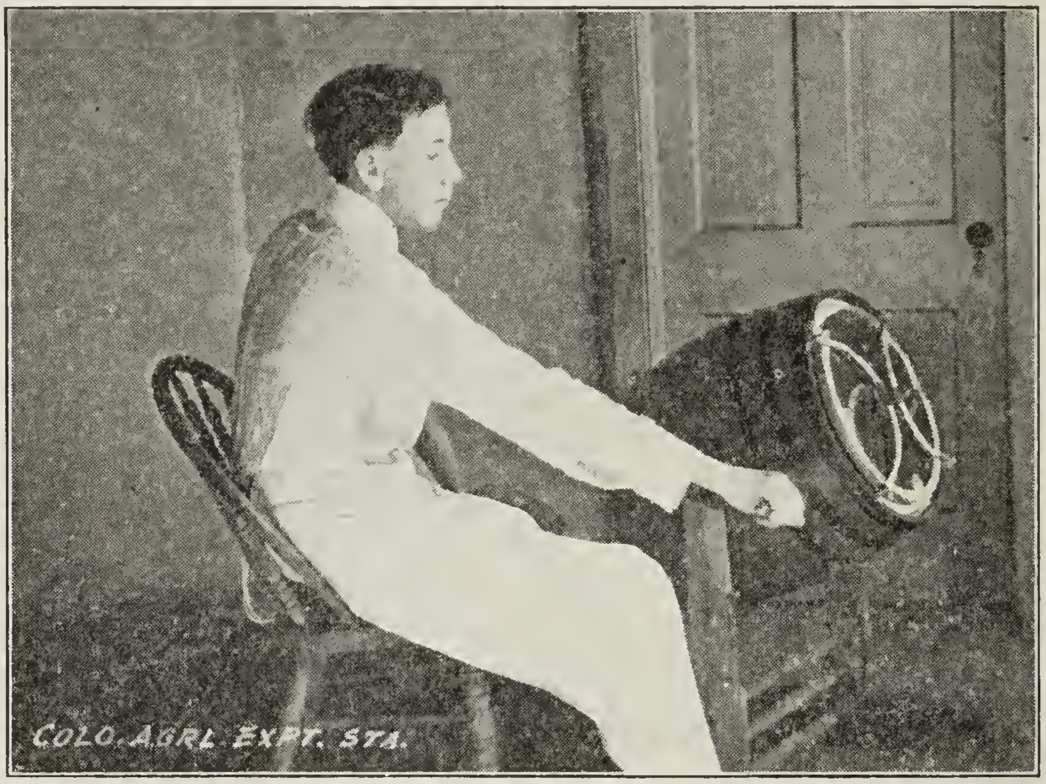

Fig. 3—Churning with Barrel Churn.

will prove more satisfactory than the churn and worker separate. The combined churn and worker is used altogether in creamery practice.

A common error is made in securing churns that are too small. The churn should never be filled more than half full of cream and one-third full is better.

Temperature.—Every butter maker should secure a good dairy thermometer and then use it. One of the main causes for having to churn from one to several hours, is that the cream is not at the right temperature. With a temperature of from 52° to 60° F., butter should be produced in from 25 to 40 minutes, providing the other conditions are right.

After the cream has been ripened it should be cooled to the churning temperature and then held at that temperature from one to three hours before churning.

Churning.—The churn should be first scalded and then thoroughly cooled with cold water.

It is very important that all cream be strained into the churn. This will remove all clots and particles or curd and there will be less danger of white specks in the butter. It is not uncommon to find flies, solid impurities, etc., in the cream, even if handled with the best of care.

Do not fill the churn much over one-third full, but rather give the cream room for agitation, which helps to insure quick churning. Turn the churn just fast enough to give the cream the greatest amount of agitation. In case a barrel churn is used, turn it so the cream has time to fall from one end of the churn to the other, with a distinct thud.

Coloring.—In order to make a uniformly colored butter for the entire year, some color must necessarily be used. Very little will be required during the spring and summer months when the cows are getting green feed. During the fall and winter months more color will be required. No harm is done by moderately coloring butter with a good standard color, of which there are several brands on the market. Colored butter can be sold for a

Fig. 4—Taking Washed Butter from the Churn in Granular Condition.

very much better price than that not colored. White butter is not nearly so appetizing and good in appearance as that which contains color.

The color should be added to the cream in the churn before starting to churn.

When to Stop Churning.—The old practice of churning until all the butter has gathered in one body in the butter milk cannot be considered a good one. In this way too much butter milk is mixed into the butter which cannot be worked out or washed out, this not only gives the butter a poor flavor but poor keeping qualities as well.

The butter should be gathered until the granules become about the size of a grain of wheat. Then draw off the butter milk through a strainer and wash the butter. If the butter is gathered in larger grains or chunks it will be found harder to properly salt, and at the

Fig. 5 – Butter on Table Worker just from the Churn. Note Fine Granular Condition.

same time there will be more danger of mottled or spotted butter. It is generally understood that an uneven distribution of salt is largely responsible for mottled butter.

Washing the Butter.—After thoroughly drawing off the butter milk, the butter should be washed in good clean and pure well or spring water. Under good churning conditions, the temperature of the wash water should be about the same as the butter milk. If the butter comes too soft, use water that is colder and if it is too hard, use water slightly warmer.

Pour the wash water into the churn over the butter and turn the churn but four or five quick revolutions. Then draw off the first wash water and put on the second and turn churn as before. If the butter is hard enough after the second washing, draw off the water at once and the butter is ready for salting.

Salting and Working.—If the butter has to be salted and worked outside of the churn, it should be taken out in the granular condition and the salt should be added before it has been worked at all. Nothing but a good grade of dairy salt should be used. As a general rule, about one ounce of salt is added for each pound of the granular butter. The salt should be worked through the butter with a ladle or some good type of worker and not with the hands.

The best way to work butter outside of the combined churn is by use of the small table worker. Next to this, is the butter bowl and ladle.

Fig 6 —Working Butter in Butter Bowl.

One working, at the time of salting, is usually sufficient, providing the butter is hard enough when removed from the churn and providing, also, that it is worked in a cool place. If the butter

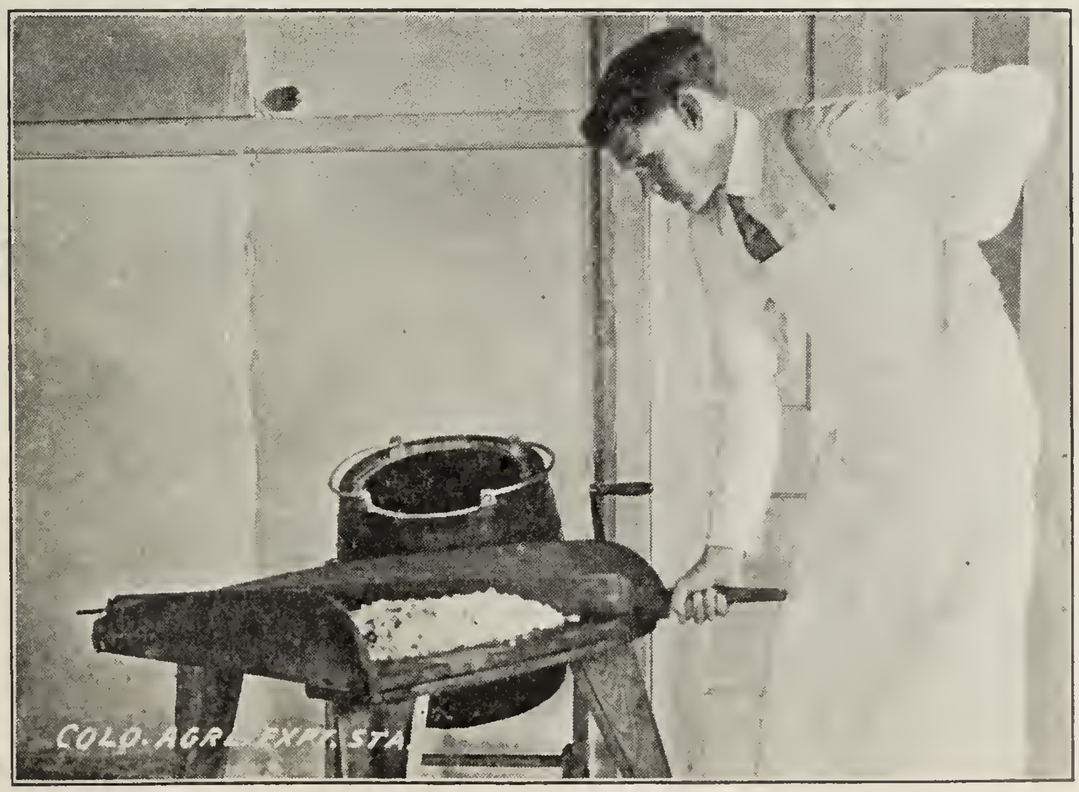

Fig. 7—Working Butter on Table Worker, a Better Method than with Butter Bowl.

becomes too soft before the process of working is completed, it can be set away in a clean, cool place for a short time, until it gets hard enough to finish.

The butter maker will have to judge by taste, distribution of salt, and general appearance, when the butter has been worked enough. Butter has usually been worked enough when the salt is evenly distributed and when the water has been sufficiently removed so that the butter will bend without breaking, when rolled. Too much working will spoil the grain of the butter and make it salvy; while leaving too much water in it will tend to spoil its keeping qualities.

Printing.—Butter should be packed or printed as soon as it has been worked sufficiently, after which it should be put in a cool place until taken to the market.

The appearance of the package, as well as the way the butter is printed or packed, has a great deal to do with the selling price.

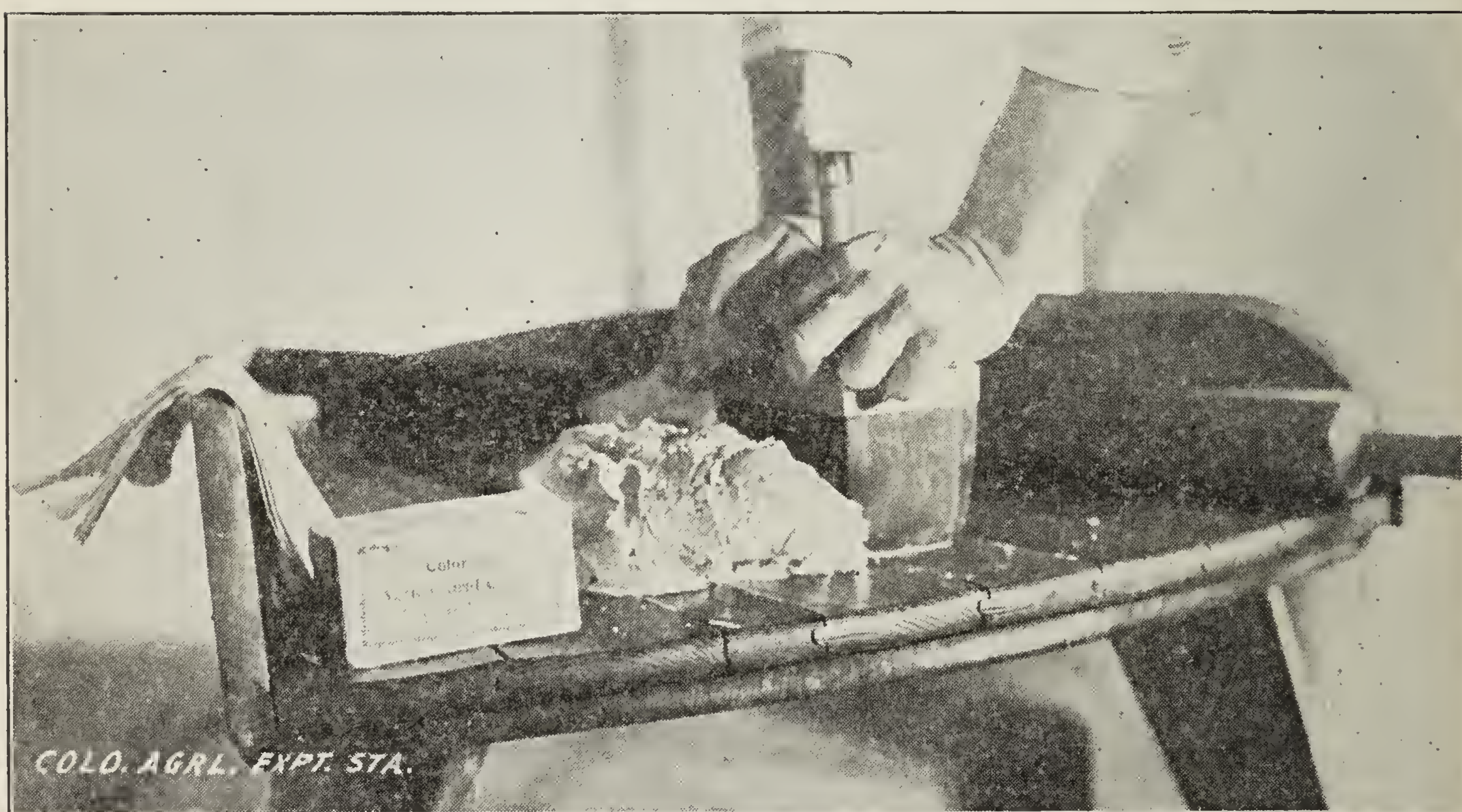

Fig. 8—Printing Worked Butter in 1-lb. Bricks. Note Parchment Paper Wrapper.

The country roll must be considered a thing of the past. The one pound brick print which stamps the name or brand of the maker in the surface of the butter is one of the most popular types of package. Instead of this, it may be better to put up the plain pound print and wrap it with a printed parchment paper which shows the name of the maker and the brand or quality on the outside.

WHY DO I HAVE TO CHURN SO LONG?

1.—The cream should be churned at a temperature of 52° to 60° F. depending on the time of year and the room temperature.

In winter this temperature may run from 57° to 60°, especially if the room in which the churning is done is cool. In summer the temperature should be somewhat cooler, 52° to 57°, especially if the room is warm. If the cream is too cold, it will foam and expand, and sometimes the churn will get too full. When this takes place little can be done, except to allow the cream to stand for sometime, or to warm it gradually four or five degrees before starting to churn again. There is less danger of the cream foaming in revolving churns, such as the barrel churn, than there is with the dash churn, or almost any other class of churns.

2.—The cream may be too old. It should be churned at least twice per week, even in winter.

3.—The cream may not be perfectly ripened. (See "Ripening the Cream").

4.—The individual cows of the dairy may have been milked for a long period without new cows having been added to the herd. The butter fat globules become smaller as the period of lactation advances. The smaller the fat globules become, the longer it is necessary to churn.

5.—When cows are taken off grass and fed dry feed, it often has the effect of making it necessary to churn longer. This may be overcome, somewhat, by feeding succulent feeds, such as silage and roots.

6.—Often the butter will collect in the churn in very fine grains, and further churning seems to do but very little good. Under these conditions, the butter can usually be made to gather by diluting the cream with a small amount of water at the churning temperature. It may also be overcome by adding a handful of salt to the cream in the churn. The solution of the salt affects the viscosity of the cream in such a way as to hasten the formation of butter fat globules.

SUMMARY.

Good butter can be made from good cream only.

The kitchen is not a good room in which to ripen and churn the cream.

The dairy should be arranged so that all water which is pumped for live stock has to pass through a cement tank and out through an overflow pipe into the watering trough or supply tank.

The cows should be kept and milked under sanitary conditions.

The milk should not be allowed to stand in the stable longer than is absolutely necessary.

Poor feed, weeds, and poor water will give the milk and butter a bad flavor.

Of the different methods of skimming milk, the hand separator is best; deep setting, second; shallow pan method, third, and water dilution, fourth.

Do not add warm cream to cold cream. Keep the cream thoroughly stirred, especially while it is being ripened.

The process of ripening, largely controls the quality of the butter, therefore it must be considered as the most important step in farm butter making

The barrel churn is a very good farm churn.

From 25 to 40 minutes is about the proper length of time to churn.

Strain all cream into the churn.

To properly color butter, add the coloring to the cream in the churn just before starting to churn.

Stop churning when the butter fat granules become the size of a grain of wheat.

It pays to wash the butter.

Too much working will spoil the grain of the butter and make it salvy; while leaving too much water in it will tend to spoil its keeping qualities.

The good butter maker will place his name and brand on his product.

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POULTRY RAISING

BY

W. E. VAPLON

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FORT COLLINS, COLORADO

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POULTRY RAISING

By W. E. VAPLON

The call for information relative to conditions for successful poultry raising in Colorado has become so great that it seems necessary to issue a bulletin of general information which can be sent in answer to inquiries.

The information here given is not the result of experimentation on the College farm, but of several months of investigation reaching to all parts of our State among expert poultrymen, added to the experience of fifteen years' work with poultry in Colorado by the writer.

While we hope this bulletin will be an encouragement to those expecting to raise poultry on a commercial scale, we also hope that it may disillusionize some who are being carried away by fables of immense profits derived by using get-rich-quick systems. Enthusiasm is a splendid factor in poultry raising, but should be tempered with knowledge.

LOCATION OF THE POULTRY FARM.

In discussing the matter of choosing a location for a poultry farm, we are not considering the farmer who is already established on his land, and to whom the hen is only a side issue, but rather the man or woman who is intending to make poultry raising or egg production the means of livelihood. Success may, and often does depend upon location, and once decided upon, a change is not easily made. In the choice of a location the following factors should be carefully considered;

Nearness to market.
Character of soil.
Water supply.
Convenience.
Cost of land.

Nearness to Market.—To produce large numbers of eggs is only half of the poultryman's problem, he must be able to market his products cheaply at a good average price to make a profit, hence nearness to market, or good transportation facilities, are important considerations. The Colorado poultryman is very fortunate as to markets, as it is doubtful if there is a community in the State which furnishes its own poultry products for the entire year. Our mining towns, health resorts and large cities are entirely dependent upon outside sources for their supply. About four millions of dollars' worth of poultry products are shipped into Colorado annually, and every dollars' worth should be produced at home. This means that practically all the output of our silver mines goes to neighboring states for poultry products.

Character of the Soil.—While it is true that poultry will do well on any of our soils, it is also true that soils best adapted to general farm crops give best results to the poultryman. The soil should be porous enough to dry off quickly after a rain, but heavy enough to produce good crops of vegetables, alfalfa, grain, berries or any crop desired, these crops to be used for the poultry, or as added sources of income. This character of soil can be kept cultivated with less labor than heavy clay soil, thus insuring clean, sweet range for the fowls. While it may be true that grain can be bought as cheaply as it can be raised, we believe that it would be advisable to grow some of the grain used if possible, if only for the added value of the straw thus produced. We find that our poultrymen are inclined to be rather chary in the matter of litter for their fowls, as one will naturally be where straw is as expensive as it is in some portions of our State. Especially if the land is level should it be somewhat sandy, as heavy clay soil, when frequently wet, soon becomes filthy by reason of becoming packed.

A south slope is ideal on account of drainage and sunny exposure. A north slope is undesirable and wet land should never be considered.

Water Supply.—No other water system can equal a living stream or spring, and if the fowls can help themselves at will, so much the better for them and for their keeper also. Every device or convenience that lessens labor, especially if it costs little or nothing, means so much more profit, and carrying water to a large number of fowls is certainly very expensive by reason of the time and labor consumed. Where water is furnished, cleanliness should be carefully observed. Galvanized iron or stoneware drinking vessels are preferable. Wooden troughs are objectionable because they furnish lodgment for disease germs. The water dishes should be kept clean, and be frequently replenished with fresh water. During warm weather the water should be kept in a shady place to keep it as cool as possible.

