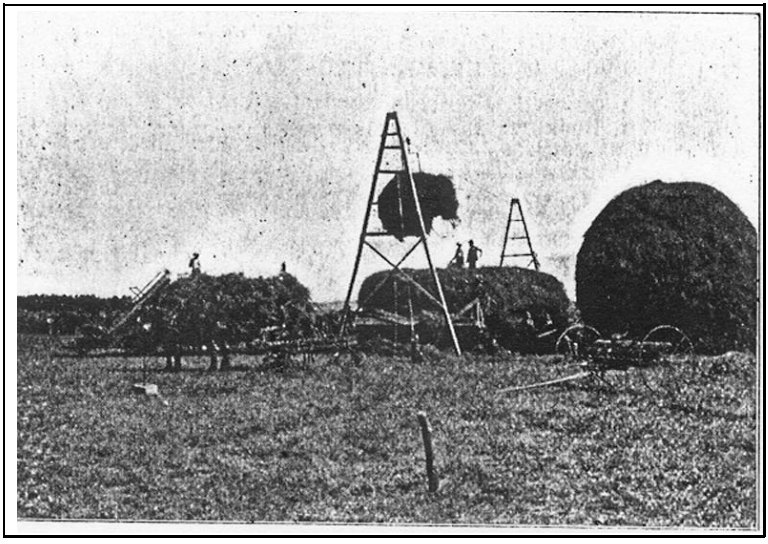
JUNE, 1908. BULLETIN 155

Kansas State Agricultural College

Agricultural Experiment Station

ALFALFA.



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Address, *Director of Experiment Station, Manhattan, Kan.*

ALFALFA.

Alfalfa is the imperial forage crop of Kansas. While other field crops surpass in acreage and total yield, in net returns per acre alfalfa is clearly in the lead.

The empire over which alfalfa rules, while not as large as that of corn or wheat, is yet the most remarkable because of the quality and riches that follow in its wake wherever this monarch goes. The time is not far distant when alfalfa will occupy every available acre in every congenial area in the state; when the demand for the crop and for its products for seed and hay at home and for meal abroad will be even greater than the supply.

To-day interest in this crop is unprecedented. Scarcely a day passes that a score or more of inquiries are not made of the Station in reference to alfalfa alone. To supply the demand for definite information concerning this wonderful plant, the several members of the Station staff have prepared this bulletin, presenting a brief but comprehensive résumé of the latest knowledge on the crop.

Alfalfa was early appreciated in the state, and for years the fostering and promotion of the crop has been in the hands of the Station. It has been estimated that the impetus given to the raising of alfalfa (bringing the crop acreage almost up to the million mark) by circulating the practical facts about the seeding, growing, curing, and using of the crop, if given in figures, would pay in a single year the entire expense of not only the Station, but of all departments of the Agricultural College from the time when first established to the present. By promoting the successful production of alfalfa the Station has not only extended the dominion of an imperial forage crop, but in so doing has discharged its own entire expense, and in addition has added millions of dollars to the wealth of the state.

CHARLES W. BURKETT, *Director.*

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ALFALFA.

HISTORY AND VARIETIES.

The past history of alfalfa is very closely related to the history of civilized man himself. Originating with him in central Asia it has followed him like a true and faithful friend to the uttermost parts of the earth. For the ancient Persians it was the most important forage plant. Whether it was domesticated by them or by a more ancient people is not known. It followed the invasion of Xerxes into Greece and from the Grecians the Romans obtained it. From these centers it spread throughout the Mediterranean littoral into France, Spain and northern Europe.

The Greeks called it "Medike" and the Romans "Herba Medica" on account of its Median or Persian origin. During the middle ages, however, these earlier names were lost sight of by its European growers and it was named "luzerne," "luserne" or "lucerne" after a river valley in northern Italy. To the Arabs, on the other hand, it was known as "alfacfacah." which means "the best kind of fodder." By the Moorish invasion and influence over northern Africa and southern Europe this Arabic name was implanted, and out of it finally came the Spanish name alfalfa. Thus the plant which botanists now call *Medicago* (referring to its ancient Median origin) was called alfalfa in Spain and lucerne in the remainder of Europe.

Alfalfa was introduced into North America from both of these sources. It followed the Spanish invasion of South America into Mexico, Peru and Chili. In many sections of these countries it found a congenial climate and soil and so at once became a permanent addition to the agricultural resources of those countries. From Mexico and central and western South America it gradually worked northward into southern California and southwestern Texas, and thence spread throughout the Rocky Mountains and plains region, adding untold wealth to the value of the farm lands of these states. With this migration has come the Spanish name alfalfa.

With the colonists from those European countries outside of

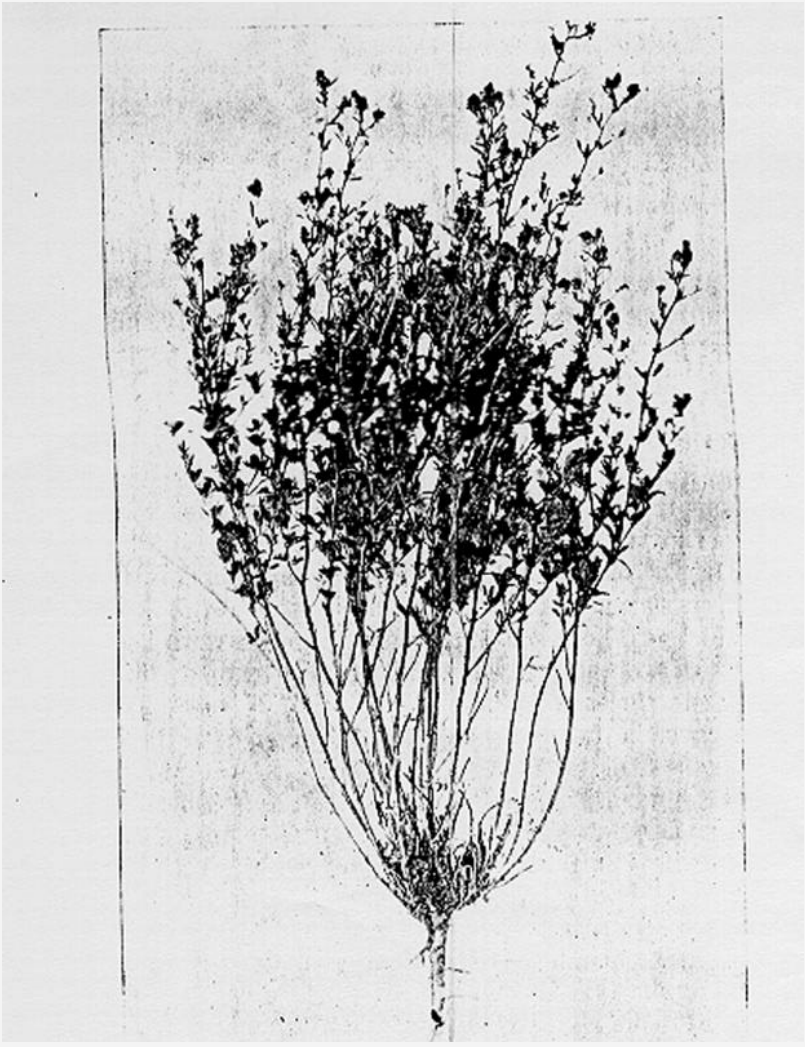


PLATE 1. ***Plant of alfalfa (Medicago sativa).***

Spain, who settled principally in the eastern part of North America, alfalfa was also introduced under the name of "lucerne," but since its culture did not prove highly successful this name has never become popular. However, with the wonderful development in the production of this forage plant in the West and with the increased knowledge concerning its proper care and management, the successful culture of alfalfa is be-

ing pushed further and further eastward under its Spanish name, while the European name lucerne is to-day becoming almost totally unused in America.

BOTANICAL DISCUSSION.

The botanical name of alfalfa is *Medicago sativa* L. This means that it is one of the species of a genus or group of closely related plants which are classified under the general name of *Medicago.* There are between fifty and one hundred species of this genus, all of which are native to the eastern hemisphere. Their natural range seems to extend from eastern Asia to southern Africa. Some of the species are woody shrubs while others are weak and trailing. Most of them are perennial, at least in their underground parts, but some are annuals, *i. e.*,

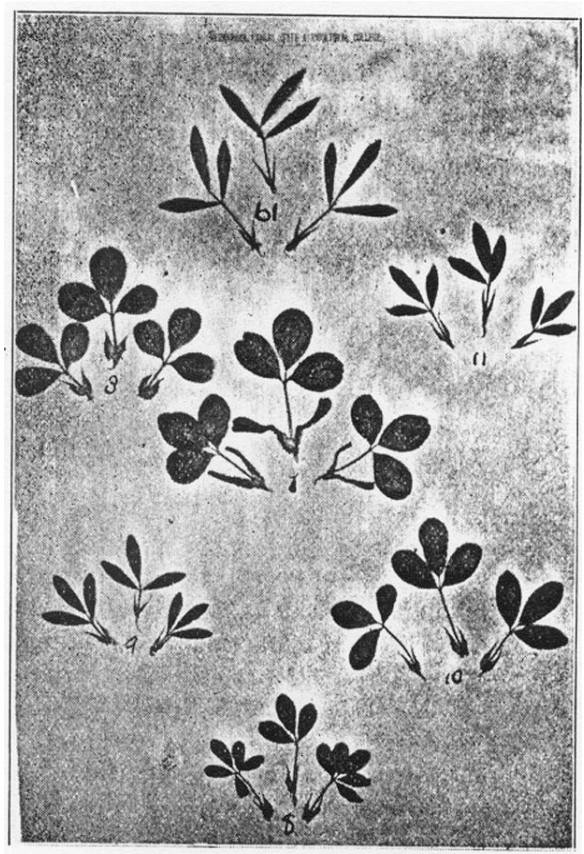


PLATE 2. A few striking leaf-types of alfalfa.

they die out completely at the end of the season and must come from seed each year. Notwithstanding the great number of species within the genus *Medicago* and their wide range of habitat and habit, and notwithstanding that many of them may have desirable and valuable qualities, the fact remains that only six have come into general notice as forage plants, and of these only one or two have any special merit. Short descriptions of each of these follow:

Alfalfa *(Medicago sativa* Linn) is an upright, much branched, smooth or slightly pubescent perennial plant one to three feet high. The branches arise from a rather woody base which crowns a long tap-root. This root with its branches may extend three to twelve, or, in rare cases, even fifteen feet deep, rendering this species very drought-resistant on account of its being able to bring up water from the subsoil far beyond the reach of ordinary plants. The leaves are arranged alternately on the stem and are trifoliate or three-parted, each part being slightly broader above the middle and usually tapering each way, although the apex may he frequently rounded, blunt, or even slightly notched. The pea-like flowers, varying in tint from pale, almost white, to deep reddish purple, are arranged in rather elongated loose clusters borne on the ends of the many branches. The pods are spirally twisted through one to three complete curves, forming a coil one-fourth to one-fifth inch in diameter. This pod contains from one to eight seeds. The seeds are kidney-shaped, about one-eighth of an inch long and a little more than half as wide. From an agricultural standpoint this species is by far the most important, being probably the most widely grown and most valuable forage plant in the world.

Yellow lucerne or Swedish clover *(Medicago falcata)* is a perennial plant strongly resembling alfalfa, but it differs from alfalfa in being of somewhat lower, more spreading habit and having bright yellow flowers. It is a native of northern Europe, extending into Sweden and probably far into northern Siberia. It shows greater cold resistance than the ordinary alfalfa and is less liable to winter-killing. This species is probably identical with the yellow Siberian alfalfa recently introduced by Prof. N. E. Hansen, of South Dakota.

Sand lucerne *(Medicago media* Pers.). “There has been a difference of opinion among European botanists in regard to the relationship of Sand lucerne to other lucernes or alfalfas,

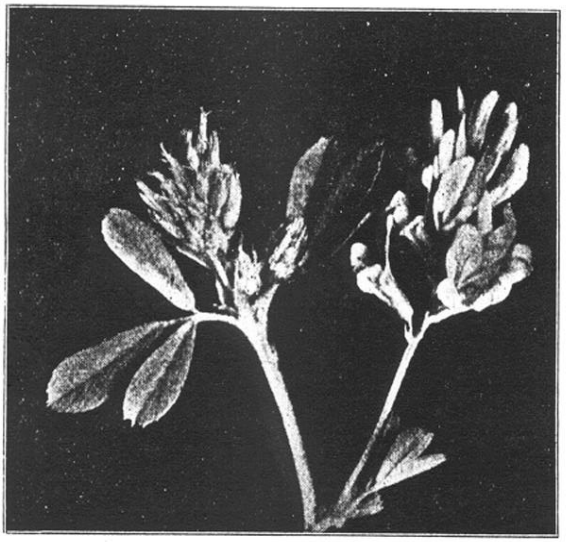


PLATE 3. A flower-cluster of alfalfa slightly enlarged.

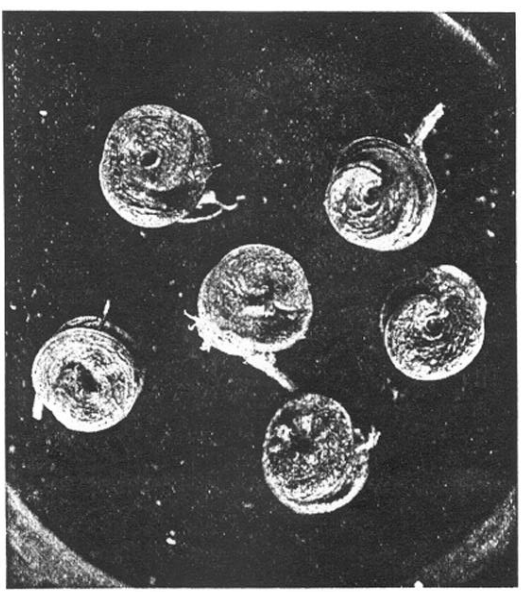


PLATE 4. Pods of alfalfa magnified four diameters.

viz., *Medicago sativa* (ordinary alfalfa) and *Medicago falcata* (Yellow lucerne). Alefeld and other botanists unite common alfalfa, Sand lucerne, and Yellow lucerne into a single species. Some botanists look upon alfalfa and Yellow lucerne as distinct species and consider Sand lucerne as a hybrid between them. Others regard them all as distinct species. The three forms, however, differ so widely in agricultural value and other characters that they cannot be treated together."

"The ordinary distinguishing characters between alfalfa and Sand lucerne are easily recognizable when the two are grown side by side."

"The stiff habit of alfalfa differs from the more spreading habit of Sand lucerne. The flowers of the former are bluish to violet purple, while those of the latter range from bluish and purple to lemon yellow, with many intermediate shades. The pods of alfalfa are coiled in about two turns, while those of Sand lucerne are in about three-fourths of one coil. The seeds of the Sand lucerne are lighter than those of alfalfa. Five hundred seeds of Sand lucerne weigh from 0.8 to 0.9 gram, while the same number of seeds of common alfalfa weigh from 1 to 1.037 grams."

"Sand lucerne, although a perennial like alfalfa, is not so productive in lands sufficiently moist for the latter or where it is hardy."

However, in non-irrigated land in parts of Wisconsin and in Utah it is said to surpass any other variety except the Turkestan. In the moist climate of Michigan and in the irrigated land of Utah, on the other hand, it was much inferior to the ordinary sorts. Seedsmen advertise it as being hardier, more drought-resistant and better able to stand grazing than alfalfa, and say that it will succeed on sandy soil which is too light to produce profitable crops of other forage plants.

Yellow trefoil or Hop clover *(Medicago lupulina* L.) is an annual species and may be distinguished from alfalfa by its more spreading habit, its shorter and broader tipped leaves, by its yellow flowers, and, finally, by the fact that the pods are not coiled as with alfalfa, although coiled to make a single incomplete spiral. These pods also differ from those of alfalfa in being black when ripe. This species has some value in moist regions but is far inferior to alfalfa.

Bur clover *(Medicago denticulata* Willd.) and Spotted Medic *(Medicago arabica* All.), like Yellow trefoil, are also annual

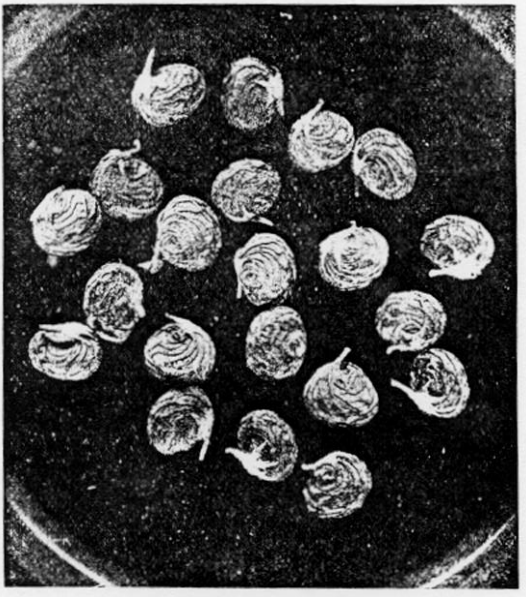


PLATE 5. Pods of yellow trefoil magnified four diameters.

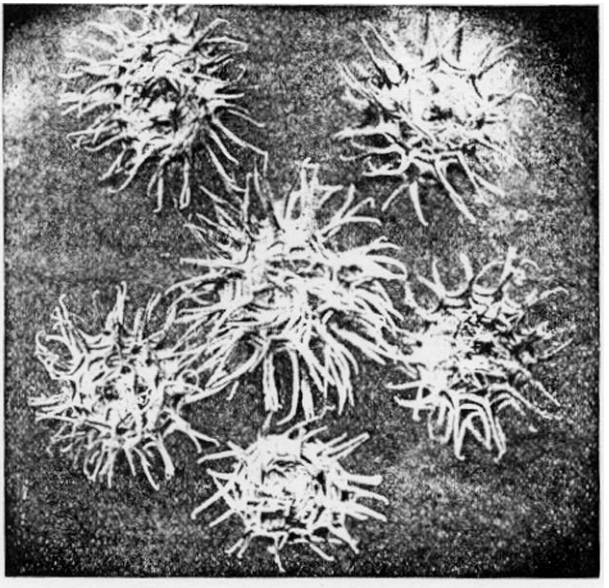


PLATE 6. Pods of bur clover magnified four diameters.

plants and have yellow flowers. They differ, however, from all of the above-mentioned species in having burry pods. Although grown in some localities, they are of little agricultural consequence.

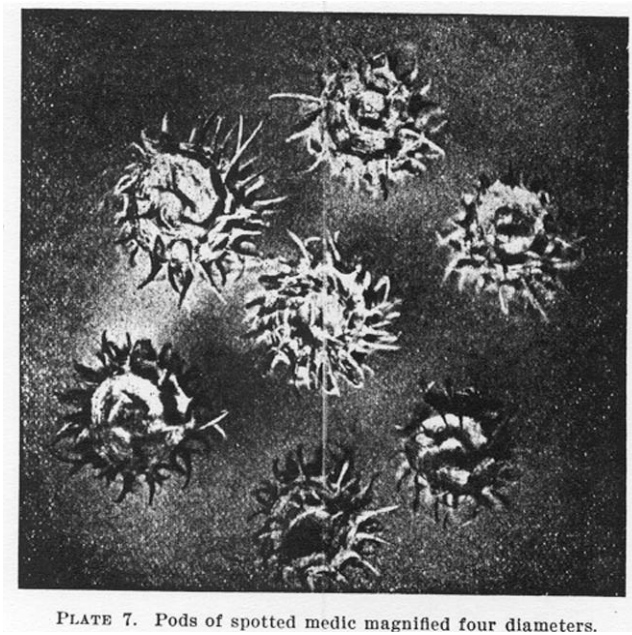


PLATE 7. Pods of spotted medic magnified four diameters.

VARIETIES.

The natural variability of the species and the wide range of soil and climatic conditions under which it has been grown for hundreds of years has caused to be formed a large number of races and types of alfalfa. These types are formed by adaptive modifications in response to some particular environment. The degree of distinctness of the types seems largely to depend on the distinctness of the environmental factors and to the length of time that alfalfa has been grown in that locality. A visit by a careful observer to any alfalfa field will be sufficient to reveal to him the probable manner by which differences in climate or soil may soon produce differences in the types of alfalfa produced therein. These differences manifest themselves in respect to habit of growth, form, size and color shade of the leaves, density of the foliage, size and succulence of the stems, and later in the color of the flowers. With these differences in external appearance it is but natural to suppose that

there occur also many physiological differences as regards drought-resistance, vigor of growth, resistance to heat or cold, seed production, etc. Many such differences have been measured and recorded at this station (bulletin 151). In a dry region those plants which were most drought-resistant would best succeed while all others would gradually die out; in a cold country resistance to winter-killing would be the prime factor and would thus naturally select plants of this type and exclude those inferior with respect to this character; whereas in a moist climate with mild winters drought-resistance or the ability to withstand extremes of heat or cold would be of little consequence, and under these circumstances plants most vigorous in growth and most productive of seed would crowd out the remainder without regard to other characters.

That there are but few named agricultural varieties of alfalfa is probably due to the fact that this plant has not been very extensively grown in northern Europe, England and eastern America, outside of which the conscious selection and breeding of plants and the consequent improving and naming of varieties has never, until recently, at least, materially developed.

It is for this reason that the varieties which we now possess are termed regional varieties rather than having assigned to them special names as are applied, for instance, to the varieties of wheat or corn. It is true that many of these regional varieties are identical in form, habit, and value, but some of them are very distinct and perhaps, when more is learned of them, may have to be assigned to other species than *Medicago sativa* or else to hybrids between this and other species.

NAMED VARIETIES.

Aside from Sand lucerne, which is considered by some authors to be only a variety of alfalfa, by others a hybrid between alfalfa and Yellow lucerne, but which is here given under the name of *Medicago media,* there is only one variety of alfalfa to which has been given a proper name. This is the Grimm alfalfa, now grown to a limited extent in North and South Dakota, and in Minnesota and Wisconsin. This variety, however, bears many characters in common with Sand lucerne and they may eventually be shown to be identical. It is very drought- and cold-resistant and succeeds in the same localities in which Turkestan alfalfa is successful, *i.* e., in the northern part of the plains region, including such states as the Dakotas, Minne-

sota and Wisconsin, and such mountain states as Montana, Utah and Idaho. On the other hand, in the more moist regions and in the South it would probably be lacking in productivity,

Such names as "Hardy alfalfa," "Dry-land alfalfa," "Northern grown," found in seed catalogues, are usually misnomers entirely, or else are names the seedsmen have applied to importations of regional varieties.

REGIONAL VARIETIES.

For the many regional varieties of alfalfa which are now being introduced into the United States, thanks are for the most part due to the agricultural explorers sent out by the United States Department of Agriculture. Samples have been secured from almost all parts of the world where alfalfa is grown, and these have been distributed from time to time to individuals and experiment stations in various parts of the country for trial. It has been from a comparative study of these importations that the characteristic differences and great economic importance of regional varieties have been discovered. The long-continued growth of alfalfa in a given locality stamps the characters of that region upon it and makes of it a more or less distinct variety, much superior in that or similar localities to other sorts which have been produced by different sets of environmental factors. It must not be assumed, however, that all seeds imported from a given country have similar characteristics. We may take Siberia as a concrete example. It is a very large country, and, as Professor Hansen says, the whole of the United States could be spread out within it and still allow a sufficient border around the edges for a good size frame. One could not, therefore, expect all Siberian alfalfas to have the same characteristics, for parts of Siberia are so cold as to be almost uninhabitable, while other parts are as mild as the most favored sections of our own country. Another factor which must be borne in mind when seeds are imported from a dry region is whether they came from irrigated or non-irrigated districts, for the reason that irrigated alfalfas, though brought from a rainless region, would be but little more drought-resistant than would the ordinary sorts.

The regional varieties of alfalfa may be divided into five fairly distinct types. The following paragraphs will attempt to give some of the chief characters of these types and the regions in which they may be expected to succeed in America,

but it must be added that much yet needs to be learned before the varieties and types of alfalfa now in existence can be properly classified and described and their comparative values determined.

THE TURKESTAN TYPE.

This variety, coming from a country where the summers are long and extremely dry and hot, had developed very hardy and drought-resistant characters. Along with this hardy nature also goes the ability to withstand extremes of cold as well as of heat. This character places it on an equal footing with the Grimm alfalfa and the Sand lucerne in being suitable for northern climates.

In habit the Turkestan alfalfa is lower than the ordinary sorts, slightly more spreading, and the stems are smaller and somewhat wiry. The leaves are usually somewhat narrower, smaller and slightly more hairy than are those of American alfalfa. However, these differences are so slight that they are frequently overlooked and it would be extremely difficult if not impossible for a farmer or even a trained botanist to take up any given plant and say whether it was American or Turkestan. As above mentioned, however, its chief difference is a physiological one, which enables it to withstand extremes of dryness, heat or cold and produce crops where ordinary alfalfa would fail entirely or else be so injured as to become unprofitable. Such are the unirrigated lands of New Mexico, Arizona, Colorado and the colder and dryer regions of North and South Dakota, Wisconsin and Minnesota. However, where there is a sufficient supply of moisture, and the winters are not extremely cold, lack of productivity renders the Turkestan variety much inferior to the ordinary sort. It has therefore proven a failure in the Central states and the states of the middle West.

THE GERMAN TYPE.

This type of alfalfa is of little importance in America. In habit of growth this more nearly approximates the Turkestan than the American alfalfa, but the leaves are a little broader, less hairy, and the plants are more succulent. In productivity it slightly exceeds the Turkestan, but falls short of the American in the West. In the Middle and Eastern states, however, notably in Michigan and South Carolina, this type has outyielded the others in a comparative test. In hardiness against cold and in drought-resistance it is inferior to either of the above-mentioned sorts.

THE AMERICAN TYPE.

This type is sometimes called Western alfalfa to distinguish it from the German or eastern type. It grows taller and is more productive than either of the types above mentioned. It withstands more cold and drought than the German, but less than the Turkestan. These characteristics have probably been acquired by thorough acclimation during the slow migration of Spanish or Arabic types of alfalfa through the arid and semiarid regions of Chili, Mexico, California, Colorado and southwest Texas, so that by the time it has reached the plains of the central West and is beginning to invade the Eastern states, a type distinctly American has been fixed.

This alfalfa succeeds in California, the middle Rocky Mountain states on irrigated or moist lands, in the plains region from northern Texas to South Dakota and eastward to and somewhat beyond the Mississippi river. To the northward, on account of lack of winter hardiness, it is outyielded by the Turkestan type, by the Grimm alfalfa and by Sand lucerne, while to the south other types yet to be described are more productive.

THE ARABIAN TYPE.

This type may be made roughly to include the Arabian and Algerian types of alfalfa. These alfalfas are more upright, have larger, more succulent stems and larger, broader and lighter colored leaves, than do any of the types already described. Arabian alfalfa is more productive and vigorous than is the American, but lacks the ability to withstand cold. The range of usefulness of this type is therefore confined to such states as Arizona, New Mexico and parts of Texas and California. How much further eastward along the southern Gulf and Atlantic states its culture could be profitably extended has not yet been ascertained.

THE PERUVIAN TYPE

This type of alfalfa, recently introduced from Peru by the Bureau of Plant Industry, is a very promising sort for southern climates. It is taller, more upright, has fewer and larger stems to the crown than either American or Arabian alfalfa. It is also said to be more productive than either of the above; and that, within its range, will grow at lower temperatures than any other alfalfa known. Unfortunately, however, its range is limited to the warmer sections of the United States,

being about the same as that of the Arabian and Algerian sorts already described.

"The most evident botanical differences between Peruvian and Arabian alfalfa are to be found in the leaves. The leaflets of the Peruvian alfalfa are very long compared to their width, being from three to five times as long as broad. The leaflets of Arabian alfalfa are, on the other hand, very broad in comparison to their length, giving the impression of roundness. They range from one and one-fourth to three times as long as broad."

"In its floral characters the Arabian is much nearer the common form than is the Peruvian alfalfa. The flowers are usually smaller; and the calyx teeth, which in common alfalfa are about as long, are in the Peruvian type much longer than the calyx tube."

The advantages and disadvantages of Peruvian alfalfa may be summed up in the following extract from the bulletin already quoted: "When compared with other sorts, it has greater vigor, grows more rapidly and recovers more quickly after cutting. By reason of its low zero point of growth it has a longer growing season, under favorable conditions continuing growth throughout the winter. It is more resistant to frost and matures its seed later in the autumn. These factors result in the addition of one or two more hay crops during the year. When grown in the region to which it is suited but two disadvantages have been noted--hairiness and a tendency to become woody. It has been found that both of these adverse conditions can be largely prevented by thick seeding. Lack of hardiness will always confine the Peruvian variety to limited areas. On account of the tendency of the stem to become hard and woody, it is not suitable for cultivation in regions where dry-farming is practiced, for in order to secure the best results in the dry-land culture of alfalfa thin seeding is a necessity."

THE SEEDING OF ALFALFA.

With good seed, a proper seed-bed, and land adapted for growing the crop, a careful farmer should be almost as sure of establishing a successful stand of alfalfa as the average farmer is of getting a stand of wheat or oats. This may seem like a strong statement, since failure to get a good stand of alfalfa has often been the experience of many farmers, especially those who were inexperienced in growing this crop. However, it is generally true that the longer alfalfa is raised on any farm the more readily it grows and the easier it becomes for the farmer to start the crop. Whether this is due largely to the fact that a farmer learns better how to seed and handle the crop, or whether the land becomes better adapted for growing alfalfa, is a question. Perhaps both are important factors in the successful production of the crop.

THE SOIL.

Alfalfa will succeed in a variety of soils, grading from sandy to heavy clay and "gumbo," although with unfavorable soil conditions it becomes more difficult to establish a good stand. The crop, however, does not thrive alike on all soils; perhaps a deep, fertile loam or clayey loam well supplied with the mineral elements of plant-food is the most favorable soil for growing alfalfa. The crop needs a deep, well-drained soil; on wet land, with underground water too near the surface, alfalfa will often produce poorly and the plants soon die. Alfalfa will not thrive on a soil deficient in lime, which shows an acid reaction. Some old lands in eastern and southeastern Kansas being originally rather deficient in lime, after years of cropping have become deficient in humus and organic matter and so deficient in lime that they will hardly produce alfalfa successfully until the soil is fertilized by manuring and the acid condition is corrected by applications of lime.

It is a fact well known to old clover growers that clover cannot be readily started on old, "worn" lands, until the soil has been improved in texture and fertility by manuring. The same is true also of alfalfa, and it is often advisable before seeding alfalfa on "thin" or "worn" land to take a year or two in preparing the soil by green manuring, deep plowing and thorough cultivation, with the application also, when possible, of barnyard manure. Alfalfa may be started on very "thin" land,

deficient in humus and nitrogen, but which contains a sufficient supply of the mineral elements of plant-food, but under such conditions it starts very slowly, and may not produce profitable crops for a year or two after seeding; yet, in time, when the plants have established a deep root system and are well supplied with the nitrogen-gathering bacteria, the alfalfa makes a thrifty growth and produces excellent crops, even without manuring or fertilization. The writer knows of fields within the vicinity of this Experiment Station, which before seeding to alfalfa would not produce thirty bushels of corn per acre in a favorable season, that are now yielding annually four to five tons per acre of good alfalfa hay.

In order that alfalfa may make a good stand and continue to produce large crops, the land must contain or be supplied with the nitrogen-gathering bacteria which live on the roots of the alfalfa plants and supply a part of the plant's food. Lands that have been farmed for many years and never seeded to alfalfa may not contain these bacteria, and before alfalfa will grow well it may be necessary to supply the bacteria by inoculating such land with soil from an old alfalfa field. From 200 to 300 pounds of infected soil, carefully spread and mixed with the soil by cultivation before the alfalfa is planted, is sufficient to inoculate the new field and infect most of the alfalfa plants within a year or two after seeding. The nitro-culture preparations for treating the seed before sowing, now manufactured and sold, may also give good results when used carefully according to directions. The average farmer will secure better results by using the infected soil, when it can be secured at a reasonable cost, rather than to treat the seed with nitro-culture preparations.

The bacteria which grow on the roots of sweet clover (*Melilotus alba*), a common roadside weed, will also grow on alfalfa roots, and the soil of cultivated fields may be infected by spreading soil from sweet clover patches, or the same result may perhaps be accomplished by growing sweet clover (seed of which may be secured from seedsmen) on the field for a year or two previous to seeding alfalfa and plowing it under for green manure. Likewise this is a good method for fertilizing and improving the physical condition of soils which are deficient in humus and hard and compact in texture.

THE SEED.

The first requisite in getting a stand of any crop is good seed. Not only should alfalfa seed be of good quality and strong in vitality and germination, but it should be clean and free from foul weed seeds. It seems hardly necessary to enlarge on this point, yet many farmers are careless, much poor seed is sold and sown, and many costly failures result. Alfalfa seed costs so much, and the expense of a failure to get a stand is so great, that many farmers are discouraged by an unsuccessful trial, while others hesitate to make the venture. Those who are familiar with alfalfa seed can usually recognize seed of low vitality. Seed of good quality has a characteristic bright, clear color, while seed which has received injury from wetting or heating has a dull dead color, indicating its impaired vitality. Seed which is badly shrunken is also apt to contain a large percentage of seeds of low vitality which will not germinate and grow under ordinary soil conditions.

The only way to determine the actual vitality of the seed is to test its germination. This can be done in several ways. A simple and handy method is to use a cigar box: place several folds of wet paper in the bottom of the box, over it sprinkle the seed and cover with several folds of wet paper; close the box and set it in a favorably warm place. Examine the seed in four or five days and count the germinations, remoistening the paper if necessary. At the end of eight or ten days the test may be discontinued and the percentage of germination calculated. A large percentage of germination the first three to five days indicates a strong, vigorous seed, while a slow, weak germination indicates seed low in vitality, which may not germinate when planted except under the most favorable soil conditions. For the best seed the percentage of germination should be eighty-five per cent or more. A low percentage of germination, and fairly quick and strong, indicates a mixture of good and poor seed, and such seed may be sown, but more seed will be required per acre to insure a stand.

Carefully examine the seed for impurities, and if weed seeds are present the alfalfa should be carefully cleaned before seeding. The parasite dodder is now appearing quite extensively in alfalfa fields in some parts of the West. This is a most dangerous pest, and it is usually unsafe to sow seed infected with dodder, even after thorough cleaning; but dodder seed is only about one-half as large as alfalfa seed, and by

careful cleaning, using a "dodder sieve," which will also remove many of the smaller alfalfa seeds, the dodder may be removed, leaving only the choice, plump, clean alfalfa seed to sow.

AMOUNT OF SEED TO SOW.

The amount of alfalfa seed to sow will depend to some extent upon the quality and vitality of the seed. The general practice has been, and perhaps still is, to sow about twenty pounds of seed per acre, but many of the oldest and most successful alfalfa growers are now using much less seed. Good stands have been reported from sowing as little as six pounds of good seed per acre. The seeding trials at the Kansas Experiment Station also prove that ten or twelve pounds of good seed per acre, sown in a well-prepared seed-bed, will produce an excellent stand of alfalfa. With alfalfa, as with clover, doubtless the season has much to do with securing a successful catch, but even in an unfavorable season it is possible, with an average amount of good seed sown at the right time in a properly prepared seed-bed, to secure a good stand of alfalfa.