Convenient Arrangement.—In all the work of selecting a location, building, fencing, etc., the matter of convenience should never be lost sight of. The relation of each building to all the others, to the roads and highways, and to the residence, should be very carefully considered. Convenience means a saving of time and labor, which means added profits. The usual way of building each new poultry house in the most convenient place left vacant, without reference to those that may follow, will mean many unnecessary steps, discomfort and dissatisfaction. Lay out your plant as though you expected at some future time to have your entire farm, whether large or small, devoted to poultry. Whether you expand to such proportions or not, if you have planned wisely, you will be saved much annoyance and labor and your work will be better done.

Cost of Land.—How much to pay for land must depend largely upon the object in mind in engaging in poultry raising.

If the intention is to supply both poultry and eggs to the consumer, thus necessitating weekly or semi-weekly trips, it would be advisable to pay more for land in order to get nearer to market, and use less acreage. Time is money, and long drives take time. On the other hand if the intention is to wholesale the products, and make eggs the primary object, or perhaps to employ the colony system of housing, it would be advisable to buy cheaper land farther from market and ship the products by train. With daily mails, telephones and fast trains, one can easily keep in touch with the markets; and while the prices received would be less than in retailing, the cost of production and delivery would also be less, and the net profit would perhaps be about the same.

BREEDS.

We have no space to take up the history of our various breeds. We wish to aid the beginner to choose the right breed of fowls for his or her special purpose, and from a commercial standpoint the choice necessarily falls upon the so-called "general-purpose" fowls, commonly classified as the American breeds, or upon the so-called "egg breeds"—the Mediterraneans and other smaller fowls.

General Purpose Breeds.—Under this head will come the different varieties of Plymouth Rocks, the Wyandottes, the Rhode Island Reds, and the Orpingtons. These breeds are spoken of as "general purpose" because they answer the call for a fowl which will give the owner an early broiler, a plump, good-sized roaster, and also a goodly number of eggs in the course of a year. Where the intention is to furnish both eggs and fowls for the market, and especially where one can sell directly to the consumer, no mistake can be made in selecting any variety of any of these breeds. Perhaps the variety chosen should be the one most nearly pleasing the fancy of the individual.

Egg Breeds.—Almost invariably where "eggs for the market" is the principal object of the poultryman, one of the smaller breeds is chosen, and usually the Single Comb White Leghorn is the variety. Often where the object is "eggs and broilers" the same variety is chosen, as the chicks come to broiler size, one to one and a half pounds, nearly as quickly as the larger breeds.

For roasters they are found wanting, nor do we believe it will pay to raise any chicken to roaster size in Colorado until our markets will pay as much per pound for a roaster as for a broiler. As it is now, a broiler worth fifty cents will bring no more if kept to twice the size and weight at an added expense and risk, and sold as a roaster. Our poultry raisers are mostly to blame for this, as no attempt is made to finish their products nor to educate the consumer's taste to the toothsomeness of a fine, plump, specially fattened roaster.

Other varieties of Leghorns, the Brown and Buff especially, are quite popular in certain localities and furnish the same white egg and yellow carcass as the White. The Minorcas and Black Spanish, Anconas, Hamburgs, Polish, and many others might be mentioned as belonging to this class or type, but on a large scale from a commercial standpoint, a beginner had better stick to the better known and more popular varieties.

Meat Breeds.—The feather-legged Asiatics, the Langshans, Cochins, and Brahmas, weighing when mature seven to twelve pounds, are generally classed under this head. In the East, where large roasters and capons are in demand at certain seasons at good prices, these varieties are profitably raised for their flesh, but the reason we gave in the preceding paragraph for not raising poultry in our state for the flesh, will bar these larger breeds for the present from our commercial poultry farms.

Choosing a Breed.—Until our people wake up to the great possibilities of poultry keeping in Colorado, the advantages of soil, sunshine, foods and markets, that we possess; and until each community produces more than it consumes, and has a considerable amount to send out, the matter of choosing a breed is very much a matter of personal preference; but when Colorado as a State produces eggs and poultry for export, we must make choice of a breed or variety that will produce a uniform product in order to get the best prices.

FEEDING.

A hen craves and seeks a variety of food, and must have it to be healthy and profitable. If the hen has free-range, grain is all that need be provided during the summer, as she can find sufficient vegetable and animal foods. In the winter, and also if confined in summer, everything must be provided. The nearer we can come to providing just the right proportion of these foods, the nearer we come to an economical and balanced ration.

Hopper Feeding.—It woud be easy to provide a balanced ration by giving her free access to hoppers containing all these different foods, but we must not forget the matter of exercise. On free range, a hen will seldom overeat of grain, even if it is kept before her all the time. Hunting worms, bugs, grasshoppers, etc. affords her the necessary exercise to keep her in good condition; but in close confinement, especially in cold weather, exercise should be provided as carefully as food. Confinement does not hurt the hen, it is really much better during cold and stormy weather than freedom, but she must have something to do. Every inch of the floor space should be clear for her use, covered deep with straw or other clean litter, and all grains should be scattered in this to induce scratching. A busy hen is a healthy hen, and only a healthy hen is profitable.

Grains.—All grains are good, but a steady diet of any one grain is neither good nor economical. Where milo and Indian corn can be most successfully grown, these can be made the principal grain feed, but a hopper of dry bran kept before the fowls all the time and occasionally a feed of wheat or oats, even if comparatively high in price, will be found beneficial and economical. Cooked beans and cracked peas are a splendid addition to the grains and are cheaply grown. In most sections of Colorado, however, wheat, corn and oats will be found cheap enough to use largely, and a poultryman will find that it will pay well to lay in a winter's supply of wheat and oats at threshing time, as the price usually advances twenty-five per cent. or more later in the season.

Animal Food.—Something should be provided to take the place of the worms and insects so relished by the hen on free range. Green bone and meat scraps from the butcher, and blood meal from the packing house, the flesh and bones of any farm animal, all are rich in those elements necessary for growth and for egg production. An old cow, no longer profitable for milk production, may be worth more as egg material than for beef, and a horse worn out or crippled will make the finest addition to the grains: Fresh cut bone and beef scraps can usually be procured at a fair price, but where meat is not easily obtained and the prepared foods are expensive, milk in some form will be found to be a satisfactory substitute.

Green Foods.—During the winter if the fowls are confined, we are apt to overfeed with the grains, and under feed with the more succulent vegetable foods. Alfalfa leaves, either dry or steamed, make as good a green food as we can furnish. So good is it, that eastern poultrymen are paying as high as $65 per ton for cut alfalfa, which is not as good as the leaves, as all the hay is used in making it. Any of the root crops, sugar or stock beets, turnips or carrots, cabbage, potatoes, onions, waste apples, would be equally welcome and beneficial to the fowls.

It pays to keep a supply of grit, oyster shell and charcoal before the fowls. The more you can coax your laying hen to eat and assimilate, the more material will she have to turn into eggs. Her body must be nourished and material supplied for eggs. To provide for both purposes during cold weather means grinding up a great deal of food. The grit helps to do this and the oyster shell furnishes material for the egg shell. Charcoal furnishes no nourishment but promotes digestion, and is a bowel corrective.

Nutritive Ratio.—A poultryman should know the approximate food value of his feeding stuffs in order to supply the necessary nutrients at the least cost. No one has yet proven the superior value of wet or dry mash, and whether or not you keep a hopper of dry, ground grains before your fowls, they will occasionally relish a moist, steamed mash of vegetables and ground grain, seasoned as you would like it for yourself. Let the morning meal in winter be cracked grain of some kind in the litter, and feed the mash either at noon or in the evening, and never more than they will clean up. We have as yet found nothing more gratifying to our fowls for supper than corn, either whole or cracked, and this should be fed in clean straw, or in such a manner that the fowls must use some energy in digging it out. When you find your hens becoming anxious for their meals is the time to feed rather than at some fixed hour.

Feeding Chicks.—What we have said about feeding fowls can be applied to the chicks, when they get hungry do not withhold food because a certain time has not elapsed. Some of the brood will eat very heartily, some not at all and a little prepared chick feed, rolled oats, bread crumbs moistened with milk, or a hard boiled egg, will certainly do no hurt to the hungry chick. It may be possible to raise them without water, as some advocate, but we cannot understand how anyone who has ever seen the little fellows pile into a water dish can withold this from them; so provide cool, clean water and milk in any form in clean dishes. What applies to the hen applies also to the chickens, variety and plenty with exercise. For a few days the chicks should be fed regularly, after that much time and labor may be saved by having plenty of cracked grain in fine litter (alfalfa leaves are good) where the chicks can get it at any time.

Bear in mind in poultry raising that cleanliness is one of the necessary factors for success. Cleanliness of buildings and coops means freedom from vermin. Cleanliness of yards and runs will be a more or less difficult matter depending upon how your plant has been arranged and upon your methods of housing and yarding. When many fowls and chicks are kept on a small acreage, frequent turning up of fresh earth is essential to cleanliness. To do this by hand is a very difficult job, so have the yards and runs of such size and shape that a horse can be used.

Cleanliness of water dishes, food troughs and nest boxes is also important. Get the habit of cleanliness and you need not fear poultry diseases.

INCUBATION.

The beginner can profitably follow both methods of incubation, the hen and the incubator. The production of strong, thrifty chicks depends upon other factors than the broody hen or the make of incubator used. As long as we follow the common practice of helping the chicks from the shell when they do not want to be hatched, compelling them to live by the use of flannels and soothing syrup when they wish to die, calling in the doctor whenever the growing chick or the hen has the colic, using roup and cholera and all the other "cures"; just so long will we have eggs of weak fertility and the same incubation difficulties.

Hatching with Incubators.—The beginner should follow closely the instructions sent with the machine he is using. It will be time enough to disregard the rules when experience has proven something else better. There are many different makes proving good in our state and we would advise buying the machine doing well in your own community. Do not hatch more chicks than you can well care for, but hatch your season's crop in as short a time as possible. To do this where many chicks are wanted will require large incubator capacity, but it will be found advisable not to prolong the hatching season unless broilers are turned off regularly. In this way the broods will be larger and fewer, the chicks will be of more uniform size, therefore more thrifty, and the poultryman will be able to devote more time to other work and thereby lessen the cost of labor.

Hatching with Hens.—The relative merits and advantages of natural and artifical incubation would not be altered by our discussion. Each method has advantages under certain conditions, and some poultrymen under their own peculiar conditions succeed with one method where failure results from trying the other.

Early in the season, when few hens are broody, the incubator will be found necessary to produce early chicks; later the hens will give good results if given good care.

Where to Set.—One of our poultrymen, for over thirty years raising poultry in Colorado, builds his nests tier upon tier along the wall of a small room. Each hen has a nest about a foot square and is fastened in. Every day at a certain time the attendant lifts out a few hens to feed, drink and exercise. When they are ready to return they are carefully lifted in and others are released for a time. To be certain that each hen is returned to her own nest she is banded with a number that corresponds with her nest number. While this means considerable work, this breeder claims it pays as he has very little trouble with broken eggs, restless hens, etc., and has uniformly good hatches. A row of nests on the floor of an isolated room or building with the center of the floor left free and covered with loose dirt for the use of the hens, is a common and good way of caring for the setting hens. Nests should be about fourteen inches square, ten or twelve inches high, and covered so the hens cannot fight each other when on the eggs. The hen should be allowed to walk into the nest rather than jump down from a height, and loose dirt covered with a little straw or chaff should be placed in the bottom. Remove the setting hen after dark and try her with a few eggs before giving her those for hatching; fasten her in securely; in the morning lift her out to eat and drink and fasten her in until the second morning; then give her twelve to fifteen eggs and see that she has plenty of fresh water and food, preferably corn. She will probably return to her own nest now and need not be fastened in. Besides a dusting place for the hen she should be thoroughly dusted with prepared lice powder during her time on the nest, but care should be taken not to use too much powder, just a light sprinkling well into the feathers.

Hens, like incubators, should not be disturbed at time of hatching. Some hens will kill their chicks and such should be removed and the eggs given to another if possible. It will not be found profitable to help chicks out of the shell. The breeding stock should have enough vigor to produce eggs that will hatch good lively chicks on time.

Brooders.—The fireless brooder seems very successful and popular with our poultrymen, especially where chicks are kept in heated brooders the first two or three weeks, and are then placed in fireless brooders. This plan works very well where a comparatively small number of chicks are raised, but we would advise beginners to provide heated brooders, and only transfer the chicks to the fireless brooder when large enough to readily go in and out of their own free will, and then have the brooder in a good comfortable building. We believe there will be very little bowel trouble in the little chicks if they are never chilled, and we know the fireless brooder is responsible for many deaths among our chicks on account of chilling. When many chicks are raised a stove heating system should be installed to lessen expense and labor.

Rearing Chicks With Hens.—We do not like to give hens with chicks unlimited range. Certainly for a week or two after the hatch the hen should be confined to her coop or a small run attached to the coop to give the chicks time to gain strength. The chicks can be given their liberty as they will not stray far away from the mother hen. A floor or a platform of boards on which a bottomless coop is placed is necessary on account of heavy showers which are at any time possible, and which often flood the coops and drown the chicks where no floors are provided. A packing case covered with roofing paper, makes a cheap, comfortable coop. Where straw is scarce dry sifted earth makes a good covering for the floors and should be often replaced, daily after the chicks are two or three weeks old. When two hens hatch at the same time all the chicks can be given to one hen and the other hen can be re-set if she is in good condition. We have found that hens confined to coops give their chicks more brooding, are soon contented with their narrow quarters, and will raise more chicks than when given full liberty.

MARKETING.

Higher cost of living seems to be troubling a great many people just now, yet they are more willing than ever to pay an extra price for quality. Produce a good egg, market only eggs of uniform color and size, send clean eggs in clean, attractive carriers, and get them to the market during the summer at least twice a week.

Marketing Chicks.—Be careful in preparing your chicks and fowls for market. Have them uniform in size and color, the broilers one and a half to two pounds, and the roasters four to five pounds in weight. It pays to give both old and young stock a little special preparation before shipping. Keep in close quarters without exercise for a week before selling, feeding mashes of fattening foods. In supplying a family trade with dressed poultry, it will undoubtedly pay to crate and fatten for a better finish and appearance of the carcass as the extra quality means a better price. The Denver market prefers the yellow skinned fowls, alive.

RECORDS AND ACCOUNTS.

Daily laying records should be carefully kept and if the hens are not doing their duty, the cause should be found and the remedy applied. Perhaps the feeding method can be bettered, or more likely the drones have not all been discovered. Incubation records which will show the fertility of different flocks or pens will help to greater success. Breeding, mortality and feeding records will be found very instructive and helpful to better results.

Poultry raising means dollars and cents, debit and credit, and every poultryman should know his exact financial position at any time. By means of carefully kept accounts of receipts and expenditures, he will be able to know what branch of his business is most proiftable or is not paying; where leaks and wastes occur, what branch of his business can be profitably enlarged, and which might better be curtailed.

POULTRY LITERATURE.

Too much value cannot be placed upon good poultry literature, and there is much to be obtained. However, one must be able to read between the lines of much that we find in our poultry journals, as the writers often have an "ax to grind", eggs to sell from the hen that laid 333 eggs in a year, a system or a method.

POULTRY SECRETS.

There are no mysterious poultry secrets which you need to buy in order to succeed in the work. All the so-called "secrets" and "processes" can be procured through experiment stations and government bulletins. It is not the breed, nor the feed, nor the house, nor the care; not any one or two of these factors, but all carefully applied that are necessary to success.

SELECTION AND CULLING.

Continued selection of the best, elimination of the weaklings, eternal cleanliness, comforable shelter, plenty of fresh air, sunshine and exercise, a variety of good nourishing, succulent foods; all thoroughly mixed with love for the work and faith in the hen, seasoned with common sense and business ability; these are the great secrets of success with poultry.

POULTRY BUILDINGS.

We might revive one of Solomon's very wise sayings and make it read: "Of the making of poultry houses there is no end," and perhaps add, "There is nothing new under the sun." Old ideas of poultry house construction are about as regularly revived as styles in hats, answer the demand of a certain class of poultrymen and are condemned by others. Limited space forbids our going into detailed instructions for building. We are giving the matter much thought and attention at the present time, and are trying out five distinct types that have been adopted by successful poultrymen, which are considered about right, and intend to build some other models for comparison. All are good, each has some advantages and some disadvantages. Location, conditions, circumstances, amount of land, price of materials, many factors must necessarily govern the type and size of the buildings.

Reasons for Housing.—The object of the house is to provide shelter for the fowls, and should be wind and rain proof, a single thickness of drop-siding or sheathing with building paper, being sufficient in our climate. Where lumber is used the best is cheapest, and we prefer the four-inch drop siding. Good sheathing, covered or battened will cost as much or more than drop siding, and will never make as tight a wall. Shiplap is not satisfactory as it soon dries out and leaves a crack. Whatever the materials used, have them good. If you must economize do it in the size of the building rather than in the quality of the material. Have your buildings face south, one third or one half of the south end covered with burlap or muslin curtain to be raised whenever the weather will permit, which will be nearly every day in the year. Some glass in the front may be convenient but is not necessary. The burlap curtain will furnish plenty of fresh air when closed, providing all the necessary ventilation. The door should be either in the east or south, the west and north walls and roof being absolutely tight. We know of quite a number of poultry houses in Colorado facing east or west, but know of no good reason for it, and many against it. You will find no stronger ally in fighting disease and discomfort in your flocks than the sunshine, and the south front, especially in the long house, permits the greatest amount of it. Let it flood the coops and buildings as much as possible.

Comfort and Convenience.—A hen would probably consider a house about three feet high ideal, especially in cold weather, but for the convenience of the caretaker we must build them higher; unnecessary height means a colder and more expensive house, so build as low as possible, consistent with convenience. The farther the roosts are from the open end the better for the fowls—twelve feet is better than less. Make the pen shorter rather than narrower, if you want a certain floor space.

Nests.—Nests placed on the ground outside and against the building, covered with a slanting board to shed the rain, are sometimes very satisfactory. If within the building, they should be above the floor and boxes about fourteen inches square will be found to answer the purpose. They are preferable to expensive lumber nests as they can be destroyed when mites get into them. When trap nests are used, one nest should be provided for each two or three hens, otherwise half the number of nests will be sufficient.

Cost of Building.—It is easy to be extravagant in building. Don't do it. Extravagance and waste are the cause of as many failures as inexperience. Limit the cost of providing house room to sixty dollars for material per hundred hens. It can be done for less, perhaps, but ought not to cost more. A poultryman should be able to do his own building, even if he hires it done. By knowing how, it will be done right and to hire a carpenter for every little job is expensive.

Fixtures.—Have all fixtures such as grit boxes, feed hoppers, water dishes, etc., off the floor. We build our hoppers for grit, charcoal, oyster shell and ground grain, between the 2x4 studding and prefer them to anything we can buy. Have them two feet above the floor so no litter or dirt can get into them. In permanent houses have a platform two feet above the ground across the entire rear of the pens, above which the roosts are placed. This platform catches all the droppings, means less labor in cleaning, and means a clean floor for the hens in bad weather. The water dish can be placed on the edge of this platform.