THE SEED-BED.

The seed must grow, else all the care and labor of seeding is for naught; but with good seed to plant, the most important factor in establishing a stand of alfalfa is the preparation of the soil or seed-bed. Although this matter of a proper seed-bed has been studied and discussed much in the last few years, yet the principles involved in the preparation of a seed-bed, and its condition at seeding time as related to a favorable environment for germinating the seed and starting the young plants, are not always fully understood. A deep, loose seed-bed is not a favorable one in which to seed alfalfa, clover, or grasses. Such a seed-bed may be in a favorable condition for planting potatoes, or perhaps corn may sprout and grow well under the conditions named, since the seed is large and strong in vitality and contains much nutriment to nourish and start the young plant. But with clover, alfalfa, grasses and other small seeds the ideal seed-bed should be mellow, but finely pulverized only about as deep as the seed is planted. Beneath the point at which the seed is placed and covered in the earth the soil should be rather firm, but not too hard or compact; such a condition as may be secured by cultivating the surface of well-settled fall plowing, or by disking and harrowing unplowed corn land in the spring.

METHODS OF PREPARATION.

The proper seed-bed for fall seeding may often be prepared by summer plowing immediately after harvesting wheat or early spring grain and harrowing or disking at intervals until seeding time. It is often advisable to disk clean stubble-land in preference to plowing, starting the disking as soon after harvest as possible. Millet or cow-peas cut for hay make good crops with which to precede the fall sowing of alfalfa.

On foul land or in a dry climate it is well to fallow the land, practicing frequent cultivation during the summer previous to seeding in the fall. Such preparation will clear the land of weeds, store and conserve soil moisture and cause the accumulation of some avai1able plant-food for the use of the tender young plants, thus insuring a rapid germination and strong early growth of the alfalfa.

Another method of seeding, adapted to weedy land or to land which is deficient in available plant-food, is to start the preparation of the seed-bed early in the spring, when the land may be either plowed or cultivated with the disk-harrow. The cultivation with the common harrow, disk or Acme harrow should be continued at intervals of a week or ten days, in order to destroy the weeds, conserve the moisture and develop available plant-food. Late in the spring, seed the alfalfa, choosing a time to sow, when possible, soon after a good rain, so that the soil may be in good condition to germinate the alfalfa seed. Alfalfa seeded by this method should sprout very quickly and the weeds should not be troublesome, since the weed seeds in the surface soil will have already germinated and the weeds will have been destroyed by the early cultivation. The cultivation also causes some of the latent fertility of the soil to develop and become available to the young plants, and this, with the abundant moisture supplied, should usually insure a good start of alfalfa, provided weather conditions are not too unfavorable.

When the seeding follows closely upon the plowing of the land, whether in the fall or spring, a proper seed-bed may only be prepared by using such an implement as the subsurface packer, by which the bottom of the furrow-slice is pulverized and firmed, thus reëstablishing the capillary connection of the soil with the subsoil, by which the moisture may be drawn up ward into the surface soil to supply the germinating seeds and the roots of the young plants.

The firm condition of the soil beneath the seed and a good connection with the subsoil not only offers favorable conditions for supplying the seed with moisture, but the mellow covering over the seed allows the air and heat to reach the seed from above, and these three--moisture, heat, and air--are the essential factors in seed germination; but if any of these are lacking the seed will not germinate. Moreover, the mellow surface above the seed allows the young plantlet to readily push its way up into the sunlight, when it throws out its green leaves, and through the action of heat and light the work of assimilation begins and the plant grows and soon establishes its roots deep in the soil and becomes able to withstand drought and unfavorable weather conditions.

TIME TO SOW.

Alfalfa may be successfully seeded throughout the eastern half of Kansas either early in the spring or early in the fall. Alfalfa may be destroyed by a hard frost just after the young plants have appeared, showing their first leaves, but when the plants have thrown out a few leaves and have made some growth they are not likely to be destroyed by frost. Thus very early seeding is perhaps more apt to be successful than medium early seeding, while late seeding is most apt to suffer from heavy rain packing the soil and from the effects of hot, dry weather.

In western Kansas, late spring or early summer seeding may often be recommended, since the fall and early spring are apt to be dry, and severe winds often prevail during the spring which may blow out or cut off and cover up the young, tender plants.

Just how late it is safe to sow alfalfa in the fall is determined to some extent by the season. During a favorable moist, warm fall, seedings up to the last of September have succeeded at the Kansas Experiment Station, but on the whole the later seedings are much less apt to prove successful than the earlier seedings. Again, if the seeding is done too early in the fall, as early as in August, a period of dry weather may cause a poor germination of the seed or destroy many of the tender plants before they have established a root growth. This is a general rule which may be practiced with success: Prepare the seed-bed early, either in the fall or spring, and seed when the soil is in a fit condition to germinate the seed.

There is little use of sowing alfalfa unless the soil conditions are favorable to germinate the seed at once for the seeds are much more apt to be injured and lost if they must lie for any considerable time in a seed-bed which is not in fit condition to germinate seed.

By fall seeding the land usually returns a fair yield of hay the first season after sowing, whereas with spring seeding the alfalfa is not likely to make sufficient growth to produce a profitable crop of hay the first season, and should the alfalfa make sufficient growth, the weeds will usually be so abundant as to greatly reduce the value of the first season's cuttings for hay. On weedy land fall seeding has the advantage of spring seeding, in that the weeds are not troublesome in the fall and the fall-seeded alfalfa starts ahead of weeds in the spring, giving a comparatively clean growth of hay the first year after seeding.

METHODS OF SEEDING.

A large amount of alfalfa has been seeded with the ordinary grain-drill. At present the greatest objection to this method is that it requires too much seed. To sow in this way requires twenty to thirty pounds of seed per acre. The feed on the ordinary grain-drill cannot be set up close enough to sow less pure seed than the amount named, and diluting with bran or other material is often unsatisfactory, causing an uneven distribution of seed. A better plan than to sow with the grain-drill is to have a grass-seeder attachment to the drill, which will allow close adjustment, and with spouts emptying into the grain tubes, so that the seed may be dropped in the drill furrows and evenly covered. In some soils and in some seasons there is little doubt but that the method of seeding with the drill may give more favorable results than broadcasting. As a rule, however, alfalfa may be successfully started by sowing broadcast in a well-prepared seed-bed, care being taken to seed at the right time and when the soil is in favorable condition for sprouting the seed. Alfalfa is successfully sown by hand, but in recent years the little wheelbarrow seeder, several makes of which are on the market, has come into use for broadcasting grass, clover, alfalfa, and other small seeds.

The seed should not be covered deeply ; usually less than one inch is better than more than one inch of soil covering, while on heavy, compact soil or in wet seasons the seed should be covered very lightly. The seed-bed should be fully prepared

before seeding, and one brush with the harrow is usually sufficient to cover the seed in a seed-bed having a mellow, even surface. If the seed is planted too deep, the young shoots will often be unable to reach the surface. The vitality of the small seed being quickly exhausted, the plant and the seed are lost.

There is always danger in using the drill for seeding that the seed may be planted too deep. Even if the seed is covered very lightly it must lie in a furrow which may fill with the first beating rain, thus covering the seed or young plants and often destroying them.

As a rule the writer does not recommend rolling after seeding, preferring to do the firming of the soil before the seeding. In light soils or dry seasons, however, it may become desirable to roll to cover the seed and press the soil about the seed. It will always be well to follow the roller with a light harrow, leaving the ground furrowed and with a surface mulch, and not smooth and hard as left by the roller.

NURSE CROP.

It is safest, as a rule, to sow alfalfa without a nurse crop, and this is the method usually practiced, although it is possible to get good stands in the most favorable climate, soil and season by seeding with spring grain crops. Again, in light soil which is apt to blow it may be advisable to sow some crop with the alfalfa in order to protect the young plants from the drifting sand. If this method is practiced a lighter seeding of grain should be made than when the grain is seeded alone, and in a dry season it may become desirable to cut the grain crop for hay before it matures in order to prevent the alfalfa from being destroyed by drought. The nurse-crop method cannot be considered a safe one for establishing a stand of alfalfa.

TREATMENT AFTER SEEDING.

Alfalfa seeded in the spring needs little care after the first season, more than to mow the weeds a few times during the summer to prevent the weeds from seeding and to keep them from "smothering" the young alfalfa plants. It is well to mow the field two or three times during the season, but the growth of weeds and alfalfa should not be cut too close to the ground until the alfalfa blooms, when it may be mowed close without injuring the plants. It seems to be true that when alfalfa has become well established, frequent close cutting seems to benefit the plant and cause it to grow more vigorously, but this is not

true of the young, tender plants. It is true of alfalfa as with any other young plant, that it must form a top growth before or at the same time that it is producing roots. The leaves are the stomach and lungs of the plant, and before the roots can develop the leaves must manufacture the products which are built into the cells and tissue that constitute the roots. If this top growth of leaves is kept cut off before a sufficient root growth has been established to easily restore the top growth, the effect is to check the growth of the plant, weaken it, and perhaps destroy it. The writer has known of good stands of alfalfa that were destroyed by a single close mowing, not due wholly perhaps to the reasons assigned above, but to the fact that the young, tender alfalfa plants which had been strongly shaded by a growth of weeds were suddenly exposed to the heat of the summer sun and a dry period of weather, which, together with the factors named, resulted in killing out the alfalfa almost completely. Clover seeded with a nurse crop of grain is often destroyed by too sudden exposure to the hot sun when the grain is harvested. Others have ascribed this to the reflection of heat from the dry stubble cooking the young clover, and advise mowing the stubble close to the ground as a preventive.

The fall-seeded alfalfa needs no care in the fall; the full growth of plants and weeds should be left as a winter covering. The next season the alfalfa may be regularly cut for hay, and with a good catch will often produce three or four cuttings the first year, yielding three or four tons of good hay per acre, although on foul land the hay is apt to be a little weedy.

MANAGEMENT OF ALFALFA IN THE FIELD.

A GOOD STAND OF ALFALFA.

A good stand of alfalfa is a variable quantity as regards the number of plants required per unit area. In a newly seeded field, where plenty of seed has been sown and the conditions have been favorable to start the young plants, as many as 120 plants per square foot have been counted. As few as 10, strong young plants per square foot fairly evenly distributed may be considered a fair stand--thick enough to leave. It is questionable whether a very thick stand is as good as a thin or medium stand. Those who advocate sowing a small amount of

seed claim that the thinner sown alfalfa starts stronger and will be more productive and remain a good stand longer than that which is sown thicker. One advantage perhaps of the thicker seeding on fertile land is the less coarse growth of stem, which produces a finer quality of hay than the larger, coarser growth resulting from thin seeding.

ALFALFA DIES OUT.

Alfalfa plants gradually die out, so that a very thick stand may show a much smaller number of plants per unit area two or three years after seeding. Some notes have been taken on this point at the Kansas Experiment Station. In the spring of 1903 an area of ten feet square was staked out in an alfalfa field seeded in the fall of 1902. On June 18, 1903, 1133 plants were counted in this plot, or an average of 11.33 plants per square foot. It will be observed that this count was made some six months after seeding. On June 29, 1906, a recounting of this field showed only 670 plants, or 6.8 plants per square foot. On August 9, 1907, the number of plants counted was 403, or 4.03 plants per square foot. This field was plowed up in the fall of 1907. The decrease in the number of plants between the first and last countings, a period of fifty months, was 730 per 100 square feet, which is a loss of 64.4 per cent.

Another plot seeded in the spring of 1904 contained 1130 plants on June 20, 1904, on an area five feet square, or 45.2 plants per square foot. On May 1, 1905, the number of plants in the plot had been reduced to 403, or 16.1 plants per square foot. On May 25, 1908, the plot contained only 148 plants, or an average of 6 plants per square foot. Only 13 per cent. of the plants counted in the original seeding survived four years after seeding. Although the number of plants as shown by these counts was greatly reduced, yet these fields did not decrease in production, and the stand of alfalfa was, apparently, as good as ever. This is explained in this way: As the plants decrease in number, those that remain increase in size, sending out more shoots or stems, thus occupying the space. In time, however, as the field grows old, the stand of alfalfa becomes too thin to produce a maximum crop, when it is usually advisable to break up the old field after seeding down a new field.

THICKENING UP A THIN STAND OF ALFALFA.

It is sometimes possible and advisable to thicken up a thin stand of newly seeded alfalfa by reseeding. This may best be accomplished by harrowing early in the spring the field which was seeded the previous fall or spring, sowing a little seed, and covering it with the harrow. The earlier this work can be done the better. The difficulty in starting new plants among the older ones is that the plants which are well started will exhaust the soil moisture and plant-food and shade the younger, more feeble plants, often destroying them, especially if a period of dry, unfavorable weather should occur.

It is not advisable or practicable to attempt to thicken up a thin stand of alfalfa on an old field, since the younger plants, even if they can he started, will hardly survive the season in competition with the old, well-established plants. The old field which has become weedy or full of grass had best be broken and rotated with corn or other crops for a year or so before reseeding. In fact, the preferable plan is to seed down other fields, using the alfalfa in rotation with corn and other crops, rather than to attempt to keep the same fields in alfalfa continuously.

CULTIVATION OF ALFALFA.

Reference has already been made regarding the importance of thorough preparation of the soil before seeding alfalfa. In the opinion of the writer three-fourths of the failures to grow alfalfa successfully have been due to lack of soil cultivation and to wrong methods of preparing the seed-bed and sowing the alfalfa. The cultivation of alfalfa after the plants are well established may also benefit the crop.

It pays to cultivate alfalfa just as it pays to cultivate corn and other crops. The next season after seeding, a heavy straight-tooth harrow may be used in the spring to loosen the surface soil and, as soon as the alfalfa has become well established, the field may be disked or cultivated with the spike-tooth disk-harrow regularly each spring and perhaps during the season after each cutting. By thorough cultivation late in the season, after the third or fourth cutting, it is often possible to destroy many weeds such as crab-grass and foxtail, the great weed enemies of alfalfa.

REASONS FOR CULTIVATION.

The surface soil becomes packed by the running of machinery, the tramping of horses, and the beating of heavy rains. Cultivation loosens the soil, favors aeration, forms a soil mulch to conserve soil moisture, and at the same time presents a surface favorable to the absorption of rains. It is especially desirable to cultivate alfalfa fields which are pastured with hogs or cattle, since such fields become very hard and compact at the surface, and unless the soil is loosened again the alfalfa will soon die out.

The presence of fresh air in the soil is very necessary in order to secure the best development of the alfalfa. The roots must breathe, and require oxygen the same as the roots of other plants, and the alfalfa bacteria must have free nitrogen in order to thrive and multiply and perform their important function of supplying the alfalfa with this important element of plant-food.

Again, cultivation may destroy the eggs and larvæ of certain insect enemies of alfalfa. Grasshoppers may be materially decreased by winter or early spring disking. Late fall, winter, or early spring cultivation may destroy the larvæ or pupæ of several other insects injurious to alfalfa, namely, the web-worm, army-worm, cutworm and fall web-worm.*

The winter disking at this Experiment Station in 1908 of an old alfalfa field appeared to do no injury to the plants. The use of the "alfalfa harrow" late in the fall on a plot of young alfalfa sown the previous spring did some injury; a number of the plants were found to be dead or dying in the spring.

Cultivation incorporates with the soil much fertilizing material, such as alfalfa leaves which have been lost during the operation of haying, and it is always advisable to disk or harrow the alfalfa field after applying manure.

The splitting or spreading of the crowns of the alfalfa plants is another advantage urged for disking alfalfa, especially on old fields, since this seems to cause the plants to stool and produce a larger number of stems, thus apparently producing a thicker stand. However, this increased growth is perhaps due largely to the other benefits of cultivation already mentioned.

Alfalfa fields which have been covered with a deposit of silt by the washing of heavy rains, flooding of streams, or by irri-

* See discussion of this point on a later page.

PLATE 8. Crowns of alfalfa roots showing effect of disking.

gation, are very greatly benefited by cultivation, which breaks up the impervious crust left by the water, letting the air and moisture into the soil and leaving a mellow surface through which the new shoots may again readily penetrate and grow. By a proper use of the disk-harrow or "alfalfa harrow" on such fields it is often possible to save a stand of alfalfa which may even be benefited and caused to make a greater growth by reason of the deposit of sediment.

METHODS OF CULTIVATION.

At this Station the usual practice has been to disk alfalfa once each year, quite early in the spring. Usually the soil is more mellow and in better condition to cultivate in the spring than it is later in the season. A proper loosening at this time puts the soil into good condition to catch the early spring rains, increasing the water supply of the soil, and thus benefiting the alfalfa perhaps for a whole season. The cultivation may be continued after each cutting, and it is often advisable to cultivate in the fall after the third or fourth cutting, especially if the field is weedy.

In comparing methods of disking alfalfa at this Station it was found that less injury was done the alfalfa and the best work accomplished by setting the disks rather straight and weighting the harrow so as to make it cut two or three inches deep; then the field was cross-disked and harrowed with the common straight-tooth harrow. As the soil is left by disking with the common disk-harrow it does not form a perfect soil mulch to conserve the soil moisture; also the clods thrown up

by the disk interferes in mowing, thus the advantage of using the smoothing-harrow to finish the work.

It is not advisable to cultivate newly seeded alfalfa. Usually cultivation should not begin until the next year after seeding. As soon as the plants have become well rooted the disk may be used, especial care being taken not to set the disks too sloping, since the crowns of the young alfalfa plants are much more readily cut off than are the crowns of older, well-established plants.

The writer has disked spring-sown alfalfa a year after seeding without apparently doing it any injury. A close examination showed that very few of the plants were cut off or injured. Sometimes newly seeded alfalfa, after it has become well set (as may be the case with fall-seeded alfalfa the next spring after seeding), may be benefited by simply harrowing with the common straight-tooth harrow.

IMPLEMENTS TO USE.

The common disk-harrow is more generally used than any other implement to cultivate alfalfa, and when properly adjusted does good work. The spike-tooth disk, known as the "alfalfa harrow," was used on the alfalfa fields at the Experiment Station farm during the seasons of 1907 and 1908. This harrow does good work when properly adjusted, and is perhaps a better implement for this purpose than the common disk-harrow. There is less liability of injuring the alfalfa plants with the "alfalfa harrow" than with the common disk-harrow. By going over a field once, which had been cultivated once during the previous season, the surface to a depth of two or three inches was thoroughly loosened and yet not left in a rough, cloddy condition. The "alfalfa harrow" does not ridge the ground as does the common disk-harrow. The revolving spike teeth thoroughly loosen the soil but slip past the alfalfa plants, doing them little or no injury. On a very hard, compact soil it was found necessary to cross-harrow in order to loosen the soil well. The "alfalfa harrow" does not split the crowns of the alfalfa plants as does the common disk-harrow, which may or may not be an advantage.

The "alfalfa harrow" is well constructed and appears to be a strong and durable machine. It has a disadvantage compared to the disk harrow in that it is perhaps not so useful an implement for other cultivation in the preparation of the seed-bed, etc. Care must be taken, also, not to run the spike-tooth

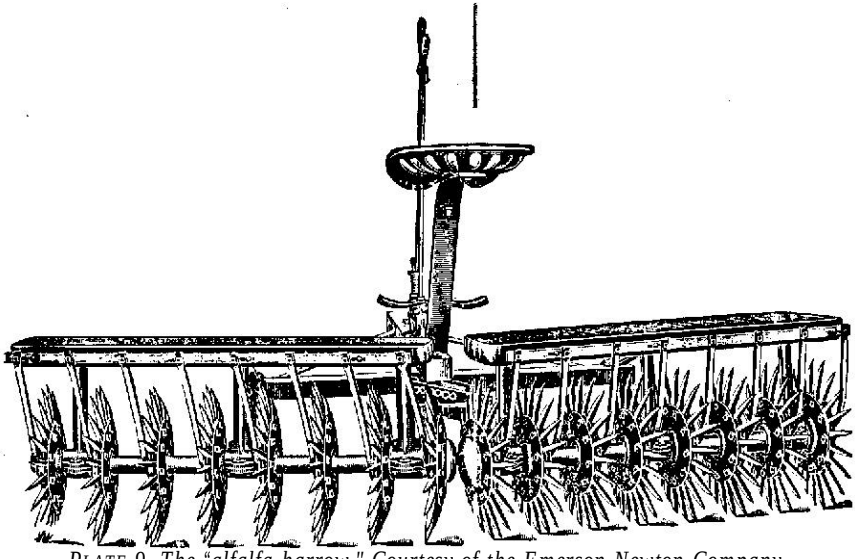


PLATE 9. The "alfalfa harrow." Courtesy of the Emerson-Newton Company.

disk over hard or stony roads, since the points of the spikes are easily bent or broken.

With a small area of alfalfa the farmer may not be justified in purchasing one of these harrows, since the common disk will do the work, but with a large acreage of alfalfa, there would be profit in owning and operating one of these implements.

RECENT EXPERIMENTS IN DISKING ALFALFA.

Experiments in disking alfalfa with the common disk-harrow were carried on at this Station in 1903-'04-'05, with the purpose, in part, of comparing the different methods of disking. Plots were single-disked, double-disked, double-disked and harrowed, and cross-disked. The better class of work was done by cross-disking and harrowing. However, the yields were not regular and on the average were unfavorable to disking. The cultivation was given quite early in the spring, before the alfalfa had started much. There were two check plots, not disked, and several disked plots in each yearly trial. Resulting average yields of cured hay are given as follows :

Average yields of plots, in pounds per acre.

Date.	*Disked.*	*Not disked.*
1903	11,165	10,906
1904	9,844	10,565
1905	8,756	9,337
Total average	9,922	10,269

The same cultivations were repeated on each plot for the years 1904 and 1905. Another field was used the first season, 1903. The fields disked had been seeded several years and the alfalfa was a good stand and in thrifty condition.

Cultivation by disking has apparently not given increased yields of alfalfa on these fields. The same results may not follow under other conditions of soil and climate and should not be considered as disproving the benefits, described above, which may be derived from cultivating alfalfa.

FERTILIZING ALFALFA.

MANURING–Note has been made of the importance and even the necessity of fertilizing old "worn-out" lands which are deficient in available nitrogen in order that alfalfa may start successfully. The condition is nicely illustrated by an experiment which is now being carried on by the Agronomy Department of this Station. One plot was manured at the rate of about ten tons of well-rotted barn-yard manure per acre as a dressing for winter wheat sown in the fall of 1906. A second plot received no manure. Alfalfa was sown on these plots in the fall of 1907, and the plots were photographed April 23, 1908. At that date the relative stand and height are given as follows :

Manured, 13 inches high, 63.7 plants per square foot.
Not manured, 4½ inches high, 50.4 plants per square foot.

The plants on the unmanured ground, although a good stand, were weaker and much smaller in size than those on the manured plot. This difference in growth is readily observed in the cut.

It has been the observation of the writer that while alfalfa may start more slowly on worn land, soil lacking in humus and nitrogen but well supplied with the mineral elements of plant-food, that if it makes a stand at all it will gradually improve in the course of two or three years without the application of fertilizers, the plants becoming vigorous and productive. Many farmers have plowed up a good stand of alfalfa, which, if it had been left another year, might have come out all right. A dressing of manure with cultivation will always help in a case of this kind, but the manure would have had a much greater beneficial effect if applied before rather than after seeding.

Alfalfa responds readily to manure, even when the plants

are vigorous and growing in good soil, and it may often be advisable to manure alfalfa, especially if the plan is to use alfalfa as a crop in rotation with other crops. The alfalfa field is a handy place to haul and spread manure during the winter months. The increased growth of alfalfa from manuring may be as great as that secured from manuring other crops, and this greater growth of foliage and roots may add more fertility to the soil for the use of the crops following the alfalfa than is represented in the manure applied.

Manure applied to the alfalfa field should be well rotted or at least not coarse and trashy, and should be be evenly and thinly distributed. Prefer to give a light application to a large area rather than a heavy dressing to a small area. It is advisable to disk and harrow the alfalfa field after applying manure.

It has been a common practice to manure alfalfa at this Station, but the results of only one comparative trial of manuring old, well-established alfalfa has been recorded. In 1903 the application of a rather heavy dressing of twenty loads of good manure per acre during the winter and early spring gave an increased yield for that season of only 0.29 tons of cured hay per acre, the total yields from manured and unmanured plots being, respectively, 5.74 tons and 5.45 tons per acre. The yields for succeeding seasons were not recorded.

LIME FOR ALFALFA.—When the soil is acid alfalfa will not succeed well until the acidity has been corrected by the application of lime in some form. This acid condition in soil is apt to prevail in old worn land in eastern and southeastern Kansas. The acidity of the soil may be determined by testing the moist soil with blue litmus paper, or samples of soil may be sent to the Experiment Station for testing. The ordinary tests, however, are not always decisive, and when in doubt as to whether soil needs lime it will usually be best to make a trial by applying lime to small areas in the field to be seeded to alfalfa, leaving strips untreated, and note results.

Methods of Liming.— It is not usual to apply lime directly to the crop. In fact, if quicklime is scattered in alfalfa it is probable that some of the plants will be injured or destroyed by the lime. Lime in the form of carbonate of lime, namely, air-slaked lime, may be applied in small quantities directly to the crop without danger of injuring the plants. Lime may also

be applied as land-plaster and in wood-ashes: the ashes also contain considerable amounts of potash and phosphoric acid.

As a rule it is best to apply lime some little time before the field is to be seeded. The autumn is the best time to apply lime to soil to be used for spring crops. Some practice scattering the lime and plowing it under, but this is not the best method, since the tendency is for lime to move downward into the soil. It is preferable to plow first, then scatter the lime and mix it with the surface soil by disking and harrowing. In case of fall seeding, the lime may be applied after plowing and mixed thoroughly with the soil by harrowing.

A good plan in liming soil for alfalfa is to plow the field sevéra1 weeks or months before the alfalfa is to be seeded, scatter the lime soon after plowing and mix it with the surface soil by harrowing or disking, and continue the disking or harrowing at intervals until the time of seeding. On soil that would be benefited by applying lime, the application of lime before seeding will greatly improve the chances for getting a good stand and a good start of alfalfa. The experiments at several experiment stations indicate that it is often absolutely necessary to apply lime before successful stands of alfalfa can be produced.

The amount of lime required by soils, in order that liming will have the most beneficial effect, seems to vary greatly. It is usual to apply from 1000 to 2000 pounds every four or five years where lime is used as a fertilizer. From the work at the Illinois Experiment Station it seems that ground limestone has much the same effect when applied to the soil as lime itself. The action of the ground limestone is not so rapid, and it must be applied in greater quantity; at least two or three times as much ground limestone as would ordinarily be used of quicklime or air-slaked lime.

The cost to prepare and ship the ground limestone in Illinois is from fifty cents to a dollar per ton. Kansas is well supplied with limestone deposits. If these great beds of limestone could be mined and the stone ground and distributed to the farmers of southeastern Kansas, not only might a new industry be created, but much of the soil of that section of the state, which apparently is acid in condition and unfit for growing alfalfa, might by the application of the limestone be put into favorable condition for seeding to alfalfa. According to Dr. C. G. Hopkins there is no danger of applying too much lime-

stone, while, as is well known, the application of large amounts of lime or the continued application of lime tends to exhaust the fertility of the soil.

CHEMICAL FERTILIZERS. — Kansas soils will perhaps seldom be much improved for growing alfalfa by the application of chemical fertilizers. In the states farther east some benefit may often be derived from the use of chemical fertilizers, especially in starting the crop. At the Illinois Experiment Station the application of lime and phosphorus increased the yield nearly 100 per cent. the first season after seeding, while the application of lime alone increased the yield over 50 per cent., as compared with the crop from the unfertilized land. This great increase in yield occurred only on plots which were inoculated with the alfalfa bacteria (the unfertilized check plot was also inoculated), thus indicating that the presence of bacteria is the determining factor. Inoculation alone increased the yield nearly 100 per cent. There were 320 pounds of air-slaked lime and 320 pounds of acidulated bone-meal applied in the above referred to experiments

At the Ohio Experiment Station the application of 320 pounds of acid phosphate with 3666 pounds of lime per acre increased the yield of cured hay the first year after seeding 1221 pounds per acre, or about twenty per cent.

In the above-named tests the fertilization with potash and nitrates seemed to have little effect. It is doubtful whether the continued application of chemical fertilizers after the alfalfa becomes well established would show as marked an increase in yield.

THE ALFALFA SEED CROP.

THE SOIL.

Good crops of alfalfa seed may be produced on a variety of soils, ranging from black gumbo to sandy loam, but the general experience is that the soil should be well drained and of average fertility. Very fertile land, and soil supplied with an abundance of moisture, produces plant, not seed. On this account, in central and eastern Kansas, upland or second bottom is usually considered superior to bottom-land for alfalfa seed production. A soil poor in fertility will produce only light crops of seed, while large yields of seed may be produced from fertile land in a favorable season, but with un-

favorable weather conditions the seed crop is more apt to fail on the more fertile soil. Rankness in growth of plant is not conducive to the production of seed. Alfalfa will not thrive on a shallow soil with hard-pan subsoil, or on low or poorly drained land.

THE WEATHER.

In the opinion of many alfalfa growers the weather is a more important factor than the soil in determining the production of a good crop of alfalfa seed. On a given soil capable of growing alfalfa the weather is the determining factor in seed production, or it may be as truly said that the moisture supply, in time and amount, largely determines the alfalfa-seed crop on any field. On this point a majority agree that the alfalfa should have a moderate supply of water in the early part of the season, and during the early growth of the seed crop--just sufficient moisture to produce a vigorous, healthy plant. To insure a good crop of seed no heavy rains should fall after the alfalfa begins to blossom until most of the bloom has fallen, and then the weather should continue rather dry until the seed crop is harvested and thrashed, or put into the stack. Wet weather in the latter stage of its growth causes a continuation of blooming and the starting of a second growth of alfalfa, which interferes with an even and proper maturing of the seed. Also, it has been observed that very hot, dry weather, with a deficiency of moisture in the soil during the seed-forming period, has resulted in light, blasted seed and a low yield. It is said that under the conditions observed alfalfa flowers fail to secrete nectar and are hence not fertilized because not visited by bees and other insects.

OTHER FACTORS.

A rather thin stand of alfalfa with vigorous plants of average growth favors the development of seed, while a thick stand and a rank growth of plant are considered unfavorable conditions for seed production. The seed fields should be comparatively free from weeds. By cultivating the alfalfa early in the spring, or perhaps after the first or second hay crop is removed, the weeds may be held in check and the soil kept in good tilth, resulting in strong, well-developed plants, capable of producing large yields of sound, plump seed.

EFFECT OF BEES AND OTHER INSECTS.

Until recently it was generally understood that to fertilize alfalfa blossoms required that pollen from a separate flower be brought in contact with the pistil of another flower. This, it was explained, was doubtless largely accomplished by insects, which transferred the pollen from blossom to blossom while they sipped the nectar which each flower secretes apparently for this very purpose of attracting insects. It is probable that cross-fertilization is largely accomplished in this way, but, as shown by Roberts and Freeman of this Station,* alfalfa blossoms may be self-fertilized. It is only necessary that the "trigger mechanism" which controls the fertilizing organs be sprung by the touch of an insect or other means, possibly the shaking of the plant in a strong wind, when the confined stamens and pistil fly up and the pollen is dusted against the stigma and over the insect, or, in case of hand pollination, the instrument which is used to spring the little flower trap. Thus the insect, passing from blossom to blossom, mixes the pollen of many flowers, but the hand pollination has shown that the blossom may be fertilized with its own pollen.

Farmers are divided upon this point as to whether insects are necessary or useful in the pollenization of the flowers. Many maintain that as good crops of seeds were produced many years ago, before bees were introduced into a certain locality, as are produced now. Others state that in a locality where bees are kept there is no noticeable difference in seed yields near apiaries compared to yields from fields further away. Such data, however, do not disprove the facts as stated above. Doubtless other insects besides bees assist in fertilizing the alfalfa flowers. If you will observe an alfalfa field in full bloom you will usually find it swarming with insects of various kinds--bees, flies, butterflies, millers, ants, and sometimes grasshoppers--although it is doubtful whether the latter are of any benefit, and certain it is that they are often a pest when numerous. It is quite possible that ants are among the important insects concerned in fertilizing alfalfa blossoms. There is some proof that bees do assist in pollinating the alfalfa flowers.

Although reports on this point have not been very authentic,

* See bulletin No. 151.

there seems to be little question but that bees may assist in fertilizing the alfalfa blossoms and thus increase the yield and improve the quality of the seed. At this Station alfalfa plants covered with fine netting produced no seed except in flowers which pushed through or against the netting, allowing fertilization by insects from the outside. On the other hand, adjacent plants not covered were well filled with seed pods.

There should be a double benefit to the alfalfa-seed grower who keeps bees, for not only may he secure larger yields of a superior quality of seed by reason of the work of the bees, but the alfalfa is one of the most valuable honey plants. In the alfalfa districts of the state the yield of honey per hive, according to the report of Secretary Coburn, of the State Board of Agriculture, is much larger than in the sections where alfalfa is but little grown ; and not only may the bees in alfalfa districts make double or treble the usual amount of honey, but this honey is very superior in quality, unequaled even by the white clover honey of the Eastern states. "In favorable seasons, 100 pounds of honey per hive is no uncommon yield in alfalfa regions."

WHICH CROP TO SAVE.

The region lying west of the Missouri river grows most of the alfalfa seed produced in the United States. A large part of this seed is grown by irrigation in the western part of the great plains region, in several of the mountain states, and in California. Much seed is also produced without irrigation in the eastern part of the great plains region. The dry climatic conditions of the West make this section of the country better adapted for the production of alfalfa seed than the more humid regions of the Central and Eastern states. The best quality of seed and the largest crops are produced in an arid climate by irrigation. The supply of water and the weather conditions during the growing period of the crop largely determine which crop to save for seed. Any one of a season's crops may produce good seed provided the soil and weather conditions are right for growing and maturing the seed. About the same time is required to produce a crop of seed as is required to produce two crops of hay. In the irrigated districts of Colorado and western Kansas the first crop is often saved for seed, the practice being not to irrigate this crop, thus causing a medium but thrifty growth of plant, which, with the favor-

able weather conditions prevailing in the arid regions, usually seeds well.

On the whole, especially in the more humid regions, the second or third crop is more often saved for seed than the first crop, mainly because more favorable weather conditions prevail in the late summer and early fall for maturing the seed. Also, the insects which may help to fertilize the blossoms are more numerous in the latter part of the season. Only in the Southern states is it possible to use a later crop than the third for seed.