Roosts.—I see many 2x4 scantlings used for roosts; a 2x2 is better and costs half as much. A round pole is objectionable as it soon splits and the cracks offer a lodging place for mites. Instead of hinging them to the wall, try driving a nail through the 1x2 used to support the roosts, to the upright studding. Your roosts can then be swung up out of the way when cleaning. Have the roosts about ten inches above the platform, and after cleaning, dash a shovel of litter or dirt over the platform which will prevent the droppings sticking and make cleaning easier.

DISEASES.

The Veterinary Department of our College, under the direction of Doctors Glover and Kaupp, is working on poultry diseases at the present time. When their investigations are completed, a bulletin will be published which will be sent to all who send a request for one. Later we expect to publish separate bulletins on buildings, feeding, incubation, etc., to give the results of our experimentations along these lines. In the meantime we will gladly answer any specific questions as far as possible.

RECENT BULLETINS.

The following recent bulletins of the Experiment Station are still available and will be sent, while the supply lasts, to anyone sending his name and address to the experiment station, giving the name or number of the bulletins he especially desires.

No.

43. Colorado Lepidotera. A Few Species of Deltocephalus and Athysauns from Colorado. A list of Original Types etc. in Colorado.
83. Irrigation Waters and Their Effects.
84. An Apricot Blight.
97. Feeding Steers on Sugar Beet Pulp, Alfalfa Hay and Farm Grains.
100. The Flora of Colorado.
108. Development of the Rocky Ford Cantaloupe Industry.
110. Alfalfa—Results Obtained at the Colorado Experiment Station.
122. Fruit Growers' Associations.
124. Colorado Fodders—An Examination into Their Composition and Comparative Values.
125. Colorado Fodders—A Study of Comparative Values Based on Bulletin 124.
127. Climate of Colorado—Temperature—21 Years Record at Fort Collins.
131. Arsenical Poisoning of Fruit Trees.
135. The Australian Salt Bush—Its Composition and Digestibility.
136. Dewberry Growing.
138. Some Bacterial Diseases of Plants.
139. Pruning Mature Fruit Trees.
141. Grape Growing.
142. Tillage, Fertilizers and Shade Crops for Orchards.
143. Cabbage Growing.
144. Celery Growing in Colorado.
146. Raising Hogs in Colorado.
147. Top-Working Fruit Trees.
151. Ration Experiment With Lambs—Self-Feeders for Hay.
149. Carrying Range Steers Through the Winter—Sugar Beets for Fattening Steers.

152. Two Common Orchard Mites—The Brown Mite and the Red Spider.
154. Alfalfa Studies—Third Progress Report.
155. The Fixation of Nitrogen in Some Colorado Soils.
156. Butter Making—Clean Milk and Commercial Starters.
157. Arsenical Poisoning of Fruit Trees.
158. A Bacterial Disease of Alfalfa.
159. A New Alfalfa Disease—Stem Blight.
160. Nitrates in the Soil—An Explanation of so-called "Black Alkali" or "Brown Spots."
161. Cement and Concrete Fence Posts.
162. Rabies.
163. Farm Butter Making.
165. Ration Experiment With Swine.
166. Information Concerning the Carriage Horse Breeding Experiment.

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BY

W. L. CARLYLE *and* G. E. MORTON

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J. E. PAYNE, M. S.	Field Agent, Plains
J. W. ADAMS, B. S., Cheyenne Wells	Supt. Plains Substation
D. H. MATHIAS, B. S.	Assistant Irrigation Investigations
J. C. SUMMERS, B. S.	Assistant Chemist

RATION EXPERIMENTS WITH SWINE, 1906--1908

W. L. CARLYLE *and* G. E. MORTON

INTRODUCTION

This bulletin records two experiments, the first conducted during the winter of 1906-07, and the second during the winter of 1907-08. Both experiments were planned to discover what protein feeds would prove most economical when fed with barley and with corn. These two grains are the most available and commonly used of any of the feeds used in this State, with the possible exception of field peas. But neither corn nor barley is an economical feed for hogs when fed alone. This is now recognized in the corn belt, after much experimental work by the various experiment stations. Our problem, therefore, is to find what available feeds may be used in this State to best advantage for supplementing these grains.

THE FEEDS SELECTED.

Alfalfa hay, wheat, field peas, wheat shorts, and packing house tankage were the feeds selected because of their availability throughout the State. Wheat shorts consist of the finer particles of bran and a portion of the kernel within the bran. They contain more starch and less crude fibre than bran, and are less bulky. Selected tankage, a packing house product, is made from residue meat scraps, and has a large percentage of protein.

1906--1907 EXPERIMENTS

Ten lots of ten head each were fed. The pigs averaged from 66 to 70 pounds each when they were put on feed. They were Poland China grades, about six or seven months old, bought in the country surrounding Fort Collins. They were very small for their age but of good enough breeding to show fair returns for feed. They were uniform in breeding, age and condition. At the close of thirteen weeks feeding, the lots ranged from an average weight of 154 pounds per head to 200 pounds per head.

The following table gives the results:

TABLE A.

FEED FOR GAIN AND COST OF GAIN, 1906-07

(Ten head in pen.)

PEN NO.	RATION	Gain per Head 13 Weeks. Lbs.	POUNDS FEED FOR 100 POUNDS GAIN				*Cost of Feed for 100 lbs. of Gain	Standing of Lots
			Grain	Hay	Tankage	Beets		
I.	Barley; alfalfa hay at pleasure	107	508	75	...	...	$5.27	5 and 6
II.	Corn; alfalfa hay at pleasure	115	508	76	...	...	$5.27	
III.	Barley and corn, equal parts; alfalfa hay at pleasure	131	435	67	...	...	$4.52	1
IV.	Barley one part; wheat one part	115	476	..	...	...	$5.95	7
V.	Barley one part; peas one part	111	482	..	...	...	$7.23	10
VI.	Barley one part; shorts one part	117	457	..	...	...	$4.57	2
VII.	Barley ten parts; tankage one part	130	405	..	46	...	$4.97	4
VIII.	Corn ten parts; tankage one part	142	386	..	42	...	$4.70	3
IX.	Barley; beets at pleasure	94	475	..	...	478	$5.95	8
X.	Corn; beets at pleasure	86	544	..	...	498	$6.69	9

* Note—Prices of feeds figured as follows:
Grain, one cent per pound, except wheat 1½ cent and peas 2 cents.
Tankage, at $40.00 per ton.
Beets, at $5.00 per ton.
Alfalfa, at $5.00 per ton.

POUNDS FEED FOR ONE HUNDRED POUNDS GAIN.

The number of pounds of feed required to produce one hundred pounds of gain in live weight is the point of chief interest to the feeder, and it is probably the best comparative method of stating our results from the experiment. So we depend upon this column chiefly for our conclusions.

SUGAR BEETS WITH GRAIN.

Lots IX and X were fed sugar beets with barley and with corn respectively. It will be noticed that each of these lots consumed about as much grain for each one hundred pounds of gain as did the lots fed grain alone, and in addition they consumed about as much beets as grain, making the ration very expensive. Practically no returns were secured from the beets. It is true that these lots ate about one-fifth less grain during the entire period of feeding than the lots not fed beets; but they also gained very much less in live weight as the foregoing Table "A" shows. They gained only 94 and 86 pounds per head in thirteen weeks, whereas the other lots gained 107 to 142 pounds per head in the same length of time.

And it must be remembered that the beets were not forced upon the pigs by withholding the grain. The beets were supplied as the pigs desired them. Evidently they relished the succulent feed. and ate enough of it so that they had not the capacity for a quantity of grain sufficient to produce a large gain in live weight.

These results with beets were so marked that it was not thought necessary to duplicate this portion of the experiment another season. And we believe that the conclusion is warranted that for light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute about half the ration by weight—in this instance all the beets which the pigs would voluntarily eat.

ALFALFA HAY WITH GRAIN.

Lots I, II and III were fed alfalfa hay and grain. Of these, lot III, fed equal parts of barley and corn, did the best, making the heaviest gains, and requiring the least amount of feed for one hundred pounds gain. This lot, in fact, made the best showing of any in the experiment, and figuring the price of the various feeds upon any reasonable basis, the cost of producing pork with this ration of corn, barley, and alfalfa hay, was less than with any other ration used in the experiment.

Lot I, fed barley and alfalfa hay; and lot II, fed corn and alfalfa hay, came out almost equally well, although lot II showed slightly greater gains than lot I. Neither barley and alfalfa hay nor corn and alfalfa hay gave such good results as corn, barley and alfalfa hay, being surpassed in amount of gain produced and in economy of ration, by several rations in the experiment.

COST OF FEED AND STANDING OF LOTS.

In the foregoing Table "A" a column is given showing the cost of the rations with the feeds figured at given prices. One cent per pound will approximate the market prices of barley, corn, and shorts, and is a convenient round number from which an advance or lowering of prices may easily be computed. Peas and wheat are ordinarily higher in price and therefore are figured at two cents and one and a half cents respectively. In looking down the column showing the standing of lots, a series of numbers are found showing the relative order of the rations according to their economy. This column is given only for the purpose of facilitating the finding of the most economical rations.

BARLEY AND WHEAT SHORTS.

It will be seen that after the barley, corn and alfalfa ration, the barley and shorts ration, half and half, was the most economical. There was so little difference, however, in the economy of these two rations that one cannot say either proved better than the other. The barley, corn and alfalfa lot required 435 pounds of grain and 67 pounds of hay for 100 pounds gain; while the barley and shorts lot required 457 pounds of grain for 100 pounds gain. Both rations were very satisfactory.

GRAIN AND TANKAGE.

Lots VII and VIII were fed barley and tankage, and corn and tankage respectively, ten pounds of grain being fed for each pound of tankage. The corn and tankage produced slightly better results than barley and tankage, and both rations were good, coming next to lots III and VI in point of economy.

BARLEY AND WHEAT, EQUAL PARTS.

This ration gave good gains, and required only 476 pounds of feed for 100 pounds gain in live weight. But with wheat at any ordinary figure, the cost of the ration is high. If cheap wheat can be gotten—that is, wheat at the price of corn or barley, the wheat and barley ration will prove a satisfactory one. Barley offsets the tendency towards production of soft and flabby flesh which wheat favors, and the two together give good gains.

BARLEY AND PEAS, EQUAL PARTS.

This ration is not equal in production of gain to any of the other rations except the beet rations, and one alfalfa hay ration. Also, the amount of feed required for gain was 482 pounds—considerably greater than that required by the other rations in which grain or grain by products only were fed. And since peas are ordinarily higher in price than corn or the small grains, the ration does not prove economical.

This, of course, does not mean that a ration of barley fed to swine hogging off peas in the field might not prove economical. These results apply only to threshed peas when fed with barley to hogs that are confined to feed yards.

The following Table "B" gives the digestible nutrients required for one hundred pounds of gain in live weight. The nutritive ratio shows the proportion of protein to carbo-hydrates and fat in each ration; for example with Lot I, the nutritive ratio is 7.8; that is, there was one pound of protein to every 7.8 pounds of carbohydrates and fat in the ration.

TABLE B. (See Table F, in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	TOTAL GAIN (Lbs.)	POUNDS OF DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN			NUTRITIVE RATIO
		Protein	Carbo-Hydrates	Ether Extract	
I.	1066	49.51	377.49	9.01	7.8
II.	1145	49.25	366.41	22.18	7.9
III.	1303	42.64	319.42	13.42	7.81
IV.	1153	43.19	328.10	8.08	8.05
V.	1112	62.41	252.43	5.86	4.27
VI.	1168	46.40	273.63	12.65	6.55
VII.	1299	52.19	281.60	12.76	5.98
VIII.	1417	41.78	259.84	21.99	6.40
IX.	940	63.09	690.21	8.98	11.28
X.	863	69.29	741.13	24.36	11.54

1907--1908 EXPERIMENT

Six lots with eight head in each lot were fed during this experiment. They were fed during the same season of the year and were the same class of hogs and of about the same weight as those described in the previous experiment. The experiment lasted fifteen weeks—two weeks longer than the previous winter's experiment. The pigs were of uniform breeding, age, and condition.

The most promising rations, as shown by the previous winter's feeding, were tried again and selected tankage was tried with various grains.

TABLE I.

FEED FOR GAIN AND COST OF GAIN

(Eight pigs in each pen)

PEN NO.	RATION	AV. GAIN PER HEAD, 15 WEEKS. LBS.	POUNDS OF FEED FOR 100 POUNDS GAIN			*COST OF 100 LBS. GAIN	STANDING OF LOTS
			Grain	Tankage	Hay		
1.	Barley three parts, corn three parts, alfalfa hay at pleasure.	116	496	..	56	$5.10	4
2.	Barley three parts, corn three parts, tankage one part	171	338	56	..	$4.50	1
3.	Barley six parts, tankage one part	158	367	61	..	$4.89	3
4.	Corn six parts, tankage one part	164	353	59	..	$4.71	2
5.	Durum wheat six parts, tankage one part	161	360	60	..	$6.60	6
6.	Durum wheat three parts, corn three parts, tankage one part.	173	334	56	..	$5.30	5

* Note—Prices of feed figured as follows:
Corn and barley at one cent per pound.
Wheat at one and one-half cent per pound.
Tankage at $40.00 per ton, (two cents per lb.).
Alfalfa at $5.00 per ton.

DURUM WHEAT, CORN, AND SELECTED TANKAGE.

Lots 5 and 6 were fed rations containing these grains. Lot 5, which received six pounds of durum wheat to every pound of tankage, made a very good gain in weight, and required only about an average amount of feed to produce 100 pounds gain, so that if the prices of these feeds were not considered the ration would be pronounced a good one. Both feeds are expensive, however, and consequently the cost of gain is too high.

Lot 6, fed durum wheat, three pounds, corn, three pounds, and tankage, one pound, made the best gains of any lot, gaining an average of eleven and one-half pounds per head each week. These required less feed for gain than any of the other lots. If durum wheat can be obtained at the price of corn, this ration will prove very economical.

BARLEY, CORN, ALFALFA HAY.

This ration proved very satisfactory the previous winter, but did not show quite so great economy in the present experiment. The amount of feed required for gain was somewhat greater than the previous winter, and the gains made were less than those made by the other lots in this experiment. This might be accounted for by a difference in the quality of the hays. At any rate, in this instance, the barley, corn, hay ration proved more costly than barley and tankage; corn and tankage; or barley, corn and tankage; although at a cost of $5.10 for each hundred pounds gain, it is still a very good ration.

BARLEY, CORN AND SELECTED TANKAGE.

This ration, with the feeds in the proportion of 3 : 3 : 1, gave the best results of any tried in this experiment. The gain made was eleven and two-fifths pounds per head each week. The amount of feed required for gain was only 336 pounds of grain and 56 pounds of tankage, and the cost was $4.50 for each hundred pounds gain. This cost was practically the same as that for the corn, barley, and alfalfa lot and for the barley and shorts lot of the previous year.

CORN AND TANKAGE, AND BARLEY AND TANKAGE.

The corn and tankage ration was not quite as economical as the barley, corn, and tankage; but was slightly better than the barley and tankage, the cost of 100 pounds gain for the three lots being $4.71, $4.50 and $4.89. All three of these rations were satisfactory and economical.

It will be seen from the following table that the tankage and the wheat rations all supplied a large proportion of protein, while the alfalfa ration apparently did not. It is probable, however, that the alfalfa rations actually furnished a larger percentage of protein than the tables show, because the pigs eat only the leaves and finer stems of the hay, while the entire amount of hay is necessarily charged up to them.

TABLE II. (See Table VI in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	Total Gain in 15 Weeks lbs.	DIGESTIBLE NUTRIENTS, POUNDS			Nutritive Ratio
		Protein	Carbo-Hydrates	Ether Extracts	
1.	931	45.86	355.86	15.13	8.1
2.	1368	51.32	231.97	17.33	5.33
3.	1260	55.79	255.89	14.05	5.19
4.	1309	53.55	238.50	22.63	5.47
5.	1286	62.75	251.79	13.77	4.54
6.	1383	54.52	229.93	17.14	4.97

CONCLUSIONS.

Sugar Beets.—For light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute approximately one-half of the ration by weight. Our experience indicates that when such pigs are fed beets at pleasure, they will eat the beets and grain in about equal proportions by weight.

Alfalfa Hay.—Where a good quality of leafy alfalfa hay may be had at reasonable cost, and other protein feeds are difficult to obtain or are high in price, the alfalfa hay may be used to supplement grain feed for fattening pigs. It should not be fed with the grain, but should be put in specially constructed racks where the pigs may go to it at pleasure. Mixed grains, with alfalfa hay will give better results than a single grain with hay as a rule.

Barley and Shorts.—Two home grown feeds that can be secured almost anywhere in the State. They make a first class ration when fed together. The millers of Colorado do not ordinarily separate shorts from bran, but will usually do so upon request, at a price about ten cents per hundred in advance of the price of bran.

Barley and Wheat.—Another home grown combination that gives good results. Where a sufficient yield of durum wheat can be secured on the dry lands of the State, this ration will prove particularly well suited to those regions.

Barley and Peas.—Field peas, threshed, are more expensive than a number of other high protein feeds, so that it is well to confine pea feeding to the hogging off of field peas.

Selected Tankage.—This is a very high protein feed containing over 40% of protein; so that only a small quantity of it is necessary with grain. It proved satisfactory when fed either in the proportion of one-eleventh of the ration, or one-seventh of the ration. With grain at one cent per pound and tankage at two cents per pound, the grain and tankage ration, with the grain forming five-sixths to nine-tenths of the ration, will cost from about $4.50 to $5.25 for each 100 pounds gain upon fattening pigs under two hundred pounds live weight.

What Selected Tankage Is.—The following description of the manufacture of Digester Tankage by Swift & Co., of Chicago, under date of Oct. 3, 1908, gives a good general idea of the methods used in the manufacture of selected tankage for feeding purposes. Such tankage does not contain any part of the animal carcasses condemned because of disease, and if any disease germs should find their way in with foreign matter they would be destroyed by the cooking process with live steam under pressure.

"Digester Tankage is made from small scraps of meat trimmed from residues left in tanks after edible lard and tallow have been extracted from the carcass trimmings, and residues incident to the production of meats for human food purposes. These materials are taken only from animals which have been U. S. Government inspected and passed. This meat is a finished product and is a safe feed, absolutely free from diseased germs.

"In the process of manufacture, the materials mentioned are placed in large tanks which are then sealed and the mass subjected to live steam, usually under a pressure of 40 pounds. The cooking process is timed for four to six hours, depending upon the character of materials handled. When the cooking is completed the steam is turned off and tanks allowed to settle. When the liquid fat is found in a layer at the top it is removed. The residues consist of a watery solution, and at the bottom of the tanks a mixture of small pieces of meat and bone. The liquid is drained off to be dried separately and the solid meat—"The Tankage"—allowed to drain; it is then dried in large steam-heated rotary ovens in which a high temperature is maintained. The dried tankage is ground and put through a mill and screened to the desired fineness. It is then packed in 100-pound sacks ready for shipment.

"Digester Tankage has a very uniform composition, guaranteed 60% Protein, 6% Phosphates, and 8% Fat."

Armour Packing Company, of Kansas City, make the following statements under date of October and November, 1908:

"Our guarantee to the State of Kansas regarding meat meal is as follows:

> 'Made from regular run of good conditioned cattle and sheep offal from which oils and greases have been extracted. Sold under guarantee to contain a minimum of sixty per cent (60%) Protein, but will run as high as sixty-five per cent (65%) in certain lots.'

"This means too only the best of the offal, for what is commonly known as "peck" never goes into such tanks, being kept apart, and the residue of "peck" tanks goes to fertilizer only.

"Recent analyses of our Meat Meal show that in addition to 60% proteids, it contains about 13% fat, and 14.5% ash.

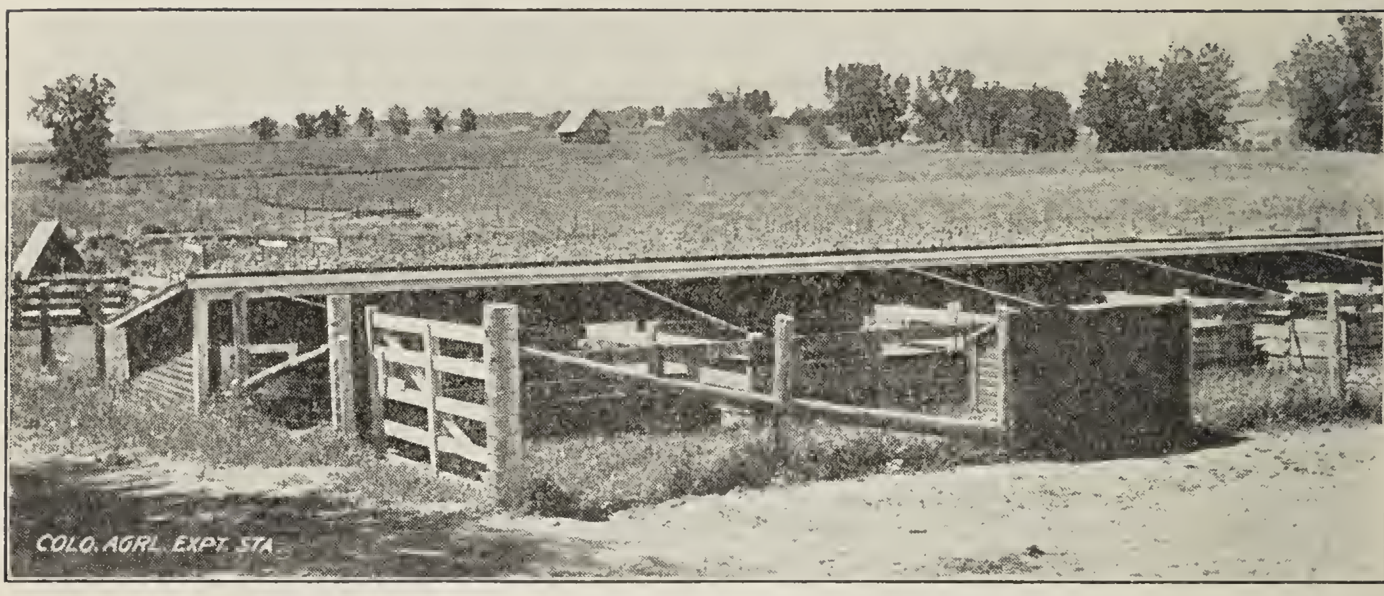
"There is not properly any crude fibre in this, and what foreign matter may get in will not exceed half of one per cent."

The Colorado Packing and Provision Company of Denver, who furnished the selected tankage used in these experiments, have the following to say concerning their product, under date of Oct. 19, 1908:

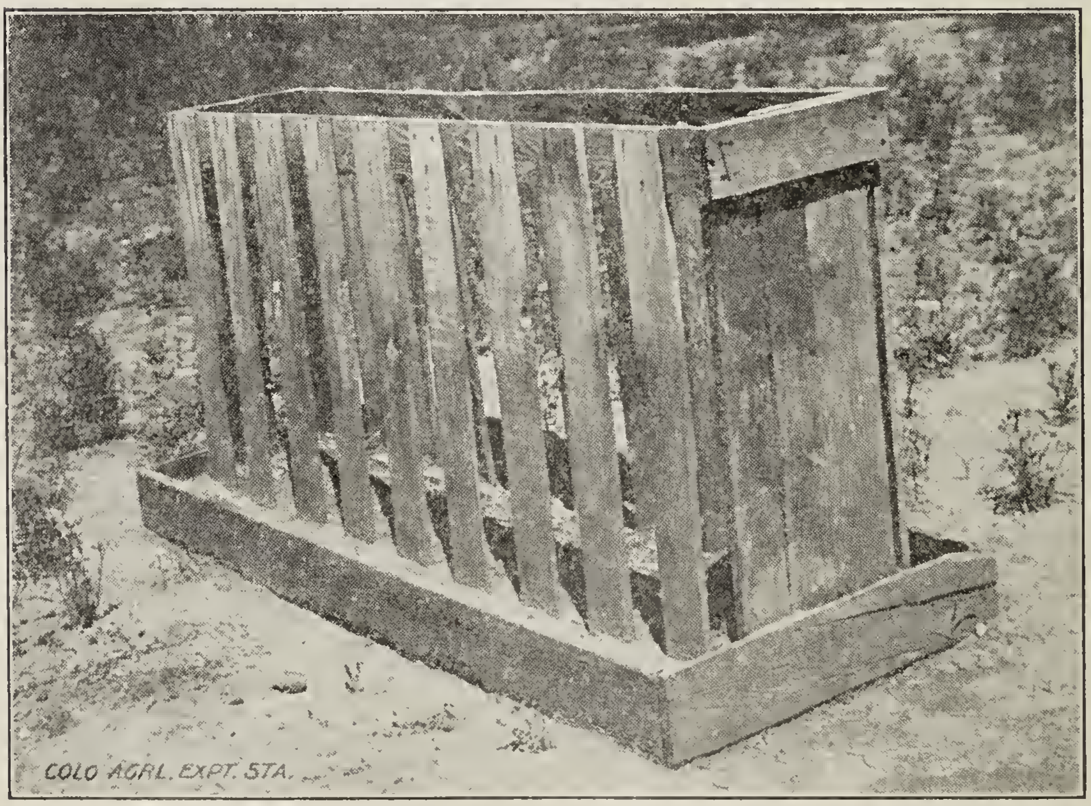
"We will state as near as possible the analysis of our Selected Beef Tankage for stock food:

Water	10%
Protein	55%
Crude Fibre	5%
Free Extract of Nitrogen	7%
Fat	8%
Phosphate of Lime	15%

"This will vary some, as our material is not always uniform, but we will make it as near the above as possible."



SHED AND FEED YARDS USED FOR EXPERIMENTS



RACK FOR FEEDING ALFALFA HAY TO HOGS

APPENDIX

The Tables in the Appendix give the original data of the experiments. The Tables in the body of the bulletin were compiled from these.

WEEKLY DATA, PEN 1. 1906-07

(Ten head in each pen.)

Barley; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Alfalfa Hay
Beginning	838	...	...	...	...
1st week	811	—2.7	—2.7	303	144
2nd week	937	126	12.6	390	90
3rd week	1025	88	8.8	406	54
4th week	1102	77	7.7	395	54
5th week	1156	54	5.4	395	76
6th week	1243	87	8.7	445	20
7th week	1390	147	14.7	473	60
8th week	1479	89	8.9	397	60
9th week	1530	51	5.1	430	60
10th week	1522*	102	10.2	420	60
11th week	1573	51	5.1	450	60
12th week	1694	121	12.1	485	20
13th week	1794	100	10.0	445	40
		1066§	106.6	5434	798

* piggy sow, weight 205 lbs., put out; 95lb barrow put in.
§ 956 lbs. plus 110 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 2. 1906-07

(Ten head in each pen.)

Corn; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Alfalfa Hay
Beginning	669	...	...	...	...
1st week	823	154	15.4	303	144
2nd week	896	73	7.3	384	90
3rd week	995	99	9.9	406	54
4th week	1066	71	7.1	420	54
5th week	1125	59	5.9	420	76
6th week	1202	77	7.7	450	60
7th week	1310	108	10.8	483	60
8th week	1393	83	8.3	467	60
9th week	1477	84	8.4	470	60
10th week	1548	71	7.1	440	60
11th week	1622	74	7.4	530	80
12th week	1737	115	11.5	565	40
13th week	1814	77	7.7	475	40
		1145	114.5	5813	878

WEEKLY DATA, PEN 3. 1906-07

(Ten head in each pen.)

Barley and corn, equal parts, and alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.		
				Barley	Corn	Alfalfa Hay
Beginning	688	...	...	...	...	...
1st week	796	108	10.8	152	152	144
2nd week	894	98	9.8	176	176	90
3rd week	992	98	9.8	190	190	54
4th week	1084	92	9.2	189	210	54
5th week	1145	61	6.1	193	210	76
6th week	1230	85	8.5	248	210	60
7th week	1368	138	13.8	230	230	60
8th week	1474	106	10.6	210	210	60
9th week	1549	75	7.5	240	240	60
10th week	1661	112	11.2	220	240	60
11th week	1737	76	7.6	290	280	80
12th week	1868	131	13.1	260	250	40
13th week	1991	123	12.3	240	250	40
		1303	130.3	2838	2848	878

WEEKLY DATA, PEN 4. 1906-07

(Ten head in each pen.)

Barley and wheat, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Wheat
Beginning	671	...	...	...	...
1st week	788	117	11.7	152	152
2nd week	879	91	9.1	187	187
3rd week	970	91	9.1	192	192
4th week	1034	64	6.4	167	208
5th week	1103	69	6.9	193	210
6th week	1193	90	9.0	241	210
7th week	1313	120	12.0	235	210
8th week	1395	82	8.2	191	210
9th week	1460	65	6.5	239	230
10th week	1544	84	8.4	220	210
11th week	1621	77	7.7	250	260
12th week	1729	108	10.8	240	250
13th week	1824	95	9.5	195	250
		1153	115.3	2702	2779

WEEKLY DATA, PEN 5. 1906-07

(Ten head in each pen.)

Barley and peas, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Peas
Beginning	687	...	...	...	...
1st week	812	125	12.5	140	140
2nd week	879	67	6.7	161	161
3rd week	988	109	10.9	180	180
4th week	1062	74	7.4	166	210
5th week	1121	59	5.9	167	210
6th week	1103*	59	5.9	235	210
7th week	1241	138	13.8	249	210
8th week	1333	92	9.2	210	210
9th week	1402	69	6.9	247	230
10th week	1509	107	10.7	246	240
11th week	1588	79	7.9	240	240
12th week	1686	98	9.8	250	250
13th week	1722	36	3.6	182	182
		1112 §	111.2	2673	2673

* 147 lb. pig taken out; 70 lb. pig put in.
§ 1035 lbs. plus 77 lbs. lost in exchanging pigs.

WEEKLY DATA, PEN 6. 1906-07

(Ten head in each pen.)

Barley and shorts, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Shorts
Beginning	665	...	...	...	...
1st week	772	107	10.7	152	152
2nd week	873	101	10.1	176	176
3rd week	974	101	10.1	180	180
4th week	1049	75	7.5	210	210
5th week	1138	89	8.9	202	210
6th week	1195	57	5.7	203	210
7th week	1322	127	12.7	194	210
8th week	1396	74	7.4	190	210
9th week	1464	68	6.8	249	210
10th week	1582	118	11.8	222	210
11th week	1619	37	3.7	240	250
12th week	1765	146	14.6	220	210
13th week	1833	68	6.8	230	250
		1168	116.8	2668	2688

WEEKLY DATA, PEN 7. 1906-07
(Ten head in each pen.)

Barley and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Tankage
Beginning	688	...	...	...	...
1st week	786	98	9.8	252	28
2nd week	898	112	11.2	324	36
3rd week	1035	137	13.7	400	44.4
4th week	1148	113	11.3	389	47.6
5th week	1188	40	4.0	393	50
6th week	1319	131	13.1	426	50
7th week	1430	111	11.1	511	50
8th week	1533	103	10.3	398	50
9th week	1610	77	7.7	433	50
10th week	1721	111	11.1	400	45
11th week	1768	47	4.7	450	45
12th week	1925	157	15.7	495	50
13th week	1987	62	6.2	395	50
		1299	129.9	5266	596

WEEKLY DATA, PEN 8. 1906-07
(Ten head in each pen.)

Corn and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	686	...	...	...	...
1st week	778	92	9.2	252	28
2nd week	889	111	11.1	324	36
3rd week	1005	116	11.6	400	44.4
4th week	1126	121	12.1	423	47.6
5th week	1190	64	6.4	392	50
6th week	1210*	117	11.7	432	50
7th week	1351	141	14.1	453	50
8th week	1444	93	9.3	362	50
9th week	1516	72	7.2	457	50
10th week	1652	136	13.6	435	45
11th week	1707	55	5.5	495	45
12th week	1869	162	16.2	540	50
13th week	2006	137	13.7	510	50
		1417 §	141.7	5475	596

* 162 lb. pig taken out and 65 lb. pig put in.
§ 1320 lbs. plus 97 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 9. 1906-07

(Ten head in each pen.)

Beets and barley, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Beets
Beginning	686	...	...	...	...
1st week	737	51	5.1	160	320
2nd week	838	98	9.8	219	438
3rd week	921	86	8.6	320	640
4th week	1006	85	8.5	284	700
5th week	1056	50	5.0	336	350
6th week	1125	69	6.9	408	300
7th week	1205	80	8.0	359	300
8th week	1276	71	7.1	343	300
9th week	1337	61	6.1	373	300
10th week	1403	66	6.6	350	250
11th week	1440	37	3.7	460	250
12th week	1537	97	9.7	460	150
13th week	1626	89	8.9	390	200
		940	94.0	4462	4498

WEEKLY DATA, PEN 10. 1906-07

(Ten head in each pen.)

Beets and corn, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Beets
Beginning	680	...	...	...	...
1st week	776	96	9.6	160	320
2nd week	848	72	7.2	219	438
3rd week	921	73	7.3	320	640
4th week	981	60	6.0	350	700
5th week	1044	63	6.3	350	150
6th week	1090	46	4.6	400	300
7th week	1158	68	6.8	425	300
8th week	1221	63	6.3	349	300
9th week	1297	76	7.6	426	300
10th week	1351	54	5.4	385	250
11th week	1390	39	3.9	440	250
12th week	1478	88	8.8	440	150
13th week	1543	65	6.5	435	200
		863	86.3	4699	4298

TABLE C.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS, 1906-07

(13 weeks. 10 pigs in each pen.)

PEN NO.	INITIAL WEIGHT	CLOSING WEIGHT	GAIN	TOTAL FEED CONSUMED								NUTRITIVE RATIO
				Corn	Barley	Shorts	Peas	Wheat	Beets	Tankage	Alfalfa Hay	
I.	838	1794	1066*	----	5434	----	----	----	----	----	798	7.80
II.	669	1814	1145	5813	----	----	----	----	----	----	878	7.90
III.	688	1991	1303	2848	2838	----	----	----	----	----	878	7.81
IV.	671	1824	1153	----	2702	----	----	2779	----	----	----	8.05
V.	687	1722	1112§	----	2673	----	2673	----	----	----	----	4.27
VI.	665	1833	1168	----	2668	2688	----	----	----	----	----	6.55
VII.	688	1987	1299	----	5266	----	----	----	----	596	----	5.98
VIII.	686	2006	1417‡	5475	----	----	----	----	----	596	----	6.40
IX.	686	1626	940	----	4462	----	----	----	4498	----	----	11.23
X.	680	1543	863	4699	----	----	----	----	4298	----	----	11.54

* 110 lbs. credit. See weekly data.
§ 77 lbs. credit. See weekly data.
‡ 97 lbs. credit. See weekly data.

TABLE D.

ANALYSES OF FEEDS, 1906-07

	Dry Matter	Protein	Crude Fibre	Nitrogen Free Extract	Ether Extract
3. Barley	93.465	11.372	7.795	70.713	1.95
3. Peas	93.325	21.743	3.580	63.822	1.345
1. Alfalfa Hay	93.39	16.11	37.24	28.90	1.18
2. Sugar Beets	98.338	8.578	8.515	75.398	0.378
3. Denver Tankage	97.265	46.744	2.730	7.308	13.078
4. Swift's Tankage	93.75	42.15	6.95	15.50	16.30
4. Armour's Tankage	90.95	39.10	10.90	8.60	11.70

1. Analysis obtained from Colorado Bulletin No. 35, page 31.
2. Analysis obtained from Colorado Bulletin No. 46, page 37.
3. Analysis by Douglas of C. A. C.
4. Analysis from Iowa Bulletin No. 65, (1902). Given for comparison.

TABLE E.

* PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1906-07

	DIGESTIBLE NUTRIENTS			
	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Corn	89.1	7.9	66.7	4.3
Wheat	89.5	10.2	69.2	1.7
Barley	80.4	7.96	68.9	1.7
Peas	81.2	18.0	36.1	0.74
Shorts	88.2	12.2	50.0	3.8
‡Denver Tankage	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46
§Sugar Beets	87.5	5.3	75.9	0.19

* Co-efficients taken from "Feeds & Feeding," by Henry.

‡ Percentages (Meat Scrap), "Feeds & Feeding," by Henry. Carbo-Hydrates estimated at 50%.

§ Percentage of crude fibre and ether extract digestible estimated at 50%.

TABLE F. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED BY ALL PENS. 13 WEEKS, 1906-07

PEN NO.	TOTAL FEED				TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Beets	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I	5434	798	....	...	528	4024	96.0	7.8
II	5813	878	....	...	564	4185	254.0	7.9
III	5686	878	....	...	556	4162	174.9	7.81
IV	5481	...	....	...	498	3785	93.2	8.05
V	5346	...	....	...	694	2807	65.2	4.27
VI	5376	...	....	...	542	3196	147.8	6.55
VII	5266	...	....	596	678	3658	165.8	5.98
VIII	5475	...	....	596	692	3682	311.7	6.40
IX	4462	...	4498	...	593	6488	84.4	11.28
X	4699	...	4298	...	598	6396	210.2	11.54

WEEKLY DATA, PEN 1. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per head Lbs.	FEED LBS.		
				Barley	Corn	Alfalfa Hay
Beginning	484	..	...	..	..	..
1st week	543	59	7.38	83	83	28
2nd week	610	67	8.38	105	105	34
3rd week	666	56	7.00	117	117	39
4th week	745	79	9.88	132	132	44
5th week	793	48	6.00	143	143	47
6th week	850	57	7.13	143	143	40
7th week	921	71	8.88	150	150	42
8th week	972	51	6.38	150	150	36
9th week	1034	62	7.75	162	162	40
10th week	1101	67	8.38	162	162	30
11th week	1152	51	6.38	172	172	34
12th week	1200	48	6.00	195	195	30
13th week	1280	80	10.00	195	195	28
14th week	1368	88	11.00	200	200	25
15th week	1415	47	5.88	200	200	22
		931	116.00	2309	2309	519

WEEKLY DATA, PEN 2. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVERAGE GAIN PER HEAD LBS.	FEED LBS.		
				Barley	Corn	Tankage
Beginning	487	...	....	...	...	..
1st week	520	33	4.13	83	83	28
2nd week	634	114	14.25	105	105	34
3rd week	700	66	8.25	117	117	39
4th week	775	75	9.38	132	132	47
5th week	850	75	9.38	143	143	47
6th week	962	112	14.00	144	144	48
7th week	1081	119	14.88	150	150	50
8th week	1158	77	9.63	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1376	114	14.25	162	162	54
11th week	1475	99	12.38	172	172	57
12th week	1569	94	11.75	195	195	65
13th week	1660	91	11.38	195	195	65
14th week	1752	92	11.50	198	198	66
15th week	1855	103	12.88	204	204	68
		1368	171.00	2312	2312	769

WEEKLY DATA, PEN 3. 1907-08

(Eight head in pen.)