In those latitudes where the third crop may mature seed before cool weather and frost, the choice between the second and third crop for seed is decided mainly by the weather conditions at and before the blossoming period. If the supply of moisture has been moderate and the alfalfa has made a proper growth and little or no rain falls during the blossoming period, the second crop will likely seed well. However, if the second crop is rank in growth, or heavy rain falls just previous to or when the alfalfa is in bloom, it is best to cut for hay. In the non-irrigated area of the semiarid portions of Kansas and other Western states drought is apt to prevail in the latter part of the season, by which the growth of the third crop is greatly reduced, causing only a small development of seed. In such districts the second crop should be saved for seed, or perhaps the first crop, especially on dry uplands which may produce. only one good crop (the first crop) in a season. In northwestern Kansas and Nebraska it is doubtless safer to use the second crop for seed, as the third crop is apt to be caught immature by frost. In central-northern Kansas a farmer must usually decide whether to save the second or third crop; if the third crop is to be saved for seed it is best to cut the first and second crops a little early, giving as much time as possible for the third crop to mature. Also, the early cutting for hay may give not only an earlier but a more vigorous growth to the third crop, insuring a large production of seed in favorable seasons.

Some growers state that the third crop should be preferred for seed because it blooms and matures more evenly and in a shorter period than the second crop. If this is a fact, it may be largely due to the favorable weather conditions which are more apt to prevail during the season of the year when the

third crop is growing and maturing. When it can be successfully done, using the third crop for seed has an advantage over using the second crop in that it allows the harvest of two good hay crops, while if the second crop is harvested for seed only one crop of hay is usually secured that season, the growth after the seed crop being insufficient, as a rule, in the sections of Kansas named, to produce hay.

On the other hand, when the third crop is matured for seed sufficient growth of the alfalfa usually takes place after removing the crop to give a good winter cover, and it is the general report by those who practice this plan that, taking the third cutting for seed does not exhaust the alfalfa plants so much as taking the second crop for seed, and a similiar observation is made as regards the seeding of the first or second crop, some growers reporting that when the first crop was allowed to mature seed there was little or no growth after the seed crop was removed, during the balance of the season.

Insect pests, as the grasshopper and web-worm, are also a factor in determining whether the second crop, or any crop, may be safely saved for seed. The web-worm is more likely to attack the second crop, but in southern Kansas the third crop is also apt to be injured by this pest.

WHEN ALFALFA WILL MAKE A GOOD SEED CROP.

Alfalfa is a very uncertain seed crop, and it is a difficult matter to estimate with any degree of accuracy early in the growth of the crop what the yield of seed will be. If the weather and soil conditions have been favorable and the alfalfa has made a proper growth (not too thick and rank, but rather the stems should be of medium height and stout, with many branches), and there is an even, heavy bloom over the field in five or six days after the first bloom appears, and no rain falls, the prospect for seed is good. The blooms should be large and of a dark rich color. When the blossoms are small and light in color it is evidence of a light crop of seed. Again, if the blossoms fertilize properly the flowers dry and stick to the stem a few days, while if they are not fertilized they drop quickly and the stems stand bare. Even before the bloom falls the circular pods are visible. The pods should appear thickly set on the stems, two or more in a group, to insure a good seed crop. Finally, if by examination the pods are found

to be well filled with seed, the crop is assured, barring accidents by which the seed may be lost in harvesting and thrashing.

From the above suggestions it may seem to the novice that he would be able to judge fairly well when a crop of alfalfa should be left for seed ; yet old growers do not find it easy to decide. A grower who has had twenty years' experience writes as follows : "I cannot tell when a good crop will be made until near maturity, as the blossom often fail to seed, and then too much rain may cause well-fruited alfalfa to take a second growth and continue to bloom and ripen seed irregularly. Also, during damp, rainy weather the ripe seed may sprout, or when the weather turns dry the ripe pods may burst, shattering their seed." It is even possible that after a crop is ready to harvest it may be lost or badly damaged by excessive rain, causing the seed to sprout or the pods to burst when they dry in the sun.

Relative to saving a crop of alfalfa for seed these suggestions may be given: If the weather has been wet and the alfalfa grows too rank, cut for hay. If heavy rains fall while the alfalfa is in bloom, or before the flowers are fertilized, cut for hay. If for any reason the flowers are not fertilized and the bloom falls quickly, leaving bare stems, cut at once for hay. Even after the seed is formed, if excessive rains come and a second growth starts, cut the crop and remove it, because it will fail to ripen seed evenly and is almost certain to be an unprofitable crop, and the sooner it can be taken from the ground the sooner another crop may start and mature.

WHEN TO HARVEST FOR SEED.

The harvesting depends a little upon the evenness of blooming and the weather conditions during the period of maturing. In a favorable season, with even blooming and even maturing of the seed, the rule is to harvest the alfalfa when a large proportion of the pods have turned brown. In the average season, as the alfalfa matures, part of the seed will be ripe while some of the seed is overripe and shattering and some is yet immature. With such a crop it is necessary to strike an average and harvest when the largest amount of plump, sound seed may be saved.

The opinions of farmers vary widely regarding the proper stage of maturity at which to harvest alfalfa. While the majority prefer to harvest when most of the seed is ripe and when

two-thirds to three-fourths of the pods are brown, others recommend to harvest when one-half of the pods are brown. One grower harvests the crop when one-third of the pods are black, one-third brown, and one-third green; others harvest as soon as the ripest seed begins to shatter, while still others maintain that the first seed that ripens is the best and prefer to cut a little early, claiming that the seed will be of as good quality and that there is less loss from shattering in handling and less danger of damage by unfavorable weather.

Mature alfalfa seed has a clear, light-golden color ; immature seed has more of a greenish tinge and may be shrunken; but if the crop is not harvested until the seed is fully ripe the pods drop off, the seed shells easily, and the crop is hard to handle without great loss, even if it escapes unfavorable weather after harvest. On the whole, it seems to the writer safest to cut the crop a little green rather than to risk loss in ways mentioned. The greenish-colored seed, if not too shrunken, is good vital seed and germinates well.

METHODS OF HARVESTING.

A crude method is to cut with a mower and rake into windrows the same as hay. Handled in this way, much seed may he wasted. If the alfalfa is mowed in the morning, when the dew is on, and raked immediately, there is much less shattering of seed. If cut during the heat of the day, to prevent the shelling and waste of seed men should follow the machine with forks, moving the cut alfalfa out of the way of the team and the machine. When provided with a buncher or windrower attachment, the mower does better work and may be economically used. There is some objection to leaving the alfalfa in loose bunches or in open windrows, and unless the weather is very favorable and the purpose is to thrash at once, it is best to follow the mower closely, placing the alfalfa in larger piles or cocks, about what a man may lift at one forkful, thus avoiding pulling the bunches apart in loading, which would cause the pods to break off and the seed to shatter. Also, if the alfalfa is placed at once in the cock in this way, the seed is prevented from bleaching so much and the straw settles and sheds rain and is preserved and cured better than when left in the loose bunch or windrow, and well-cured alfalfa straw is said to have one-half the feeding value of alfalfa hay.

The self-rake reaper is in common use, and is an excellent

machine with which to harvest the alfalfa-seed crop. The gavels are dropped from the platform out of the way of the horses and the machine. Usually men follow with forks and lay three or four gavels in a pile. These bunches shed rain and preserve the seed and straw in better condition than the single gavels, and the seed does not shatter so badly in handling the larger compact bunches as in handling the smaller ones.

Some few growers cut the crop with a header, leaving the alfalfa in windrows across the field. This method is only satisfactory in a dry season, when the alfalfa is thrashed or stacked at once, as soon after harvest as possible.

Many western growers harvest alfalfa with a binder. The usual practice has been to remove the binder part, but leave the packers on and throw the bundles out loose, dropping in bunches by use of the bundle-carrier, or bunching with the fork as already described in the use of the self-rake reaper. In recent years, however, some prefer to bind the alfalfa in bundles and shock the same as wheat or other grain. The advantage claimed for this method is that it requires less help, since one man may do the harvesting and put the crop into the shock if help is scarce ; the alfalfa may be cut a little greener, the seed does not shatter so readily, and the straw may cure and keep better than when put up loose.

When bound and shocked the alfalfa should stand a couple of weeks, until dry enough to thrash. If put into the stack, thrashermen prefer to have it loose, as bundles are more apt to be damp and tough, but if fully dried when stacked alfalfa should keep well in the bundle. It is suggested to stack with layers of straw between layers of alfalfa, in order to take up the moisture.

STACKING AND THRASHING.

The common practice, when it can be done, is to thrash from the field as soon after harvest as the seed is dry and the straw fully cured. If a machine cannot be secured and weather conditions are favorable for stacking, better put into the stack at once when the crop is cured than to run the risk of damage by wet weather. A single rain will not injure the alfalfa much if it is well bunched or cocked, but continued wet weather causes the seeds to swell and perhaps sprout, and when the pods dry they burst, scattering the seed. Some growers estimate that half of the seed is lost in this way by a few days of

unfavorable weather. Also, if the crop is allowed to lie in the field for a long time there is more or less loss of seed from the effects of heavy dew and damage from mice and insects, and the longer the alfalfa lies the easier the pods break off and the seed shatters when it is finally handled and stacked or thrashed. The largest amount and best quality of seed may be secured by stacking or thrashing the crop as soon after cutting as it is in fit condition.

Care should be taken not to stack or thrash when the straw is too green or tough and the seed not fully dry. It requires even more time to properly cure the seed crop of alfalfa than it does to cure the hay crop; the stems are largely stripped of leaves and cure slowly and pack closely in the stack. If stacked green, the alfalfa is sure to heat and thus injure or destroy the vitality of the seed. Also, if thrashed green or damp much seed will be lost, since it will not hull properly, and if damp seed is stored in bulk it may heat and spoil. To cure the alfalfa fit to stack, from three to seven days of favorable weather are required, and a longer period if it is thrashed from the field. When bound and shocked the crop should have a couple of weeks of drying weather to cure before stacking or thrashing. It is safest to put into narrow stacks, and it is also a good plan to mix with layers of dry straw, especially if the alfalfa is bound and there is any indication that the straw is damp or green in the middle of the bundles. The straw improves the ventilation of the stack and absorbs the excessive moisture. The practice of using straw in this way, however, is seldom practicable--better stack only when fully cured.

To prevent loss of seed in stacking or thrashing, racks are sometimes covered with canvas and canvas is spread under the machine or along the stack in order to catch the shattered seed and the bolls which break off; also, care must be taken to handle the alfalfa carefully in pitching and loading. Large growers of alfalfa often stack the seed crop in the field with the sweep-rake and hay-stacker. Those who practice this method usually cut with the mower and leave in bunches or windrows, drying the alfalfa quickly and stacking as soon as possible. This is a rough way to handle the crop and occasions more or less loss of the seed, but where a large area is handled it may be more profitable to handle the crop in this way than by a slower method and run the risk of damage from wet weather. When the alfalfa is left in gavels or bundles, as thrown off by

the harvester, it should be taken up with a barley fork. There will be less shattering of seed, however, if the alfalfa is in small, compact bunches, not too heavy to be lifted in one forkful.

When the alfalfa is stacked, unless thrashed within two or three days after stacking, it should be allowed to pass through the sweat before being thrashed, which requires several weeks or months. The best plan is to cover the stacks well to prevent damage by rain, and thrash late in the fall when the weather is dry and cool. In order to secure seed for fall sowing it is often desirable to thrash from the field, and in a favorable climate or season, if a machine can be secured, this is the safest and most economical method of handling the crop.

Farmers differ in their opinions as to whether it is preferable to thrash with a huller or with a common grain separator provided with a huller attachment. Some growers favor the use of the latter machine because the work can be done more rapidly. As a rule, however, when farmers have had a chance to use both kinds of machines, and have compared their work, the huller is preferred. Although it takes longer to thrash with a good huller, yet with a good crop enough more seed may be secured to amply pay for the extra time and expense required; in fact, the owner of a huller will often pay something for the privilege of thrashing over again the straw-stacks left by the common thrasher. Among the machines used, the Bidsell huller is well recommended; also, the Advance thrashing separator with huller attachment has received favorable mention. One farmer who has used both machines prefers the Advance thrasher to the huller.

STORING AND MARKETING THE SEED.

A good method is to sack the seed and store in a dry place which may be kept free from mice and rats. It is stated by some growers, however, that mice and rats will not touch alfalfa seed when they have free access to other grain.

The seed should be cleaned with a good fanning-mill before selling, and all light seed, dirt and weed seed removed as far as possible. This extra work is usually well paid for in the better price received for clean seed. If the alfalfa is green or damp when thrashed, the seed had best be spread twelve or eighteen inches deep on a tight floor in a dry place and shoveled over once or twice to dry before it is cleaned and sacked.

Prime alfalfa seed should have a bright, clear, light-golden or slightly greenish color. Seed which has been wet or bleached in the field will be darker in color, while heated seed will have a brownish dead color, indicating its lack of vitality.

From the grower's standpoint, the best time to sell the seed is when the price is highest. Prime seed usually sells at a high price early in the fall; when there is apt to be a shortage of seed for fall sowing, and again early in the spring, about March 1, seed often brings the highest price, depending largely upon the supply and demand. Alfalfa seed retains its vitality for several years if carefully stored and saved, and it may often be to the interest of the grower, when seed is plentiful and the price low, to hold the seed for a better market.

Aside from its use for sowing, alfalfa seed has a standard market value in Europe for dyeing purposes, being used in the printing of cotton fabrics, and large quantities of seed have been exported from this country to supply the foreign demand. For different years and in different parts of the country the price has ranged from seven to fifteen cents per pound. A bushel of alfalfa seed weighs sixty pounds. Three to four bushels of good seed per acre is a profitable crop. The average crop in the more favored alfalfa regions ranges from five to seven bushels per acre, while yields as high as twelve bushels per acre have been reported. A yield of less than two bushels per acre is an unprofitable crop.

THE ADULTERANTS, SUBSTITUTES AND IMPURITIES OF ALFALFA SEED, AND THEIR DETECTION.

Properly matured seed of alfalfa is of a bright golden-yellow color, with a faint greenish cast. Immature seeds are greener, and seeds that have heated or "sweated" become discolored and are brown or black. This discoloration does not always mean lowered vitality. In twenty-one cases tested at this Station the average germination percentage from brown, blackened and green immature seed taken together was 65, the range lying between 39 and 80 per cent.

As a general rule, however, green and immature seeds give weakly plants, and brown and blackened seeds are apt to be dead or greatly lowered in vitality. We further find, however, that as between high-grade and low-grade samples of alfalfa seed the average germination percentage runs higher, even

with the apparently defective seed, than it does in low-grade samples. The average germination of five high-grade samples, as a whole, was 98 per cent. The apparently bad seed from these samples gave an average germination of 70 per cent.; whereas an average from four low-grade samples gave corresponding germinating percentages of 75 per cent. and 46 per cent. for the whole sample and for the apparently bad seed respectively, thus showing that conditions which impair the quality of the seed as a whole make the browned and blackened and immature seeds in the sample less likely to germinate, and in a greater ratio than is the case in samples in which the average condition of the seed, as a whole, is better. This means, in plain words, that bad appearing seeds are not in equally bad condition in all samples with respect to vitality, although their appearance may be the same in all samples.

In general, it may be said that the common fault to be found with alfalfa seed on the market lies in the large amount of immature, dead and decayed seed so frequently present. In one case the dead and defective seed of alfalfa reached 60 per cent. of the total, from 5 to 10 per cent. being very common in the samples analyzed. One of the best samples of alfalfa seed received analyzed 95.6 per cent. pure and apparently sound seed of the species, with but 4.4 per cent. of all impurities, which latter consisted entirely of dead alfalfa seed, there being but a trace of foreign seed and inert matter in the sample. The germination test of the sample showed but 63.9 per cent. of pure, good alfalfa seed, while the impurities amounted to 36.1 per cent., and consisted of dead and decayed alfalfa seed, 28.1 per cent.; foreign seed, 7.1 per cent.; and inert matter, 0.9 per cent.

Let us examine the results in this case. There are about 211,350 alfalfa seeds in a pound. In a pound of seed of the character analyzed there would be as follows :

Good alfalfa seed, capable of germinating 135,053
Dead and defective alfalfa seed, incapable of germinating. 59,389
Foreign seeds of all kinds. 20,593

Sowing at the rate of fifteen pounds to the acre, with an absolutely pure sample of alfalfa seed, there would be, if equally distributed, seventy-three alfalfa seeds sown on every square foot of ground. The amount of impurities in this sample would reduce the number of alfalfa seeds to the square foot to forty-six, and would substitute for good alfalfa seven foreign

seeds for every square foot. The positive damage possible is evident here when we consider that these weed seeds are paid for and are added to the weed seeds already existing in the soi1; and that very frequently they are perennial weeds of a nature very difficult to eradicate. If alfalfa seed costs seventeen cents a pound, there would have been, in a case like this, as much as six cents absolutely thrown away for every pound of the seed bought ; and to the amount thus lost must be added the rental value of the land occupied by the weeds, the seeds of which have been bought and sowed.

Primarily, it may he said that the first requisite in a good sample of alfalfa, as of other seed, is that it be pure, *i. e.*, that it contains a minimum of inert matter (trash or debris), and of seeds other than alfalfa.

Secondly, the seed must be high in vitality, from 80 to 85 per cent. being the standard germination test for good alfalfa seed.

It is a fact, however, that from the actual analyses we find the seeds of no less than 132 species of foreign seeds present in alfalfa seed marketed in Kansas in the past two and one-half years.

While it is true that many of these are not “noxious” weeds in the strict sense of the word--in the sense of being perennial weeds difficult to eradicate--yet weeds of comparatively harmless species may, if present in large quantities, become noxious in the sense that they occupy ground that should be filled with alfalfa plants, and by their growth smother out the alfalfa seedlings. In this sense all weeds may be noxious on occasion.

Our attention is, however, especially directed to eight species of weeds that are always and everywhere to be treated and considered as noxious. These weeds are: English plantain (also called buckhorn or rib-grass), wild carrot, Russian thistle, dodder, dock, chicory, charlock (or wild mustard), and, to a lesser degree, sand-bur.

Based on tests made at this Station we find that approximately one-third of the samples analyzed contained English plantain or buckhorn, one-seventh contained dodder, one-seventh contained dock, one-sixth Russian thistle, and one-sixth wild carrot. Now, of all of these, the first two are, in most cases, the worst weeds that are encountered in alfalfa, in the sense of combining great powers of reproduction with

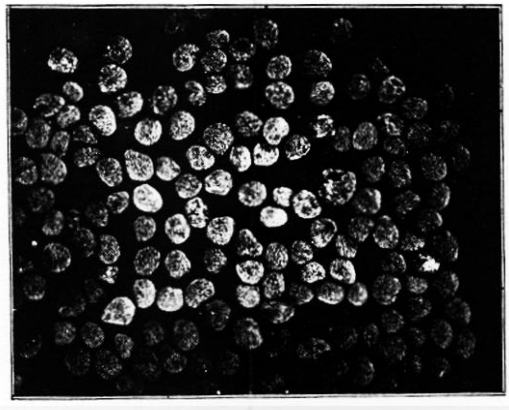


PLATE 10. Clover dodder (*Cuscuta epithymum*).

difficulty of eradication. Any alfalfa sample containing any seeds whatever of these two weeds should be absolutely rejected.

The seeds of English plantain slightly resemble the "flax-seed" stage of the Hessian fly, but are smaller. They are dark brown in color, long-oval or oblong in shape, with a lighter, rather wide, colored crease or groove on one face. Their presence is easily recognized in alfalfa seed by inspection. The plants themselves are perennials, low growing like the other plaintains, bearing a dense rosette of leaves close to the ground, growing from a crown, which increases in size by offsets from year to year. The leaves are long, narrow, dull green, rather strap-like, with prominent veins or ribs running lengthwise, from which the name "rib-grass" has arisen. From the center of the crown arises the flower spike, bearing innumerable seeds. The plant can be eradicated in no way but by plowing under, and in fields markedly infested this should be done.

Dodder is represented in this state by two species principally as infesting alfalfa fields, *Cuscuta arvensis* and *Cuscuta epithymum*, represented in plate 10 above. The seeds of dodder are roundish, although in the case of some species they are somewhat kidney-shaped. The seed is from a dirty to a bright-yellow color, and with a seed-coat roughened by minute pits and elevations.

The dodder plant itself is a yellow vine, which, after starting from the seed, requires a host to feed upon. Reaching such a plant, it twines around it, sending suckers into its tissues and absorbing the food supply that properly belongs to the

PLATE 11. Clover dodder and alfalfa seed, showing relative size and shape.

host. When once thus established, the root of the dodder plant dies and it continues to live entirely as a parasite.

Sometimes the yellow dodder vines form dense mats or patches overlying the alfalfa, and spreading in all directions from the center of infection. In the course of time, the dodder bears its flowers and seeds, and in the fall dies throughout together with the stems of the alfalfa from which it has obtained its food through the growing season. These seeds, falling to the ground, germinate the following spring, and spread the evil. It is readily recognized that such a plant is of direct and immediate injury to alfalfa, and no alfalfa seed containing dodder should be bought or sold. Where dodder is present in

PLATE 12. Chicory (*Cichorium intybus*).

PLATE 13. Seeds of docks. From above: Sour dock or field sorrel (*Rumex acetosella*), Tall dock (*Rumex altissimus*), and Curled dock (*Rumex crispus*).

the field, the patches affected should be mowed and burned before the dodder blossoms.

Of the other noxious weeds mentioned, Russian thistle is an annual and can be more or less kept under control by mowing. Moreover, its seeds are so large that their presence in alfalfa seed should readily be recognized. Chicory is a biennial plant, bearing its flowers and seeds the second season after sowing. It can be killed out by mowing when the tall flower-stalks are in full bloom. Dock, when once established, can be eradicated only by plowing out. Charlock (wild mustard) can be completely eradicated by spraying with a twenty per cent. solution of sulfate of iron (copperas). In a field that is very foul, however, the cheaper way, in the long run, would be to plow under and replant with good seed. As wild mustard is an annual, it is not especially difficult to deal with if plowed under in time. Its immense seed capacity, however, enables it to render a field foul in an extremely short time if left unchecked.

Our attention must now be directed to the other impurities present in alfalfa samples, most important of which is what is designated as "inert matter"; in other words, trash, dirt and debris of all kinds not living. In studying the analyses of alfalfa seed, we find that about 97 per cent. of the samples contained from 0 to 10 per cent. of both inert matter and foreign seed. It is true, however, that while 60 per cent. of the samples analyzed contained 0 to 10 per cent. of foreign

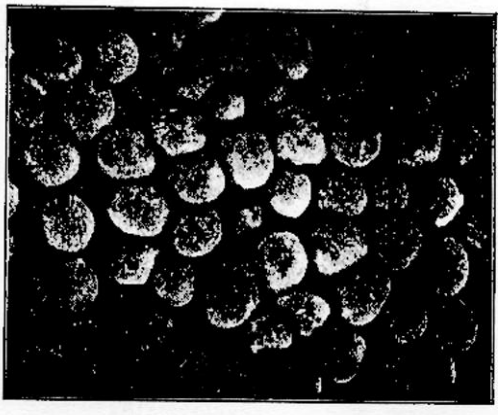


PLATE 14. Charlock (*Brassica sinapistrum*).

seed, 50 per cent. of these samples contained 0 to 10 per cent. of inert matter. It is noticed also that those samples which contained percentages of foreign seed contained also somewhat closely similar percentages of inert matter, and vice versa. This simply means that careless growing, thrashing and handling brings into the market seed which, if it is trashy and dirty, is almost certain also to have a definite and almost a corresponding percentage of weed seed. Such is the character of the low-grade samples of alfalfa seed.

These analyses show, also, that 35.2 per cent of the total number of samples analyzed, or over one-third, had a percentage of seed failing to germinate ranging from 15 to 25 per cent.; or, in other words, one-third of the samples had a positive germination percentage of from 75 to 85 per cent., while nearly 18 per cent., or about one-sixth of all of the samples, had a germination percentage of 75 to 80 per cent.

A germination percentage of not to exceed 64 per cent. was found in 30 per cent. of all the samples analyzed, while the mean germination percentage of all of the 253 samples was 75.4 per cent. (100-24.6).

With 30 per cent. of our Kansas alfalfa seed in the market (if our analyses represent the average condition) having a germination percentage not exceeding 64, and averaging not to exceed 75 per cent. for the whole range of the analyses, we certainly have a condition calling for amendment.

The general impression, however, very largely prevails among farmers that cheap alfalfa seed should be purchased rather than the higher-priced seed. It is well to look into that

phase of the question. It costs more to produce and market pure, clean, bright, high-grade seed, free from debris and weed seed, than it does to produce and market the opposite.

Necessarily, therefore, a higher price must be asked for the better seed. The question, however, is not what is the initial cost of the seed alone, but what the subsequent cost may be, in the case of "cheap seed," in the way of poor stand and land rendered foul with noxious and troublesome weeds. The following table presents the relative cost of good and bad seed, by showing how much more the low-grade samples cost for seeding an acre of land. In other words, it would always require very much more of a low-grade of alfalfa seed to produce the same stand as a high-grade sample would produce. In this table the cost of both the poorest and best seed of alfalfa, as well as that of standard seed, is calculated at nine dollars per bushel. (Standard seed should have 83.3 per cent. of seed true to name and capable of germination, requires 15 pounds per acre, and costs $2.25 to seed one acre.)

The poorest 10 samples.				Principal Impurities.	The best 10 samples.			
Seed analysis No.....	Per cent. of seed true to name and capable of germination.....	Pounds of sample required to properly seed one acre.....	Cost of seeding one acre with seed of this sample.....		Seed analysis No.....	Per cent. of seed true to name and capable of germination.....	Pounds of sample required to sow one acre.....	Cost of seeding one acre with this seed..
645	49.1	25	$3 75	Defective alfalfa seed.	276	96.4	13	$1 95
535	48.1	26	3 90	Defective alfalfa seed, plantain, dodder.	478	96.1	13	1 95
119	46.6	27	4 05	Defective alfalfa seed, crab-grass, foxtail.	476	95.5	13	1 95
593	45.0	28	4 20	Defective alfalfa seed.	532	94.6	13	1 95
225	42.7	29	4 35	Defective alfalfa seed.	491	94.1	13	1 95
661	37.2	34	5 10	Defective alfalfa seed, Russian thistle.	434	93.6	13	1 95
433	36.5	34	5 10	Defective alfalfa seed and trash.	700	93.3	13	1 95
556	34.3	37	5 55	Defective alfalfa seed, plantain, dock.	486	92.8	13	1 95
267	20.7	60	9 00	Defective alfalfa seed, trash, Russian thistle, rush-grass.	685	90.8	14	2 10
269	4.8	260	34 00	Defective alfalfa seed, Russian thistle, rush-grass.	517	90.5	14	2 10

The cost of seeding one acre, as shown in the preceding table, is based on the assumption that both the poorest and best ten samples would sell at nine dollars per bushel, whereas, as a

matter of fact, many, and perhaps most, of the poorer samples could have been obtained cheaper. It is still a fact, however, that many of the high-priced samples are the poorest in quality. The farmer is not always able to judge the quality by the price. It is against high-priced low-grade seed that he should guard, and it is here that the seed expert at the Station stands ready to help him.

It is apparent from this table that should the farmer plant only fifteen pounds to the acre of the poor samples his stand would be imperfect. On the other band, if he should plant a sufficient amount of seed to insure a stand as computed in the third column, the cost of seeding the acre (the price of the seed being the same per hundredweight) would be from two to fifteen times as much as when the better seed were used. Compare columns giving cost per acre of seeding in the table.

In judging the value of a sample of alfalfa seed, the amount and kinds of foreign seed should first be considered. If a large amount of harmless weed seeds occur, the seed should be rejected for the reason that the weeds will come up along with the alfalfa and by choking out the young seedlings prevent a perfect stand. If, on the other hand, there are any seeds of bad weeds present at all, that seed should be rejected for the reason that a few bad weed seeds are almost as dangerous as a large number. Only a few of such plants will, in a few years, produce seeds enough to infest an entire farm. If, now, there are but a few harmless weed seeds and no seeds of bad weeds at all, then the next question as to value of the sample in hand is the cost as compared with the germinating strength.

If every seed germinated, 12.5 pounds would be sufficient to plant one acre. In order, therefore, to find how much of a given sample to sow, divide 12.5 by the germinating strength of the seed. Stated as a formula we would have:

(1) $\frac{12.5}{\text{Germinating \%}}$ = pounds required to sow one acre. In order to find the cost of seeding an acre with a given sample, multiply the result obtained in the above example by the price per pound of the seed. This process may be shortened by using the following formula:

(2) $\frac{12.5 \text{ X price per bushel}}{\text{Germinating \% x lbs. per bu. (usually taken as 60)}}$ = cost of seeding one acre.

(3) $\frac{12.5 \times \text{price per hundred lbs.}}{\text{Germination percentage} \times 100} =$ cost of seeding one acre.

As a practical example, let us say a farmer has been offered two samples of alfalfa by different seed men. No. 1 is offered at $10 per bushel and No. 2 at $13 per hundred pounds. He sends these samples to the Experiment Station for analysis and finds them equally free from bad weed seeds, but No. 1 shows a germinating strength of 92 per cent., whereas that of No. 2 is only 81 per cent. Which of these should he buy? Applying the above formula to No. 1, we have $\frac{12.5 \times 10}{.92 \times 60} = \frac{125}{55.2} =$ $2.26, the cost of seeding one acre. For No. 2, on the other hand, we would have: $\frac{12.5 \times 13}{.81 \times 100} = \frac{162.5}{81} =$ $2, or 26 cents per acre in favor of No. 2. Deciding to use No. 2, he now finds how much to sow per acre by the use of formula (1) above: $\frac{12.5}{.81} = 15.4$ pounds per acre.

In order to ascertain whether the quality of alfalfa seed as found on the market is growing better or worse the samples analyzed during the years 1906, 1907 and 1908 have been grouped, and their impurities classified and averaged. These are shown in the following table:

COMPARISON OF IMPURITIES IN 1906, 1907, AND JANUARY TO MARCH, 1908.

Impurities.	1906.		1907.		1908.	
	No. of samples tested.	Average per cent.	No. of samples tested.	Average per cent.	No. of samples tested.	Average per cent.
Foreign seed	82	3.0	128	1.6	50	1.3
Inert matter	82	1.9	128	1.7	50	2.4
Defective seed	77	27.0	122	25.0	46	26.0
Total impurities	77	30.4	122	27.3	46	27.0

A glance at the above table is sufficient to convince one that there is practically no improvement in the total impurities, although the percentage of foreign seed does show a gradual decline. The fact so little improvement is rather disappointing, especially in view of the constant improvement in the machinery used in hulling and cleaning. These conditions call for continued and constant agitation of the question of pure seed, free from trash and strong in germination. The farmer must insist on getting nothing but the best and he must be willing to pay for it. Remember that the seedsman's standard of purity will never be higher than that demanded by the farmer.

ADULTERATIONS.

The conscious adulteration of alfalfa seed, while occasional, is not common. Such adulteration is accomplished by the partial or complete substitution of the seeds of some other plant which are not so expensive as are those of alfalfa. To escape detection, these seeds must be approximately of the same size and general appearance as are the seeds of alfalfa for which they are substituted.

Alfalfa belongs to the large botanical genus *Medicago,* numbering some fifty species of annual or perennial herbaceous, or occasionally woody, plants which grow over central and southern Europe, and are especially abundant in the Mediterranean littoral, as also in central and farther Asia and the Cape of Good Hope region. Of all these species, but four or five are of economic interest or value. Besides alfalfa itself, which is perennial, there are three annual species which have been introduced into America *: Medicago lupulina* (Yellow trefoil, Hop clover or Hop medic), *Medicago denticulata* (Bur clover or Toothed medic), and *Medicago arabica,* also called Bur, Heart or Spotted clover, or Spotted medic. The similarity of the seeds of the first two of the above-named species to the seeds of alfalfa, and the fact that they are somewhat cheaper, have led to their use as adulterants of the higher priced alfalfa seeds. It is true that all of these three species have some local and restricted forage value, and in places they are cultivated as forage plants ; but the fact that they are not perennial plants renders them at once, and for this reason, inferior to *Medicago sativa.*

A number of cases have been called to the attention of the staff of this Station in which the seeds of *Medicago lupulina* and *Medicago denticulata* have been substituted absolutely and entirely for, and sold as, alfalfa seed. *Medicago arabica* and other *Medicago* species have not yet come to our attention as adulterants.

In order to aid in the distinguishing of the seeds of *Medicago lupulina* and *denticulata* from those of *Medicago sativa* the seeds of these two species will now be described and the differences between them and the true alfalfa seed will be pointed out.

Medicago lupulina, or Yellow trefoil, appears, thus far, to constitute the principle substitute for alfalfa seed, and in some

respects it is the most dangerous adulterant and the most difficult of detection. The plant of Yellow trefoil grows to about the same height as alfalfa, but the leaflets of the compound leaves are much shorter and broader at the tips than are those of alfalfa, and, in fact, have much more of a "clover aspect." The flowers are borne on dense-clustered racemes, and are very much smaller than are those of alfalfa, although curved to form a single incomplete spiral. The pods are black when ripe and covered with a spiral network of prominent veins and are one-seeded. These pods are so distinctively different from the pods of *Medicago sativa* that no difficulty need be experienced in knowing the two species apart where the pods are available.

With respect to the seeds, the distinctions are more subtle, and it is with the seeds alone that the buyer has commonly to deal. The seeds of Yellow trefoil average smaller in both directions, than those of alfalfa, and in their general outline they are usually oblong or orbicular. The hilum, or seed-scar, which in the case of alfalfa tends to be approximately at the center of the seed, in trefoil always lies near the end. It is, moreover, often noticeable that in the case of trefoil a rather prominent central beak protrudes from the hilum edge of the seed. This point is not nearly so prominent in seeds of alfalfa.

So far as the plant of Bur clover *(Medicago denticulata)* is concerned, it may be noticed, that the leaves are much larger and broader at the apex than those of the Yellow trefoil, and that at the point where the petiole or stem of the compound leaf joins the axis of the plant, the "stipules," or leafy appendages, are large, broad, and bordered with fine teeth, while in the trefoil the same structures are narrow and lanceolate, ending in a single point. The flowers are much fewer on the flowering axis than in the case of alfalfa or trefoil, are yellow in color, and of about the same size as those of trefoil, or less than a third the size of alfalfa flowers. The pods are large, spirally twisted in two or three flat coils, which are covered with a pattern of prominent reticulated veins, and which are armed at the edges with one or two rows of long, curved prickles, hooked at the tips, whence the name Bur clover. These pods contain several seeds, which, in their appearance and general outline, more nearly resemble those of *Medicago sativa* than do the seeds of Yellow trefoil. But there need

not be the slightest difficulty in distinguishing them from alfalfa seeds, since their size, which is from a third to a half greater than that of the seeds of alfalfa, would clearly distinguish a bulk sample of Bur clover from a bulk sample of alfalfa seed.

With respect to the differences which distinguish the smaller seeds of Bur clover from the larger seeds of alfalfa, distinctions that are practically available for their recognition cannot easily be given.