Ration: Barley 6 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVG. GAIN PER HEAD LBS.	FEED LBS.	
				Barley	Tankage
Beginning	485	...	....	...	..
1st week	531	46	5.75	166	28
2nd week	636	105	13.13	210	34
3rd week	696	60	7.50	234	39
4th week	775	79	9.88	264	44
5th week	852	77	9.63	286	47
6th week	920	68	8.50	288	48
7th week	1027	107	13.38	300	50
8th week	1100	73	9.13	300	50
9th week	1222	122	15.25	324	54
10th week	1319	97	12.13	324	54
11th week	1400	81	10.13	344	57
12th week	1470	70	8.75	390	65
13th week	1578	108	13.50	390	65
14th week	1672	94	11.75	396	66
15th week	1745	73	9.13	408	68
		1260	158.00	4624	769

WEEKLY DATA, PEN 4. 1907-08

(Eight head in pen.)

Ration: Corn 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain Per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	486	...	....	...	..
1st week	510	24	3.00	166	28
2nd week	600	90	11.25	210	34
3rd week	679	79	9.88	234	39
4th week	736	57	7.13	264	44
5th week	826	90	11.25	286	47
6th week	922	96	12.00	288	48
7th week	1026	104	13.00	300	50
8th week	1112	86	10.75	300	50
9th week	1219	107	13.38	324	54
10th week	1332	113	14.13	324	54
11th week	1425	93	11.63	344	57
12th week	1510	85	10.63	390	65
13th week	1617	107	13.38	390	65
14th week	1704	87	10.88	396	66
15th week	1795	91	11.38	408	68
		1309	164.00	4624	769

WEEKLY DATA, PEN 5. 1907-08

(Eight head in pen.)

Ration: Durum wheat 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Durum Wheat	Tankage
Beginning	484	...	....	...	..
1st week	515	31	3.88	166	28
2nd week	598	83	10.38	210	34
3rd week	692	94	11.75	234	39
4th week	760	68	8.50	264	44
5th week	856	96	12.00	286	47
6th week	892	36	4.50	288	48
7th week	1013	121	15.13	300	50
8th week	1123	110	13.75	300	50
9th week	1218	95	11.88	324	54
10th week	1315	97	12.13	324	54
11th week	1433	118	14.75	344	57
12th week	1492	59	7.38	390	65
13th week	1602	110	13.75	390	65
14th week	1673	71	8.88	396	66
15th week	1770	97	12.13	408	68
		1286	161.00	4624	769

WEEKLY DATA, PEN 6. 1907-08

(Eight head in pen.)

Ration: Durum wheat 3 parts, corn 3 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs,	FEED LBS.		
				Durum Wheat	Corn	Tankage
Beginning	487	...	....	...	...	..
1st week	533	46	5.75	83	83	28
2nd week	606	73	9.13	105	105	34
3rd week	692	86	10.75	117	117	39
4th week	767	75	9.38	132	132	44
5th week	857	90	11.25	143	143	47
6th week	950	93	11.63	144	144	48
7th week	1066	116	14.50	150	150	50
8th week	1158	92	11.50	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1370	108	13.50	162	162	54
11th week	1469	99	12.38	172	172	57
12th week	1552	83	10.38	195	195	65
13th week	1644	92	11.50	195	195	65
14th week	1768	124	15.50	198	198	66
15th week	1870	102	12.75	204	204	68
		1383	173.00	2312	2312	769

TABLE III.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS 1907-08

(15 weeks, 8 pigs in each lot.)

PEN NO.	Weight at Beginning	Weight at Close	Gain in Weight	TOTAL FEED CONSUMED					Nutritive Ratio
				Barley	Corn	Durum Wheat	Tankage	Alfalfa Hay	
I.	484	1415	931	2309	2309	....	...	519	8.10
II.	487	1855	1368	2312	2312	....	769	...	5.33
III.	485	1745	1260	4624	....	....	769	...	5.19
IV.	486	1795	1309	....	4624	....	769	...	5.47
V.	484	1770	1286	....	....	4624	769	...	4.54
VI.	487	1870	1383	....	2312	2312	769	...	4.97

TABLE IV.

ANALYSES OF FEEDS, 1907-1908

	Dry Matter	Protein	Crude Fibre	Nitro-Free Extract	Ether Extract
Barley	93.465	11.372	7.795	70.713	1.95
Durum Wheat	90.189	10.394	2.746	71.185	2.217
Selected Tankage......	97.265	46.744	2.730	7.308	13.078
Alfalfa Hay..........	93.39	16.11	37.24	28.90	1.18

TABLE V.

PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1907-1908 *

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Barley	80.4	7.96	68.9	1.7
Corn §	89.1	7.9	66.7	4.3
Durum Wheat	89.5	10.2	69.2	1.7
Selected Tankage †	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46

* Coefficients obtained from Henry's "Feeds and Feeding."
§ Coefficients used from common wheat.
‡ Percentages used from meat scraps.

TABLE VI. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED, 1907-1908

(All pens, 15 weeks.)

PEN NO.	TOTAL FEED			TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I.	4618	519	..	427	3313	140.90	8.10
II.	4624	...	769	702	3173	237.14	5.33
III.	4624	...	769	703	3224	177.03	5.19
IV.	4624	...	769	701	3122	297.25	5.47
V.	4624	...	769	807	3238	177.04	4.54
VI.	4624	...	769	754	3180	237.04	4.97

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Information Concerning the Colorado Carriage Horse Breeding Station

BY

JOHN O. WILLIAMS

PUBLISHED BY THE EXPERIMENT STATION
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The Agricultural Experiment Station

FORT COLLINS, COLORADO

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Information Concerning the Colorado Carriage Horse Breeding Station

By JOHN O. WILLIAMS

This circular is not intended as a publication of any results attained in the carriage horse breeding experiment, but is intended as a *circular of information* so that interested persons may acquaint themselves with the object of the experiment conducted at the Colorado Breeding Station and the conditions by which they may avail themselves of the services of the various stallions in use at the station.

HISTORY AND OBJECT OF EXPERIMENT.

On July 1. 1904 an appropriation of $25,000 by Congress became available to the U. S. Bureau of Animal Industry for experiments in animal breeding and feeding in cooperation with the State Experiment Stations. Under this Act, carriage horse breeding was inaugurated in cooperation with the Colorado Experiment Station.

The first purchase of foundation stock was made in December, 1904 from George D. Rainsford, Diamond, Wyoming, and comprised six mares of excellent breeding and good carriage conformation. The next purchase was made in February, 1905 and included the standard-bred stallion "Carmon" 32917 (formerly shown as Glorious Thundercloud) and twelve trotting-bred mares of superior merit as show animals. These mares were bred in the various middle-western states and in Kentucky. The next purchase was made in June, 1906 and included the two saddle-bred mares Beatrice 2079 (S) and Mambrina 2400 (S). The last purchase was made in March, 1908 and comprised four mares from various breeders in Kentucky. These mares were Golden Picture 2788 (S); Bethel Princess 4796 (S); Barthenia McCord 4223 (S), and Elvira Lindsey 3083 (S).

The above named animals constitute the foundation animals of the experiment. The progeny of the foundation mares are carefully selected, and those adhering closely to the desired type are retained for breeding purposes. New blood will also be introduced from time to time through mating the offspring of the foundation mares to stallions other than those in use at the station, as well as through the purchase of additional animals.

The object of the work is to study the possibilities of evolving an American carriage horse from the American trotter, Morgan, and American saddle horse. The trotter is being used as the basis of the work and the two other native-blood lines are being used to supply the desired qualities they are known to possess. Through judicious blending of these blood lines, the ultimate American carriage horse will be realized. This does not mean that animals which will fill the requirements are not already available as many specimens of "native" breeding have demonstrated their high carriage qualities by defeating the best imported animals in competition in the show ring. The encouragement for the retention of these outstanding individuals for breeding purposes is one of the admirable objects of the work by the department.

The qualities desired in a high class carriage horse are substance, quality, stamina or endurance, high-balanced action, good temperament and speed. The latter qualification is very desirable in most cases, but not in itself essential in the production of either a marketable or high-class carriage individual.

In order to present the desired qualifications of a carriage horse to the breeders, and also to encourage the production of a uniform type of carriage horse, the U. S. Department of Agriculture in cooperation with the American Association of Trotting Horse Breeders, has formulated a classification for American carriage horses which has been adopted by the various State Fairs throughout the United States. *

The classification is as follows:

TYPE.

The type desired for the American carriage horse is as follows: Not under 15 hands for mature horses; smooth, compact, and symmetrical conformation; neck of good length, inclined naturally to arch; sloping shoulders; well-set legs of medium length; sloping pasterns and good feet; short, strong back; well sprung ribs well ribbed up to coupling; smooth loins; full flanks; straight croup, with well-set tail; full round quarters.

CONDITIONS GOVERNING ENTRIES.

Classes open only to horses of American blood.

Stallions in classes 1 to 5, inclusive, must be registered either in the American Trotting Register as standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries in all classes for mares must be registered either in the American Trotting Register as standard or non-standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries as get of sire in class 5 and produce of mare in class 10, and entries in class 11 must be sired by a stallion registered as above, out of mares registered as above.

No mare having any draft cross will be eligible.

*From Twenty-Fourth Annual Report, B. A. I., U. S. Department of Agriculture.

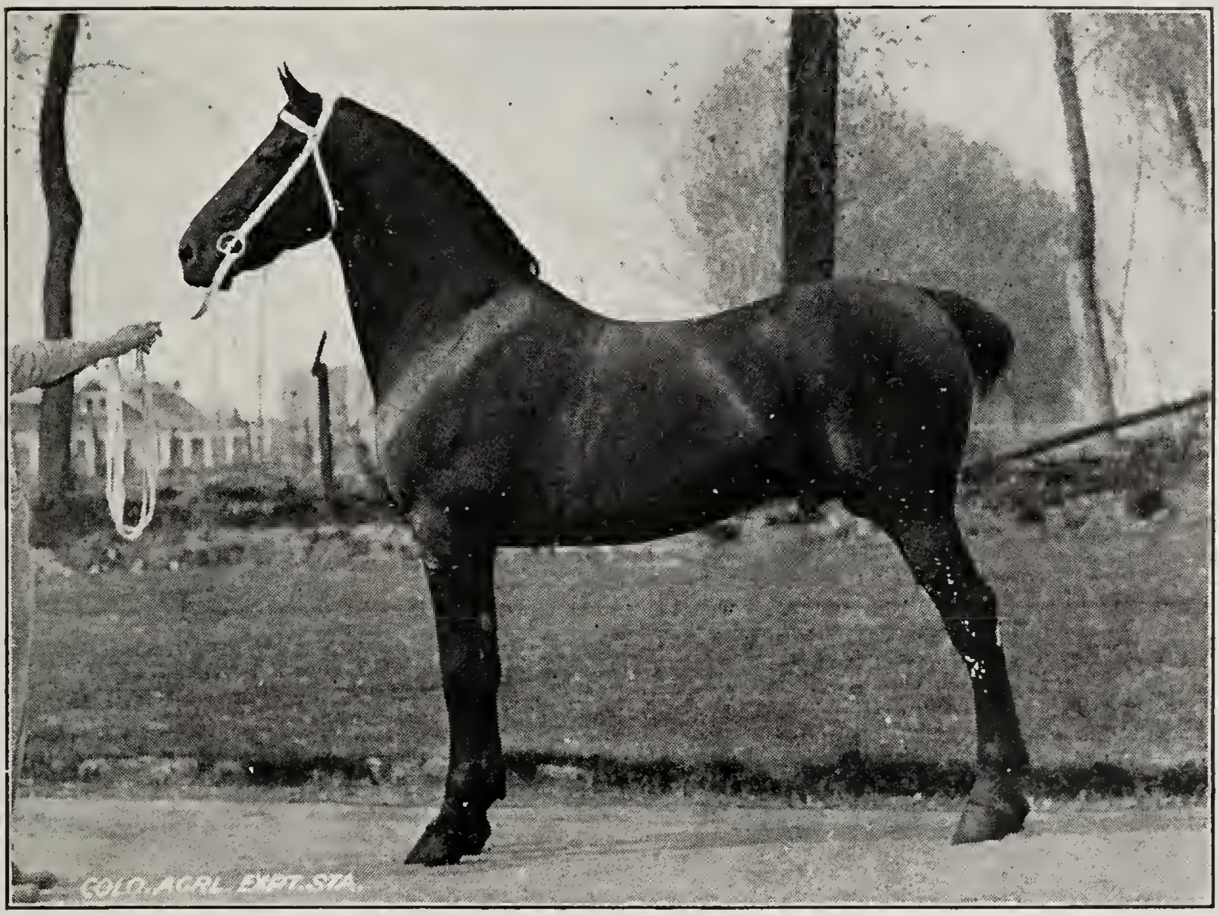
Any exhibitor falsifying the breeding of entries will be barred.

Entries in all classes must be practically sound.

JUDGING.

Entries in all classes to be judged on conformation, style, action, and manners as a suitable type of carriage horse. Special attention will be given to trueness of action. Good knee and hock action are essential. Entries in all classes should trot and walk straight and true, and judges will especially avoid horses showing a tendency to pace, mix gaits, paddle in front or sprawl behind.

The following percentages will govern judges in classes 1, 2,

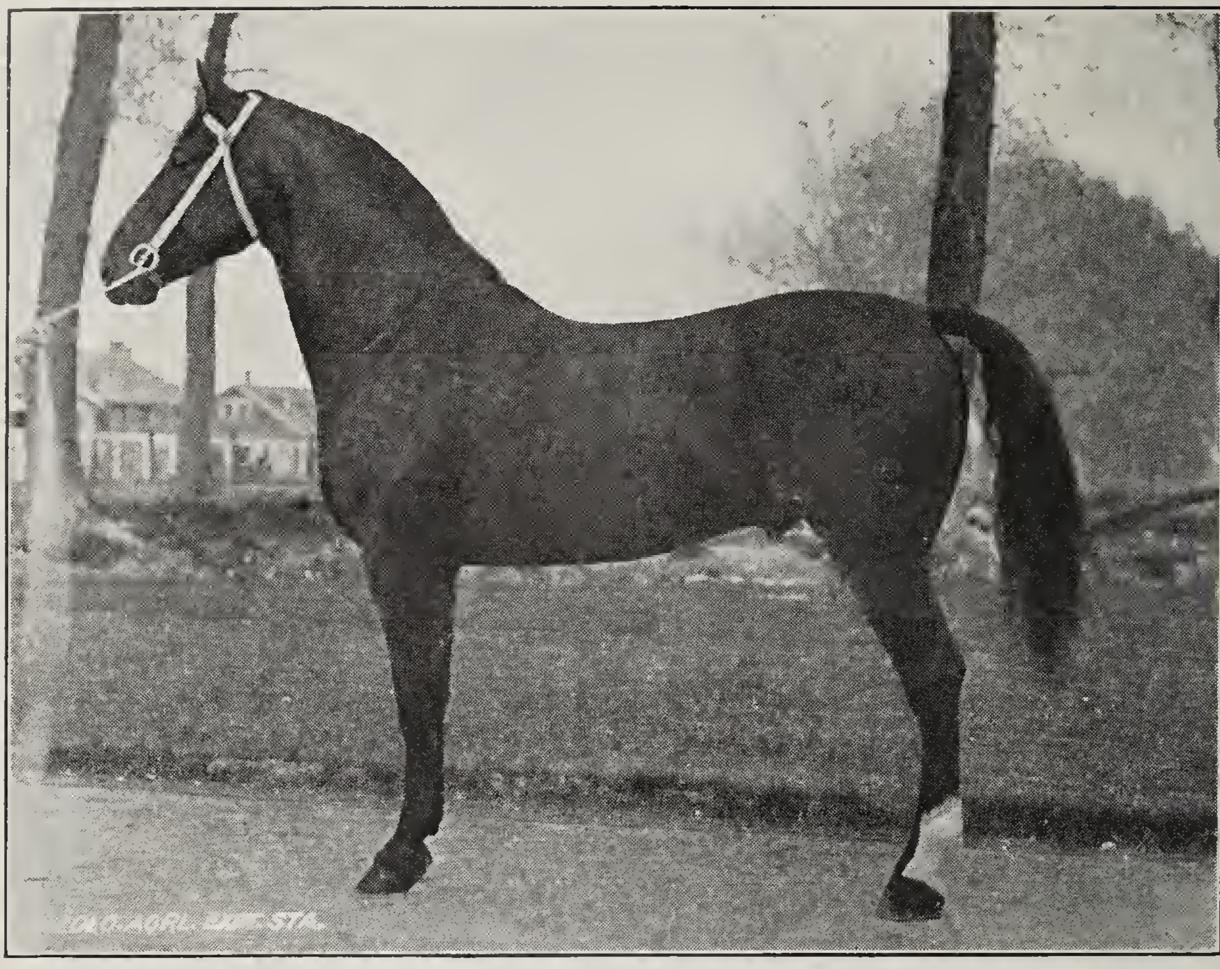


STUD NO. 1. CARMON 32917, AT 15 YEARS OF AGE.
Standard bred carriage stallion, shown as "Glorious Thundercloud." At the head of the Government stud at the Colorado Experiment Station.

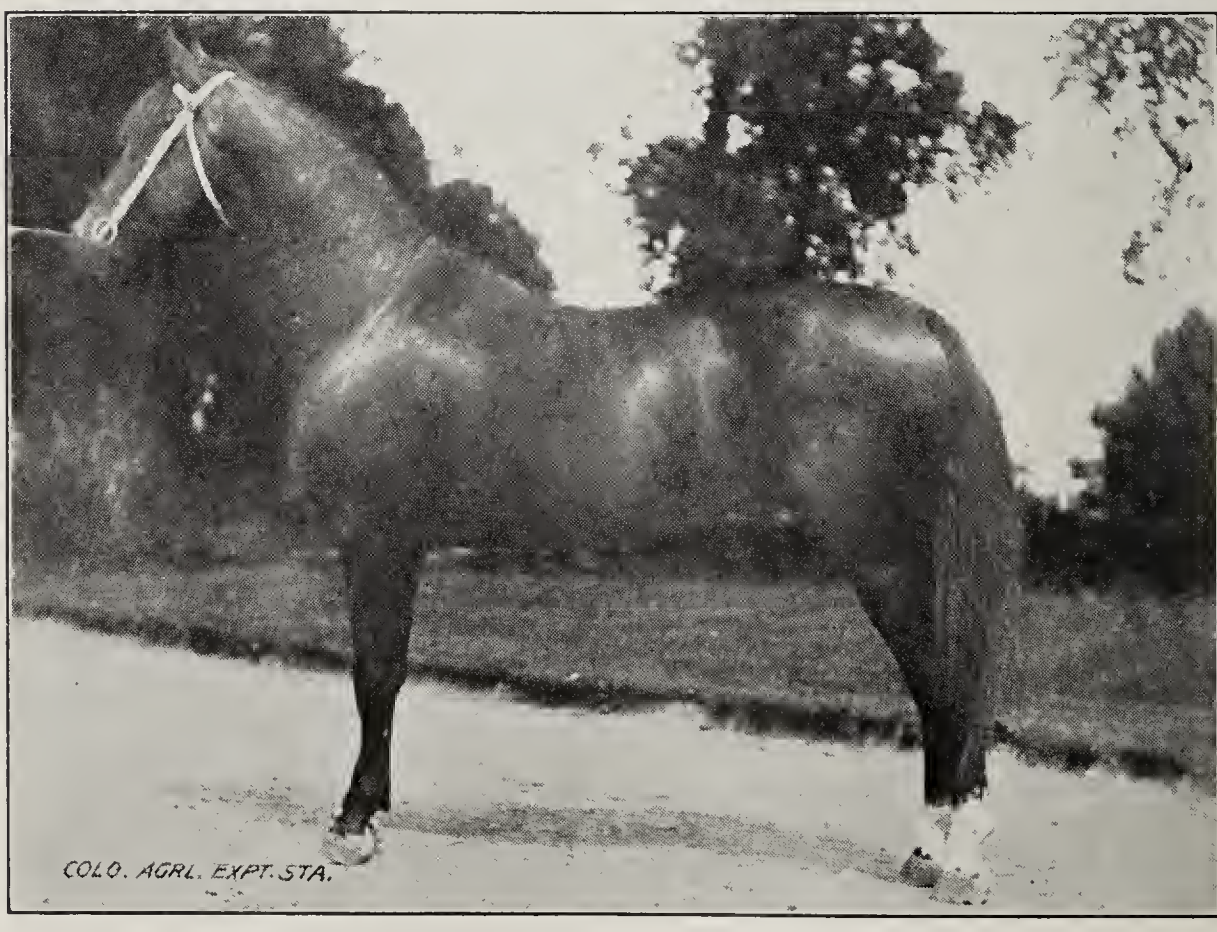
3, 4, 6, 7, 8, 9: General conformation and all-round suitability as a carriage type, 60 per cent; style, action, and manners, 40 per cent.

The following percentages will govern in class 5: General conformation and all-round suitability of sire as a carriage type, 30 per cent; style, action, and manners of sire, 20 per cent; general conformation and all-round suitability of get as a carriage type, taken as a whole, 30 per cent; style, action, manners, and uniformity of type in get, 20 per cent.

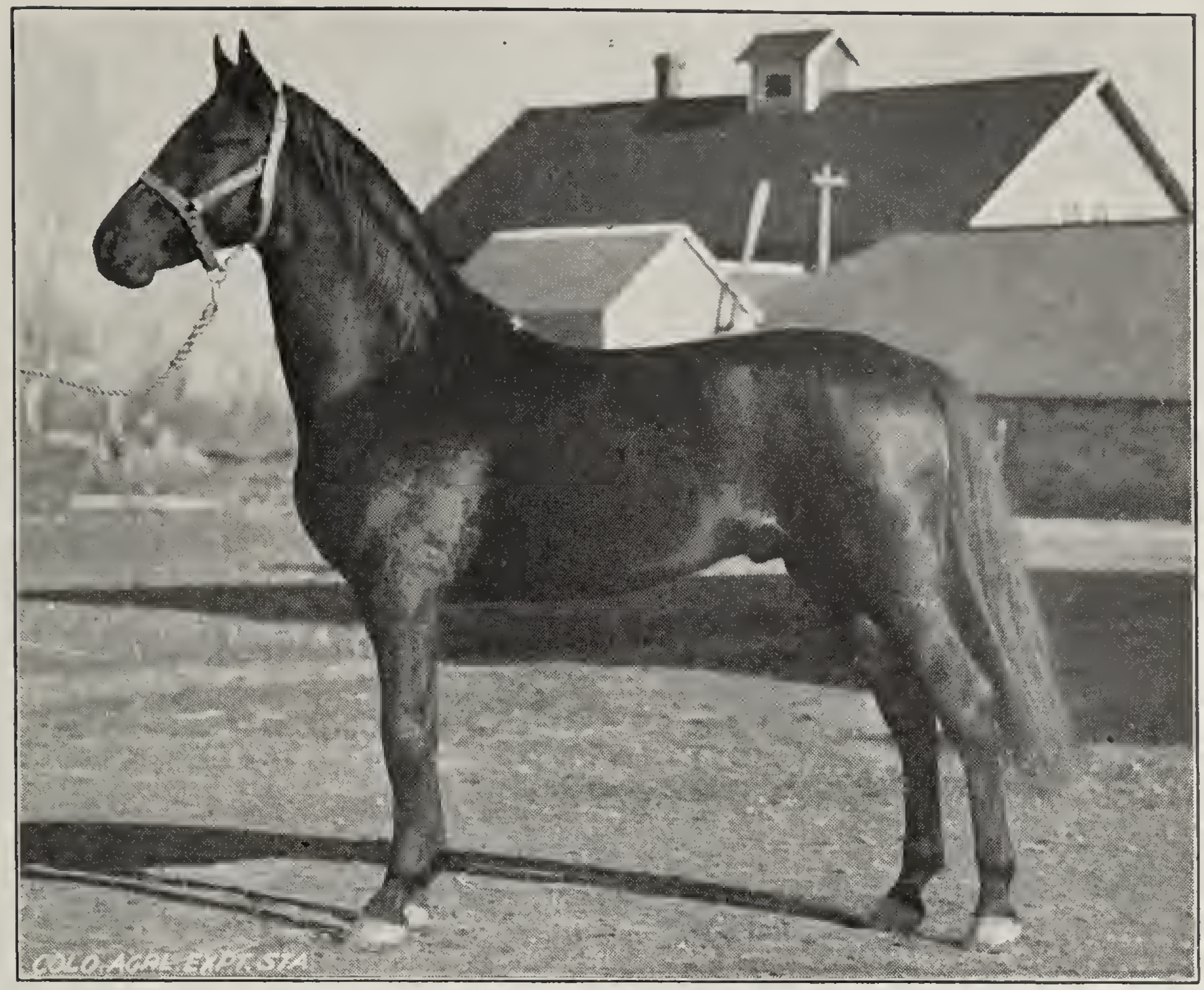
The following percentages will govern in class 10: General conformation of dam as a brood mare of the carriage type, 50 per



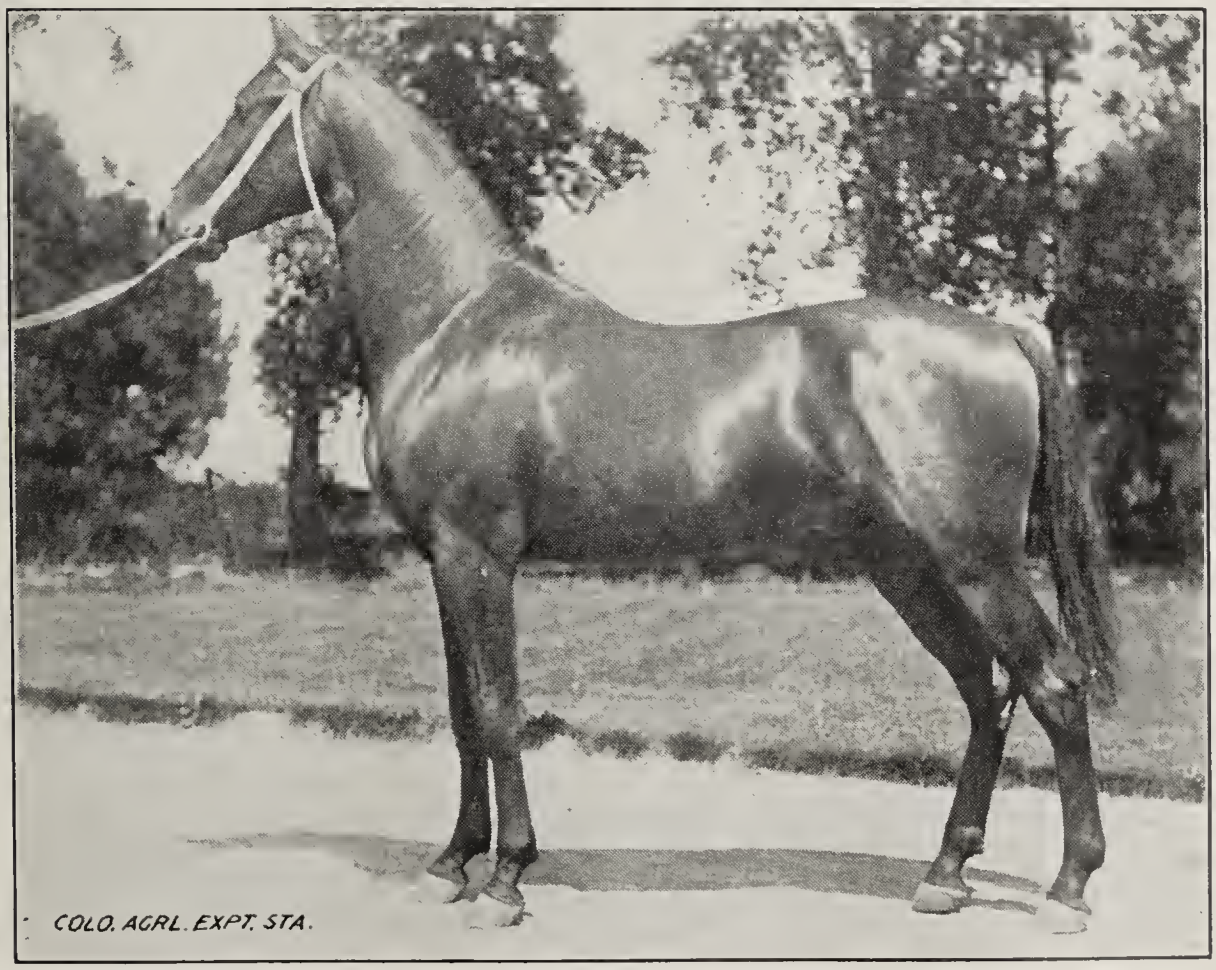
STUD NO. 37, ALBION, AT 4 YEARS OF AGE.



STUD NO. 39, ALVA, AT 4 YEARS OF AGE.



STUD NO. 40, BALFOUR, AT 3 YEARS OF AGE.



STUD NO. 46, CHESTER BOURBON 3577 (S), AT 2 YEARS OF AGE.

cent; general conformation, style, action, and manners of the foal, 50 per cent.

The following percentages will govern in class 11: General conformation of entry as a carriage type, 70 per cent; style, action, and manners, 30 per cent.

MANNER OF SHOWING.

Entries in classes 1, 2, 6, and 7 to be shown in harness, hitched to any suitable vehicle. Entries in all other classes to be shown in hand to bridle or halter. Excessive weight in shoeing in any class is forbidden.

CLASSES.

Class 1. Stallion 4 years old or over.
Class 2. Stallion 3 years old and under 4.
Class 3. Stallion 2 years old and under 3.
Class 4. Stallion 1 year old and under 2.
Class 5. Stallion with three of his get of either sex; get need not be owned by exhibitor.
Class 6. Mare 4 years old or over.
Class 7. Mare 3 years old and under 4.
Class 8. Mare 2 years old and under 3.
Class 9. Mare 1 year old and under 2.
Class 10. Mare and foal of either sex.
Class 11. Foal under 1 year old, either sex.

The above classification, if carefully studied, will give the breeder a definite idea of what is desirable in an American carriage horse. The classification is not intended to antagonize or conflict in any way with the classifications offered for individuals possessing the blood lines mentioned therein. The type desired is distinct from either those required in the American Trotter, American Saddle or Morgan classification.

SALE OF SURPLUS ANIMALS.

The animals used in connection with the breeding operations at the station, along with their offspring, are inspected annually by a Board of Survey consisting of Mr. Geo. M. Rommel, Chief of Animal Husbandry Division, U. S. Department of Agriculture; Professor C. F. Curtiss, Director of Iowa Experiment Station, and the officer in charge of the breeding establishment, with a view of determining the producing qualities of the various animals in the stud and the progress made during the preceding year. In the past the inspection has resulted in the elimination of some of the original herd of mares and many of the offspring produced at the station and placing them on sale to the public at auction. The animals eliminated from the stud in this manner are sold without reserve and also without obligation on the part of the station to the buyer after the animal is sold.

STALLIONS IN SERVICE.

The stallions described herein will be allowed to stand for public service to a limited number of approved mares.

CARMON—32917, Stud No. 1. *

The stallion Carmon is the foundation sire in service at the breeding station. He is a bright bay, standing 16 hands in height and weighs 1250 pounds. Carmon is a standard bred stallion of carriage type.

PEDIGREE OF CARMON

CARMON No. 32917. [Breed standard bred; sex, male; color, bay; height, 16 hands; weight, 1,250 pounds; date of birth, 1895. Breeder, Norman J. Colman, St. Louis, Mo. At Stud, Colorado Experiment Station, Fort Collins. Colo.	Carnagie No. 8405.	Robert McGregor No. 647.	Major Edsall No. 211.	Abdallah. No. 15.
				By Harris's Hambletonian No. 2.
			Nancy Whitman	American Star No. 14.
				Nance, by Young Messenger Duroc
		Annie Nutwood (non-standard) Vol. VI. p. 376, A. T. R.	Nutwood No. 600.	Belmont, No. 64
				Miss Russell by Pilot. jr., No. 12
			Annie Watson	Vermont Boy.

	Monitor Maid Vol. XI. p. 646, A. T. R.	Monitor No. 1327.	Merchant No. 599.	Belmont, No. 64.
				Lady Mambrino by Mambrino Chief No. 11.
			Trojana	Trojan. No. 312
				By Hercules
		Clara C. Vol. XI, p. 389, A. T. R.	Seth Warner No. 281.	Ethan Allen. No. 43.
				Sontag, by Harris's Hambletonian, No. 2.
			Grace	Abdallah, jr. No. 5720.
				Glencoe Belle, by Old Bull.

* In giving registry numbers the following system is used to indicate the register in which any given number appears: Those in the American Trotting Register are printed open, thus: Carmon 32917. Those in the American Saddle Horse Register are followed by a capital S in parenthesis, thus: Chester Bourbon 3577 (S). Thoroughbred horses are designated thus: (TH).

ALBION—Stud No. 37.

Albion is a bright bay stallion, standing 16:1 hands in height and weighing 1300 pounds. He was sired by Carmon and his dam, Arizona, was sired by Emigrant. His pedigree is as follows:

PEDIGREE OF ALBION

ALBION Stud No. 37 Sex, male, color, bright bay; height, 16.1 hands; weight, 1,300 pounds; date of birth, April 9, 1906; breeder, Colorado Exp. Station, Fort Collins, Colo.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor, No. 647.	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
		Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327.	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
	Arizona Stud No. 17	Emigrant	Lord Winbeam	George Peabody by Hamiltonian No. 10

			Lady Spartan	Spartan by Ethan, Allen 43 (Morgan).

		Hoyden	Red Bud (Th)	Tom Bowling, by Lexington.
				Oleander, by Tipperary.
			Cora	Spartan Jr., by Spartan (Morgan)
				Lady Fauna

ALVA—Stud No. 39.

The stallion Alva is a bright bay in color, standing 15:1½ hands in height and weighing 1100 pounds. His pedigree is as follows:

PEDIGREE OF ALVA

ALVA Stud No. 39 Sex, male; color, bright bay; height, 15.1½ hands; weight, 1,100 pounds: date of birth, March 23, 1906; breeder, Colorado Exp. Station, Fort Collins, Colorado.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No. 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson ----
		Monitor Maid Vol. XI. p. 646, A. T. R.	Monitor No. 1327	Merchant No. 559
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
	Washington Stud No. 2	C. H. Purcell, 2:19¼ No. 25226	Morgan Messenger	----------
		----------	Clermont, 2:28¼	Red Wilkes, 1749, by Geo. Wilkes 519

BALFOUR—Stud No. 40.

Balfour is a dark bay stallion, standing about 15 hands in height and weighing 1025 pounds. He is a stallion of exceptional quality and action. His pedigree is as follows:

PEDIGREE OF BALFOUR

BALFOUR Stud No. 40 Sex, male; color, dark bay; height 15 h'ds: weight, 1,025; pounds; date of birth, April 19, 1907; breeder, Colorado Exp. Station, Fort Collins, Colo.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No, 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
	Dakota, Stud No. 7 (In service at Experiment'l Station)	Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace

CHESTER BOURBON—3577 (S).

This stallion is a registered American Saddle stallion which will be placed in the stud during the season 1911 to a limited number of approved mares. This horse stands 15:2 hands, and weighs 1000 pounds as a two year old. His description and pedigree follows:

PEDIGREE OF CHESTER BOURBON

CHESTER BOURBON No. 3577 (S) Breed, American saddle; sex, male; color, bay; height, 15.2 hands; weight, 1,000 pounds; date of birth, May 5, 1908; breeder. A. G. Jones, North Middletown, Ky.	Bourbon King No. 1788 (S)	Bourbon Chief No. 976 (S)	Harrison Chief No. 1606 (S)	Clark Chief No. 89, A. T. R.
				Lute Boyd
			Belle	Latham's Denmark No. 69
				Dau of Bellfounder
		Annie C No. 3025 (S)	King (Wilson's) No. 2196 (S)	Harrison Chief No. 1606 (S)
				Dau. of Parson's Abdallah
			Kate	Richlieu, he by Indian Chief 1718 (S)
				Kate by Kentucky Chief
	Barthenia McCord No. 3223 (S)	Chester Dare No. 10 (S)	Black Squirrel No. 58 (S)	Black Eagle No. 74 (S)
				Mollie No. 70 (S)
			Nannie Garett No. 472 (S)	Dave Akin (Th) No. 755 (S)
				Nannie
		Dau.	Peavine No. 85 (S)	Rattler
				Dau. of Wagner Jr. (Th.)
			Dau.	Trojan
				Dau. of Brinker's Drennon, 1600 (S)

The stallions herein named are in service at the station during the season of 1910. Other stallions will mature and be placed in service during each succeeding year, thereby adding to the number now in service.

TERMS OF SERVICE.

Private individuals can avail themselves of the services of the above named stallions under the following conditions:

1. The mares to be bred must be approved by the officer in charge.

2. Service fee must be paid at the time of first service, the amount for each stallion being given below. The groom is instructed not to furnish service unless authorized by the officer in charge.

3. Owners of mares will be allowed return privileges at any time during the breeding season of the same year in which the first service is given. The following fees will prevail until further notice:

Carmon	$25.00
Albion	15.00
Alva	10.00
Balfour	10.00
Chester Bourbon (will be placed in stud, 1911).	

4. The utmost care will be exercised to prevent any accidents while mares are in the custody of the Colorado Experiment Station, but neither the Station nor the Department will be responsible should any occur.

FACILITIES FOR KEEPING OUTSIDE MARES.

The Station is equipped to keep a limited number of mares belonging to private individuals. This arrangement is provided for those who send mares from a distance. Owners of mares living within a convenient distance of the Station cannot be provided with accommodations for their mares.

The following fees will be charged for mares kept at the Station:

For pasturage alone, 50 cents per week for each animal.

For paddock at Station (with hay and pasturage), $1.00 per week for each animal.

For box stall and stable accommodations, $1.50 per week for each animal.

If grain ration is desired, and additional charge of $1.00 per week for each animal will be charged.