The main objection to the use of the above species of *Medicago* as adulterants of alfalfa lies in the fact that the plants in question are but annuals, and their inferiority to a long-lived perennial like alfalfa, other things being equal, is self-evident. If it were the case that the Yellow trefoil and Bur clover were always sold under their true names there could be no possible objection to their introduction, or, indeed, to that of any other species of *Medicago,* since many of them have some forage value; but when we remember that, sowing at the rate of fifteen pounds to the acre, it costs about $2.50 an acre at the very least for alfalfa seed, as the market generally runs, it is self-evident that where the species substituted, instead of living twenty years or more on the same ground, finishes its life-history in a single season and renders the farmer dependent upon the annual appearance of self-sown plants, every means should be afforded for protecting buyers against deception, and the state, if necessary, should, by adequate legislation, in a pure-seed and seed-control law, prevent the practice of adulteration and substitution in the case of this and other important crops.

ALFALFA HAY: ITS MAKING, HANDLING AND MARKETING.

CUTTING.

Alfalfa should be cut for hay when it begins to bloom. Several experiments conducted at the Kansas Experiment Station and at other state experiment stations have shown that alfalfa hay has a higher feeding value when cut at an early stage of maturity, about one-tenth in bloom, than when cut in full bloom. It has also been observed that when cut at the beginning of the blooming period the next crop, under favorable soil and weather conditions, starts quickly and there is no delay in the growth of the alfalfa.

It appears that as the alfalfa approaches maturity the young shoots start again from the crowns of the plants. If the crop is not harvested until in full bloom or past bloom these young shoots may be cut off, thus checking the growth of the alfalfa and delaying the harvest of the next crop. By taking due care to always cut alfalfa as soon as it starts to bloom it is often possible to secure an extra cutting in a season above what may

PLATE 15. An alfalfa hay field on the Station farm.

be secured if the cuttings are made at a later stage in the growth of the crop.

The leaves of the alfalfa are much richer in protein than the stems, and the leaves drop off and shatter worse in cutting if the plants are allowed to become too mature before harvesting. For feeding horses, however, it is advisable and often recommended to allow the alfalfa to become more mature and to reach full bloom before cutting. The more mature hay may be fed to horses with less danger of injurious effects, which sometimes occur from feeding the immature hay.

CUT FROSTED ALFALFA.

Sometimes a severe late spring frost injures the tops of the alfalfa plants, killing the stems back several inches. If this occurs, the crop should be cut at once, even if it is only half matured. The new growth will start quicker from the newly cut crowns than from the stems of the frosted alfalfa plants. Also the frosted alfalfa, if it is not cut and removed from the field, will injure the appearance and quality of the next hay crop.

A RECENT EXPERIMENT IN CUTTING ALFALFA FOR HAY AT DIFFERENT STAGES OF MATURITY.

A single experiment in cutting alfalfa at different stages of maturity has been carried out and the results recorded at this Station. Duplicate plots, each about one-third acre in area, were cut when the alfalfa was in first bloom, one-tenth bloom, one-half bloom, and full bloom, respectively. The resulting yields and other data are given in the following table:

YIELDS OF ALFALFA HAY, CUT AT DIFFERENT STAGES OF MATURITY.

Stage Of Maturity.	Full crops.	First cutting.		Tons per acre. all cuttings.
		Date.	Tons per acre.	
First bloom.	4	May 16	1.36	4.69*
One-tenth bloom.	4	May 29	1.76	5.35†
One-half bloom	4	May 31	1.81	4.52
Full bloom.	3	June 7	2.04	5.99‡

* Includes 0.24 tons of fifth cutting not mature.
† Includes 0.20 tons of fifth cutting not mature.
‡Includes 0.53 tons of fourth cutting not mature.

The moisture in the hay when stacked varied from 12 to 26 per cent. The yields were calculated with the same degree of moisture, namely, 17 per cent.

The yields for the first cutting seemed to vary quite regu-

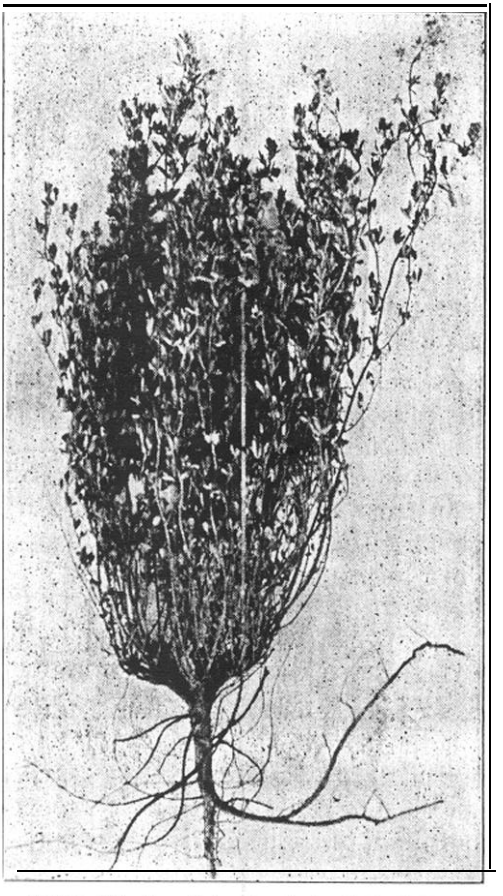


PLATE 16. A well-developed plant of alfalfa.

larly with the maturity of the alfalfa. The succeeding cuttings varied irregularly in yield, the growth of the crop seemingly being more dependent upon weather and soil conditions at the time of cutting the preceding crop than upon the stage of maturity of the alfalfa when harvested. The larger yield of the alfalfa cut when in full bloom was, in part, due to the better growth of the second cutting, which was largely due to timely rains, the weather being dry when the "first-bloom," "one-half bloom," and "one-tenth bloom" plots were cut.

No tests were made of the composition or feeding value of the several lots of hay. All of the hay was well cured and put up in good condition and was good, palatable hay, well relished by stock. This experiment will be continued in 1908.

PERCENTAGE OF LEAVES AND STEMS.

In 1902 A. L. Cottrell, a senior student, made a careful study of alfalfa to determine the percentage of leaves and stems in alfalfa plants. The alfalfa was taken from an old field, on May 30, being the first cutting. It was found that 223 plants contained 6335 stems, or an average of 28.4 stems per plant. On the average, 55 per cent. by weight of the cured hay was found to be stems and 45 per cent. leaves. Plants and groups of plants varied considerably in the relative percentages of leaves and stems. One group, which was selected for leafy character, had 49 per cent. leaves and 51 per cent. stems ; another group, selected for stemmy characteristics, contained 41 per cent. of leaves and 59 per cent. of stems.

CURING.

Effect of Sun and Wind.

The most important factor in making good hay is favorable weather. Hay exposed to excessive rains, especially hay from leguminous plants, such as clover and alfalfa, is greatly injured in quality and feeding value. Every farmer knows that hay is injured by rain and dew, which causes it to bleach and mold and takes from it the natural aroma and palatability essential in hay of good quality, but not all are aware that hay that is cured too much in the sun not only bleaches and loses leaves by becoming too dry but also loses in palatability and often in weight.

When curing hay of any kind the aim should be to expose it to the sun no more than is absolutely necessary. The curing should take place to the greatest possible extent through the action of air and wind, as hay cured in this way retains its natural color and other good qualities which make it nutritious and palatable to stock.

The best hay is therefore made by curing largely in cocks rather than while spread over the ground in the swath or windrow, exposed to the sunshine. Hay in the swath and windrow is also more exposed to injury by rain and dew than hay in the cock. On account of the shattering of leaves and the greater tendency to bleach, the loss in curing clover or alfalfa hay in the swath or windrow is apt to be greater than the loss from curing grasses in this way.

The writer would especially urge the importance of quality

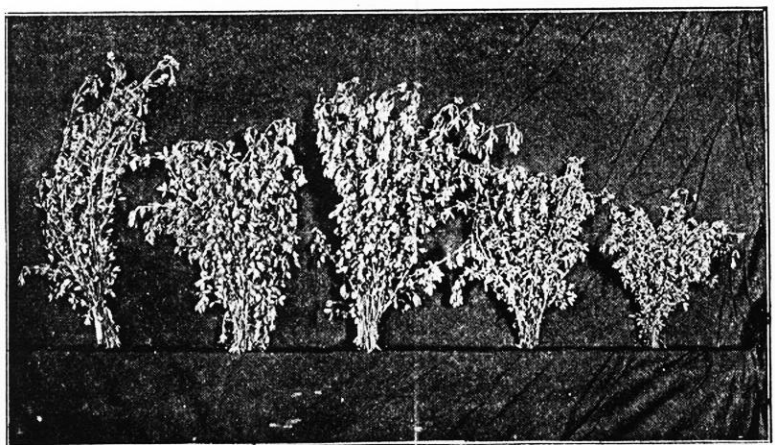


PLATE 17. Samples of five types of alfalfa.

in hay. Good quality, as indicated by the bright-green color of well-preserved hay, will readily add a dollar or two per ton to the selling price; and there is an equal advantage to the farmer and much more satisfaction, both to the live stock and to the owner, in feeding prime hay on the farm.

Bunching and Cocking.

Hay cures more evenly and thoroughly in the cock than in the swath or windrow. If left too long in the swath the leaves become thoroughly dry, while the stems may still retain a large amount of moisture. Such hay will not cure fully and evenly, and is often put into the stack in a partly cured condition. *If hay is raked before the leaves are dry and placed in cocks, the leaves continue to pump water out of the stems, thus allowing the hay to cure out fully and evenly.*

Alfalfa hay, well cured in the cock in this way, will keep perfectly in the stack or mow, while when cured in the swath and windrow alfalfa is often stacked in such condition that it will burn or spoil in the stack. Also, the greater shattering of the leaves which must take place by curing alfalfa or clover in the swath and windrow reduces the yield and makes the hay less palatable and less nutritious than hay which has been properly cured.

Windrow cuttng.

Although it is doubtless true that the best quality of hay may be made by curing in the cock, as described above, yet it is also a fact that a large part of the hay made in the United

States is cured in the swath and windrow or in shocks made by bunching the hay with the horse-rake. When a farmer has a large amount of alfalfa to put up and little help with which to handle it, it becomes necessary to do the work in the most rapid and economical way ; putting up the hay directly from the windrow is not only labor-saving but enables the haymaker to do the work rapidly, so that the danger from losses by exposure in unfavorable weather are lessened, and he is enabled also to harvest the crop when the alfalfa is in the best condition to make hay.

In the Central states it is common to cure timothy and clover in the swath and windrow and put it on the wagon by means of the hay-loader, which makes the work more rapid and does away with the hard labor of pitching hay.

In the large hay-fields of the Western states, both of alfalfa and prairie-grass, the common method is to use sweep-rakes, by which the hay is taken directly from the windrow and hauled to the stacker.

Where a large amount of hay is made it is almost necessary to handle the crop by some such method, and the method of curing hay in cocks is more applicable to the small farmer and to those regions where the value of the product makes it profitable to handle it in this more expensive way.

Good Methods of Curing Alfalfa.

These general suggestions may be given with reference to making clover or alfalfa hay: As soon as the dew is off in the morning, start the mower. When the hay has wilted somewhat run over it with a tedder, if the crop is heavy and needs lifting. After an interval of a few hours, before the leaves have begun to get dry and brittle, rake the hay into windrows.

If the plan is to cure in the windrow, allow the hay to remain this way, in good weather, for a day or two, when it may be put into the stack or mow. If the plan of curing in cocks is followed, the hay should be placed in small cocks soon after raking, when it will be necessary for it to remain in the field for two or three days during drying weather before it is ready to put into the stack.

Some alfalfa growers start the mower late in the afternoon, cutting until dark, raking the hay the next forenoon and bunching or cocking as described above. Good hay may be made in this way, since the dew does not blacken the green

alfalfa, and even a light rain during the night may not damage the hay in the swath which has not begun to cure.

There is some objection to this method, however, in that the dew falling on the green hay in the swath seems to favor the development of white mold in the cock or in the stack. Cutting only in the forenoon after the dew is off is perhaps the preferable method, provided the farmer can handle his crop rapidly enough in this way.

Hay is much more apt to be injured by the moisture on it than the moisture in it. This should be an invariable rule—that ***hay should not be raked or bunched or placed in the stack or mow when there is moisture on it either from dew or rain,*** because such hay will almost surely mold in the cock and is very apt to heat and blacken or burn in the stack.

Hay-caps.

It is now becoming quite a common practice in the more humid sections, where the method of farming is intensive rather than extensive, to protect the alfalfa and clover hay in the field by covering the cocks with canvas or paper caps, which are manufactured and sold to be used especially for this purpose. There is little question regarding the practicability and economy of such a practice on small farms, and there is little question also but that the same method may be profitably used when alfalfa is put up in a large way, especially if the plan is to bale the alfalfa from the field. The canvas covers are doubtless to be preferred, since they may be more durable and are more easily handled and stored than the paper caps.

STORING HAY.

Hay should preferably be stored in sheds or barns. Grass-hay sheds the rain better than clover or alfalfa, and may be stored out of doors with little loss, provided the stacks are well made and covered ; but a good hay-shed, when it is needed, is a profitable investment on any farm.

When hay is fed on the farm the plan should be to store it in a convenient place so that it may be conveyed to the live stock with the least amount of labor. If possible, the hay should be stored and the live stock fed under the same roof, to avoid expense of handling the hay a second time, and the loss from the shedding of the leaves and heads which usually accompanies a second handling.

Methods of Stacking.

The most rapid way of putting up hay is by the use of the sweep-rakes and sweep-stackers or swinging stackers, but this necessitates stacking the hay in the field in the immediate vicinity where it is made. This method of putting up hay is cheap and rapid and is adapted to the large prairie and alfalfa meadows of the Western states, from which the hay is largely sold. On the average farm the practical way is to load on wagons and haul to the stack or mow, when the hay is rapidly removed from the load and dumped into the mow or stack by means of the horse-fork or hay-sling.

Slings are often preferable to hay-forks for unloading hay on account of the cleaner and more rapid work which may be accomplished by the use of the sling. For barn or shed storing a pulley and track is usually most convenient, while for field stacking some form of hay-poles with the pulley and rope are in general use, either with or without the track.

Hay should not be stacked on the ground but on an elevated bottom made of poles and brush. Hay stacked directly on the ground with no air-space beneath the stack will spoil at the bottom, and if the hay is green or unevenly cured it is apt to burn or spoil when there is no ventilation beneath the stack.

In stacking out of doors great care should be taken to keep the middle of the stack full, so that when the hay settles the slope will be outward toward the edges of the stack, in order to shed the rain.

There is no better grass covering for stacks than marsh hay, but when the stack is finished and topped out do not fail to bind on the cover with good hangers of wire attached to stones or heavy sticks of wood on either side of the stack. As a rule, canvas or board stack-covers are troublesome and expensive and not to be recommended. Better build a good hay-shed rather than to use such temporary means of protecting the stacks from rain.

Storing Green Alfalfa.

A new method of harvesting and storing alfalfa is coming into use in central and western Kansas. The plan was first brought to public notice by Hon. J. W. Berry, Jewell, Kan., formerly a member of the Board of Regents of the Kansas Agricultural College. His plan is to cut the alfalfa as soon as the dew is off in the morning, rake it green and haul it in the same day it is cut, the only precaution being that the hay be

free from moisture other than that contained in the green stems and leaves. He stores the hay in a shed, the bottom of which is elevated about two feet above the ground and covered with strips of board or poles with open spaces, allowing free movement of air and good ventilation beneath the mow. The shed is large enough to store a single cutting of alfalfa from eleven acres of ground and only cover the bottom of the shed to a depth of three or four feet. The hay is spread over the whole shed bottom in an even layer and not tramped, but left light and loose as it is thrown in. The second cutting of alfalfa is placed above the first, and the third above the second, until the shed is full to the top.

For five seasons Mr. Berry has put up the hay from this field in the manner described above, and each winter he has baled the hay and sold it at an average of two dollars per ton above the market price of good alfalfa hay. Hay stored and cured in this way is greener in color and of better quality than alfalfa put up by the usual methods.

Experiments at the Kansas Station.

A single experiment in storing and curing alfalfa by the method described above was undertaken at the Kansas Experiment Station in 1905. The second and third cuttings of alfalfa were stored in a small shed above an elevated, well-ventilated bottom, in layers four or five feet thick, the third cutting being placed above the second, as described above. When the second cutting was stored the weather was very wet and the alfalfa which was left in the field was very badly spoiled by the rains, but the green alfalfa which was put in between showers cured out almost perfectly, showing only a little moldy hay in the center of the mow. During the harvesting of the third cutting the weather was very favorable and this hay cured out perfectly. During the last two years a number of farmers from different sections of the state have reported good success from putting up green alfalfa by the method described above.

Shed Curing Explained.

The curing of alfalfa stored in this way may be explained in the following manner: The heating of the hay causes the air in the hay to become warmer and lighter. The light air rises and the cooler, drier air from beneath the stack or mow is driven through the hay to take the place of the warm, moist air which has been forced upward. Thus there is established a

circulation of air which removes the moisture from the hay, preventing it from becoming too warm, and thus gradually curing it, retaining the natural green color of the alfalfa.

If the work is carefully carried out, the hay may be cured in this way without danger of burning or spoiling; but the difficulty will be, if this method becomes a general practice, that many farmers will be careless and will not have the stack or shed bottoms raised or well ventilated, or they may pile the hay too deep or too tight, any of which conditions may result in a lack of ventilation, and the hay will become too hot, so that it will spoil or burn. Probably, also, the larger the area of the mow or shed the more danger there will be of the hay getting too hot in the center of the shed, where the ventilation may not be sufficient to cure the hay rapidly enough to prevent the generation of too great heat.

Although it is possible to make prime hay by curing it in the shed, yet the writer cannot recommend this method for general use in harvesting and storing alfalfa. Doubtless the safer method is to cure the hay in the field before stacking, but the trials described above are interesting and emphasize the importance of good stack bottoms and of elevated, well-ventilated bottoms in sheds and barns in which hay is stored.

Perhaps the old method of piling the hay in narrow bays is wrong; rather the hay should be spread over a large surface and not piled very deeply. This method of storing hay is more practicable for the alfalfa grower of the West than for the farmer of the Central and Southern states, since alfalfa yields several cuttings during the season.

Storing Alfalfa in the Silo.

The method of storing alfalfa green in the shed or stack is better adapted for dry climate than for moist climate, the very conditions under which it is often impossible to cure and make prime alfalfa hay. In regions of very moist climate it is often advisable to silo alfalfa. The difficulty, when alfalfa is siloed, is to get it into the silo green enough to pack well and make good silage. To accomplish this it is advisable to rake directly behind the mower and load and haul to the silo as quickly as possible. It is even advisable to cut the alfalfa when it is wet with rain or dew, handling it rapidly, so that the moisture and succulence may be retained. Wet weather is therefore not undesirable when the alfalfa is made into silage instead of hay.

For silage cut the crop in the early stage of maturity. The more mature the alfalfa becomes the less water is contained in the green plant. Some have practiced wetting down the cut alfalfa as it is put in the silo and report favorably on this method. The wetting maintains the succulence and causes the silage to pack better.

BALING.

It is necessary to bale all hay which is sold on the general market. Locally the farmer may sell a little loose hay, but loose hay cannot be handled and hauled very far and sold with profit to the grower.

Probably the best time to bale hay is in the fall or winter after cool weather has come and other work is not pressing. Some are now practicing baling from the field, and on the large prairie meadows of the West this method of handling hay may be practical and economical; as a rule, however, baling in the field is too slow a method of putting up hay.

As already explained, it is necessary to harvest hay at the right time and store it rapidly in order to secure the best quality of hay. With prairie hay this matter of time in cutting and making is not so essential as with other grass hays, alfalfa, and clover. Not only does baling from the field necessitate slower harvesting of the crop, but the work is done at a time when labor is dear; also, hay baled from the field is perhaps more apt to spoil in the bale than if the hay were stacked.

Bale Cured Hay Only.

It has been shown from the experiments conducted at this Station that it is not advisable to bale alfalfa except when the hay is well cured and dry enough to stack. All hay which was baled green or in a partially cured condition spoiled in the bale. The following is quoted from bulletin No. 123 of the Kansas State Experiment Station, being a part of the report of the above-mentioned experiment :

"The question as to whether it will pay to bale cured alfalfa from the field depends upon the amount of hay that must be put up in a given time, the capacity of the press, the force or crew that can be kept at work, the facilities for handling and storing the baled hay, and the market price. If it is desired to ship the hay or sell it in the bale, it would seem advisable to bale it from the field, if the necessary help and machinery can be obtained, as in this way labor will be saved, and without doubt a larger percentage of the leaves will be retained,

giving a better quality of hay than would result as a rule by baling from the stack. The main question is, whether the baling can be done fast enough to take care of the crop at the proper time and as rapidly as the hay should be put into the stack.

"With a large power-press, having a capacity of fifteen to twenty tons per day, it will be practicable to put up alfalfa by baling it directly from the field. To handle hay economically in this way with a press of the above capacity, without loss of time and with the least possible expense, will require five teams and nine men, besides the necessary equipment. This assumes that the hay will be hauled to the baler by means of sweep-rakes and that the bales will be piled in the field, to be removed later.

"Such an outfit should be able to put up eighty acres of alfalfa, averaging one and one-fourth tons of hay per acre, in from five to six days of good weather. The same outfit should handle the crop on 160 acres in from ten to twelve days. Thus, it would take about two weeks of actual work, if the weather was favorable, to take care of the crop on 160 acres, and with unfavorable weather interfering the period might be extended a week or two longer.

"It does not seem advisable to extend the cutting of one crop of alfalfa over a period of more than two or three weeks. Therefore if the acreage is doubled it would be necessary to double the equipment and the number of men and teams required to handle the crop properly. In case the hay is stacked it would require practically the same number of men and more teams, but the work might be done more rapidly and a larger acreage could be taken care of by stacking than by baling from the field."

HAY-SHEDS.

Attention has been called to the importance of shedding hay, especially alfalfa and clover. By carefully stacking hay and covering the stacks well it is possible to preserve the hay in large stacks with comparatively little loss. However, haying-time is a hard-working, busy time with the farmer, and he may be careless and neglect to stack the hay well or cover the stacks properly. Rains will come sometimes when they are not wanted and least expected, and some stacks will blow over or wet in, so that on the average stacking out of doors is expensive and wasteful.

When alfalfa is put up in a large way with sweep-rakes and stackers, stacking in the field seems to be about the only practical method; but on the average farm, where the hay is largely fed to live stock, the hay-shed becomes a hay saver, a

labor saver, and a profitable investment. Some farmers who have built sheds estimate that the saving of hay and labor will pay for the shed in two years. This may be figuring the value of shedding hay a little too high.

From experiment station reports and from the experiences of farmers, the writer concludes that the ordinary loss on hay stored in a shed will be, on the average, ten per cent. less than on hay stacked out of doors. A shed large enough to store seventy tons of alfalfa will cost about $420. The value of ten per cent. of seventy tons of alfalfa hay valued at $10 per ton is $70. If the hay is stacked it must, as a rule, be handled twice in feeding it, while if stored in the shed or barn one handling may get it to the live stock. The extra handling of the hay will cost at least 50 cents per ton, or $35. Again, many leaves are shattered by the extra handling, which may easily reduce the feeding value of the hay 50 cents per ton, which makes another loss of $35 ; or the shed would save $140 a year. At this rate the original cost of the shed will have been paid for in three year's, and a good shed ought to last fifteen or twenty years.

Plan of Construction.

On a stock farm it will usually be advisable to build a combination hay- and feeding-shed. This may consist simply of a main shed for hay with lean-tos for the stock; feeding mangers should surround the sides of the hay-shed, into which the hay may be thrown. The lean-tos may be closed or open at the ends as desired.

Forty-eight feet to sixty feet long, twenty-four feet wide, and sixteen feet to the eaves are good dimensions for a single shed, and a shed sixty by forty-eight by sixteen feet should hold about sixty tons of well-settled hay, or the annual crop from twelve to fifteen acres of good alfalfa land. A pair of such sheds may be built end to end with a driveway between them, the roof being continuous. The hay should be taken in at the end of each shed by a hay-fork and carrier.

A hay-shed should be well braced and strongly constructed. The system of long bracing, such as is shown in the accompanying figures, gives great rigidity and strength, and is much preferable to the method of short bracing commonly practiced. The short braces readily work loose and the shed soon

becomes "rickety" and unsafe, and is apt to blow over in a strong wind.

The roof should be strongly constructed and securely fastened to the posts. Galvanized iron or steel roofing makes a durable roof covering, and the same material or boards may be used for siding. It is advisable to side hay-sheds, at least part of the way down, otherwise there may be considerable damage from drifting rain and snow. If the hay is stored a bent at a time the side protection is not so necessary, but if the plan is practiced of spreading the hay over the whole area of the shed, side protection should be given from driving rains during the summer.

A Good Shed.

Plates 18, 19, 20 and 21 illustrate the plan of construction of an alfalfa-shed which the writer recently built on his home ranch on College Hill, near the Agricultural College. The shed is 48 x 24 x 18½ ; or about seventeen feet high in the clear from the floor or ground walls to the eaves. The plan of construction of this shed may be readily understood from the illustrations. The floor walls average about eighteen inches in height and are made of loosely laid rock which were near at hand. The posts were set in cement, which was rounded at the surface about the posts in order to shed water. The floor of the shed consists of loosely laid poles--young trees which were being grubbed in clearing a neighboring piece of land.

The posts are white oak trees, averaging about seven inches in diameter at the top and ten to twelve inches at the base. The frame timbers and braces were fastened to the posts with lag-screws and were usually bolted together rather than nailed; some nails were used along with the bolts.

The roof is braced as shown in plates 20 and 21, and securely tied to the frame by braces at each post as shown in plans, and each rafter was securely nailed to the plate.

The hay-carrier track is attached to a two-by-ten ridge timber for the first ten feet and a two-by-eight for the remaining thirty-six feet, the two-by-ten extending four feet over the end of the shed, from which the fork is lowered to the load. The ends of the rafters flush with the top edge of the roof timbers and are securely nailed.

When built this shed was left open, but it was sided this season with boards to within four feet of the floor at an estimated cost of about $86.50.

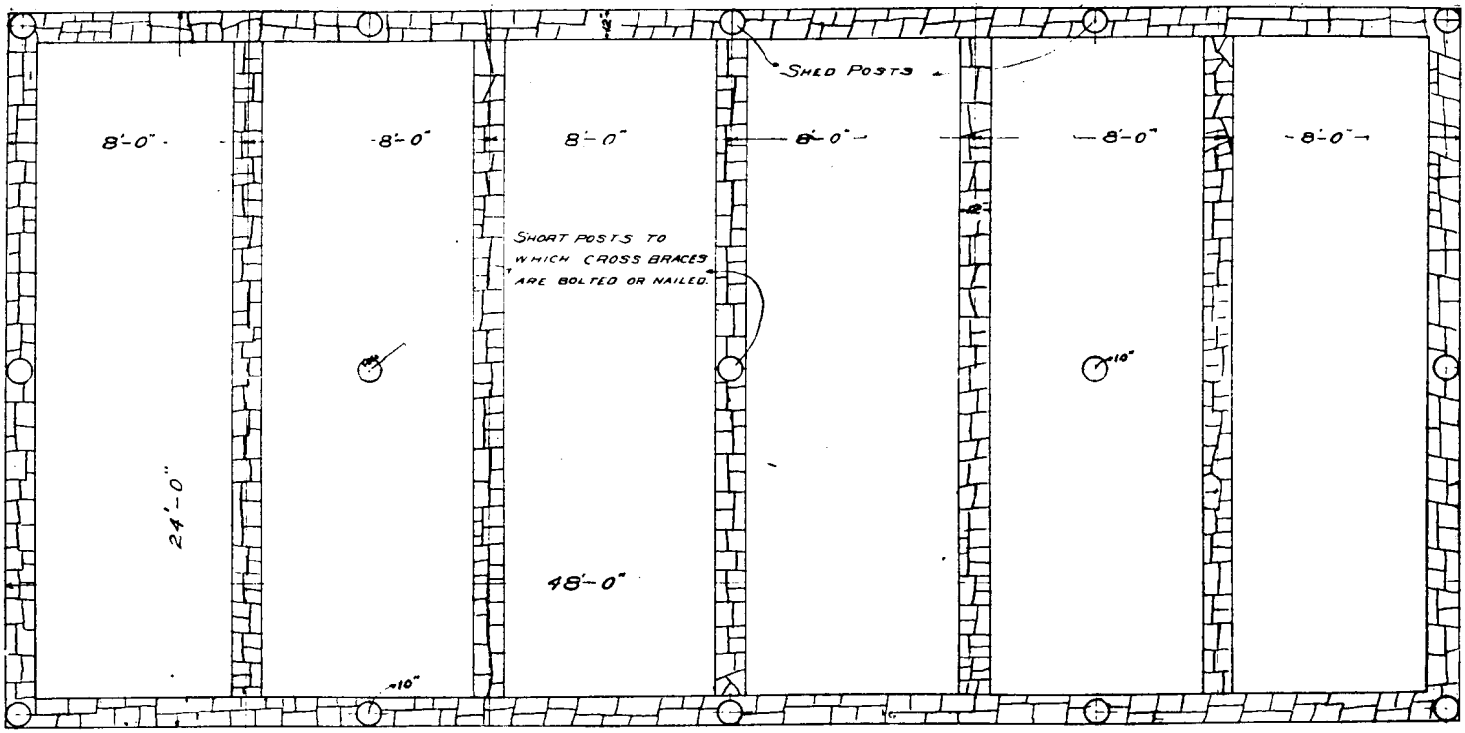


PLATE 18. Ground plan of hay barn. (Walls do not extend lengthwise of shed, as shown in plan, but the spaces between cross-walls are left open for ventilation.

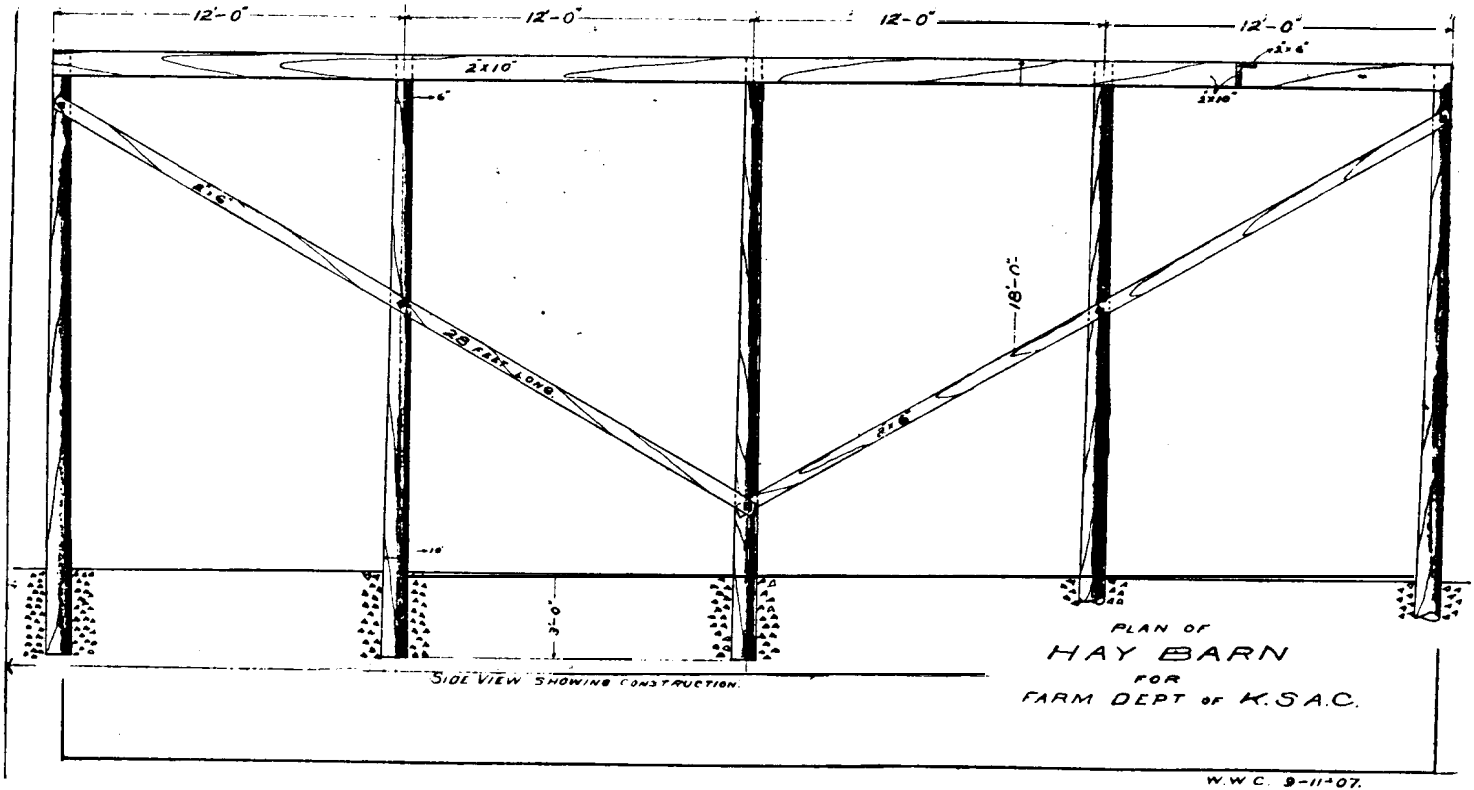


PLATE 19. Side view of hay barn, showing method of bracing.

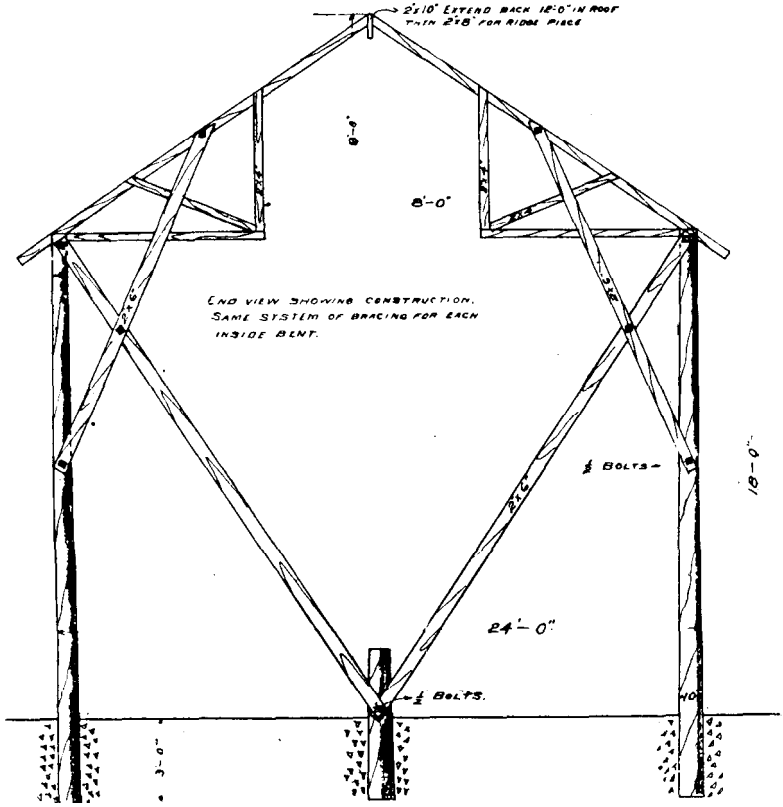


PLATE 20. Showing plan of construction of end section of hay barn and general plan. of bracing for middle sections.