Bulletin 167 September, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A Too Common Farm Scene

LIFE AND CARE OF FARM MACHINERY IN COLORADO

BY

H. M. BAINER *and* H. B. BONEBRIGHT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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The Agricultural Experiment Station

FORT COLLINS, COLORADO

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LIFE AND CARE OF FARM MACHINERY IN COLORADO

By H. M. BAINER and H. B. BONEBRIGHT

The twelfth census report of 1900 places the valuation of the agricultural implements on the farms of Colorado at $4,746,755.00. Knowing of the wonderful development of agriculture in Colorado within the past decade, a conservative estimate would not place the present valuation at less than $10,000,000.00.

In traveling over the state, the ordinary observer is unfavorably impressed with the methods now commonly found in use by our farmers for taking care of their machinery. As a general rule, the prosperity of the farmer may be estimated by the way he cares for his machinery. Poor care indicates shiftlessness, waste, lack of energy and the necessity of buying more machinery in a short time.

Plate 2. The profits from many Colorado farms are found in such "junk heaps" as this.

Good care, on the other hand, indicates prosperity, development, bank deposits, and long lived machinery.

At the present time there is a growing demand for information on the subject of the life and care of farm machinery in Colorado. With the idea of obtaining this information, the Farm Mechanics Department has carefully investigated the machinery conditions on over two hundred representative farms in all parts of the state. This information is summarized in the following remarks:

SELECTION OF MACHINERY.

Type.—The proper care of a farm machine begins in the careful and intelligent selection of the correct type of machine for the work which it is expected to do. This point is too often overlooked by the man who is strongly prejudiced in favor of some particular make or so-called "line" of implements.

Size.—When the correct type of machine has been selected, its size should be carefully considered. By the use of sufficiently large and strong implements, with large capacity, a great deal of time and labor is saved and the life of the machine is greatly lengthened.

For example, on a fair sized field, a three section harrow will do one-half more work with the same amount of man labor. The teeth, having to travel less distance in harrowing the field, will remain sharp longer, and, consequently, the efficiency of the harrow is increased, while the time required for the work is decreased.

Three section harrows were found in operation on one-third of the enumerated farms of 80 acres and over. Three section harrows were used on but one-half of the enumerated farms of 160 acres and over, the remaining one-half using nothing larger than the two section harrow. In no case was a farmer found who had used a three section harrow and was willing to discard it for one of two sections.

A man of ordinary ability can handle a two bottom gang plow nearly as easily as a sulky, or one bottom plow. By the use of the gang the capacity of man and plow are doubled, while the wear on each plow is only one-half what it would be on the single plow, were it made to cover the same number of acres as the gang. Then too, time is saved in case the shares must be taken to a shop for sharpening, as only one-half as many trips are necessary for the gang as with the single plow, for a field of equal size.

Gang plows, ranging from two to four bottoms, are now being used on less than nine per cent of the farms of 80 acres or more which have been investigated. In communities where suitable gang plows have been tried, the demand for them is increasing.

In some cases, such as gardening, special farming deep work, etc., it is often not advisable to try to cover too much ground at once. Again, some of our special implements are made only in single units, such as the modern two-way plow. This plow has many advantages that will often justify its use in place of the two and four bottom gang plows.

Accessibility to Repairs.—In selecting machinery, it is usually advisable to consider the matter of securing repairs. Repairs or new parts must be secured for nearly every farm implement some time, or perhaps several times, during the life of it. Usually, the repairs are not ordered until the implement will not run any longer without them and then they must be secured in a hurry. For example, the binder, mower, or other important implements or machines must be repaired at once, or the farmer may lose part of his crop while waiting for repairs. In this case, the question of being able or unable to secure the necessary repairs, may represent the difference between loss and gain on the season's crop. For such implements as are absolutely necessary during certain seasons, the owner should be able to get repairs on not over one day's notice, if not at once. Instances were found where the farmer was compelled to buy a new machine of another make simply because he was unable to ge a repair for his old machine in time to do the necessary work.

Oiling Devices.—Good visible oiling devices should be found on every farm machine. In selecting machinery this point should be kept in mind, as the life of the machine depends to a considerable extent upon whether or not it can be kept thoroughly oiled. Often all the necessary oiling provisions are made, but they are not in as plain sight as they should be and for this reason are likely to be overlooked.

Again, the oil holes should be well protected from dirt, and should also be easy to clean. Fast running machinery and that which needs oil constantly should be provided with good, self feed-

Plate 3. Machinery loses much of its value if kept in an agent's back yard for several years.

ing oil cups. Hard oilers have proven very satisfactory, especially where the parts are subjected to a great deal of dirt and there is no question but that they should be used even more than they are at present.

Thoroughly Painted.—The new implement or vehicle, as it comes from the dealer, should show a good grade of paint. This is especially true of buggies and wagons. The paint should show that it has been applied in smooth thin layers, which have been well rubbed down, and should not show a tendency to clottiness or scaliness. The paint should be covered with a good coat of varnish.

The character of the implement or vehicle is reflected to a certain extent by the paint which covers it. Certain implements are known by their good paint, others are known by their poor paint.

New Machinery.—In buying new machinery or implements, the farmer should see to it, that he is not paying the price of a new machine for one that stood in an open back yard of some implement dealer, from one to three years. This is often the case and there is no good excuse for it from either the standpoint of the dealer or the farmer.

In the first place, the dealer should not allow his new machinery to stand in the open for long periods, and thus let it become weather beaten and damaged. In the second place, the farmer should not buy this damaged machinery at new machinery prices. He must consider that an implement is damaged as much by standing out one year, as it would be by actually using it one season.

PROPER ADJUSTMENT AND REPAIRS.

Adjustments.—Nearly every one understands the importance of making proper adjustments on farm machinery. A large percentage of the machines found in the field are badly out of adjustment. In many cases the improperly adjusted machines do such inferior work that they are discarded long before they are worn out.

For example, on one of the farms investigated, a binder, of reliable make, was found which had cut but ten acres before being discarded eight years ago, simply because the operator was unable to properly time the binder driving gear, after he had removed the cog wheel to replace a defective spring. The same make and type of binder has been in active operation on another investigated farm for the past twelve years. It has cut at least nine hundred acres and is still in first class condition.

The improper adjustment of one part of a machine often leads to the ruination of several other parts, much time of man, team and machine is lost "tinkering" with improperly adjusted machinery. In a large percentage of cases, the draft of the implement is unnecessarily increased because of improper adjustment. Not only is the draft increased, but it is not uncommon to find side draft produced in the machine as a result of improper adjustment.

The loss due to the discarding of machines before they are worn out, the inferior work, the damage to teams from excessive draft and side draft, and the valuable time lost in "tinkering" always justifies the spending of sufficient time to put the farm machinery in proper adjustment before it is put into regular service. Many of these adjustments may be made long before the machine is needed.

Repairing Machines.—Every machine, in active operation will sooner or later need repairs. The operator should be able to forsee the need of a large part of the necessary repairs some time before they are actually needed. Of course, in the case of parts that break unexpectedly, due to defects or accidents, the operator has a reasonable excuse for not forseeing the trouble. But in cases where parts are worn, or weakened, there is little excuse for not making repairs long before the machine is to be operated again. In some cases it may be desirable to operate the old part for some time after it is badly worn. Under such conditions, good judgment demands the keeping of the extra part on hand ready to be substituted when occasion demands. As a worn part often ruins some unworn part, it is often advisable to replace the badly worn part at once. The main gear on a binder is an excellent example of the last mentioned case. After the pinion becomes worn, it is likely to either cut out the gear wheel or slip cogs, thus endangering chains and other gears.

It is advisable to place a tag upon each machine at the end of the season, stating just what repairs and adjustments are needed, so that these may be secured or made during the time when work is not pressing.

The investigation, which was carried on in May and June, showed that out of 1,716 machines (not including any discarded machines) 60.6 per cent were not in need of repairs. 27.15 per cent were in need of repairs according to statements received on the farms. The investigator could easily see, without careful examination, that 18.6 per cent of the machines needed repairs that were not reported. On 109 or 6.35 per cent of the machines the investigation showed that repairs in addition to those reported on the farms were needed. (The discrepancy of 6.35 per cent is thus explained.)

Sharpening.—There is little doubt in the minds of experienced farmers but that dull implements do an inferior grade of work, and at the same time, they unnecessarily increase the draft.

In general, with the exception of the smoothing harrow, the implements investigated proved to be as sharp as could reasonably be expected. Plows, disc harrows, cultivators and weeders were found to be in first class condition so far as sharpening was concerned. On the other hand, the smoothing harrow, one of the most important of farm implements, was found to be too dull for good service in 77 per cent of the investigated cases. Nearly 7 per cent of the harrows were too nearly new to be badly dulled, while only 16 per cent of the harrows had had the teeth reversed or sharpened. In the records of the dry farming sections over 83 per cent of the harrows (not including new ones) were sharp. In a great many cases, all that was necessary was the reversing of the teeth in order to give all the advantage of the sharp harrow, yet in only a few cases had this been done.

The investigation discovered harrows which had been in use for twenty years, and which had covered 3,000 acres without being sharpened or reversed.

Plate 4. It costs no more to do good work with a sharp harrow than it does to slide over the ground with a dull one.

THE FARM WORK SHOP.

If the observer was to draw conclusions from the farms investigated, he would have to conclude that very few farmers realize the importance of the farm work shop. As a matter of fact, a great many of those farmers who do not own shops understand the advantage of them. Again, many farmers are under the impression that they haven't the "knack," which they believe is a necessary adjunct, if they are to do repair work. Many have not investigated the cost of a small shop outfit, neither have they figured the matter on a basis of dollars and cents.

In cases where farmers are not very handy to the local shop, the time which is lost while going to and from the distant shop often amounts to several times the actual charges. At critical times, such as harvesting or seeding seasons, one long trip to town for repairs may cause a loss more than equal to the value of a well equipped shop.

The following table shows that the machinery found on farms having well equipped shops is in need of less repairs than that on farms without shops:

	Farms without Shops	Farms with Shops
Percentage of machinery not needing repairs.....	59.25	71.36
Percentage of machinery needing repairs as reported by the farmer........................	27.7	22.4
Percentage of machinery needing repairs as reported by investigator and not by farmer......	20.2	6.24
Percentage of machinery reported by investigator needing repairs in addition to those reported by the farmer	7.15	0.0

The fact that machines are found in a better state of repair on the farms having well equipped shops goes to show very plainly that there is a real value to the shop beyond the occasional emergency job. These facts in themselves are strong arguments in favor of the farm shop. Of the farms investigated a little over 9 per cent were equipped with suitable shops.

Equipment.—In order to obtain the best results, the shop should be fitted with both carpenter and blacksmith tools. It should be handy to the place where the implements are stored, and some means of heating it in winter should be provided. A very serviceable farm carpenter equipment may be procured for less than $20.00 as follows:

One—grindstone and frame.
" —oil stone.
" —good square.
" —fine cross cut saw, at least 24 in. long.
" —rip saw at least 26 in. long.
" —compass saw.
" —claw hammer.
" —Jack plane.
one—¼-in. bit.
" —⅜-in. bit.
" —½-in. bit.
" —⅝-in. bit.
" —¾-in. bit.
" —1-in bit.
" —¼-in. firmer chisel.
" —½-in. firmer chisel.
" —1-in. framing chisel.

One good, adjustable brace, strong enough to operate drills as well as bits.

In case the shop equipment is to be more nearly complete, a coarse, cross-cut saw may be added. A full set of bits, including an expansion bit, may be substituted for the above list of bits and a full set of planes will be found handy at times. A carpenter's combined level and plumb will be useful as will also a wood bench vise. The bench is easily constructed upon the farm.

In the line of blacksmith tools a great deal of difference of opinion exists. A small forge and anvil usually prove satisfactory, although some insist on large forges and heavy expensive anvils. It is safe to say that a serviceable farm blacksmith equipment as listed below may be secured for $30.00.

One small, combined portable hand blower and forge.
Two pairs tongs.
One hardy.
One steel-faced anvil.
One set of screw plates and taps, in sizes 1/4, 5/16, 3/8, 7/16, 1/2, 5/8 and 3/4 inches.
One triangular file about 6 inches.
One round file 10 inches.
One flat plow file about 14 inches.
One blacksmith hammer.
One combined vise and drill press.

By using the tools furnished with the farm machinery, in connection with the above enumerated outfit, a great deal of very good repair work may be done.

In case more money is to be expended, a strong blacksmith's

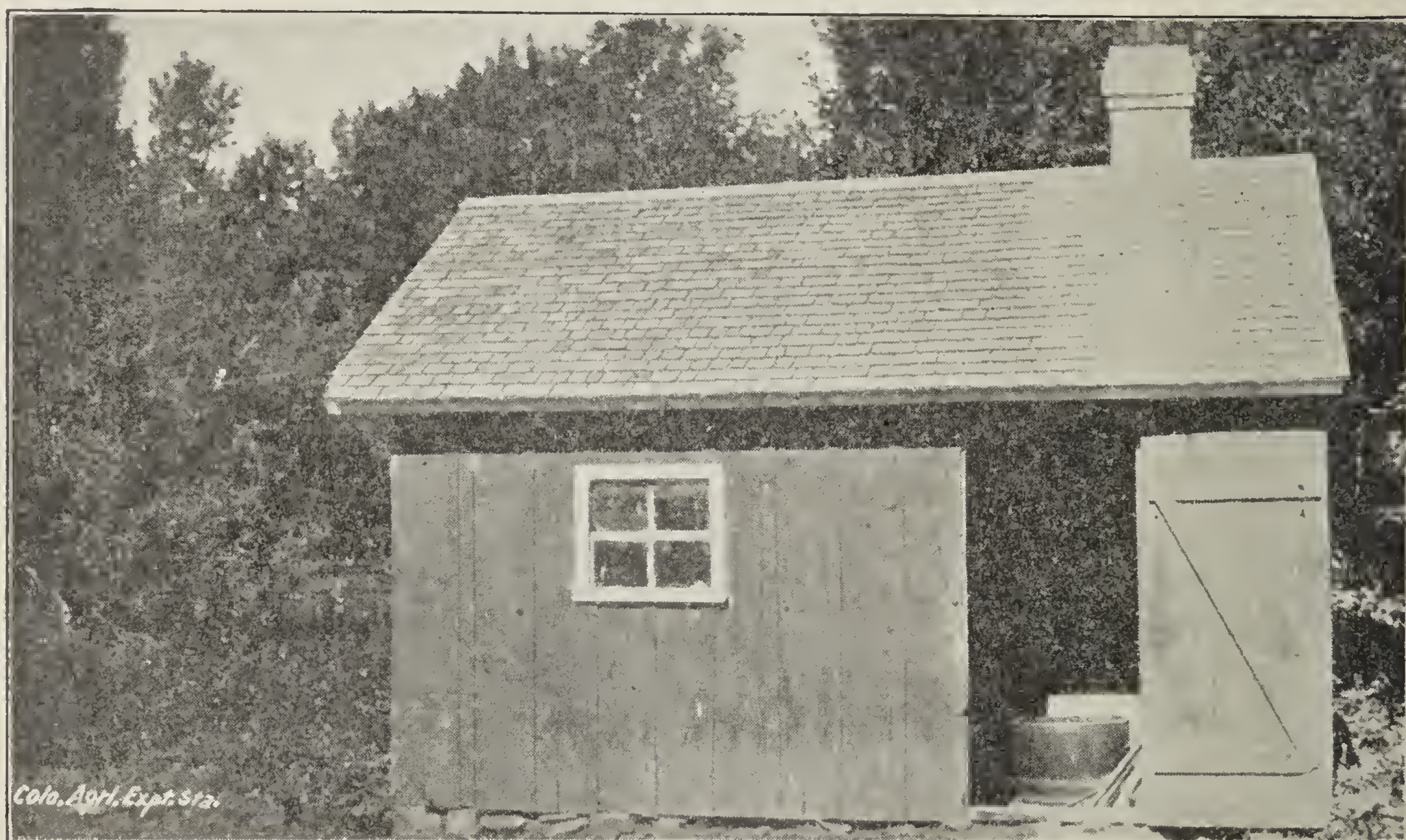

Plate 5. A Small Farm Shop

vise and a separate drill press fitted with twist drills should be substituted in place of the combined outfit. A complete set of screw plates and taps, ranging from one-fourth inch to one inch will be found useful. A heavy blacksmith's hammer and sledge will also come in handy. On large ranches the tire shrinker soon pays for itself.

LUBRICATION.

One of the first steps toward properly oiling farm machinery is to select it with good oiling provisions as described under "Oiling Devices."

Someone says: "Oil is the cheapest machinery we have." It is better to spend fifty cents for oil than to spend $5.00 for a new part.

Application.—Surfaces of the wearing parts of a bearing must be covered with a thin film of oil to prevent cutting and to lighten the draft.

A bearing does not have to be "swimming" in oil in order to be well lubricated, but oil should be applied often in small quantities and should reach the place which needs it. All oil holes must be kept open and free from dirt. Sometimes they become clogged, and while they may appear to be open, still they do not convey the oil to the wearing parts and a great deal of damage is done. Many machines have been condemned, simply because one or two oiling places have been entirely overlooked. Often, for lack of a few drops of oil, the entire machine is brought to a standstill.

Kind of Lubricant.—There are many good grades of machine oils or lubricants on the market. There are also many poor grades of lubricants which are adulterated with rosin or paraffine, and may appear to be of excellent quality, but they are too gummy and dry up in a short time. Good oils will cost a little more than the cheap oils, but the higher priced oils really cost less in the end.

For farm purpose oils may be classified into heavy oils, light oils, cup grease or hard oil and axle grease. These do not necessarily include gasoline engine and steam engine oils.

The heavy oils are thick or viscous and are adapted to use only in such places as drive at slow speeds and carry heavy weights, as axles of wagons. The heavy oil is not easily forced out of the bearings and it lasts longer.

Light oils or thin oils come in several grades. For ordinary farm machinery, a medium thin oil will answer a large share of the needs. For high speed, light running machinery, such as cream separators, a thinner oil is used than that advisable for ordinary farm machinery. This oil is not adapted to machinery that carries heavy loads as it will squeeze out of the bearings too easily.

Cup grease or hard oil has many qualities to recommend it. It remains on the bearing very well, and is easily applied and can be used in place of heavy and medium oils. It is usually applied through an automatic compression cup or a hand screw cap cup.

In using hard oil, dirt cannot enter the bearing with the oil, in fact, if any dirt enters the bearing from the end, the oil will force it out. Again, if the bearing should begin to heat, the oil will begin to melt and feed faster, if the grease cup is placed above the bearing.

For gasoline and steam engine cylinders, special cylinder oil must be used. Gasoline cylinder oil is lighter and thinner than steam engine oil and is less expensive. The cylinder oils must be able to stand a great deal of heat. A good grade of ordinary machine oil will lubricate all parts of the engines, excepting the cylinders.

Oiling New Machinery.—On account of paint in the bearings of new machinery, the moving parts often run hard for the first few days. This paint can be easily removed by the application of kerosene or a mixture of equal parts of kerosene and machine oil, as the machine is being started.

CARE OF MACHINERY WHEN NOT IN USE.

To properly care for the farm machinery means that it must be well selected, kept in good repair and adjustment, oiled thoroughly, cleaned before housing, and it must have all wearing parts well greased when not in use, and painted when necessary, and it must be properly housed.

At least one-half of "good care" consists in keeping the machinery properly repaired, in good adjustment and thoroughly oiled when in use. To neglect any of the lines of care mentioned, means serious damage and loss to the machine.

The investigation showed that a small percentage of the farmers were taking the proper care of their machinery all the time. Certain farmers were found who gave their machinery excellent care when it was in use but it was given no care between seasons.

The investigation shows that there is a decided tendency to neglect the housing of machinery throughout the State. On but 22.15 per cent of the investigated farms was all the machinery housed. It was partly housed on 39.60 per cent of the farms, and on 38.25 per cent of the farms no attempt was made to house any of the machinery except the buggies, carriages and automobiles.

With the one exception of binder canvasses only 2.01 per cent of the farmers removed bright or delicate parts of their machinery for storage.

The fact that such a large percentage of the machinery is allowed to stand in the open is partly, but not wholly, explained by the marked scarcity of suitable machine sheds upon the farms.

Of the investigated farms only 19.46 per cent were equipped with closed machine sheds. 34.23 per cent had some form of open shed and 46.31 per cent had no machine sheds at all. In 74 per cent of the open sheds the machinery served as a hen roost while the chickens were allowed to roost in but 31 per cent of the closed sheds. Hogs, calves, etc., were allowed to run at will in 19.6 per cent of the open sheds and in only 10.3 per cent of the closed sheds. The fact that in 62.5 per cent of all the sheds investgated the machinery served as a hen roost, and in 15 per cent of the total number of sheds the farm animals were allowed to run at will, will explain to a large extent why the housing of machinery apparently does so little good in Colorado.

In a large number of cases the housing consists of "going through the motions" rather than actually preparing the machinery for storage and then properly storing it in a suitable shelter.

MACHINERY SHOULD BE CLEANED AND OILED BEFORE STORING.

Whether the machinery is to be housed or not, it should be cleaned and thoroughly oiled at the end of the season. With such machinery as the binder or mower, it is a good plan to thoroughly oil all bearings and wearing parts just before finishing the season. After removing all dirt, wipe the entire machine with an oiled rag or waste. The wearing parts especially should be well greased with tallow or axle grease. If the entire machine is to be housed these wearing parts do not need to be removed from the machine, but they should be removed and stored in a dry place under all other conditions.

HOUSING THE MACHINERY.

To house machinery does not always do as much good as is commonly supposed. In making the investigation, the following question was asked many times: "How should farm machinery be cared for?" It is usually answered by the farmer: "Everyone knows that it should be housed." This is a good answer as far as it goes, but to house machinery under any condition, and not properly care for it otherwise, constitutes very poor care.

Machinery may be just as well cared for if it is allowed to stand in the shade of a tree, as if it is stored in some of the leaky sheds, open sheds, poorly drained sheds, or combined machine sheds and hen roosts, such as were found during the investigation.

There is no question but that to properly house machinery is a great saving, as it not only adds a great deal to the life of the machine but it also adds to the general appearance of the farm. It was generally found that where a farmer was interested enough in his machine to properly house it, he was also interested enough in it to care for it otherwise.

The investigation showed that the life of farm machinery depended a great deal upon the owner. Individual farmers were found who took very good care of their machinery and left it in the weather, when not in use; others were found who gave their machinery very poor care and housed it when not in use. A great deal of housed machinery was found which had done no more work and was no better or older than some which had not been housed but which had been well cared for otherwise.

Cultivator shovels, plow shears, and attachments, which have been removed and greased, should be placed where there is no chance for them to get damp. It is a good plan to place them in a gunny sack and suspend them from the rafters of the shed or barn.

A great deal of farm machinery can be placed in a small space if properly arranged. At the time of storing the machinery, it should be placed in the shed according to the time it will have to be removed. The machinery that will be used late during the following season should be placed in the back part of the shed and that which is to be used early in the season should be placed in front. In this way, it will not be necessary to remove a great deal of machinery in order to get what is needed first.

The following illustration gives an idea of the amount of machinery which may be stored in a small shed if the man who stores it studies the problem thoroughly.

The following list of machinery was found in a two-story shed 20x30 feet. The shed has a small side door and a large double door at one end. On the first floor: A set of blacksmith tools with bench (repair work is done in the shed), riding plow, 2 cultivators, beet cultivator, binder, mower, grindstone, hay rake, grain drill, 2 smoothing harrows (2 sections each), slip scraper, and lister. On the second floor: A hay tedder (taken apart), several light tools, stoves (stored while not in use), some household goods, and other articles to numerous to mention. In case of large crops, grain is sometimes stored on the second floor of the shed.

The owner of the above described shed unhesitatingly states that the shed is plenty large enough for the implements on 160 acres, providing the wagon and buggy can be stored in some other building.

The time required for storing this machinery and removing it each year is estimated by the farmer to be one-half day for himself and hired man.

As the machinery is being stored, all that which needs repairs or paint should be labeled so that it cannot be overlooked during the time when the farm work is not crowding.

PAINTING FARM MACHINERY.

There is no question but that it pays to keep the farm machinery thoroughly painted. This is especially true with such machinery as is largely constructed of wood. The paint fills all pores and cracks, prevents checking, prolongs the life of the machine and also adds very much to its appearance. Two or three dollars' worth of a good, reliable, ready-mixed paint for outside use, or carriage paint, applied each year to the machinery found on the average sized farm will add many times the cost of the paint to the value of the machinery.

THE IMPLEMENT HOUSE.

It is not always necessary or advisable to construct a special building for storing farm machinery. Often a very good place can be made in the barn or other buildings. By taking some of the parts off of certain machines, they can be easily stored in what otherwise might be waste space.

The characteristics of a good implement shed are:

1. It must be thoroughly drained so the implements do not stand in a wet place.
2. It must protect against sun, wind and moisture.
3. It must not be too expensive.
4. It should be located in a convenient spot and so arranged as to be easily used.

The material from which the shed is made will depend upon the cost and the locality. In the investigation, very good sheds were found which were of wood frame construction, covered with sheet iron. Other good ones were found of wood frame construction, sided with barn siding, drop siding, and in some places with ship-lap. Shingles or corrugated iron generally make the best roofs for machine sheds.

Description of Shed Shown in Plates 6 and 7

This shed was built on a Colorado farm and has been in use for several years. The owner makes a practice of storing his machinery as it should be.

Plate 6. An Excellent Closed Machine Shed. For plans see Plate 7.

The shed is built upon posts which rest upon concrete bases 12 inches by 12 inches. A strong iron dowel pin set in the concrete and projecting up into the post keeps the latter from slipping. The sides of the shed are 8 feet high. The roof is one-third pitch, shingled. Rafters 2 in. x 6 in. x 3 ft. on center. The lower girt is 2 in. x 6 in., the middle girt (placed just below the windows) is 2 in. x 6 in., while the upper girt is 2 in x 8 in. and serves as plate.

As the posts do not extend into the ground, it is necessary to brace the sides and ends of the shed. Braces also extend from the side posts to the collar beams, where the rafters come nearly over the posts. On the south side at the west end is a rolling door 7 feet 6 inches high by 8 feet long. At the east end the opening is 8 feet high by 10 feet wide. It is covered by two rolling doors 5 feet by 8 feet.

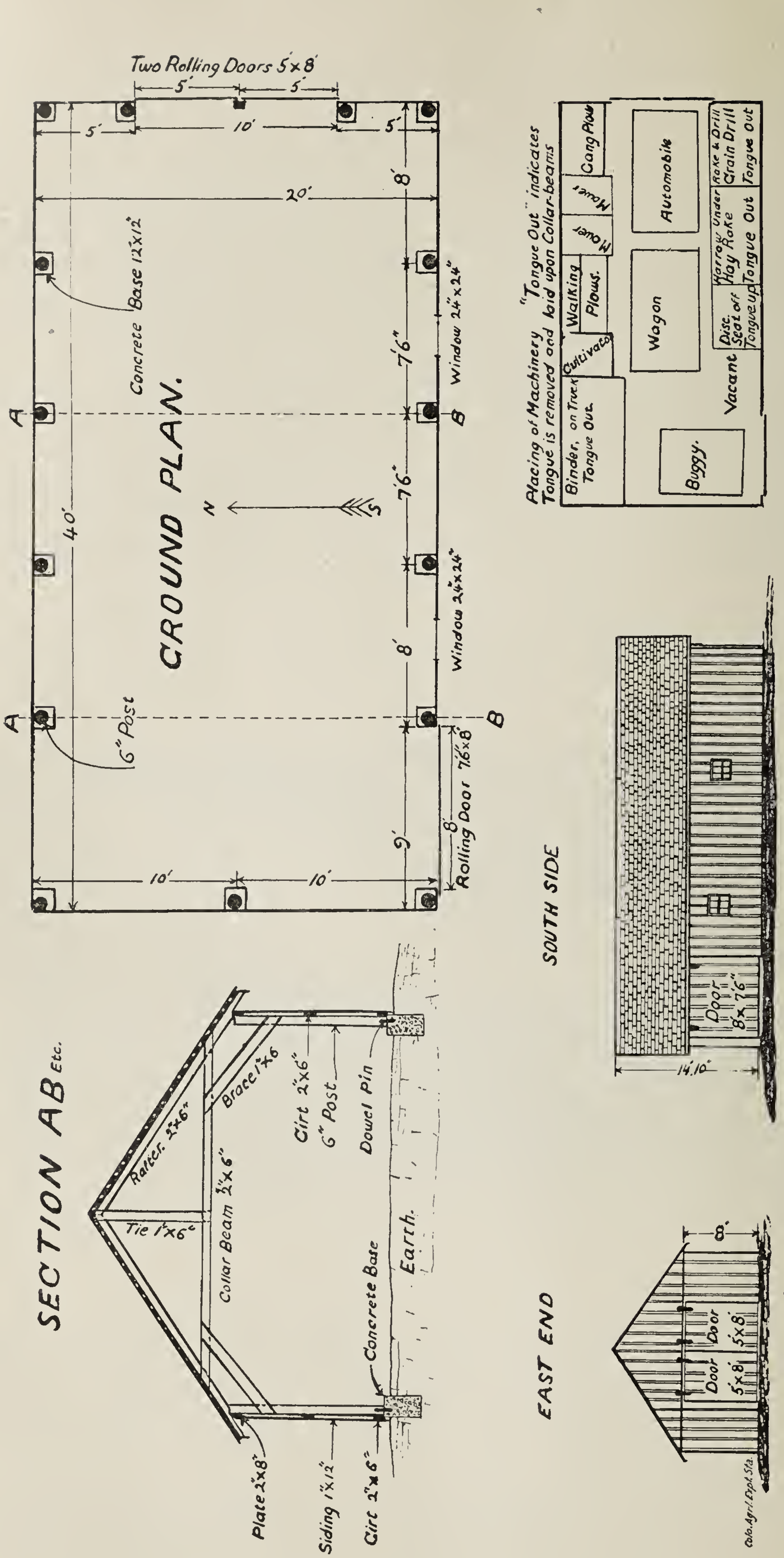

Plate 7. A Very Good Type of Closed Machine Shed

The sides are made of 12 inch stock boards. The cracks are covered with O. G. battens. The ground upon which the shed sits is about a foot higher than the surrounding ground. This gives a hard, dry dirt floor for the machinery.

In the lower right hand corner of the drawing is shown the arrangement of the machinery in the shed. In some cases (marked "tongue out") the tongues are removed from the machines and placed upon the collar beams. The cultivator shovels, mower sickles, plow shears, binder canvasses, etc., are all greased and suspended from the collar beams. A large part of the machinery may be removed by simply running out the auto. In some cases the wagon must also be removed. The transport trucks are almost a necessity for the storage of a binder in this sort of a shed. The shed is painted with two coats of mineral red in oil.

Description of Shed Shown in Plates 8 and 9

This shed has actually been built by a Colorado farmer and proves very economical and satisfactory. The only changes in the original plan is the addition of four small windows. The shed is 16x66 feet. The posts are 10 feet high in front and 8 feet high in the rear, and are set in the ground 3 feet. There is no foundation for the shed.

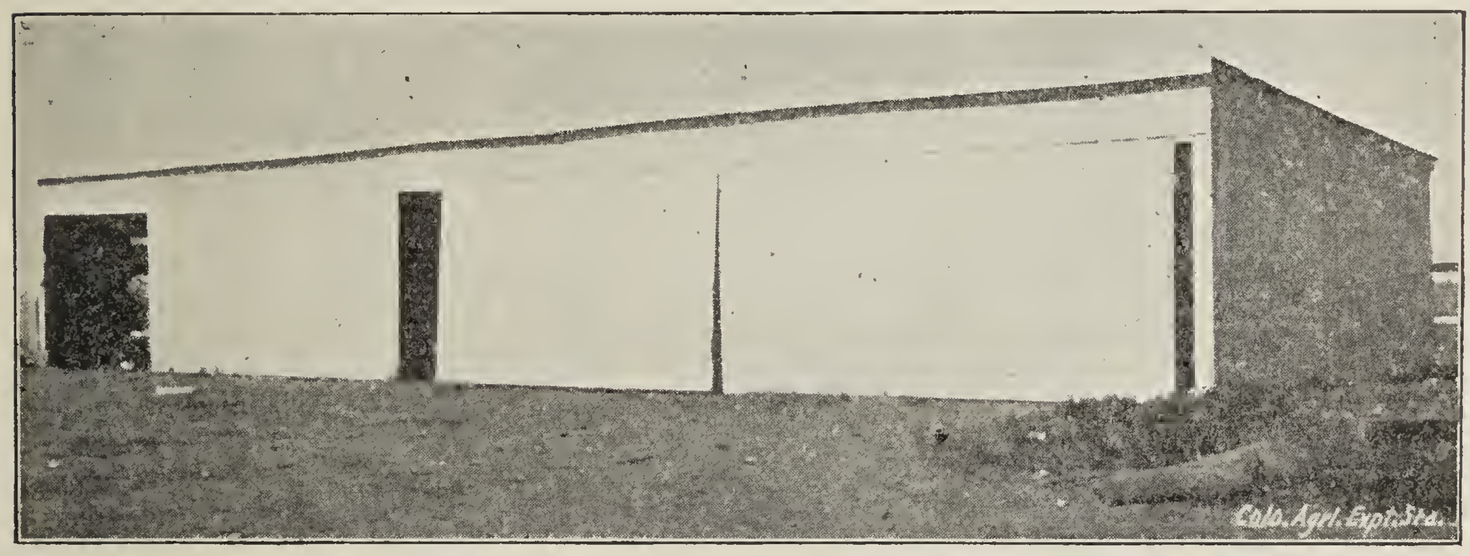

Plate 8. A Well Planned Machine Shed. For plans see Plate 9.

These posts eliminate the necessity of a frame or braces. The bottom girt is 2 in. x 6 in., the middle girt 2 in. x 4 in., and the top girt, which also acts as plate, is 2 in. x 8 in. The rafters are 2 in. x 6 in., set 3 feet apart on centers. The sheathing is 1 in. x 6 in. placed at the ends and in the middle of the sheets of corrugated iron which form the roof. At each end on the front side of the shed is located a 12 foot rolling door 8 feet high. Near the middle of the shed is a 14 foot door 8 feet high. These doors roll upon a continuous track which runs the entire length of the shed.

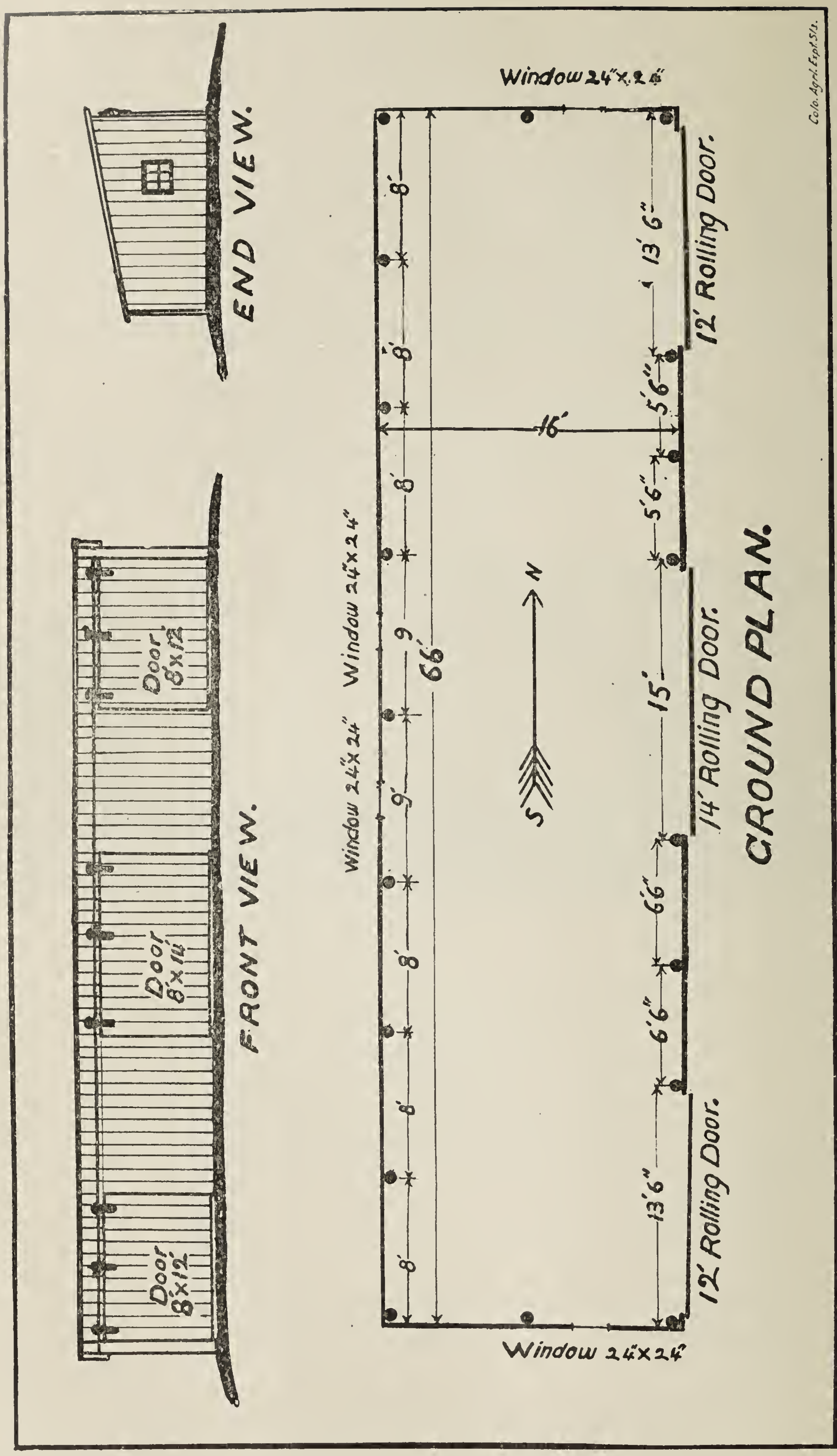

Plate 9. A Very Handy Shed with Corrugated Iron Roof

It becomes necessary to use a 2 in. x 8 in. plate and a 2 in. x 8 in. girt just above the doors to carry the weight of the doors.

The ground upon which the shed sits is about 8 to 12 inches higher than the surrounding ground. This gives a dry earth floor for the machinery.

In the drawing all the doors are closed. In the cut they are opened slightly.

The shed is painted with two coats of white lead in oil.