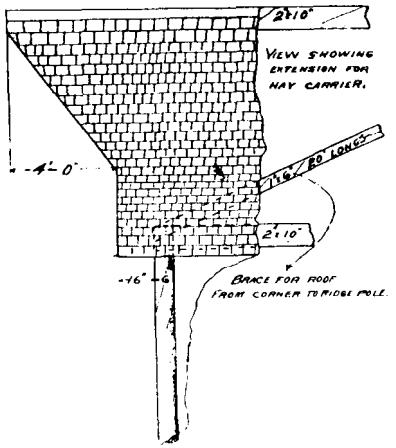


PLATE 21. Section of roof of hay barn, showing extension for hay-carrier track and plan for bracing roof.

Cost of Shed.

A fairly accurate account was kept of the material and labor required to build this shed. Most of the labor was done by unskilled workmen, an expert carpenter being hired only seven days while framing the shed. The cost of this shed may be stated as follows:

10 long posts and 4 short posts, including cost of labor for cutting and hauling	$19 05
Lumber for frame and roof	65 73
1850 sq. ft. galvanized steel roofing @ $4.15 per square, including ridge-pole,	89 50
Bolts and nails	6 00
Lime, cement, sand, etc.	9 80
Poles for bottom	6 00
Construction labor, carpenter work, etc.	91 75
Painting	12 00
Hay-fork, pulleys, track, carrier, complete	31 26
Siding, estimated cost of labor and lumber	86 60
Total	$417 09

This is a strong and durable shed and was built at a relatively low cost, yet on the average farm it might be built at an even less cost. From the above discussion, considering the cost of a shed and the saving in hay and labor which may result from shedding alfalfa, every farmer who has a fifteen-acre field of alfalfa should build a shed.

MARKETING OF THE HAY.

The most profitable way for the farmer to market hay is in the form of horses, beef, pork, mutton or dairy products. Such products are easily taken to the market, and the by-product from feeding live stock--the manure which may be returned to the soil--is almost equal in value to the hay itself. Yet some hay must be sold in order to supply the demand for this product.

There is always a local demand for hay, which may be supplied by those farmers who produce only a little more than is required for feeding on their farms. The farmer who grows hay in large quantities must seek a market farther from home, and this necessitates that the hay be baled and shipped to the central markets in the larger cities.

It is not easy to decide as to just when may be the best time to sell hay. Often the price of hay is higher in the latter part of the winter than during the previous months or immediately after the farmer turns the stock to pasture. Along in February and March there is apt to be a shortage in the supply of hay, and the larger grower may often take advantage of the advanced price and gain an additional profit from the sale of his crop.

COMPARATIVE HAY FIELDS IN POUNDS PER ACRE.

DATE.	*Bromus inermis.*	Meadow fescue.	Orchard-grass.	Timothy.	Redtop.	Tall Oat-grass.	Medium Red clover.	Mammoth Red clover.	Alsike clover.	Common alfalfa.
1904	4,840	3,680	590	4,530	3,982	1,815	9,420	4,840	2,880	4,480
1905	3,047	2,616	1,670	4,901	2,696	1,785	5,740	4,072	3,340	9,325
1906	2,560	1,747	1,386	5,393	1,570	1,434	*3,360	*3,920	4.340	9,289
1907	1,120	620	2,030	4,293	.....	1,785	3,440	3,760	....	6,286
Average, 1904–'05	3,944	3.148	1,130	4,716	3,339	1,800	7,580	4,456	3,110	6,903
Average, 1906–'07	1,840	1,184	1,708	4,843	.....	1,610	3,400	3,840	.....	7,788
Average, 1904, '05, '06, '07	2,892	2,166	1,419	4,779	.....	1,705	5,490	4,148	.....	7.345

DATE.	Turkestan alfalfa.	Sand-lucerne.	Timothy and Redtop.	Timothy and Red clover.	Meadow fescue and Red clover.	*Bromus inermis* and Red clover.	Orchard-grass, meadow fescue, and Red clover.	*Bromus inermis*, orchard-grass and Red clover.	*Bromus inermis*, timothy, and Red clover.	*Bromus inermis* and alfalfa.
1904	3,520	.....	2,178	6,360	6,712	5,580	6,208	5,920	5,020	5,440
1905	8,860	5,980	4,356	3,664	4,040	6,270	4,000	4,960	5,000	6,100
1906	6,840	5,960	4,074	4,100	1,800	3,200	.....	2,060	2,200	6,090
1907	5,100	5,280	1,631	4,293	... .	1,480	840	2,360	2,020	4,260
Average, 1904–'05	6,190	.....	3,267	5,012	5,376	5,925	5,104	5,440	5,010	5,770
Average, 1906–'07	5,970	5,620	2,853	4,196	.....	2,340	.....	2,2 0	2,110	5,175
Average, 1904, '05, '06, '07	6,080	... ...	3,060	4,604	....	4,133	.....	3,825	3,560	5,473

*Second seeding.

However, the factor which largely determines the price is the quality of the hay. Good hay will always command a fair price, and it has been the aim of the writer in the above discussion to call the attention of haymakers to some of the essential factors in the production of good hay.

YIELDS OF ALFALFA COMPARED WITH OTHER HAY CROPS.

Several common meadow-grasses, clovers and alfalfas, and combinations of these grasses and legumes, have been grown in comparative trials at this Station for the past four seasons. During this interval the clovers have been reseeded and several new plots of grasses and alfalfa have been added. The yields given for each variety are the average yields from the several plots as shown in table on page 256.

The crops of 1904 were all from seedings made in the spring of 1903. Medium Red clover made a remarkable yield the first season, greatly exceeding the yield of alfalfa. This was due, in part, to the remarkably favorable season for clover and also to the fact that the alfalfa was not yet fully established. During the same season, other fields of alfalfa on the Experiment Station farm gave yields of over five tons of cured hay per acre. As an average for the four seasons the yields of the several hay crops compare as follows :

Name of hay.	***Pounds per acre.***
Common alfalfa	7,345
Turkestan alfalfa	6,080
Medium Red clover	5,490
Bromus inermis and alfalfa	5,473
Timothy	4,779
Timothy and Red clover	4,604
Mammoth clover	4,148
Bromus inermis and Red clover	4,133
Bromus inermis, orchard-grass, and Red clover	3,825
Timothy and Red clover and *Bromus inermis*	*3,560*
Timothy and redtop	3,060
Bromus inermis	*2,892*
Tall oat-grass	1,707
Meadow fescue (English blue-grass)	1,666
Orchard-grass	1,414

The clover-grass combinations were not reseeded and the clover dying out caused reduced yields for the last two years. It should be further observed that the seasons of 1904 and 1905 were rather wet, while those of 1906 and 1907 were comparatively dry. The high yields of timothy and timothy and clover are also in part due to the fact that the timothy plots are on the lowest part of the field and somewhat favorably located, both as regards soil fertility and moisture supply.

SHRINKAGE IN WEIGHT OF HAY.

The moisture in the green alfalfa as cut for hay will vary somewhat, according to the dryness of the season and the maturity of the alfalfa when cut. Moisture determinations of the green plants when cut at several stages of maturity in 1906 showed the total moisture content as follows :

Time of cutting.	*Date cut.*	*Moisture.*
First bloom	May 16	74.64%
One-half bloom	May 31	69.72
Full bloom	June 7	64.18

The spring of 1906 was very dry. In midsummer, at the third cutting, alfalfa cut when one-tenth in bloom contained 78.65 per cent. of moisture while, when in one-half bloom, the moisture content was 70.65 per cent. Determinations of the moisture in green alfalfa at the first cutting, about one-tenth in bloom, in 1905, showed an average of 77.6 per cent. of moisture. Other determinations have shown even a higher percentage of moisture, ranging above 80 per cent.

In favorable haymaking weather the cut alfalfa readily loses part of its moisture. When well wilted, as ordinarily raked and cocked, the hay will contain from forty to fifty per cent. of moisture. As stacked, well-cured alfalfa hay will contain sixteen to twenty-four per cent. of moisture. Fully air-dried hay from the stack or mow should contain ten to twelve per cent. of moisture. The average shrinkage of well-cured alfalfa hay put into the stack or mow by loss of moisture should not be greater than ten per cent.

Men experienced in handling hay usually figure on about twenty per cent. loss in weight after the hay is put into the stack or mow until it is sold or ‘baled. Also, the statement is made that after baling each bale of alfalfa will shrink from one to four pounds. As the hay is ordinarily stacked on the farm, there is considerable loss from damage by rains, so that the actual amount of good hay taken from a stack may show a considerable loss above what has been due to the shrinkage in the weight.

RULES FOR MEASURING HAY.

The rules for measuring hay in the stack may vary according to the length of time the hay has been stacked and the kind and quality of the hay, and also according to the character of the stack. With alfalfa hay which has been stacked for thirty days, it is usual to compute an 8-foot cube, or 512 cubic

feet, as a ton. When the hay has been stacked five or six months, usually a 7½-foot cube, or 422 cubic feet, is calculated for a ton. In old, fully settled stacks, it is usual to allow a 7-foot cube, or 343 cubic feet, for a ton; or sometimes, in very large stacks or mows, only 216 cubic feet, or a 6-foot cube, are allowed per ton in weight.

The volume of mow is readily secured simply by multiplying together the length, width and height. There are different methods for measuring hay in the stack, depending upon the shape of the stack and also upon its size. With a long stack or rick, the usual method is to throw a line over the stack, measuring the distance in feet from the bottom of the stack on one side to the bottom on the other; add to this the average width of the stack in feet, divide this sum by 4 (which gives one side of the square) and multiply the quotient by itself and this product by the length of the stack in feet. This will give the number of cubic feet in the stack, which may be divided by 512, 422, or 343, in order to find the number of tons. For small, low ricks, the rule is to subtract the width from the "over," divide by 2, multiply by the width and multiply the product by the length, dividing the result by the number of cubic feet in a ton.

There is no established rule for measuring round stacks, but this one will approximate the contents of a stack of ordinary conical form: "Find the circumference at or above the base or 'bulge' at a height that will average the base from there to the ground; find the vertical height of the measured circumference from the ground and the slant height from the measured circumference to the top of the stack, taking all measurements in feet. Multiply the circumference by itself and divide by 100 and multiply by 8, then multiply the result by the height of the base, plus one-third of the slant height of top." The hay in a round stack is usually less compact than in a rectangular stack, hence a greater number of feet should be allowed for a ton--with well settled hay, probably 512 cubic feet.

The rules given may also be used in measuring any kind of hay, or cane or Kafir fodder, but with cane or Kafir only approximate results may be secured by stack measurements, because the fodder is apt to vary greatly in weight according to the moisture it contains.

HANDLING AND TREATING ALFALFA LANDS.

BREAKING ALFALFA SOD.

Farmers often complain of the difficulty of breaking up and destroying alfalfa. Much farm work is difficult to the inexperienced farmer until he has been provided with the right kind of implements and learns how to do the work properly. Breaking alfalfa sod is not such a difficult task after all when the farmer has the proper equipment; strong horses and a sharp plow, properly operated, will do the work.

It is not necessary to lose a season's crop by breaking in the summer in order to kill out alfalfa. Preferably, break rather early in the fall if the soil is in favorable condition for plowing. Early fall breaking may kill the alfalfa better than late plowing, and also the soil is put into good condition for absorbing and storing soil moisture. Do not try to plow up alfalfa when the soil is dry.

Use a good plow which turns a wide furrow-slice and set it to cut a furrow two or three inches less in width than it will turn. This is to prevent the large roots from slipping past the share uncut. If a narrow plow is used or the plow is set to take a full cut, the alfalfa plants will not all be destroyed, and the renewed growth will have the appearance of alfalfa planted in rows.

The ordinary stubble-plow may be used in breaking alfalfa sod but the point should not be given too much suction ; rather the share should be set nearly straight from point to heel, the purpose being to cut the roots of the alfalfa with a smooth, drawing cut, rather than to break them off by a lifting cut, as is the case when the plow has too much suction. If the roots of the alfalfa are cut off there is no difficulty in destroying the alfalfa by the first plowing, especially if corn or some other cultivated crop is grown the first season after breaking.

It is necessary to keep the edge of the share sharp. The plow should be in good condition when it enters the field and the operator should carry a file and use it often. When the edge of the share becomes too thick to file, have it drawn out again by the blacksmith.

Break shallow; not over three or four inches deep. If plowed too deeply the alfalfa will not be destroyed--the roots retain enough life to start again and with favorable weather will make a vigorous growth, necessitating much extra labor

with the cultivator and hoe. It is always preferable to break shallow, but it may sometimes be advisable to replow deep the next spring in preparing the seed-bed for corn or other late planted, intertilled crops.

It may be best not to cultivate the alfalfa breaking immediately after plowing, but allow the furrow-slice to dry out, thus aiding to destroy the alfalfa roots. The soil will be in good condition to absorb rains. Late in the winter or early in the spring cultivation may be given with the disk or Acme harrow to better expose the alfalfa roots or cut the young shoots and also produce a soil mulch to retain moisture. The tilth of soil may be improved by winter and early spring cultivation ; likewise the larvæ of cutworms with which the field will likely be infested may be destroyed.

At the Kansas Experiment Station the usual practice has been to break alfalfa sod rather late in the fall, after the last cutting of alfalfa has been removed. An objection to late fall or early spring breaking is that the soil is apt to be left exhausted of soil moisture and rather too loose and mellow to make the most favorable seed-bed for the first year's cropping. The result has been that in several instances corn on new alfalfa breaking has been injured by short periods of drought, resulting in immature, light ears of corn. The second season after breaking, alfalfa land usually produces its largest crop. If the alfalfa field was plowed late in the summer or early in the fall, so as to allow the soil to accumulate moisture and become more firm before planting time the next spring, better results might be secured from cropping alfalfa land the first season after breaking.

Our usual method at the Kansas Station has been to plow alfalfa sod five or six inches deep. However, the general experience of farmers seems to be in favor of shallow breaking–two and one-half to three inches deep. The objection to deep breaking is that the soil is left too loose and mellow the first season, especially if the season proves to be dry, or with wet weather shoots are apt to start again from the crowns of the alfalfa plants when the roots are cut off deep in the ground.

CROPS TO FOLLOW ALFALFA.

With a plentiful moisture supply, crops following alfalfa usually make a very rank growth of stalk and foliage, due to the abundance of available nitrogen which has been stored in

the soil by the alfalfa bacteria; hence annual forage crops, such as millet, corn, sorghum and Kafir-corn produce well after alfalfa. Wheat and other small-grain crops should not, as a rule, follow alfalfa until the second or third year after breaking.

In a trial at the Kansas Experiment Station, oats, barley, emmer, flax and corn were grown in a comparative trial on alfalfa breaking. The crops of flax and small grains were practically a failure, due to a too rank growth and lodging, while the corn, which was cut up and put into the silo, gave a yield of over fifteen tons of green fodder per acre. Corn, if allowed to mature on alfalfa ground, may make a large yield of good ears, depending upon the season and rainfall, since the alfalfa ground is apt to be deficient in stored soil moisture and a short period of drought is more apt to injure corn on alfalfa ground than on older land which has been longer cultivated.

Alfalfa is a very deep-rooting crop and a great exhauster of soil moisture. Experiments at this Station indicate that none of the ordinary farm crops leave the soil so dry in the fall as does alfalfa, hence a good crop on alfalfa ground the succeeding season after breaking may only be insured by abundant rainfall during the growing season or by storing water in the soil after breaking, previous to planting the next year's crop. Injury from drought is more apt to result when the corn is surface-planted in a deep, mellow seed-bed; better results are secured by listing corn on shallow-plowed ground, when the seed is planted in the firmer, moister soil. The new alfalfa-breaking seed-bed is apt to be too loose and mellow for surface-planting.

Potatoes and root crops require a fertile soil and a deep, mellow seed-bed, and are well adapted for following alfalfa. Alfalfa and potatoes are the principal crops on many of the large potato farms of the Kaw river valley. Alfalfa puts the soil in excellent condition for potatoes, and potatoes are a good crop to prepare the soil for the fall seeding of alfalfa.

PLANS FOR ROTATION OF CROPS WITH ALFALFA.

Alfalfa cannot be economically used in short rotations. Perhaps the crop may not reach its maximum development and productiveness until after it has been seeded several years, and when a field is well set it does not seem advisable to break it up in less than four or five years after seeding. Perhaps the

alfalfa will benefit the land about as much in four or five years as it will by leaving it on the land for a longer period. In this time the plant has fully developed its large root system, thus improving the physical condition of the soil, has transferred some of the mineral elements of plant-food of the subsoil to the surface soil, and has perhaps increased the nitrogen supply of the soil as much as it may be increased by growing alfalfa for a longer period. The alfalfa has much more than paid for its seeding and culture by the three or four annual crops of hay, or by one or more crops of hay and a good crop of seed, and in order to secure the greatest value from the crop, both as forage and fertilizer, it seems advisable to break up the alfalfa in four or five years after seeding.

The following are plans for rotating alfalfa with other crops :

Rotation Plan No. 1.

The farm plan. showing crops on all fields for one year.

Corn (manured)	*Corn.*
Small grains. (seed to alfalfa in fall).	Corn.
Alfalfa.	Alfalfa.
Alfalfa.	Alfalfa.

Rotation plan, or order of crops on each field:

First year, Alfalfa.
Second year, Alfalfa.
Third year, Alfalfa.
Fourth year, Alfalfa
Fifth year, Corn.
Sixth year, Corn.
Seventh year, Corn plus manure.
Eighth year, Small grains (seed to alfalfa in fall).

If the above plan keeps too much land in alfalfa the farm may be divided and the following systems of rotation practiced on each division of four fields for eight years, when the system may be interchanged, the first taking the place of the second, and the second of the first, as follows:

No. 1-A.

Rotation plan, or order of crops on each field:

First year, Alfalfa.
Second year, Alfalfa.
Third year, Alfalfa.
Fourth year, Alfalfa.
Fifth year, Corn.
Sixth year, Corn.
Seventh year, Corn.
Eighth year, Corn.

No. 1-B.

Rotation plan, or order of crops on each field:

First year, Legumes and forage.
Second year, Corn.
Third year, Corn plus manure.
Fourth year, Spring grains.
Fifth year, Legumes and forage.
Sixth year. Corn.
Seventh year, Corn plus manure.
Eighth year, Spring grains (seed to alfalfa).

It may be desirable to grow grass as well as alfalfa on the same farm in order to supply pasture for cattle and hay for horses, etc. If this is desirable then the alfalfa rotation plan

may be slightly changed and a system introduced making a double eight-year or a sixteen-year rotation, as follows:

No. 1-C.

Rotation plan. or order of crops on each field:

First year, Alfalfa.
Second year, Alfalfa.
Third year, Alfalfa.
Fourth year, Alfalfa.
Fifth year, Corn.
Sixth year, Corn.
Seventh year, Small grains.
Eighth year, Small grains (seed to grass).

No. 1-D.

Rotation plan, or order of crops on each field:

First year, Grass.
Second year, Grass.
Third year, Pasture plus manure.
Fourth year, Pasture.
Fifth year, Corn.
Sixth year. Corn.
Seventh year, Small grains plus manure.
Eighth year, Small grains (seed to alfalfa).

The above rotation plans are suited to a farm which has eight fields nearly equal in area. Rotation plan No. 2 is suited to a farm with four fields.

Rotation Plan No. 2.

A sixteen-year rotation with alfalfa, small grain and corn on four fields.

YEAR.	Field A.	Field B.	Field C.	Field D.
1906*	Small grain (S)	Corn.	Corn (M).	Corn.
1907	Alfalfa (M).	Small grain (CC).	Corn.	Corn.
1908	Alfalfa.	Corn (M).	Small grain (CC).	Corn.
1909	Alfalfa.	Corn.	Corn (M).	Small grain (CC).
1910	Alfalfa (B)	Small grain (S).	Corn.	Corn (M).
1911	Corn.	Alfalfa (M).	Small grain (CC).	Corn.
1912	Corn.	Alfalfa.	Corn (M).	Small grain (CC).
1913	Small grain (CC).	Alfalfa.	Corn.	Corn (M).
1914	Corn (M).	Alfalfa (B),	Small grain (S).	Corn.
1915	Corn.	Corn.	Alfalfa (M).	Small grain (CC).
1916	Small grain (CC).	Corn.	Alfalfa.	Corn (M).
1917	Corn (M).	Small grain (CC).	Alfalfa.	Corn.
1918	Corn.	Corn (M).	Alfalfa (B).	Small grain (S).
1919	Small grain (CC).	Corn.	Corn.	Alfalfa (M).
1920	Corn (M).	Small grain (CC).	Corn.	Alfalfa.
1921	Corn.	Corn (M).	Small grain (CC).	Alfalfa.
1922	Small grain (S).	Corn.	Corn (M).	Alfalfa (B).
1923†	Alfalfa (M).	Small grain (CC).	Corn.	Corn.

*** It is assumed that this farm has been cropped largely with corn and small grains and has received little rotation of crops. No alfalfa is growing on the farm in 1906, when field "A" is seeded. The rotation really begins in 1907.**

† Observe that this is a repetition of 1907 crops: viz., this rotation is repeated every sixteen years. each of the four fields having received a rotation of four years in alfalfa.

(S)=Seed to alfalfa in fall. (B)=Break alfalfa sod. (This should properly be done in the spring when the new catch of alfalfa by fall seeding is assured.)

Rotation plan No. 2 is more readily understood in this way: It is really a three-year rotation on three fields, one of the four fields being kept continually in alfalfa, as shown in the plan. The order of the rotation on each field is corn followed by corn, followed by small grain. Thus, two fields of corn, one of small grain and one of alfalfa are grown on the farm each year. At the end of four years the field in alfalfa, which has not been included in the three-year rotation, is plowed and planted to corn the succeeding season, while one of the three fields which has been in the regular rotation is seeded to alfalfa and comes out of the regular three-year rotation plan, remaining in alfalfa for four years, when this field is plowed and planted to corn and becomes one of the fields in the three-year rotation series, while another field which had been seeded to alfalfa is thrown out of the regular rotation system. It will be observed that a similar plan may be followed with five fields, six fields, or in fact any number of fields. With four fields, by the method described, one-fourth of the farm is kept continually in alfalfa. With five fields, one-fifth of the farm would be in alfalfa each year, and it would take twenty years for the alfalfa rotation to be carried out on all the fields. With three fields, one-third of the farm would be in alfalfa all the time and the rotation system would be completed in twelve years.

Much of the land in the West has already been cropped too long with wheat and corn. The fertility of the soil is showing signs of exhaustion and the land is becoming less productive. Simple tillage will not maintain the fertility of the soil. It becomes necessary finally to replace the plant-food, exhausted by the continuous growing of crops, by the application of manure or chemical fertilizers or by the rotation of crops, in which the legume crops, such as alfalfa and clover, are introduced in order to restore again the humus and nitrogen, exhausted in the ordinary methods of farming by continuous grain cropping. When land has been farmed a long time to wheat or corn it finally ceases to produce profitable crops. The soil is not necessarily exhausted in fertility, but by a long period of continuous cropping with one crop the diseases and insects which prey on the corn or wheat have

Catch crop or green manuring crop, planted in the stubble after tbe small grain is harvested. (M)=A dressing of barn-yard manure applied as a surface dressing in the fall and winter on alfalfa, or spread on corn-stubble land and plowed under previous to planting the following crop of corn.

accumulated in the soil, the organic matter and humus and nitrogen have become more or less exhausted, and, according to late investigations by the United States Bureau of Soils, each crop develops a toxin or poison in the soil which is injurious to that crop but may not injure other crops, but in fact may act as a stimulant to increase the growth of other crops planted in such soil.

The land is really "wheat sick" or "corn sick"; what is needed more than anything else is a rotation of crops which will include grasses and legumes, by which the organic matter, humus and nitrogen exhausted by continuous cultivation and cropping with grain crops may be restored to the soil.

In the previously described rotation plans, one-fourth to one-half of the farm is kept continually in alfalfa or some other soil-fertility maintaining crop.

The young farmer who will introduce and practice such a rotation of crops, keeping live stock on the farm and feeding the roughage and some of the hay and grain, returning the manure to the soil, will raise not only more bushels of grain of better quality at a less cost per bushel during his next forty years of farming, but he will also have the extra income from the alfalfa, grass, hay and live stock, and at the end of forty years of such farming he would have a farm with more fertile soil and a capacity to produce larger crops of wheat and corn than it does to-day.

ALFALFA AS A SOIL FERTILIZER IN ROTATION WITH OTHER CROPS.

Throughout the great western plains region, where alfalfa grows most successfully, there is no question regarding its great value as a forage crop. Yielding each season three to five cuttings, averaging a ton of excellent hay for each cutting, every ton of which is equal to a ton of wheat-bran or two tons of the best prairie hay or timothy hay in feeding value, alfalfa has come to be generally recognized in the West as the most profitable money crop which the farmer may grow.

The acreage of alfalfa has increased rapidly in the last few years. Kansas alone has 743,050 acres planted to alfalfa,* and it is safe to say that we might profitably grow ten times that acreage and not decrease our total yields of wheat and corn, provided alfalfa is used as a crop in rotation with grain crops.

*** Kansas State Board of Agriculture.**

Alfalfa should not be sown simply for the money return received from that crop alone. From all over the state the writer is continually receiving inquiries asking: "How shall I renew my stand of alfalfa? What shall I do? The weeds, crab-grass, foxtail, etc., are destroying my alfalfa." My general reply is: "Seed new fields to alfalfa, plow up the old fields and plant to other crops for a few years before reseeding to alfalfa." In other words, use alfalfa as a rotation crop with corn and wheat, and thus secure an additional value from the use of alfalfa as a fertilizer, instead of trying to keep the same land in alfalfa for a long period at the expense of the exhaustion of the fertility of other fields by the continuous growing of grain crops.

The writer would recommend, as a rule, to seed more land to alfalfa before plowing up the present fields, but as soon as the farm is producing about all the alfalfa the farmer can take care of, then the plan should be to seed new fields and break up the old ones, following alfalfa with corn or other grain crops, rather than to practice the present system of cropping the same land to corn and wheat continuously.

Alfalfa a Cheap Fertilizer.

Some farmers make objection to using alfalfa as a rotation crop : "The seed costs too much and it is so hard to get a stand." Many farmers have found it difficult to get a stand of alfalfa, but the failures have often been due to poor seed or to errors in preparing the seed-bed or in sowing, and as a rule these mistakes may easily be corrected. With good seed, a proper seed-bed, and land adapted for growing the crop, a careful farmer should be almost as sure of obtaining a successful stand of alfalfa as the average farmer is of getting a stand of wheat or oats.

Good alfalfa seed is costly, but if any reader of this bulletin can inform the writer of a cheaper fertilizer than ten or fifteen pounds of alfalfa seed per acre, he would like to secure the information. Consider: Twelve pounds of alfalfa seed at 15 cents per pound, or $1.80 per acre, the value of five loads of manure or of 100 pounds of commercial fertilizer; and after valuable hay crops have been removed from this acre for four or five years in succession this alfalfa will have been worth more to the soil as a fertilizer than fifty loads of manure or several tons of commercial fertilizers.

Data Indicating Fertilizing Value.

I regret that our experiment stations have not secured more definite data on the actual value of alfalfa as a fertilizing crop. Few reliable comparative tests seem to have been made on this point. The general experience of farmers, however, is sufficient evidence that we can hardly overestimate the fertilizing value of growing alfalfa for a few years on any soil which has become deficient in humus and nitrogen by continuous cropping with grain crops for a long period.

In Bulletin No. 44, of the Wyoming Experiment Station, Prof. B. C. Buffum gives some data on the use of alfalfa as a fertilizer at that station. As a result of the first year's cropping on alfalfa sod, 48 per cent. greater yield of oats and 60 per cent. more wheat was obtained from alfalfa land than from the check plots which had not grown alfalfa. The wheat on the alfalfa land yielded thirty bushels per acre and the oats seventy-eight bushels per acre.

In 1904, at the Kansas Experiment Station, flax, oats, barley and emmer were planted on alfalfa breaking. All of these grains except the barley made an almost complete failure, making a great growth of straw but producing little grain. The barley did not lodge so badly as the other grains and yielded thirty-four bushels per acre. In 1905 silage corn on alfalfa breaking yielded fifteen tons of green forage per acre, which was put into the silo. Other land adjacent, which received no rotation with alfalfa, yielded nine tons of green stalks per acre. In 1906 a field of Hildreth corn, the second crop after breaking the alfalfa sod, yielded nearly eighty bushels per acre. Other fields on the farm, of other varieties, gave yields varying from forty to seventy-five bushels per acre. No comparative tests have been made to prove the fertilizing value of alfalfa at this Station, but the general results of growing corn on alfalfa land indicate a large increase in the yield of corn after alfalfa as compared with the yield of corn from other fields which have not been rotated with alfalfa.

Jewell county, Kansas, grows more alfalfa than any other county in the state. It has also been the banner county in the production of corn. In 1906, Hon. J. W. Berry, Jewell, Kansas, formerly a member of the Board of Regents of the Kansas State Agricultural College and Experiment Station,

made some investigations in Jewell county regarding the yields of corn from alfalfa land. He reported various yields from the alfalfa land, ranging from seventy to ninety-six bushels per acre, while other land on the same farm or in the neighborhood gave yields of from forty to eighty bushels per acre.

In the fall of 1905 Mr. C. A. Thomas, of Oakley, Norton county, Kansas, stated at a farmers' institute at Norton that he broke up a piece of alfalfa sod on his farm in 1891 which had been seeded three years. In the season of 1905 he was able to trace the outlines of this field of alfalfa in the wheat which grew on the land, the wheat standing four to six inches higher on the old alfalfa field than on the land adjacent. This fact was also attested by Mr. A. F. Turner, professor of agriculture in the Norton county high school. Thus it appears that fourteen years after the alfalfa sod had been broken the fertilizing effect of this crop on the land was still noticeable in the larger growth of wheat.

How Alfalfa Increases Soil Fertility.

Alfalfa adds to the fertility and increases the productiveness of land in several ways. The bacteria which live and multiply in the tubercles that grow on the roots of the alfalfa plants take nitrogen from the air that passes through the soil, doubtless using the nitrogen as a food and changing it in such a way by this use that the nitrogen becomes available as food for the alfalfa plants, or the death of the bacteria allows their substance to be absorbed by the plant. Through this use of the nitrogen of the air alfalfa produces not only large annual crops of nutritious fodder, but also by the large root growth of the plants, the death of the bacteria, and the destruction and renewal of the tubercles of the roots, the nitrogen supply of the soil is actually increased by growing alfalfa. Thus the soil becomes richer in nitrogen after alfalfa has been grown on it for a few years than it was before alfalfa was planted.

The continual dropping of leaves also adds to the humus and nitrogen of the soil.

Dr. William P. Headden, of the Colorado Experiment Station, estimates that the fertilizing value of the stubble and six and one-half inches of alfalfa roots plowed under is about twenty dollars per acre, while the value of the stubble and the

entire root system is not less than thirty-five dollars per acre.

Dr. C. G. Hopkins, of the Illinois Experiment Station, determined from his experiments that "at least 160 pounds of atmospheric nitrogen was fixed (added to the soil) during a year." Likewise, "the percentage of nitrogen is much higher in the crops from the inoculated plots, the percentage of protein averaging 12.2 per cent. in the dry matter of the uninoculated crops, while 16.84 is the percentage for the inoculated plots." For the single cutting, May 28, when the determinations were made, the yields in dry matter per acre were 1340 pounds and 2720 pounds, respectively ; or the inoculated plots gave more than double the yield of the plots which were not infected with the alfalfa bacteria.

"Estimates made at the New Jersey Experiment Station indicate that the plant-food gathered by an acre of alfalfa in two years was equal in nitrogen to that contained in 3500 pounds of nitrate of soda ; in phosphoric acid to that contained in 600 pounds of superphosphates ; and in potash to that contained in 1200 pounds of muriate of potash: the whole having an actual value, if these fertilizers should be bought on the market, of $124.

Alfalfa Improves Soil Texture.

Alfalfa also improves the tilth or physical condition of the soil. The roots grow to a large size and penetrate to unusual depths into the subsoil. Samples of roots taken at the Kansas Experiment Station were found to reach a depth of over nine feet. At the Colorado Experiment Station Dr. W. P. Headden traced the roots of alfalfa to a depth of twelve and one-half feet, and there are several reports, not well authenticated, in which alfalfa roots are said to have been found at even greater depths. When the land is plowed to destroy the alfalfa these roots decay, forming humus, which aids in loosening the soil and gives it greater capacity to hold moisture, and the openings in the soil left by the roots form a system of channels for the penetration of air and water into the hard subsoil of heavy clay lands. Doubtless this physical effect which alfalfa has on the soil accounts for the instance given above in which the wheat grew ranker on the old alfalfa field fourteen years after breaking the alfalfa sod.

ALFALFA ROOTS.

The sample of alfalfa roots shown in plate 22 was taken from an old upland meadow on the Experiment Station farm. The soil is a rather fine, compact silt loam with a subsoil containing enough clay to make it quite tough and hard. The root system of alfalfa is simple and easily observed. The plant sends a single large tap-root almost straight downward into the subsoil. This main root in an old plant may be an inch

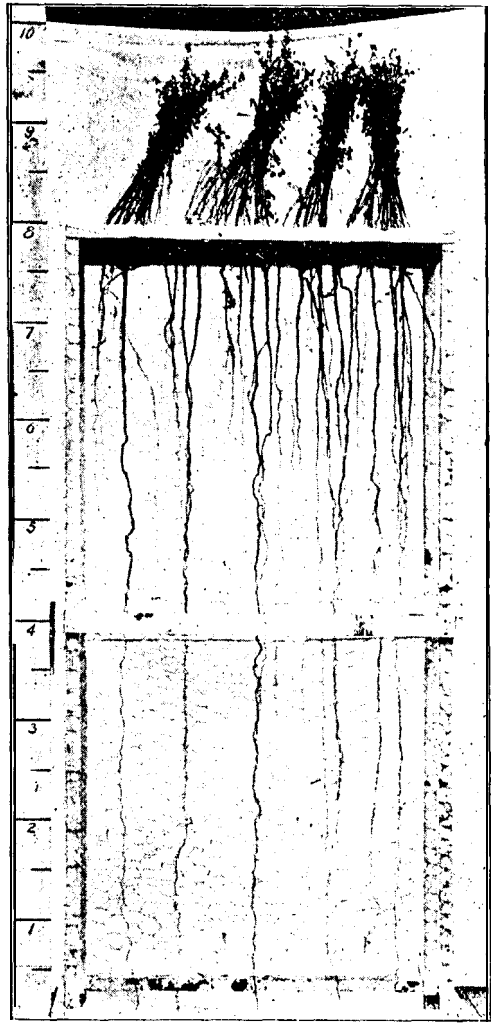


PLATE 22. Alfalfa roots five or six years after seeding.

in diameter near the crown. The tap-roots in the sample described averaged about one-half inch in diameter. There was considerable growth of fibrous roots in the surface foot of soil. These fibrous roots held quite a number of small tubercles. Usually the larger proportion of root growth lies below four feet. Several clusters of tubercles were also observed in the deeper soil. Apparently in some plants the tap-root had been destroyed and a number of smaller secondary roots had taken its place, assuming the character of tap-roots, spreading very little and pursuing an almost vertical course downward.

This study, as well as the studies of other investigators, leads to the conclusion that alfalfa is a very deep feeder. The only surprise is, considering the vigorous growth and productivity of the plant, that the roots are not more numerous and more fibrous in their development. However, the method by which the plant feeds, taking its nitrogen from the air by means of the bacteria which grow on its roots, and the great depth of the roots, compensate for the comparatively few roots and the lack of fibrous growth.

CONTINUED GROWING MAY EXHAUST THE SOIL.

It is evident from the nature of this crop and its great productiveness that it must in time tend to exhaust the mineral plant-food of the soil, if the land is kept continuously in alfalfa. By a proper rotation of alfalfa with other crops, however, there may result an actual increase of the available plant-food in the surface soil, since the alfalfa by its deep feeding may draw the mineral plant-food from the lower subsoil, where it is beyond the reach of common plants, and store some of it in the large, fleshy roots in the upper soil, which, by their decay, leave the plant-food in an available condition for the use of the surface-feeding crops.

THE MOST VALUABLE WESTERN CROP.

From a study of the root system of alfalfa, one cannot fail to appreciate the beneficial effects which such a crop should have in disintegrating and loosening the hard, compact subsoil characteristic of some lands. Drawing its water and mineral plant-food from the deeper subsoil, alfalfa is a drought-resistant crop, and receiving its nitrogen from the air, it actually increases the supply of this valuable plant-food in the soil by the dropping of its leaves and by the decay of its tubercles and roots. Meanwhile several large and profitable

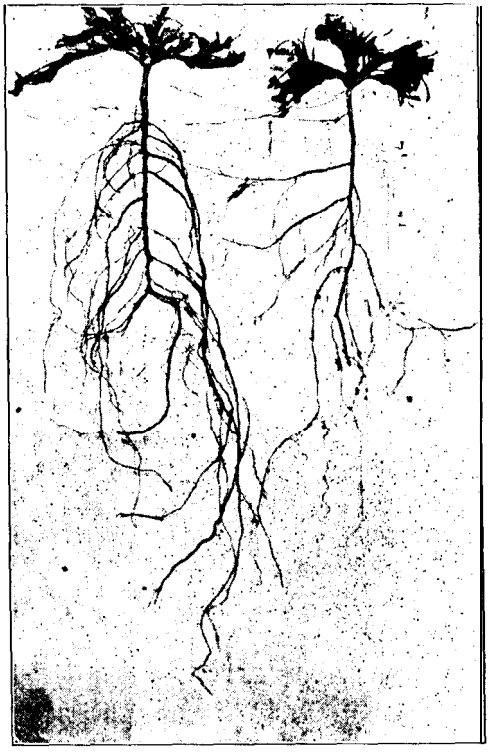


PLATE 23. Alfalfa roots nine months after seeding.

crops of the most nutritious hay are harvested each year.

In the judgment of the writer alfalfa will do more for western agriculture in the next fifty years than all the other crops which farmers may grow in this region. The soil of western Kansas and of much of the western plains is usually rich in the mineral elements of plant-food, but it is often lacking in humus, which becomes especially noticeable if the land has been farmed continuously to wheat for a few years. By growing alfalfa it is possible to increase the supply of humus in the soil, and, the roots of the plants penetrating deep into the subsoil, disintegrate and deepen the soil and altogether greatly improve its texture, giving it greater capacity to absorb and hold water. However, the beneficial effect on the soil of growing alfalfa is only incidental to the rapid introduction of the crop throughout the West. The great value of the crop as a money-maker is the main factor which is introducing

it into the agriculture of the central West. Where alfalfa can be successfully marketed or fed, no other crop grown in the West will yield so great a net profit per acre in a series of years.

THE RELATION OF BACTERIA TO ALFALFA.

During the last twenty years a series of bacteriological investigations has been conducted which is of vast importance to agriculture. We refer to the line of work which has culminated in the present knowledge concerning bacteria and their. relation to nitrogen fixation and soil fertility in general. Soil bacteriology is in its infancy. The knowledge concerning the activity of the "nitrogen-gathering bacteria" in their association with alfalfa and other leguminous plants opens the way for further research which promises well for a more clear understanding of soil fertility and its control.

WHAT ARE BACTERIA?

Bacteria, often referred to as germs, microbes, or parasites, are small plants. They are so minute that it is necessary to magnify them 400 times or more in order to clearly see them, In shape these one-celled organisms are represented chiefly by two types, viz., rod-shaped and round. Their size is measured in microns, one micron being equivalent to one twenty-five thousandth of an inch. Bacteria of the rod form vary from one to six microns in length ; in other words, if a single bacterium is two microns long, it would take 12,500 placed end to end to measure one inch in length.

The reproduction of bacteria is accomplished by simple division and also by the formation of spores. By the first method the organisms elongate somewhat, divide near the middle and thereby two organisms are formed from the parent cell. This process takes place very rapidly when conditions are favorable for the bacterial growth. Such conditions are, chiefly, proper food, agreeable temperature, absence of sunlight and plenty of moisture, It can be estimated that each bacterium may divide every twenty minutes, or give rise to three generations in one hour. Therefore it is evident that from a single bacterium countless millions may be formed in twenty-four hours.

When bacteria are placed in an environment where conditions are not favorable for growth they will cease propagating

by the method of simple division. Under these unfavorable conditions certain kinds or species of bacteria are able to form spores. These are small bodies which appear within the bacterial cell. After the spore is formed the parent cell may die. These spores may be compared to the seed of a flower or a grain. They are able to live for a long time; then, when food, moisture and temperature become favorable for development, they germinate and produce an organism resembling the parent.

Bacteria vary greatly in regard to their activities, Some species are extremely harmful because of their disease-producing powers in man, animals and plants. Others are exceedingly beneficial in their action.

The surface soil is the natural home for large numbers of bacteria. Soil bacteriology is beginning to teach us that the life of the cereal crop is often dependent upon the form of bacterial life in the soil. Through a study of this science, which is scarcely yet begun, we are being led to understand why a chemical and a physical analysis will not always determine the crops which will thrive best upon a given soil. A certain fertilizer in one soil may, be distinctly beneficial, while on another soil, precisely similar in chemical and physical properties, no beneficial effect whatever is produced. Soil bacteriology is beginning to explain to us the cause for some of these conflicting results.

THE FIXATION OF NITROGEN.

It has been conclusively demonstrated that free nitrogen, as it exists in the air, is taken from the atmosphere and converted into such form that it remains in the soil and becomes available for plant-food. Moreover, it has been definitely shown by a number of investigators that this phenomenon is accomplished by soil bacteria. These bacteria are able to combine free nitrogen gas with other elements and form new nitrogen compounds. These various nitrogen compounds are therefore fixed in the soil and are at hand when any plant, such as alfalfa, is ready to use them. When nitrogen exists in its free state plants cannot use it as food. The free nitrogen or gaseous nitrogen is able to escape from the soil ; hence, if the nitrogen gas is combined with potassium and oxygen, thus forming potassium nitrate, it is fixed in the soil and cannot escape so readily. Therefore, we mean by nitrogen fixation the

action of certain bacteria in combining free atmospheric nitrogen into various compounds, such as potassium nitrate, and thereby converting the free nitrogen into a fixed nitrogen compound.

We know that several species of bacteria which live in the soil itself are capable of fixing free atmospheric nitrogen. It is also a recognized fact that alfalfa, peas, beans and other legumes contain within their root tubercles certain definite species of micro-organisms that are able to fix free atmospheric nitrogen.

Lipman,* of the New Jersey Experiment Station, classifies the former as non-symbiotic fixation and the latter as symbiotic fixation. For our present purpose we shall deal only with symbiotic fixation and the bacteria involved therein.

Symbiosis primarily means mutual cohabitation. It is illustrated by any condition where two individuals when living together are of mutual benefit. Our concrete example of symbiosis is applied to the association of nitrogen-gathering bacteria and alfalfa living in a relationship of mutual helpfulness. The bacteria enter the roots through the root-hairs and cause the development of tubercules or nodules on the roots of the plants. These tubercules on the roots of the alfalfa plant furnish a laboratory home, and the plant itself furnishes food from its tissue-juices for these organisms. The bacteria, in performing their part of the symbiotic relationship, take free nitrogen from the air and from the pores of the superficial layer of the soil and work over this nitrogen into combination with other chemical elements, so that it is available for the alfalfa plant to take up for its own nourishment. These tubercles or nodules on the alfalfa roots are the result of the presence of nitrogen-fixing bacteria in the soil.

NATURE OF NITROGEN-GATHERING BACTERIA.

Cultures of the legume bacteria may be obtained without difficulty from the tubercles on the roots of an alfalfa plant. In making these cultures the following technique may be followed :

After washing the alfalfa nodule or tubercle in sterile water it is cut open with a knife which has been sterilized in a direct flame. With a sterile platinum needle some of the material

* Review of Investigations In Soil Bacteriology, United States Department of Agriculture, Bulletin 194, October, 1907.

from within the nodule is placed in some sterile culture medium. By culture medium is meant a "soil" or nourishing substance upon which the bacteria will grow. Gelatin, beef bouillon, milk, etc., are common examples of culture media. The inoculated medium is then poured into a sterile plate and covered. The plate culture is then placed in an incubator regulated to the proper temperature.

The minimum and maximum temperatures at which the legume bacteria will grow are 7° C. and 38° C., respectively. The best temperature for their development is about 25° C. After the plate cultures have been kept in the incubator for one or two days the characteristic colonies will have developed. Plate 24 shows the appearance of a plate culture of the alfalfa nitrifying organism. The spreading, grayish colonies which appear on the surface of the culture media on the plates are composed of countless numbers of the bacteria.

In young cultures (twenty-four to seventy-two hours old) the bacteria are seen to be very small, rod-shaped organisms. These rods are able to move about in liquid media by means of small whip-like bodies or flagella placed at either end of the organism. After a few days' growth the presence of larger

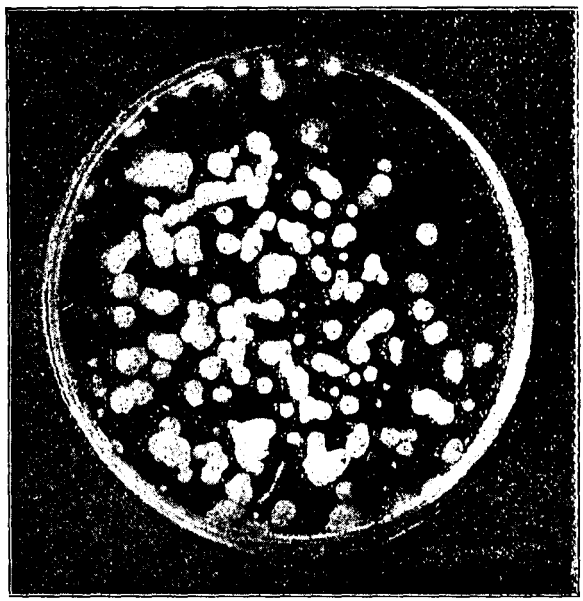


PLATE 24. Plate culture of the alfalfa nitrogen-gathering bacterium *(Pseudomonas radiciola).*

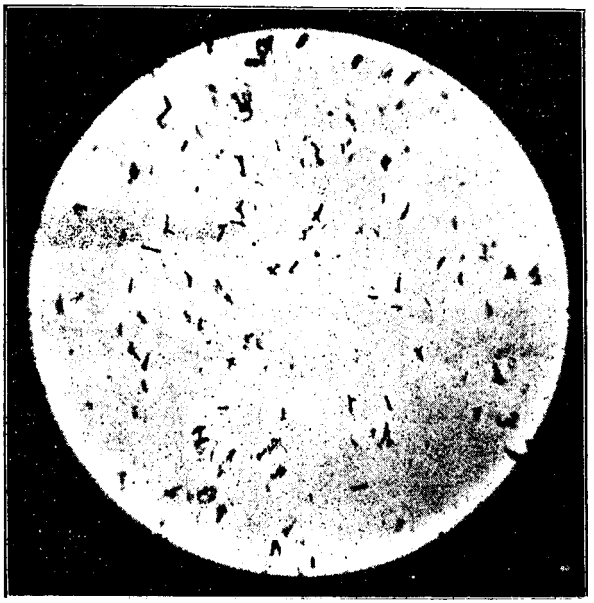


PLATE 25. The alfalfa nitrogen-gathering bacterium, magnified about 600 diameters.

branched forms may be observed. Plate 25 shows both of these forms as they appear under the microscope.

When it is desired to prepare cultures of the nitrogen-gathering bacteria for use in inoculating or treating alfalfa seed or soil, the bacteria should be grown in a special nitrogen-free culture medium. In such a medium their nitrogen-assimilating power is not weakened as it is in ordinary media containing nitrogen. An example of a very good nitrogen-free medium for this purpose is the following:

Glucose or grape sugar.	32.21 g.
Magnesium sulfate	.18 g.
Potassium phosphate	3.62 g.
Water	36.21 cc.

SOIL INOCULATION WITH NITROGEN-GATHERING BACTERIA.

The photograph reproduced in plate 26 shows the comparative results which may be obtained by inoculating soil intended for alfalfa with these bacteria. The two plants shown in this photo were grown in sterilized sand to which had been added the same amounts of potassium, phosphorus and other mineral matter. The soil in which one of these plants was grown was treated with a legume culture of alfalfa nitrogen-gathering

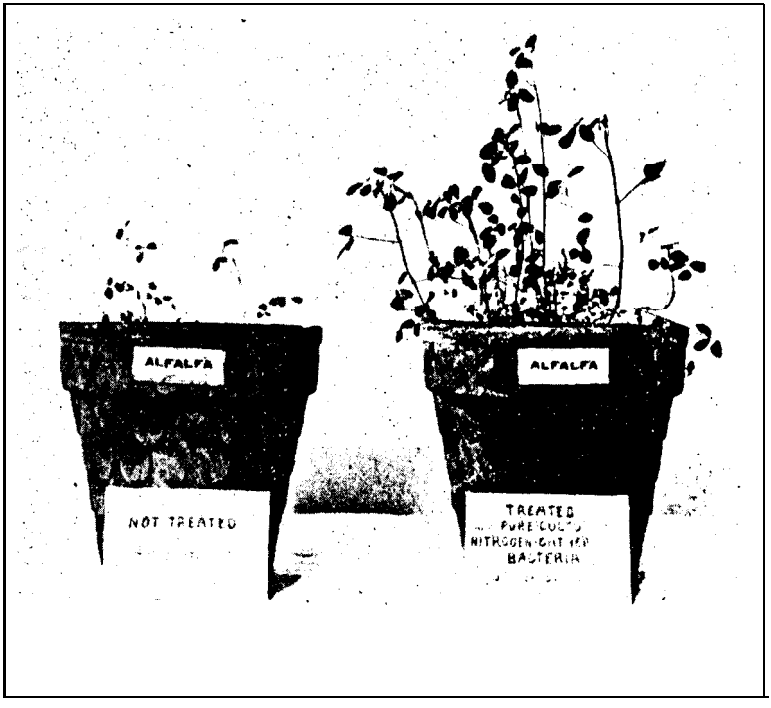


PLATE 26. Alfalfa growing in sand to which mineral fertilizers have been added. The pot on the right was inoculated with a pure culture of the nitrogen-gathering bacteria. The one on the left was not inoculated.

bacteria. The other plant was not inoculated. The difference in growth is very apparent. Soil inoculation may be accomplished in two ways : (1) With a pure culture of the particular bacteria, and (2) with soil which contains the nitrogen-gathering bacteria.

By a pure culture of any organism we mean that only the one kind or species of bacterium is growing on any particular culture medium. For instance, if any culture were labeled "pure culture of alfalfa nitrogen-gathering bacteria" it should contain only that one species. When the farmer receives cultures of nitrogen-gathering bacteria he is usually directed to add contents of package No. 1 to so much clean or boiled water. The contents of this package, when added to the given quantity of water, contain the necessary ingredients to make a suitable nitrogen-free culture medium or "bacterial soil." These chemical substances may consist of glucose or grape sugar, magnesium sulfate and potassium phosphate. To this

solution the contents of package No. 2, or the culture of the bacteria, are then added. This may be a liquid culture of the bacteria, or the dried organisms. These multiply very rapidly by simple division in the crock of culture medium, so that in twenty-four hours the organisms have developed with such rapidity that the liquid presents a cloudy, milky appearance. The alfalfa seed, after being moistened thoroughly with the mixture, is then spread out in a shady place and stirred until dry enough to sow.

The consensus of opinion of different investigators seems to be in favor of the liquid cultures. The reports of Chester, of Delaware Experiment Station, and Harding, of the New York Experiment Station, as well as others, indicate that *Pseudomonas radicicola,* the alfalfa nitrogen-gathering organism, cannot live long in a dry condition. It appears safe to strongly advise the employment of liquid cultures, as some of the desired bacteria may have been destroyed in the dry cultures. Another point which should be carefully considered is the use of unsterilized water in preparing the material for inoculation. The danger of contamination from this source has been pointed out by Lipman, of New Jersey.

The farmer is often directed to mix the chemical ingredients and culture in "clean water." If this water is not boiled it will contain a variable number of species of bacteria. These will multiply as well as the nitrogen-gathering organisms, some of them perhaps much more rapidly. As a consequence these contaminating organisms will inhabit or entirely suppress the growth of the *Pseudomonas radicicola.* Not only should the water be thoroughly boiled, but the utensils which are used should be boiled as well, and the chemical ingredients should be sterilized in some way before sending out. It is the writer's opinion that many negative results relative to the use of nitrogen-gathering bacteria have been found which are due to contaminated materials and careless handling of the pure cultures.

Sackett, of the Michigan Experiment Station, has shown that when *Bacillus ramosis* is grown in the same culture with the alfalfa' bacteria there exists a marked antagonism towards the legume bacteria. *Bacillus ramosis* is an organism which commonly lives in the soil. It is probable that certain soil bacteria may grow so actively and exert such antagonistic

tendencies that the legume bacteria are entirely inhibited in their development and activity.

The second method of inoculation is accomplished by transferring a quantity of inoculated soil to the desired locality. This soil should come from a field which has previously produced vigorous alfalfa plants with plenty of tubercles on their roots. This method often gives very positive results. Several experiment stations* advocate the use of the natural soil cultures. The inoculation with soil, however, has the following disadvantages: (1) Soil transfer is usually undesirable because of inconvenience and cost; (2) plant diseases, weeds and insect pests may be introduced with foreign soils.

If one has grown good fields of alfalfa on any given farm and has noticed the presence of well-developed nodules on the roots of the plants it is evident that the soil from that field contains plenty of active legume bacteria. If this soil comes from a clean field and is not too far distant; sufficient soil for inoculation may be removed to another field without much expense. If the alfalfa has not been cultivated in the locality, the soil may be taken from patches of Sweet clover or Bur clover. Experiments at the North Carolina and Illinois Experiment Stations suggest that soils taken from plots where either the Sweet clover or Bur clover has produced good crops will successfully inoculate land for future alfalfa crops.

PRACTICABILITY OF SOIL INOCULATION.

The inoculation of fields intended for alfalfa with nitrogen-gathering bacteria is indeed a practical procedure. To obtain a good crop without these bacteria is impossible unless the soil is very rich in nitrogenous materials. Moreover, if the legume bacteria are not present the alfalfa crop will leave the land in a somewhat depleted condition. The soil will be left more deficient in nitrogen. At the same time, care should be exercised in maintaining other conditions which are essential for a good yield of alfalfa. For instance, if the soil is too acid or too alkaline the alfalfa will not do well, and moreover, the nitrogen-gathering bacteria will not be able to grow.

The farmer should not expect the alfalfa nitrogen-gathering bacteria to work miracles. Generally considered, the soil should contain other elements than nitrogen, as potassium and phosphorus, which are essential for the growth of alfalfa

* Maine, Illinois and New York (Cornell).

plants. Neither can one expect inoculation with the bacteria to overcome the hindrances to a crop which may be brought about by improperly cultivated ground or a bad season.

The conditions influencing successful soil inoculation with legume bacteria are summed up by Ferguson, of the Virginia Station, as follows :

When Inoculation May be Beneficial.

1. On poor land that has not previously grown legumes.
2. On land that produces poor crops of legumes and where, upon examination, the roots fail to show the presence of nodules.
3. Where the legume to be planted is of a widely different species to the ones previously planted on the land.
4. Where the land has previously produced a lot of legumes, possessing nodules which, instead, of being beneficial, acted as parasites. Good results may be obtained from the use of pure cultures when a field which has previously grown good crops of legumes begins to give evidence that, all other conditions being the same, it is not producing the highest yields. The cause may be that the bacteria already in the soil are losing their virulence, and the only way to be certain of this is to try inoculation and note results.

When the Inoculation Will be a Failure.

1. When the directions for preparing the solution are not carefully followed.
2. When the soil is too acid or too alkaline to permit the development of either plants or bacteria.
3. When the soil is deficient in other necessary plant-foods, such as potash and phosphorus, as well as nitrogen.

When Inoculation is Unnecessary.

Since the only purpose in adding the bacteria to the soil is to furnish nitrogen to the plants in an available form, usually with root nodules, it is evident that where the organisms are already abundant and the crop is thriving, but little benefit can be expected from an additional inoculation. Neither is inoculation necessary where the soil *is* already very rich in nitrogen, nor where it is already full of nitrogen-fixing bacteria.

The farmer is advised not to buy or purchase cultures of nitrogen-fixing bacteria from commercial concerns without careful investigation. Two reasons may be given: (1) Expense, and (2) worthlessness of many commercial cultures.

While there may be some private concerns who may place reliable cultures on the market there are some whose products are not carefully prepared, as various tests have shown. (See New York Experiment Station Bulletin 270, November, 1905, Geneva, N. Y., and United States Department of Agriculture Circular No. 16, March, 1906.)

SUMMARY.

1. Certain soil organisms, called "nitrogen-gathering bacteria" may live on the roots of alfalfa and other legumes. Their presence causes the formation of tubercles or nodules on the roots of the plant.

2. The legume bacteria are capable of converting free nitrogen into various nitrogen compounds, or into fixed nitrogen.

3. The nitrogen-gathering bacteria are small rod-shaped forms, which may be branched in old cultures.

4. The presence of the nitrogen-gathering bacteria is necessary for a good crop of alfalfa unless the soil is exceptionally fertile. Without the bacteria, however, the soil fertility soon deteriorates.

5. The intended alfalfa-field may be inoculated either with soil in which alfalfa, Sweet clover or Bur clover has been grown, or with pure cultures of the legume bacteria.

6. If soil is used for inoculation it should contain no infective agents, such as plant parasites or insect pests.

7. If cultures are necessary and are used, precautions. should be observed in preparing the same to exclude contamination with other organisms. Contaminating organisms may suppress the growth of the nitrogen bacteria.

8. Liquid cultures are more reliable than dry cultures.

9. The farmer is advised not to use cultures prepared and put on the market by commercial concerns unless he is acquainted with the reliability of the product.

10. The use of soil inoculation for alfalfa is a practical procedure. When conditions are such that both the alfalfa plant and the legume bacteria can thrive after soil inoculation, the increase in yield will justify the expense and time in introducing the bacteria.

THE COMPOSITION AND DIGESTIBILITY OF ALFALFA AND ITS RELATION TO SOIL FERTILITY.

Many analyses of alfalfa have been made which, though varying greatly by reason of differences of soil, stage of growth, care in curing or other circumstances, unite in showing it to be a plant of the highest nutritive value. Analyses made at this Station of hay from the first crop of alfalfa cut at three stages of development may be given as representative.

COMPOSITION OF ALFALFA HAY.

	Water.	Ash.	Crude protein.	Pure protein.	Crude fiber.	Nitrogen-free extract.	Crude fat.
First stage. about ten per cent. in bloom	8.77	9.54	16.88	13.56	29.38	34.01	1.42
Second stage. about one-half in bloom	7.71	9.49	15.88	12.63	31.44	34.23	1.25
Third stage. full bloom	8.29	7.76	13.23	10.62	33.11	36.34	1.30

As the amounts of moisture present in a hay are variable and not a characteristic of the stage of maturity of the green plant, a calculation of the results to a water-free basis is often advantageous in making comparisons. Doing this for the three samples of alfalfa hay we get the following:

COMPOSITION OF ALFALFA HAY CALCULATED TO A WATER-FREE BASIS.

	Ash.	Crude protein.	Pure protein.	Crude fiber.	Nitrogen-free extract.	Crude fat.
First stage	10.45	18.50	14.86	32.20	27.29	1.56
Second stage	10.28	17.21	14.18	35.37	34.00	1.05
Third stage	8.45	14.43	11.58	36.10	39.62	1.41

Without going into the details of a discussion of the characteristics of the groups of feed principles named in these tables it may be useful to remind the reader of certain elementary facts.

The *ash* of a feeding-stuff is the residue left after burning all combustible substances. For the most part this is derived from the soil, though it may contain carbon that was secured from the carbon dioxid in the air.

The *crude protein* embraces all organic compounds containing nitrogen and may even include some inorganic nitrogenous substances.

The *pure protein* is the crude protein minus certain nitrogenous substances that are less complex than proteins proper, and possess a lower food-value. The proteins, by reason of the nitrogen, sulfur and phosphorus which they contain, are entitled to greater esteem in a feed than are fats and carbohydrates.

The *crude* fiber consists of cellulose and substances more or less like it chemically. The toughness and firmness of forage plants depend largely on this constituent. Cotton and linen are nearly pure cellulose. Obviously the crude fiber is of in-

ferior nutritive value ; indeed, there is good reason to believe that in many cases such of it as is digested by animals is utilized at an expenditure of more energy than is yielded by the digested fiber.

The *nitrogen-free extract* includes starch and the sugars as well as other less well-known carbohydrates. In some tables this group is listed as *carbohydrates*, without due regard, however, for the fact that the cellulose of the crude fiber is a carbohydrate.

The crude *fat* extracted from hay, or from other materials, obtained by drying the green parts of plants, includes some chlorophyl, the green substance of leaves, and other compounds that are not fats, as well as any fat in the feed.

The *water* of a feed possesses no nutritive power, and is not different from water taken by drinking.

Studying now the table showing the percentages of the several constituents of the water-free hay, it will be seen that there are progressive changes as the plant becomes more mature. It must not be supposed, however, that there is an actual decrease in the total amount of any food principle in the crop, but only that as maturity takes place certain constituents are produced in greater proportion, thus adding to their percentage amount while correspondingly reducing the percentage of the constituents produced at a slower rate.

The hay produced by cutting when the alfalfa was about ten per cent. in bloom is seen to be richer in ash, protein and fat than that produced by later cuttings, while the crude fiber and the nitrogen-free, extract increase in percentage as the plant matures: The especially valuable protein is present to an extent more than one-fourth greater in the hay made at the first stage than it is in that made at the third stage, while the questionable crude fiber is more abundant in the later stages.

DIGESTIBILITY OF ALFALFA.

While it is true that a certain residue of indigestible matter is necessary for animals, and especially for ruminants, which are accustomed to bulky feed, we seldom need to give attention to this in practice, as feeds are ordinarily excessively supplied with such indigestible substances. Quite the reverse, we are justified in prizing more highly those feeds which show a high degree of digestibility. A proper appreciation of alfalfa hay thus requires consideration of its digestibility.

The digestibility of the hays referred to above was ascertained and the following table shows the results:

PERCENTAGES OF THE SEVERAL CONSTITUENTS OF ALFALFA HAY DIGESTED.

First crop ; three stages of growth. Calculated to water-free basis.

	Ash.	Crude protein.	Pure protein.	Fiber.	Nitrogen-free extract.	Crude fat.	Total.
First stage	6.69	14.51	11.94	14.51	28.52	0.98	65.21
Second stage	5.78	12.89	9.90	17.11	26.96	0.42	63.16
Third stage	5.16	11.37	8.57	17.43	30.72	0.75	65.43

Here it is seen that the digestible protein diminishes markedly as the alfalfa matures, while the digestible carbohydrates increase. A calculation of the nutritive ratio in each case brings out this fact in a concise way. The *nutritive ratio* of a feed is the ratio of the energy of the digestible nitrogenous substances to the energy of the digestible non-nitrogenous substances. Making the necessary calculations, the nutritive ratios are found to be as follows: First stage, 1 to 3.11; second stage, 1 to 3.49 ; third stage, 1 to 4.38. These are all narrow ratios but widen as the alfalfa matures.

A full appreciation of the feeding value of alfalfa cannot be had without comparisons with other feeds. The average percentage of digestible constituents in certain well-known feeds is shown in the following table:

PERCENTAGES DIGESTIBLE OF CERTAIN FEEDS AND THEIR NUTRITIVE RATIO.

FEED.	Protein.	Carbohydrates.	Fat.	Nutritive ratio.
Corn	7.14	66.12	4.97	1:10.8
Oats	9.25	48.34	4.18	1: 6.2
Wheat	10.28	69.21	1.68	1: 7.1
Bran	12.01	41.23	2.87	1: 4.0
Shorts	12.22	49.98	3.83	1: 4.8
Timothy hay	2.89	43.72	1.43	1:16.2
Red clover	7.38	38.15	1.81	1: 5.7

It will be seen that alfalfa cut at the first stage gave a hay that had a higher percentage of digestible protein than any of the feeds named in the table, and that the digestible carbohydrates (fiber plus nitrogen-free extract) of alfalfa compare favorably with those in the feeds cited, and in some cases exceed them. The nutritive ratios bring out clearly the value of alfalfa as a source of protein, and its great availability in balancing rations.

Many analyses of alfalfa made at other experiment stations, with such digestion experiments as have been performed, show

the same general results as are exhibited in the foregoing. The earlier cuttings are richer in protein, but a high and nearly equal degree of digestibility for the protein present is possessed by all cuttings, so that their relative feeding value is practically indicated by their composition. Nearly three-fourths of the protein of alfalfa and about sixty per cent. of the carbohydrates are digestible.

COMPOSITION OF THE DIFFERENT PARTS.

The statements made thus far apply to hay from the entire plant. It is, however, well known that there are great differences between the stems and the leaves. The most detailed analyses in this connection have been made at the Utah station. From a mass of data concerning cuttings made at different dates and upon different crops, those concerning the first crop, cut in the early bloom, have been selected and placed in the tables shown below. The first one shows the yield of dry matter in pounds per acre, and also the weight of the stalks, leaves and flowers separately. It also shows the composition of each of these parts and of the whole plant:

COMPOSITION AND DISTRIBUTION OF NUTRIENTS IN THE DRY SUBSTANCE OF HAY FROM ALFALFA CUT IN EARLY BLOOM-FIRST CUTTING.

PART OF PLANT.	Yield per-acre. pounds.	Ash.	Protein.	Fiber.	Nitro-gen-free extract.	Fat.
Stalks	28.38	9.01	10.74	42.17	37.14	0.94
Leaves	18.56	14.33	24.05	13.81	41.82	5.99
Flowers	1.36	10.56	26.18	15.58	46.00	1.68
Whole plant	48.31	11.10	16.30	30.53	39.23	2.92

From the above table we see that the leaves and flowers are far richer in protein than are the stalks, while the reverse is true in respect to fiber. Nitrogen-free extract does not show so great a difference but the stalks are notably inferior. In the next table the data are presented in a different form :

PERCENTAGES OF ASH, PROTEIN, FIBER. ETC., IN EACH OF THE DIFFERENT PARTS OF THE ALFALFA PLANT. TO TOTAL AMOUNT OF THAT CONSTITUENT IN ENTIRE PLANT-FIRST CUTTING, EARLY BLOOM.

PART OF PLANT.	Yield, per cent.	Ash.	Protein.	Fiber.	Nitro-gen-free extract.	Fat.
Stalks	58.75	47.69	38.73	81.17	55.68	19.03
Leaves	38.43	49.62	66.74	17.39	41.01	79.34
Flowers	2.82	2.69	4.53	1.44	3.31	1.63

The above table shows that of the total yield 58.75 per cent. is in stalks, but that of the total protein only 38.73 per cent. is

in them, while they contain over 81 per cent of the total fiber. On the other hand the leaves, constituting but 38.43 per cent. of the yield, contain 56.74 per cent. of the protein of the entire crop and only 17.39 per cent of the fiber. The nitrogen-free extract is not so disproportionately divided between the stalks and the leaves. Over four-fifths of the fat is furnished by the leaves and flowers, though they make up but little over two-fifths of the weight. We see from this the exceeding importance of so handling the crop as to preserve the leaves and flowers. By the loss of all of these the feeding value will be impaired much more than the loss in weight would indicate.

LOSS BY WEATHERING.

It is apparent to all that alfalfa hay is greatly damaged by rain. This is due not only to fermentations that may accompany the process and to mechanical losses, but also to the fact that soluble substances are dissolved out and removed. Observations have been made by the Colorado Experiment Station upon a hay which was exposed in the field for fifteen days, during which time it was subjected to three rains, amounting to 1.76 inches. The following table shows the composition of the damaged and of the undamaged hay:

PERCENTAGE COMPOSITION OF ALFALFA BEFORE AND AFTER DAMAGE BY RAIN.

	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.
Original	12.2	18.7	26.5	38.7	3.9
Damaged	12.7	11.0	38.8	33.6	3.8

The above figures as given show that the damaged hay is considerably inferior to the undamaged, but like many other percentage statements is liable to be misunderstood, or at least not completely understood. It must not be supposed that the protein and nitrogen-free extract have been converted into crude fiber, although the damaged hay contains nearly 39 per cent. of crude fiber, where the undamaged hay had 26.5 per cent.; at the same time the protein and nitrogen-free extract are present in much smaller quantity in the damaged hay. The facts are that undoubtedly portions of all these food principles have been lost from the crop as a whole, but that the protein and the nitrogen-free extract have suffered much more, pro-

portionately, than has the crude fiber, this being almost insoluble and not subject to rapid fermentation.

A much more instructive view of the actual losses is obtained by additional calculations. The loss sustained by the alfalfa naturally fell most heavily upon the soluble and more easily decomposed substances. The most resistant of the constituents was the fiber, which probably suffered but little. Taking the crop as a whole, then, there would be as much or nearly as much fiber as there was before, excepting that which was lost mechanically. We may use this figure as a measure of the minimum losses by others. In every 100 pounds of the original hay there were 26.5 pounds of fiber, and after it was damaged there could not have been any more, and in fact there must have been less. If we make the most favorable assumption, viz., that there was no loss of fiber, then the 38.8 per cent. of fiber in the damaged hay is really the fiber that was 26.5 per cent. of the original hay. The apparent increase in the percentage is due entirely to the loss of other constituents. The figures representing the percentages of the other constituents as given above are all correspondingly too high for comparison with the percentages of those constituents in the original hay. In the following table the weights of these constituents accompanying 26.5 pounds of fiber in the damaged hay have been calculated. These are to the percentages of those constituents in the damaged hay as 26.5 is to 38.8.

LOSSES CAUSED BY THE ACTION OF RAIN ON 100 POUNDS OF ALFALFA HAY. ASSUMING THAT NO FIBER WAS LOST.

	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Total.
Original	12.2	18.1	26.6	38.7	3.9	100
Damaged	8.7	7.6	26.5	23.0	2.6	68.3
Pounds lost	3.5	11.2	00.0	15.7	1.3	31.7
Per cent. lost	28.7	60.0	00.0	41.0	33.3	31.7

Comparing, now, these figures, it will be seen that of the original 100 pounds of hay only 68.8 pounds remained ; that 60 per cent. of the protein was lost, one-third of the fat, and 41 per cent. of the nitrogen-free extract. As the assumption in reference to fiber was more favorable than the facts, so this calculation in respect to protein, fat and nitrogen-free extract gives figures that are more favorable than was actually the case.

Startling as the losses indicated by the preceding calculations are, the actual damage is even greater than is indicated by them. Since the materials lost obviously consisted of the most soluble and easily decomposed parts, and hence the parts most easily digested, a smaller percentage of the protein remaining was digestible, in all probability, than would have been the case with the protein that was lost. It is quite reasonable to assume that one-half of the feed value of the crop had been lost from an exposure to rain that was not excessive in quantity and fell in three different showers.

RELATION OF ALFALFA TO SOIL FERTILITY.

The draft of any crop upon the soil is in part represented by the ash or mineral matter in it. In the case of most plants the nitrogen of the crop is also furnished by the soil. Any forage crop contains a greater percentage of ash than does the grain from a crop, and any crop yielding a high tonnage must make a correspondingly heavy tax upon the mineral substances of the soil and usually upon its nitrogen. Alfalfa, by reason of its generous yield, is a gross feeder, and to produce satisfactory results must be grown upon land well supplied with the elements of fertility. Like other leguminous crops it is favored by soil rich in calcium compounds, such as limestone and gypsum. Probably no other crop calls for as much calcium as does alfalfa, and this is a very important consideration when one is locating with a view to growing this crop.

The percentages of ash observed in alfalfa vary considerably as reported. This is in part due to the fact that in rich soils crops will absorb mineral substances in excess of their actual requirements. Kellner reports 7.22 per cent. of ash in alfalfa grown in Germany. A sample analyzed at this Station which had been cut when in full bloom showed 8.29 per cent., and the average of sixteen samples in full bloom as analyzed at the Colorado station was 10.91 per cent. It is probable that the last figures represent a somewhat excessive amount, due to the predominance of mineral substances in the soils of the great plains, which have not been subjected to the leaching action of rains to the same extent as soils farther east. The Colorado station has made elaborate analyses of the ash derived from many specimens of alfalfa hay, and has also made analyses of these with reference to their nitrogen. In the following table data are exhibited which have been calculated

from the Colorado results. The figures for ash and nitrogen are based upon sixteen analyses, and those for potassium, calcium and phosphorus upon six. For comparison, Kellner's results are also exhibited. The table also includes figures showing what it would cost to obtain in the wholesale fertilizer markets of this country the quantities of potassium, calcium, phosphorus and nitrogen stated :

PERCENTAGE OF ASH IN ALFALFA HAY, AND POUNDS OF CHIEF ELEMENTS OF FERTILITY CONTAINED IN ONE TON OF ALFALFA HAY.

	Per cent. ash.	Pounds per ton of alfalfa hay and value at fertilizer prices.			
		Potas-	Calcium.	Phos-	Nitro-gen.
Kellner, Germany.....	7.22	24.88 $1.49	36.21 $0.18	6.24 $0.64	54.40 $10.88
Headden, Colorado.....	10.91	42.45 $2.55	43.81 $0.22	4.37 $0.45	48.68 $9.74

In the above calculations of values potassium is taken at six cents per pound; calcium, one-half cent; phosphorus, 10.3 cents; and nitrogen, 20 cents. The valuation of calcium is approximately that at which it can be obtained in the form of land-plaster from the gypsum-mills of this state. The valuations for the other elements are those adopted for 1908 by the experiment stations of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, Rhode Island and Vermont, and represent the retail prices at which those ingredients of fertilizers could be purchased at tide-water in the states named during the three months preceding March 1, 1908, as nearly as they can be applied.

The potassium, calcium and phosphorus are constituents of the ash, and it may be seen that if we take the quantities indicated by Kellner's results it would cost $2.31 to replace the amounts of those elements removed by one ton of alfalfa hay, while if Headden's figures be used it would cost $3.22. These amounts are of considerable significance, and the farmer should realize that in so far as his alfalfa hay is sold off the place he is diminishing the assets of his farm to that extent, and that with soils of only moderate fertility it will be impossible to secure or maintain high yields of alfalfa without providing for the application of mineral substances to the field. On the other hand, the fact that alfalfa is a very deep-rooting

plant, and thus secures its mineral matter from a considerable volume of soil, makes its tax upon the land less immediately apparent even if not less significant ultimately.

The above table also exhibits the quantities of nitrogen and their fertilizer valuation, and these valuations are considerably larger than the totals for the other three elements. In respect to their relation to soil fertility, however, the situation is quite different in the case of nitrogen from what it. is in respect to the others. Alfalfa shares with other legumes the capacity to profit by the limitless store of atmospheric nitrogen which it is able to acquire through the agency of bacteria which live upon its roots. These bacteria obtain certain of the elements of their nutrition from the sap of the alfalfa root. They may, like other forms of plant life, appropriate the nitrogen of compounds in the soil, but they possess the extremely important power of taking up nitrogen from the free state in which it occurs in the air which fills the pores of the soil. In later stages the alfalfa plant which harbors these bacteria profits by their accumulation of nitrogen.

The nitrogen-assimilating bacteria live in tubercles or nodules attached to the roots of the alfalfa. The size of these may be from microscopic smallness up to an inch or more in diameter. As usually seen they range from the size of sorghum seed to that of peas. By the assistance of these bacteria the alfalfa plant is able to accumulate its large and valuable stores of nitrogen without diminishing the soil supply; in fact, through the roots and stubble and the scattered fragments of the plants left upon the land, its content of nitrogen is largely increased by the culture of alfalfa upon it.

It is generally recognized that alfalfa and other leguminous plants exert a favorable effect upon the fertility of land, but there are many who fail to recognize that this favorable effect is limited to the addition of nitrogenous humus which accompanies the cultivation of these crops, and that as heavy feeders they really make large demands upon the potassium, calcium and phosphorus and other mineral substances of the soil. It is therefore of the highest importance in maintaining the fertility of the farm that the alfalfa produced upon it, if possible, be fed upon it, that by means of the manure produced, assuming it to be applied to the farm, the large amounts of potassium and phosphorus will be restored and the percentage of nitrogen, so important in grain production, be increased.

In this connection it may also be mentioned that the need for large quantities of mineral substances by the alfalfa crop is fortunately accompanied by a tolerance for quantities that would be unendurable by many other plants. It is able to flourish upon many so-called alkali lands, which are simply lands containing an excess of mineral substances, many of which are to a certain degree essential to plant growth. With reference to the cultivation of alfalfa upon alkali land, however, it is important to recognize that the young plants are far more sensitive than the old ones and that care should be taken to insure that the alkali is in the lower part of the soil when the seed is sown. The tendency is for alkali to accumulate at the surface, being brought up in solution in water that evaporates at the surface, leaving its saline load. After the alfalfa plant is established it is not only more resistant to the alkali, but by shading the soil and checking evaporation from its surface it minimizes the surface accumulation of the alkali.

ALFALFA FEEDING.

Alfalfa has become well-nigh indispensable to the live-stock grower of the middle West. From comparative obscurity it has come into prominence during the past ten or fifteen years in a manner never before equaled by another known plant. In Kansas alone the acreage of alfalfa has increased from 34,388 acres in 1891 to 615,000 acres in 1906, Jewell county alone having 42,000 acres. While especially adapted to the conditions of what was formerly known as the semiarid region, its great value as a feeding crop for all kinds of stock has been the means of introducing it over practically the whole of the Southwest, and those who have had the greatest experience in its use are the loudest in its praise. In all sections of this territory, where cattle and sheep are finished for market, alfalfa is the only roughage ever used to any great extent. It is greedily eaten by all classes of farm animals and is a most valuable feed for all purposes. The steer feeders and mutton producers of Kansas, Colorado and Nebraska would be lost without it, and as a means of putting pork upon the market at a low cost it cannot be excelled.

BALANCING RATIONS.

The various facts as to the composition of alfalfa have already been presented in these pages. These are important factors in considering the feeding value of any food. The composition of a feeding-stuff in connection with its palatability and digestibility determines its value. The figures already presented have shown that alfalfa stands in a class by itself as a producer of a feed value. Not only is this true as to the total bulk of actual dry matter produced per acre, but also as to the comparatively high value of the particular kind of nutrients so plentifully produced by the plant. Indian corn, although crowned king of the agricultural plants of the Mississippi valley, must yield the palm to alfalfa in total digestible nutrients yielded per acre.

Bulletin No. 26 of the Colorado Experiment Station reports a comparison in which one acre of alfalfa yielded 5611 pounds of digestible nutrients, or one and a half times as much actual digestible nutrient material as an average acre of corn, including the fodder as well as the grain. It contains more actual nutrient value, pound for pound, than any other forage crop, being almost equal to wheat-bran in digestible nutrients, as will be noticed by referring to the table showing comparisons of the digestible nutrients in various feeds.

No farmer can feed alfalfa with the best results and the greatest amount of profit without making some study of the composition of the various feeds and how to most economically combine them for the best results, or, in other words, to feed what are commonly spoken of as "balanced rations." The three general classes of substances contained in our feed-stuffs, namely, the protein or nitrogenous material, the carbohydrates (including, as they do, the crude fiber), and the fats, are required in fairly definite proportions by the animal. If any one is very much deficient the best results cannot be obtained, and an excess of any one will result in a failure of the animal to digest it, or in its wasteful use. The protein group is especially important, for without it there can be no development of muscle or tendons, brain, nerves or any tissue where the forces of life and growth are active.

Protein may be broken down in the process of digestion and supply heat and energy to the body or aid in building up fatty tissue, but the non-nitrogenous nutrients, namely, the carbo-

hydrates and fats, can, under no circumstances, perform the functions of the protein group. This fact gives the proteins a comparatively high value among feeding-stuffs.

Under ordinary conditions of feeding the daily protein requirements per l000-pound animal will be from two to two and a half pounds ; the nutritive ratio, which has already been defined, ranging from 1:6 to 1:8. Average alfalfa has a nutritive ratio of 1:3.8. It has twice as much protein as would be required under ordinary conditions of feeding. On the other hand, many of our most common farm feeds are deficient in this most essential group of nutrients. Corn, Kafir-corn, rye, barley and wheat are all lower in digestible protein than alfalfa. Corn and Kafir-corn have nutritive ratios of 1:10.8 and 1:9.8 respectively, being below the animal requirements in protein. Proper combinations of alfalfa with these carbonaceous grains are suggested by these facts, and the making of such properly balanced combinations constitutes the science and practice of feeding balanced rations to our various farm animals for the varied purposes for which such animals are fed.

Linseed-oil meal, cottonseed-meal, soy-beans, wheat-bran, wheat shorts and the various gluten feeds and meals sold on the markets are about the only concentrates which exceed alfalfa in digestible protein. All these are high in price, and, while, they would be necessary to properly balance almost all our farm-grown grain in the absence of alfalfa, their ‘high cost would oftentimes render their use unprofitable. The man with alfalfa can balance almost any farm-grown grain, and is thereby rendered practically independent of high-priced mill feeds. For example, 18 pounds of corn and 11 pounds of alfalfa daily form almost an ideal ration for a l000-pound steer on full feed. This gives a nutritive ratio of about 1:7.5. Alfalfa is the only feed grown with which such results are possible.

ALFALFA FOR CATTLE.

The great value of alfalfa as a feed for cattle became apparent coincidentally with its earliest introduction into Kansas. The eagerness with which cattle ate it and the splendid thrift and growth following its use were noted at once. Cattle no longer required grain through the winter and it became unnecessary to go around mornings “tailing up” the weakened animals unable to rise without such assistance.

FOR MAINTENANCE.

Alfalfa alone is more than a maintenance ration. Any farmer can bear evidence to that fact. It is really a wasteful use of it to make it the only ration of a bunch of cattle which are being roughed through the winter. Its narrow nutritive ratio results in a waste of the protein, it being an unbalanced ration for maintenance purposes. As a matter of fact, the protein requirements for maintenance are low. The nutritive ratio for mature cattle being maintained only is as wide as 1:8.5 or 1:9.

For the feeding of young heifers or cows in calf a narrower ratio is required, and it is here alfalfa has a most important place in supplying these animals in a cheap form the necessary material for growth and development. Cottrell reports, in Bulletin No. 114 of the Kansas Experiment Station, the results of wintering some pure-bred two- and three-year-old heifers on the College farm. No other roughage being available at any price, these heifers were fed nothing but alfalfa hay from September 2, 1901, to April 4, 1902, a period of 214 days. An average daily gain of 1.2 pounds was made by the bunch on an average daily ration of 23 pounds of hay. In addition to maintenance through this feeding period each ton of the hay fed gave an increase in weight of 104 pounds, such increase being not fat, but growth and development. These heifers were kept under the most ordinary conditions, having nothing but an open board shed for shelter. Such was their thrift, we are told, that visiting eastern feeders were sure oil-meal must have been fed.

The North Platte Substation of Nebraska has just given, in Bulletin No. 105, some valuable data on the great value of alfalfa in growing and developing beef cattle. The first test compared alfalfa, prairie hay and cane in wintering calves where all lots received two pounds of grain daily per calf. During the winter-feeding period of the experiment alfalfa produced 143 pounds of gain per head; prairie hay, 76 pounds; cane, 46 pounds, and half-and-half alfalfa and prairie hay, 133 pounds, and half-and-half alfalfa and cane, 120 pounds of gain.

The year following the same cattle were wintered as yearlings on the same rations, except that no grain was fed. The alfalfa lot gained 81 pounds per head in 120 days; the prairie-

hay lot lost 18 pounds ; the cane-hay lot lost 64 pounds ; the half-and-half alfalfa and prairie hay gained 62 pounds and the half-and-half alfalfa and cane gained 92 pounds each. The amount of hay consumed or wasted about the racks daily per steer ranged from 18.7 pounds in the prairie-hay lot to 24 pounds in the cane lot, 20.2 pounds being eaten daily per head by the steers receiving alfalfa alone. From the fact that the half-and-half ration gave equally good gains with straight alfalfa, it would seem to be economy to use some of these cheaper roughages with alfalfa for wintering steers.

While no accurate data have been kept, it has been the common practice to winter the breeding cows of the pure-bred herd of the Kansas Experiment Station upon alfalfa hay and corn-stover, the alfalfa being fed in racks and the stover fed out on the pasture as much as possible. This method of feeding has kept the cows in splendid breeding condition, and the use of the stover has resulted in cheapening the cost of their maintenance from that of straight alfalfa feeding.

FINISHING BEEF CATTLE FOR MARKET.

The system of feeding a half bushel of corn daily to a fattening steer, with all the corn-stover and prairie hay he would eat in addition, has long since become entirely too axpensive a method of finishing beef steers. In those early experiments of Georgeson's at the Kansas Station his results show that it often required from 1100 to 1400 pounds of corn to produce a gain of 100 pounds in the feed-lot, the fodder and hay eaten being from 250 to 350 pounds. In his three trials to demonstrate the value of a balanced ration, in which he states that a "judicious 'mixture of corn-meal, oil-meal, bran and shorts containing the proportions of the albuminoids and carbohydrates to approximate the requirements of the feeding standard" was fed, with corn-stover and prairie hay for roughage, the results showed that 28 per cent. less grain was required to produce 100 pounds of gain than when ear corn alone was fed. The high cost of finishing beef by such methods under present-day conditions is apparent. When alfalfa came into use as a portion of the ration for full-feeding steers, it at once reduced the grain cost of producing a hundred pounds of gain, It was more than a filler, which function was all that had been expected of the stover and prairie hay previously fed.

In Bulletin No. 112 of the Kansas Experiment Station, Cot-

trell reports the results of feeding 80 head of steers, all receiving alfalfa hay (either cut or whole) and corn-meal and shelled corn. Average daily gains of 2.34 pounds were obtained at a grain cost of 747 pounds of grain and 385 pounds of alfalfa per 100 pounds of increase. In the finishing of "baby beef," the calves being fed seven months, gains of 2 pounds daily were made. Only 439 pounds of corn and 436 pounds of alfalfa hay were required to produce 100 pounds of gain.

In a later test, planned and carried out by Otis, yearling steers fed 210 pounds gained 2 pounds daily and required but 630 pounds of corn and 409 pounds of alfalfa hay per 100 pounds of gain; and two-year-old steers fed a like period gained 2 pounds daily, consuming 733 pounds of corn and 483 pounds of alfalfa per 100 pounds of gain.

The winter of 1904 a bunch of two-year-old steers were fed 220 days and gained 2.87 pounds daily. Their ration consisted of corn-and-cob meal and corn-meal, with alfalfa for roughage. They consumed per 100 pounds of gain 708 pounds of grain and 600 pounds of alfalfa hay. Many tests of this kind might be enumerated, all clearly showing that the use of alfalfa hay as roughage in the feed-lot has resulted in a reduction of from 25 to 30 per cent. in the amount of grain required.

The question has arisen in this connection as to whether the most economical use of alfalfa is secured where it is kept be-

PLATE 27. Show herd of Angus steers; alfalfa their chief roughage.

fore the steer in unlimited quantities. As has already been stated, a ration supplying an excess of protein is as wasteful as one with an excess of carbohydrates and fats. It is becoming a common practice to restrict the amount of alfalfa given, only feeding a sufficient amount to properly balance the ration. Smith, of Nebraska, reports two tests in which alfalfa and well-cured corn-stover (equal portions of each constituting the roughage part of the ration) were fed in comparison with alfalfa alone, shelled corn being the grain in each lot. His results showed fully as good, and in one case even better, daily gains where the stover was fed. In this particular test about equal quantities of grain were required per 100 pounds of increase, 637 pounds being the amount in the alfalfa lot and 639 pounds in the alfalfa and stover lot. The cost was $6.05 per 100 pounds where stover was fed and $6.45 where alfalfa alone was the roughage. The cost of handling the stover is urged against its use, but, as Smith suggests, much of the corn fed to cattle may be fed unhusked in connection with the fodder. This may be fed in the morning, and a ration of six or seven pounds of alfalfa per steer given at night. This system of feeding reduces the labor of preparation to a minimum and supplies a balanced ration in a most palatable form as well as one low in cost.

HOGS.

The hog, by nature of his internal anatomy, is not supposed to be so constructed that he can economically handle forage crops. But there is an (exception to this rule in the case of alfalfa with the hog. It is relished by him and he will thrive exceedingly well on it, and the quality of pork made from alfalfa-fed hogs is not excelled by that made from any other feed.

As a pasture for young, growing hogs, alfalfa has no equal, and if there is a better pasture for brood-sows it has never been discovered. Even a bunch of fattening hogs do not object to it, and gains can be made much more economically when it is used than without it. In a country where alfalfa grows abundantly alfalfa hay should always be accessible to a bunch of brood-sows, shoats and fattening hogs.

The criticism commonly made of our pork is that it has too large a proportion of fat. This condition naturally follows the feeding of an almost exclusive ration of corn, and to produce pork products that are of the highest quality more nitrogenous

PLATE 28. Brood-sows on alfalfa pasture.

feeds must be used. Alfalfa, with its high per cent. of protein, can supply the nitrogenous substances cheaper than almost any other feed. It not only produces cheaper gains but puts hogs in a more healthy condition to make good gains but puts hogs better product out of the feed they consume.

In an excellent paper read by Doctor DeWolf, a government inspector, before the State Swine Breeders' meeting last winter at the College, he discussed an alfalfa-fed load of hogs that passed before him for inspection. In part, he said :

"As these alfalfa hogs came down the alley to the scales, they were certainly hogs for the packer, raised at a profit-thrifty and ready to yield good-grade pork, for a good price was realized. You could notice that they were well up on their expanded feet; their height, length, and bones all rounded out with even fat, covered with a glossy, glistening, heavy coat of hair, and keen eyes alert. Their backs were straight, broad, and well curved into long, deep sides that had plump, pointed, even-shaped hams at one end and arched shoulders at the other.

"On *post-mortem* we did not find a single parasite in livers, lungs, kidneys or intestines, as we do in hogs grown on corn and cereals. Their lungs remained expanded, that is, inflated, when cast down in the gut chute; did not collapse, and were of a perfect pink. Their stomachs were larger and did not recoil or contract readily, and same was observed of the whole intestinal tube.

"The men who pulled the intestines from the ruffle fat for casings said, 'They are as tough as clothes-lines and as large

as broomsticks.' The bung-gut cutter said that 'it seemed like taking out automobile tires, and I have not cut or torn a single one, they are so tough.' The caul fat and ruffle fat after guts were drawn off were much heavier than the average in corresponding corn-fed hogs. The leaf-lard puller and ham facers complained about so much fat and weight in lifting the leaf out, and it was more bound down to the inside of the abdominal walls. The splitter of backbones and sawyer of the shanks said 'it was like cutting iron or railroad rails.' All bones were bones, large and strong. The carcasses were symmetrically filled out like barrels, having funnel legs, and all front feet were stiff and rigid! straight out, while in other hogs the front feet are generally limpid and dangling.

"Their skins were well filled, shining and smooth as the human. When I read this sentence to Mr. Hodgins he laughed and said, 'Don't credit it to alfalfa, for we dip our hogs every two weeks in two or three inches of crude oil and never know what lice, mange or scurf are, nor hog-cholera so far, while our neighbors on all sides of us have had it and laid it to tankage. We fed the same tankage they did, for we bought it from the same parties and at the same time.' Their bodies were solid and the meat was of that marble appearance of lean and fat, for the fat of an alfalfa hog is whiter, and here is where we get the two strips of lean in the bacon-rustling for a living makes muscle.

"As we stood and looked up the slaughtering rail they looked like birds, each representing a $20 eagle, and as large as rhinoceroses. Wonderful is an alfalfa-field for this species of thick-skinned animals-the American rhinoceros bird."

This statement shows the opinion of alfalfa-fed hogs from a packer's standpoint.

At this Station some years ago a gain of 800 pounds of pork was made from a ton of alfalfa, and a little less than that amount of gain was made from an acre of alfalfa pasture. In another test here an acre of alfalfa produced $20.20 worth of pork, while an acre of rape fed to a similar lot of hogs returned $10.05 worth of pork.

In a later experiment we found that 100 pounds of alfalfa hay saved 96 pounds of corn. Figuring on the basis of 5 pounds of corn producing 1 pound of pork, the 96 pounds of alfalfa would produce 19 pounds of pork. Estimating the average yield of alfalfa to be four tons per acre, on this basis it would mean a production of 1600 pounds of pork per acre with alfalfa fed in the form of hay in connection with corn. 'This experiment was conducted during the winter season.

In an experiment during the summer we found that 170

pounds of green alfalfa, cut and fed to hogs fresh in a dry yard, was equal to 100 pounds of corn, and in this experiment it took 6 pounds of corn to produce a pound of pork. Therefore, assuming 170 pounds of green alfalfa would produce 16 2/3 pounds of pork, a fraction over 10 pounds of green alfalfa would produce 1 pound of pork. Estimating that an acre of alfalfa will yield during the season 20,000 pounds of green hay, this experiment would show that such an acre of alfalfa, cut green and fed fresh, would produce something like 2000 pounds of pork. Of course, this is fed in connection with corn, and a statement that an acre of green alfalfa would produce 2000 pounds of pork would be very misleading. Figuring on the basis of these two experiments, alfalfa hay yielding four tons per acre (8000 pounds) would produce 1600 pounds of pork, and its value at 4 cents per pound would be something like $64 per acre; and with green alfalfa producing ten tons per acre (20,000 pounds) would produce 2000 pounds of pork, which, at 4 cents per pound, would be worth $80 per acre.

HORSES.

There seems to be an almost universal opinion among horsemen, and especially among those that are raising heavy horses, that no other grass or combination of grasses equals or even approaches the value of alfalfa as a pasture for horses; and from an economical point of view it certainly has no equal, as it will furnish so much more feed per acre than any other grass. It will not only pasture more horses per acre, but it will produce horses of greater weight, larger bones and stronger muscles.

A horse that has been reared in an alfalfa pasture and fed a light ration of alfalfa all winter makes one of the finest horses to be found in any market to-day. To produce a horse of the highest type, with the cleanest bone, the best-developed muscle, the best temperament and the greatest action and finish, nitrogenous feed must be used, and in no other feed can this most essential element of nutrition be so cheaply and so abundantly supplied as it can with alfalfa.

The most successful producers of both heavy and light horses are to-day using alfalfa extensively in the development of their young horses. Its value for this purpose is not recognized by the Kansas feeder alone, for after seeing Kansas

PLATE 29. Horses fed alfalfa the year round.

alfalfa-grown horses, eastern breeders, where alfalfa cannot be grown, are sending their colts to Kansas alfalfa-fields to be developed as they could not be at home.

A majority of horse owners are inclined to waste hay in feeding horses, i.e., they feed more than is necessary for the maintenance of the horse and more than he can economically take care of. This is true of other kinds of hay as well as of alfalfa.

Either heavy or light horses that are doing regular, steady work should not, if one wishes to feed economically, have more than one pound of hay per hundred pounds of live weight. That is,. a thousand-pound horse should receive 10 pounds of hay per day and a 1500-pound horse 15 pounds per day. A 1500-pound horse that is doing steady work should have about 4 pounds of hay with his morning feed, the same amount at noon, and about double the amount at night. Many horses will eat 30 or 40 pounds of hay a day if they have free access to it. If a horse is allowed to eat such quantities half of it is wasted, and if he is eating that amount of alfalfa hay it is worse than wasted, for it does the horse an injury. From two to two and a half pounds of digestible protein is all that an ordinary horse can utilize in a day, and in 100 pounds of alfalfa there are 11 pounds of digestible protein. This fare of alfalfa, if too heavily fed, is likely to cause kidney disorder, and may even be responsible for abortion in pregnant mares that are fed too liberal a ration of it. If it does not cause abortion, weak, unhealthy foals will be the result.

Have alfalfa fed judiciously to pregnant mares, heavy or light work horses, and it is beneficial and should be used

wherever it is obtainable, but it should never be used as the exclusive roughage. Some objection is made to it on account of causing looseness of the bowels and making the horses soft and easy to sweat. This is due to their having it in too large quantities. Alfalfa hay should be fed as part of the grain ration rather than a roughage. If fed in this manner its use will be found very satisfactory.

SHEEP.

The use of alfalfa cannot be too strongly urged with sheep, either the breeding or fattening stock. As the method of farming has become more intensified and the open range grows less each year, an acre of alfalfa must be made to take the place of many acres of range pasture.

Sheep, being ruminants, are able to handle a much more bulky feed than horses. A breeding flock of sheep can be carried through the winter season very successfully with but little grain in addition to alfalfa hay. The College flock, consisting of Hampshires Shropshires, Dorset, Rambouillets and Cotswolds, have been wintered almost exclusively on alfalfa for the past three winters, and each spring have brought forth a good, large crop of strong, vigorous lambs. Ordinarily the first cutting of alfalfa is not as good for sheep as the second and third cuttings, as it is usually coarse and stemmy and sheep do not eat these stems readily.

PLATE 30. Pure-bred ewes wintered on alfalfa without grain.

PLATE 31. Carcasses of range lambs fattened on alfalfa and corn.

It is about as safe to pasture old sheep on alfalfa as it is cattle. They thrive on it and make excellent gains, but sheep bloat easily and there is likely to be some loss from this source. Lambs can be pastured on alfalfa with but little danger of bloat, and the way they grow on alfalfa is a delight to the shepherd. They should never be put on the pasture when they are empty and hungry, and it is always well to allow them access to some dry feed and keep them off the alfalfa until the dew is off; also on damp days. A mixture of alfalfa and brome-grass or alfalfa and orchard-grass is a safer pasture than alfalfa alone. A flock of ewes and lambs can be grazed for a short time each day on alfalfa with but little danger of loss. If a lamb-creep can be arranged from the sheep corral to an alfalfa pasture, the lambs will soon learn

what it is intended for and will do far better on it than if confined to a dry yard.

Newly seeded alfalfa can be pastured with less danger of bloat than an old field, and the packing of the ground by the sheep passing over it is frequently a great benefit to the alfalfa. As a roughage for fattening sheep alfalfa hay has no equal, and cases of bloat from the hay are exceptionally rare. It can be fed either whole or cut, and fed with grain. Many prefer this method of feeding, claiming that there is less waste by it.

In feeding experiments at this Station with sheep we have never found any other roughage or any combination of roughages that would equal alfalfa for fattening sheep. In a feeding experiment at this Station alfalfa and prairie hay were compared as roughages for fattening western lambs. In the test the grain ration was corn and cottonseed-meal for both lots. Those receiving alfalfa hay made an average daily gain of 0.335 pounds per head, while the lot on prairie hay made only 0.188 pounds per head daily, the alfalfa lot making almost twice as great gains. The alfalfa seemed to give the lambs a better appetite and they were always ready for their grain, and as soon as their grain was cleaned up they were ready for the alfalfa.

ALFALFA FOR A DAIRY FARM.

Alfalfa holds a unique position among the crops produced upon the dairy farm, because it is so well adapted to the feeding of dairy cows. It is palatable and contains a large amount of protein, the constituent so essential to growth and to the elaboration of milk. *Where* alfalfa is available for dairy cows, the amount of protein that it is necessary to feed in the form of expensive concentrates is materially and profitably reduced. For cows that do not give large yields of milk, a balanced ration can be made by feeding alfalfa hay and ensilage. This makes a home-grown ration that can be produced cheaply, a very important factor in the economical production of dairy products.

ALFALFA FINDINGS IN MILK PRODUCTION.

The New York station reports the results of feeding home-grown rations, consisting of alfalfa hay and corn silage, feeding four cows for sixty days, in comparison with a purchased feed ration for the same number of cows for the same length of

time. These rations cost respectively $30.03 and $47.05, or 12.5 cents and 19.6 cents per cow per day. This is a net gain of 24.3 cents per hundred pounds, and a half of a cent per quart of milk, or a saving of 33.7 and 31.5 per cent., respectively, for milk and butter in favor of the home-grown ration. They estimate that when purchased feeds average $25 per ton alfalfa is worth $16.50 to feed with corn silage.

At the New Jersey station a test was made with two lots of dairy cows to determine the comparative value of alfalfa and a combination of wheat-bran and dry brewer's grain as a source of protein. In this test the alfalfa ration produced a daily yield of 20.8 pounds of milk and 1.06 pounds of butter, while the bran and brewer's-grain ration produced a daily yield of 21.8 pounds of milk and 1.08 pounds of butter, only a slight difference in favor of the more concentrated protein foods. Bran and dried brewer's grain each cost $17 per ton, on which basis alfalfa hay proved to be worth $11.16 per ton.

At the Maryland station alfalfa and corn-meal gave better results than silage and commercial foods. Where alfalfa and silage were fed with and without grain, the grain feeding proved the more economical.

Experiments conducted at the Tennessee Experiment Station tend to show that one and one-half pounds of alfalfa will replace one pound of wheat-bran.

The New Jersey station concludes that three pounds of alfalfa is equivalent in feeding value to one pound of cottonseed-meal.

The Nebraska station compared feeding alfalfa hay with the feeding of' prairie hay; and decided as a result of these tests that alfalfa produced 10 per cent. more milk from less food.

The Utah station found that adding corn-stalks to a corn and alfalfa ration gave larger returns per unit of dry matter than alfalfa without stalks.

ALFALFA FOR SILAGE.

Due to the loss in the curing of alfalfa hay, and the trouble that is often experienced in harvesting, especially the first cutting of alfalfa hay, and the excessive losses resulting from unfavorable weather, together with the advantages of having a green succulent food, dairymen have been led to experiment in putting alfalfa in the silo. These experiments have met with varying results. Apparently the best success has been where

the alfalfa has been placed in the silo by itself. Care should be taken to see that the crop is fully in bloom before it is cut for silage, and that it does not become too dry or contain surplus moisture when it is put into the silo. If the crop is cut too green the silage will have a tendency to be sour and not make the best ensilage. Even if it keeps well it will be low in feeding value. The first cutting of alfalfa seems to produce the best ensilage.

The limited amount of experimental work which has been done in handling this most important crop for silage only serves to emphasize the need of' more experiments and more information along this line.

ALFALFA FOR SOILING.

Alfalfa is one of the best soiling crops available to the dairy farmer. The first cutting of alfalfa for soiling can be made about the third week in May, and will furnish an abundance of green succulent food throughout the summer and up until about the last week in September. Alfalfa is a most excellent green food to supply the deficiencies of late summer pasturage.

PASTURING ALFALFA.

It is usually considered a dangerous practice to pasture alfalfa. While stock under some circumstances can be pastured on alfalfa for weeks without injuring them, sooner or later some of the animals are almost sure to die. There are a great many plans recommended to make possible the pasturing of alfalfa. Some have the alfalfa planted in strips, with strips of grass between; others claim that if cattle have access to other kinds of food or pasture adjoining the alfalfa-field that there will be no danger from pasturing the crop. Others have a theory that if the stock is turned onto the alfalfa pasture in such a manner as to gradually accustom them to eat the alfalfa, the practice of pasturing it will be successful. In view, however, of the present knowledge, it is a dangerous practice, and one which must always be taken with considerable risk. Besides, the pasturing of alfalfa, especially if it is not done judiciously, has a tendency to destroy the alfalfa plants.

ALFALFA-MEAL.

Within the last year alfalfa-meal has gained a great deal of prominence as a feed for dairy cows. While we have not been able to carry out carefully conducted feeding experiments with

this product of the alfalfa-mill, we do not feel it will prove to be as valuable for feeding dairy cows as some other class of live stock. The dairy cow not only has room for but needs a large amount of roughage in her ration, and in view of the difference in price between the meal and the hay, which, by the way, must be practically the same in feeding value, we do not think that it is economical to purchase the meal, except in special cases to be used in the place of bran for lightening up a heavy grain ration. We believe the cow can do this grinding cheaper and to better advantage than the mill.

The Pennsylvania Experiment Station, as a result of experiments conducted in feeding alfalfa-meal, states that the results of this test do not warrant the recommendation of alfalfa-meal as a substitute for wheat-bran for dairy cows at the present market prices.

ALFALFA BREEDING.

The great plasticity of the genus of plants to which alfalfa belongs in its adaptability to soil and climate is strongly emphasized when we compare the extremes of the types already described. The wiry stems, the low-spreading, much-branched habit and extreme hardiness of Turkestan alfalfa present such a contrast to the large, rather stiff, tall, upright and little-branched stems of the subtropical Peruvian alfalfa, that one would ‘little suspect that he was dealing with plants of the same origin. This adaptability, or in other words ability to become acclimatized, has already been explained by the fact that. within any one of the given types many variations as to form, habit, vigor, drought- and cold-resistance occur which need only to be selected by soil and climatic factors killing out the less suited individuals in order that a type may be established. What, therefore, has been done by the slow process of natural selection may be hastened and emphasized by the conscious selection and propagation of the best plants. There is thus opened, in this wonderfully plastic and variable group, a field for the breeder, pregnant with the probability of the most profound success.

The breeding of this forage plant is just beginning to receive the serious attention of the experiment stations and the United States Department of Agriculture in the alfalfa-growing

states of the West and Southwest. By a comparative study of the adaptability of regional varieties it is clear that the work of the agricultural explorer must now give place largely to that of the plant-breeder, and that we must in the future look to the improvement of our own rather than the introduction of new varieties for the amelioration of our alfalfa crops. Especially is this true for the states of the middle West, notably Utah, Colorado, Kansas and Nebraska. These states are the home of the *American type* of alfalfa, and in them no other alfalfa has been able to compete with it. When, therefore, the breeder has found that strain or type of alfalfa which is most suited to the locality within which he must work, it is from this strain that he should look to draw his materials for further selection and improvement. He must first study the needs of his locality and determine what lines of improvement are most necessary in order to increase the yield or feeding value. When this is done he may intelligently seek out and select for breeding purposes those individual plants which seem most likely to possess valuable characteristics.

For what points should we breed? In the first place, hardiness and vigor are indispensable, in order that the plant may not be driven out by weeds or killed by severe weather conditions. Moreover, hardy, vigorous plants will live longer, be more productive, and the expense of reseeding will not be so frequent.

Another aim of the breeder of alfalfa is to secure plants of greater drought-resistance, in order that the area over which this valuable plant can be grown with profit may be further extended into the semiarid regions and that better crops may be secured in the drier sections in which it is already grown. Drought-resistance in a plant depends either upon its effectiveness in gathering water from the soil or its ability to retain it when gathered, or upon both. Obviously the best way to determine the drought-resisting qualities of plants is by means of comparative tests in dry sections, but where this is impracticable preliminary test may be made by measuring the quantity of water transpired by a given amount of leaf surface in a given time. The importance of such tests is suggested by the fact that of two plants, growing side by side in the breeding plots of the Botanical Department of this Station, one showed an average transpiration rate for equal areas of leaf surface nearly twice as great as the other. It is but natural

PLATE 32. Plant No. 6l: upright, loose, open in habit; leaves set far apart. narrow. making but 40 per cent. of total green weight of the plant.

to suppose that, other characteristics being equal, the plant showing the least loss of water would be most suited for a dry region. *Close-pollinated* seeds of the above-mentioned plants have been secured and it is proposed to test by similar methods the transpiration rates of the offspring of each in order to determine to what extent these characters may be inherited, and whether by this method there may not be isolated and propagated, at once, extremely drought-resistant strains.

Alfalfa is susceptible to several diseases, the most important of which are described in another part of this bulletin. All of these are capable of doing more or less serious damage, and there is as yet no practicable method of controlling them known. It would seem, moreover, that the only method in which there is offered any large degree of hope for success lies in the possibility of securing more disease-resistant strains by selection and breeding.

An ideal alfalfa plant should be very leafy. This is so for two reasons. In the first place, the greater the leaf surface spread out to the light the greater the assimilating power of the plant, and hence the more rapid and vigorous the growth. In the second place, the leaf forms more palatable and diges-

PLATE 33. Plant No. 80; habit dense, foliage broad, closely set, making 59 per cent. of the total green weight of the plant.

tible food than do the stems. Hence more productive crops and a better quality of hay would be secured from plants having a high percentage of leaf to the total weight.

In selecting plants for breeding, habit of growth must be considered. This should be as nearly upright as possible in order that all of the stems may be cut by the mower.

While relatively a small number of alfalfa growers produce this plant for the purpose of harvesting the seed, still the question of seed production is one of prime importance. No better emphasis on this point could be made than to call attention to the present high price of alfalfa seed. The high probability of easy improvement along this line is suggested by extreme variations with respect to the seeding ability of different individuals found in any ordinary alfalfa-field. For instance, in one experiment at this Station (see Bulletin 151 [1907], p. 105) some plants produced only 0.4 seeds per ten-gram weight of stem and leaf, whereas from other plants in the same field as high as 137 seeds per ten-gram weight were harvested. That these characters are strongly heritable is shown by the following, quoted from Bulletin 101 of the South Dakota Experiment Station :

"In the pedigree rows of 1906 a general tendency toward uniformity was observed in the plants from the same selection.

PLATE 34. Upright, stiff, dense bushy habit.

For example, all the plants in pedigree row No. 162-98 exhibited exceptional forage qualities as compared with the plants of other rows grown, whatever the source, and all the plants of pedigree row No. 65-74 bore heavily of seed pods, while others from the same original source were light bearers of the pods."

However, in the breeding, of alfalfa, the fact must not be lost sight of that 'it must be preeminently a forage plant, and that if the productivity. of seed be increased it must not be done at the expense of the forage value.

Productivity is of course the most important of the qualities to be sought in the improvement of alfalfa, and may be said to include all the others above described. Thus, in order to be productive of the largest quantity of the best quality of hay, the plant must be hardy, vigorous, disease- and drought-resistant, very leafy, and of such habit of growth as to be harvested with ease and without great loss from low-lying and prostrate stems.

METHODS OF BREEDING.

The necessity for careful and accurate records cannot be too strongly emphasized in any kind of plant-breeding work. Qualitative and descriptive records have their value, but these

should be replaced wherever possible by actual counts, measurements, weights or comparisons to fixed standards in order that we may not be deceived by mere appearances or overlook valuable plants on account of an inaccurate guess of their qualities.

Frost-resistance can be estimated by the per cent. of winter-killing or the extent of damage from early or late frost. The habit of growth may be described by erect, ascending or spreading, but since these are merely qualitative terms they should be supplemented by photographs wherever possible. Shape and size of leaves may best be recorded by keeping herbarium samples of the plants. Measurements may, however, be made. If this be done it must be previously stipulated how they are to be taken, since the leaves on a given plant may vary from very large to small, according to their position on the stem and to the stage of growth. The: leaves are always smaller on an old than a young stem, and are largest near the middle portion, decreasing in size as either base or apex is approached. A good rule is to take the average of the length and breadth of the terminal leaflets of ten of the largest leaves as a standard of comparison of the leaves of a certain plant with those of others. It must be remembered, however, that the size of leaves of the first cutting of one plant must not be compared with those of the second cutting of another, as the average size of the leaves gradually decreases as the season advances. All measurements should be taken at a certain stage of the plant, as, for instance, just as the first flowers begin to open.

The best way to record shape of the leaves is by comparison to types. Certain type shapes may be selected and numbered, and the records made by referring the shape of the leaves on a plant to one of these numbers.

Leafiness is best expressed in terms of the ratio of leaf weight to the total weight of the plant. This record, as well as all other records of the vegetative characters, should be taken at that age when the plants most strongly show their individual characteristics. This, as has already been mentioned, is approximately at the time of the first appearance of flowers and flower-buds.

While there is perhaps no form of variability in alfalfa which is more striking or easily distinguished in the field than the color of the flowers, still this is one of the most difficult of characters to record. There are differences in shade of color

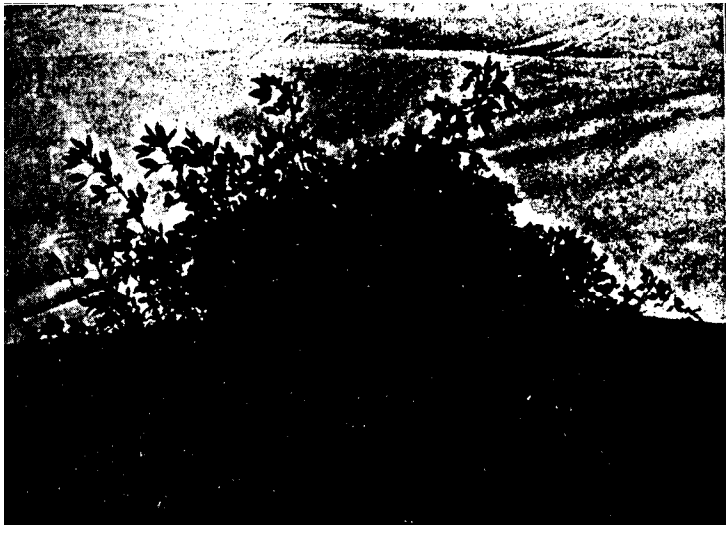


PLATE 35. Low, spreading habit.

which are at once noticeable to the eye, but which are almost impossible to describe, yet they are distinct, and remain so from year to year and throughout the blooming season from the oldest to the youngest flowers. Although it is impossible to describe these delicate differences, color groups may be arranged which are sufficiently inclusive to allow a description which would enable one to assign the flowers of a plant with a fair degree of certainty to some one of these groups. Thereafter reference to this group will recall to mind a fairly accurate idea at least of. its color. Wherever these color types can be supplemented by careful water-color drawings, the record is much more complete and can be more easily understood by persons other than the one who made the notes and established the types. For use in the Botanical Department of this Station ten types of color were selected and carefully described, after which a careful water-color drawing of a representative flower of each was made. Future records will therefore be kept by reference to some one of these types.

DESCRIPTIONS OF COLOR TYPES.

No. 1. Ground of banner and wings light lavender; banner lines deep lavender and distinct.

No. 2. Ground of banner deep lavender; lines faint.

No. 3. Ground of banner deep purple, very dark or with reddish tinge.

No. 4. Ground of banner blue, lines dark blue ; keel blue, or yellow tipped with blue.

No. 5. Ground of banner dark, smoky blue, with tinge of yellow, green or purple, any or all ; keel purple, or yellow tipped with purple.

No. 6. Ground of banner white, tinging to purple.

No. 7. Ground of banner white, tinging to blue.

No. 8. Ground of banner white, tinging to yellow.

No. 9. Ground of banner yellow, with dark purple lines ; keel yellow.

No. 10. Ground of banner greenish yellow, with smoky-blue tinge; lines greenish blue. Much lighterthan No. 5.

As has already been mentioned, the best method of recording the seeding ability of a plant is by the number of seeds produced per ten grams of total weight,

METHODS OF PROPAGATING SELECTED PLANTS.

After a careful study of the characters of many individual plants, certain ones will be selected as worthy of future tests and further propagation. Three lines of procedure are offered:

1. The selected plants may be allowed to seed in the open and these seed be harvested and planted in test-rows, subsequent selections being made from each test-row. This method has been fully described by Wheeler and Balz, in Bulletin 101, South Dakota, as follows :

"In the breeding of alfalfas the seed from various sources is sown in selection rows, each row representing a single source of South Dakota accession number. The rows are three feet apart and each plant occupies one foot of row. One hundred or more plants are grown in each row. From the selection rows the best appearing individuals from the best original sources are selected and marked by numbered stakes. The seed from these plants is saved separately and sown the next season in centgener or pedigree rows. The plants in these rows are grown the same as in the selection rows. The difference between the selection and pedigree rows is simply in the source of the seed; selection rows are from single regional sources, while pedigree rows are from single plants selected from selection rows or from older pedigree rows. Pedigree rows are known as first, second or third generation pedigree rows, respectively, as to whether they are one, two or three selected generations from the original selection row.

"On account of the labor involved no attention has been given, so far, to isolating the plants by covering or other means to prevent contamination from foreign pollen. Whether more rapid progress in improvement can be made by this method than by the open method has not, therefore, been demonstrated."

2. Vegetative propagation. By this method, which is described and advocated by Westgate and Oliver in Bulletin 102, part IV, Bureau of Plant Industry, United States Department of Agriculture, from any given selected mother plant large numbers of individuals may be secured by vegetative propagation. The above-named authors have the following to say with regard to this method:

"The practical difficulties which have presented themselves in connection with the development of improved strains of perennial forage plants have been such as to retard the progress of the work. The necessity for isolation to prevent promiscuous pollination and the time required to secure any considerable quantity of seed have together served to handicap seriously the work of developing new strains of forage plants, especially the perennial legumes. The method of propagating forage plants by means of cuttings herein described has been worked out chiefly in connection with *Medicago sativa.*

"The cuttings should be made about three inches in length, preferably from the upper portions of reasonably matured stems. Plants grown outside the greenhouse produce the best cuttings, but in case the stock plants are not close at hand it is generally advisable to transplant them to the greenhouse, cutting the stems back close to the ground. Such plants will give abundance of good material for cuttings within two weeks. It is practical, when the cutting material is limited in quantity, to utilize also the middle and lower portions of the stem. In any case, two or three nodes should be included in each cutting, the lower being near the base to facilitate rooting. It is possible to secure a second set of cuttings from the original ones when they have grown to twice their original height, usually about three weeks after potting. The slips should be inserted in sand, and when the largest roots are about three-fourths of an inch in length they should be transferred to two-inch pots and later to three-inch pots. The size which the plants can attain in such pots without becoming pot-bound will permit them to be transplanted to the permanent nursery rows, if the season be suitable, or to an outside cold-frame to remain dormant until spring, in case the cuttings are made during the winter. It is possible, with thirty square feet of greenhouse space and ninety square feet of cold-frame, to secure during a single winter 1000 plants from an alfalfa plant of medium size.

"By using cuttings it is quite practicable to produce in the greenhouse as many plants from one individual during the first winter as would be expected in at least two years from seed. Therefore, this method results in a considerable shortening of the time required to get the seed of any one selected strain in sufficient quantities for field tests.

"In cases where there is at hand but a single individual of a given strain it is possible that destruction by accident may be guarded against by increasing the stock, as here suggested. If the preliminary tests show it to be of probable value, the question of seed production can then be considered."

3. Propagation by means of close-pollinated seed. The method advocated by Westgate and Oliver has many advantages where the rapid propagation of proved superior plants is desired. In the work of this Station, however, it has been found that the first and most important question as regards the value of a promising mother plant is as to how many of, and to what degree, its promising characters are transmitted to its offspring. Now these facts cannot be learned from the plants arising from cuttings, since each of these is but a separated part of the original plant and would therefore bear all of its characters. In order, therefore, to test the hereditary characters of a plant, and these are the only ones worth while in the originating of improved races of plants, it is necessary that they be propagated from close-pollinated seed. It requires at least two generations from close-pollinated seed to fully determine the hereditary potency of a mother plant, the fact as to whether or not it was itself a hybrid, and the extent to which its offspring will be variable. Moreover, according to the already recognized laws of heredity, plants which have bred true for two generations from close-pollinated seed may be considered as fixed to that type. Until, therefore, we are sure of the purity and the hereditary ability to transmit characters of economic value of a selected plant, *it must be propagated from seed and not allowed to be contaminated by foreign pollen.* After these questions are determined, then, if necessary, it may be rapidly propagated by cuttings or placed in some isolated locality, far removed from other fields of alfalfa, and allowed to seed in the open. Moreover, by close-pollinating numerous plants of distinctive types, many pure races can be originated at once, and a greater number of progeny obtained for purposes of the study of heredity and variation at less

labor and expense than by the method of vegetative propagation.

Alfalfa is listed by Kirchner as self-sterile. Fruwirth found that, when alfalfa was caged and insects kept away from it, there was only an occasional plant having one or two pods. Henslow, on the other hand, obtained in such plants an abundance of seeds. In our own experiments it was found that when plants were separated so that one-half the stems were caged and close-pollinated while the other half was left to be cross-pollinated by insects the yield of 'seed was, on the average, about equal on each part. Where, however, the plants were caged to prevent the access of the insects and no effort was made to hand-pollinate them, the yield of seed was about one-fourth of the normal.

This inability of alfalfa to freely set seed without the aid of insects or hand pollination is caused by the peculiar shape, structure and nature of the flower. Even after the flower is open the pollen-bearing stamens and the stigma on which the pollen must fall are rolled up tightly in the keel or lower petal of the flower. Now, in order to set seed, it has been shown that these organs must be released from the keel and the stigma somewhat irritated. Insects accomplish this by alighting on the keel in their search for nectar in the flower. The weight of the insect's body bursts the keel and allows the pollen to be thrown out. At the same time the stigma on being. released springs upward, striking the lower part of the insect, and receives upon its now irritated and recepjtive surface pollen which has been previously dusted on the insect's body. Now, this same thing can be done artificially by pressing upon the keel with a toothpick, the point of a dull knife, or other suitable instrument. By this method the number of flowers pollinated may be counted and recorded and the seeding ability of a plant determined, but where a large amount of seed is wanted and it is necessary to hand-pollinate several hundred plants this method is too slow; still, after a little practice, one person can pollinate 10,000 flowers a day.

There is no difficulty in distinguishing from others the flowers that have already been pollinated, since the column of the stamens and pistil always remains pressed against the standard after having been once released ; and, furthermore, the floral organs wither soon after fertilization, while the unpollinated flowers will continue in fresh condition for sev-

PLATE 36. Showing method of grasping the flowers in rapid hand pollination.

era1 days longer. If, however, they are not then pollinated, the flowers become flaccid, and the spring mechanism ceases to operate.

However, where it is desired to pollinate many flowers rapidly, without reference to the exact number concerned, another and more rapid method may be followed. A flower-cluster, when in full bloom, is taken between the thumb and the first and second fingers, and subjected to a light pressure, while at the same time it is slightly rolled. By this operation the keels of all the flowers which are in the proper stage will be made to burst, setting free the stamens and pistils and covering the stigmas with pollen. One will soon learn by practice the manner of exerting the desired pressure, and how much to roll the cluster in order to obtain the desired result without in-

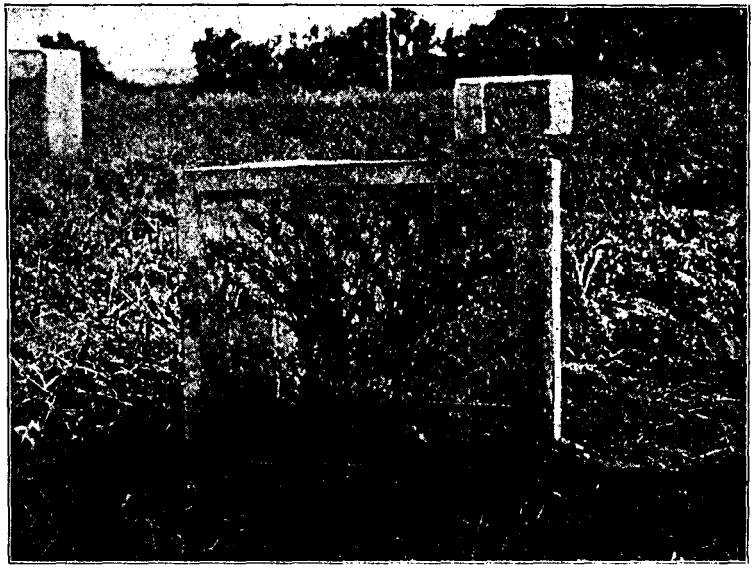


PLATE 37. Showing cage and manner of enclosing alfalfa plant for hand pollination.

juring the cluster by bruising it. While no exact counts have been made, comparing the two methods as to results, the writer is satisfied that this method is quite as effective as the other, while being from fifteen to twenty times as fast. Plate 36 shows the position of the hands when pollinating by this rapid method. Of course it is needless to say that the hands should be freed from pollen in passing from one plant to another. By the method last described, one person should be able to pollinate at least 200 or 300 plants a day.

In the process of hand pollination of alfalfa flowers on the selected mother plants, the plants selected must first be enclosed within screen-wire cages of convenient size. We employ cages of two sizes, measuring 27½ x 27½ x 24 inches and 51½ x 51½ x 36 inches, respectively, using the latter often to enclose as many as four plants at once. The earth must be carefully heaped about the base on the outside to prevent insects from crawling under, and every time the cage is replaced after lifting care must be taken to see that no stray branch of a plant is pinioned down outside the cage. See plate 37.

For the second generation areas should be screened in large enough to hold several hundred plants, and the overhead screening should be high enough to allow the pollinator to

work with comfort on the inside. By the third generation sufficient seed of the more promising sorts should be obtained to allow planting in open fields of sufficient size that, if moderately isolated from other alfalfa-fields, practically pure seed could be obtained.

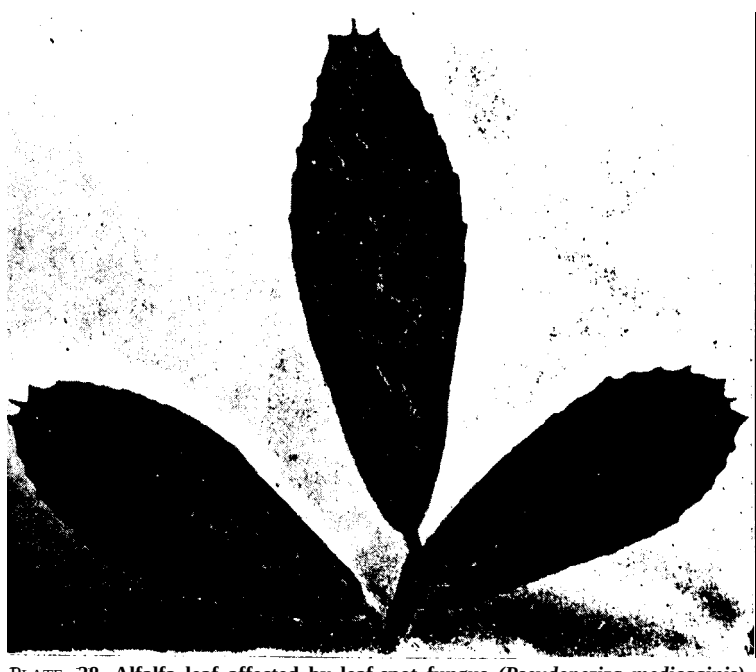
DISEASES OF ALFALFA.

RED ROOT-ROT.

This disease, although not so at present, is likely to become the most destructive disease of alfalfa. It has long been known in Europe, where the death of half the crop within one or two seasons has been recorded. It is now rapidly spreading in the alfalfa-fields in this state and will in the near future most probably demand the most serious attention of both the farmer and the Experiment Station authorities.

The disease begins in different parts of the field where at first a single plant may die. From this center of infection the fungus grows in all directions through the soil, killing the plants as it proceeds. Thus a circle of steadily increasing radius is formed, at the edge of which plants in all stages of the disease may be found. The first external sign of the disease is a yellowing of the plant, which soon after withers and dies. On pulling up a dead or dying plant the roots will be found to be covered with a violet or brownish-red mat of fungus strands or hyphæ. The infected area spreads from three to twenty feet in all directions in a season. The dying is most rapid during the hot months of summer. The fungus threads grow into the bark of the roots as far as the cambium layer, which they kill. The plant is thus girdled and will therefore soon die. This fungus forms dark knot-like tubers, which are said by Prunet to live in the ground two or three years. He therefore recommends that badly diseased fields should not be cropped to clover or alfalfa for several years.

Cause.—The cause of this disease is the fungus parasite *Rhizoctonia violacæ* Tul. "On plants with sclerotia, Fuckel found pycnidia and perithecia of *Leptosphæria circinans;* whether the various forms were related could not, however, be determined." Frank gives the following synonyms: *Rhizoctonia violacæ* Tul., *Rhizoctonia medicaginis* D. C., *Byssothe-*



PLATE, **38. Alfalfa leaf affected by leaf-spot fungus *(Pseudopeziza medicaginis).***

cium circinans Fuckel, *Leptosphæria circinans* Sacc., *Trematosphæria circinans* Winter.

Treatment.— A thoroughly practical means of controlling this disease is not known. Digging a trench around the spots from one and a half to two feet deep and working into the soil heavy applications of lime or sulfur have been recommended as being beneficial in some instances, but with these treatments success has by no means been uniform. It is the opinion of the writer that this disease should receive the most serious attention of both the farmers and experiment station workers throughout the alfalfa-growing states, in order that, if possible, some practicable means may be found of eradicating or controlling it before it becomes so wide-spread as to seriously threaten the profits now derived from alfalfa growing.

LEAF-SPOT.

This disease was first described by Libert, in France, in 1832, but it is now found in practically every part of the world where alfalfa is grown. In 1891 Professor Pammel

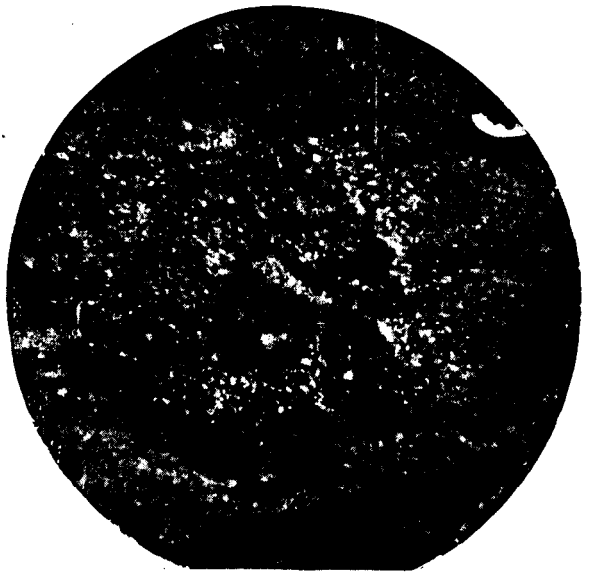


PLATE 39. Pustule of leaf-spot, greatly enlarged.

estimated the loss from the disease in Iowa to be as high as 50 per cent. of the total yield.

When the plants are about one-half grown it appears as yellowish-brown spots on the upper surface of the leaves. The affected area soon works through and appears on the under side of the leaf also. Badly affected leaves will turn yellow and drop off, thus reducing the forage value of the hay by making it more stemmy. The yield is also reduced through the loss of the fallen leaves and by the weakening of the plant. The brown spots (see plate 38) are caused by the growth of fungus threads or mycelium through the interior tissues of the leaf, which they destroy and cause to turn brown. Soon mats of fungus tissue are formed which produce small pustules near the center of the spot. These pustules consist of numerous sack-like bodies, each of which bears eight spores. Between the sack-like bodies may be seen non-spore-bearing threads which are called paraphyses. When the spores are ripe they are set free and blown by the wind or knocked by dashing rains to the leaves of other plants which they soon infect.

Cause.— The fungus causing this disease is technically known as *Pseudopeziza medicaginis* (Lib.) Sacc. Various

authors give the following synonyms *:* *Phacidium medicaginis* Lasch. and Lib., *Pseudopeziza trifolii* var. *medicaginis* Bernh.

Treatment.—The most practical treatment for this disease is frequent cutting. All of the hay should. be removed from the field as early as possible in order that few shattered leaves may be left on the ground. By this means most of the spores are removed from the field, leaving the new shoots comparatively free from infection. Whenever this leaf-spot becomes

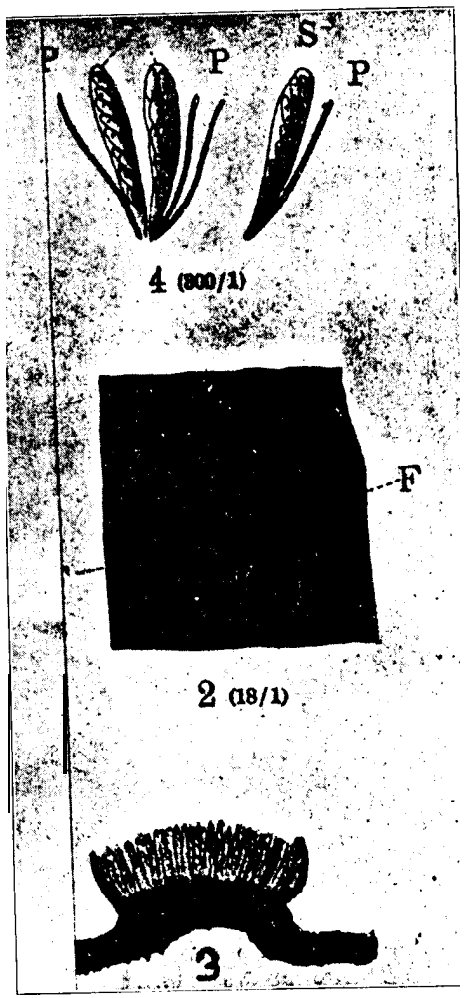


PLATE 40. Fig. 2, pustule of leaf-spot fungus; fig. 3, cross-section of pustule, showing spore sacks; fig. 4, spore sacks, greatly enlarged.

very damaging it is best to cut the alfalfa, whether it is ready or not, and allow the hay to remain on the ground long enough to become thoroughly dry, after which it should be burned over. Of course, by this means one crop is lost, but it will repay the loss in the increase of subsequent crops on account of the more effectual destruction of the fungus spores.

BROWN ROOT-ROT.

This name may be applied to a root disease of alfalfa which has been reported from Texas and Arizona in order to distinguish it from the red or violet root-rot which is appearing in the fields of this state. The dying of the plants in the fields and the spreading of the disease in circles from a given center is exactly the same as has been described for the red root-rot. It may, however, be distinguished from the latter by the fact that when diseased plants are pulled up the roots are found to be infested with a brown or brownish-yellow rather than a violet mat of fungus hyphæ.

Cause.— Prof. Geo. F. Atkinson has identified the fungus causing this disease as *Ozonium auricomum* Link. and states that it is identical with the fungus which causes the Texas root-rot of cotton. Thornber describes the spore-bearing stage, which "does not appear to have been mentioned in publication heretofore." Professor Thornber has therefore referred specimens of this fungus to Dr. W. H. Farlow for further identification.

Treatment.— In Texas and Arizona neither trenching nor chemical treatment of the soil seems to have been efficient in holding this disease in check in alfalfa-fields, but Shear and Miles state that a lack of proper soil aeration is a prominent factor in the development of this root fungus. They therefore highly recommend for the cotton root-rot deep fall plowing, disking, and a two- or three-year rotation as a means of controlling it.

RUST (*Uromyces striatus* Schrot).

This disease causes round or elongated pustules on the under side of the leaves. The epidermis is ruptured, disclosing a mass of reddish-brown spores. The rust pustule may be easily distinguished from the leaf-spot by the fact that in the former the epidermis is plainly ruptured, whereas in the leaf-spot this is not evident except in cross-section and by use of the compound microscope. While rather common, this rust does

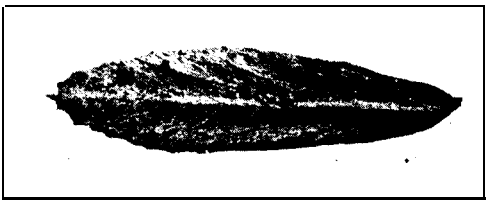


PLATE 41. Alfalfa leaf affected by the rust fungus (Uromyces striatus).

not seem to have caused serious loss in the alfalfa-fields of this country. Methods of treatment or control have not therefore been investigated.

DOWNY MILDEW *(PERONOSPORA TRIFOLIUM* DE BARY).

This disease is at first made noticeable by the large, irregular yellow or white areas on the upper side of the leaf. Upon examining the lower surface of such a leaf it will be found to be covered by a downy gray felt. This felt consists of thousands of tiny branching gray threads or stalks which protrude through the stomata or breathing pores from the interior of the leaf and which bear the spores of the fungus in grape-like clusters. These spores are carried by the wind to other leaves of alfalfa or clover, on which they germinate and produce an internal mycelium. The fungus is carried

PLATE 42. Rust pustule, greatly enlarged.

over winter by means of resting spores, which are formed inside of the old leaves in the late summer and autumn. In the early spring, when the new growth is especially tender, warm damp weather may so favor this disease that it may cause considerable damage. In fact, this has been the case in one field of alfalfa on Hunter's Island, near Manhattan, Kan., during

the month of May, 1907, but in a normal season and after the first cutting there will probably be but little to fear from it.

ANTHRACNOSE (Colletotrichum trifolii Bain and Essary).

Considerable injury is caused by this disease in the clover- and alfalfa-fields of Tennessee. It appears to attack the petioles of the leaves during hot summer weather. Many flower heads are killed by the fungus attacking the stems just below the clusters. During the period of seed-ripening whole plants may be killed by the disease attacking the stems just at or slightly below the surface of the ground.

Other diseases of alfalfa which are of less importance are: The powdery mildew *(Erysiphæ Madii* Lev.), which causes a powdery coating on the leaves ; smut *(Tilletia glomerulata* Coce. and Mor.) , said to occur on the leaves of alfalfa in Italy, and a new leaf-spot *(Pleosphærulina briosiana* Pollaci), recently described by G. Pollacci, as causing gray spots with brownish borders on the leaves.

INSECTS AND OTHER ANIMALS INJURIOUS TO ALFALFA.

Like most important field crops alfalfa constantly suffers from the attacks of many kinds of hungry creatures. Roots, stems, foliage, flowers and seeds serve to fill countless empty stomachs and to support myriads of living things.' Most of the creatures which rely wholly or in part on alfalfa for their food are either useful or too scarce to do appreciable damage, but occasionally some one species appears in such numberless hordes that the crop of large sections is devoured and great havoc is wrought. It is with such troublesome species that this discussion is concerned.

INJURING THE ROOTS.

POCKET GOPHER.—No other animal attacking the underground parts of alfalfa can equal or even closely approach the gopher in destructiveness. While the pocket gopher occurs in all parts of the state it is most abundant and destructive in the valleys of the Kansas river and its main tributaries. The plains pocket gopher *(Geomys lutescens* Merr.) holds sway on the western plains, and the prairie pocket gopher *(Geomys bursarius* Shaw) infests most of the remainder

PLATE 43. Prairie pocket gopher *(Geomys bursarius* **Shaw), reduced.**

of the state. These two species show such a similarity in life-habits that for the consideration of methods of combating a knowledge of the prairie form will Serve for both.

The prairie pocket gopher is short and stocky, showing an average length of about ten inches from the tip of its nose to the end of its stubby, hairless tail. Its body is covered with silky dark-brown hair, its eyes are small and well protected by fur, and its ears are so short as hardly to cause a ripple in the smooth-lying fur of the head. Its front feet are furnished with long, strong claws and otherwise modified for digging. In fact, the whole structure of the animal fits it for its subterranean existence.

The gopher tunnels hither and thither in search of food, at intervals digging short lateral burrows to the surface through which it pushes the excavated earth and dumps it outside, thus forming the mounds that indicate its presence and mark its progress. These animals are most active during the fall and spring, and one individual may throw up several mounds daily for several weeks at a time. During these seasons the work of a few gophers in an alfalfa-field may cause the uninitiated to suppose the field infested by dozens. Although the animals are most active at these times they work only less vigorously throughout the rest of the year. Even in winter, whenever the ground is sufficiently free from frost, they throw up mounds here and there.

PLATE 44. Front foot of the prairie pocket gopher.

Except for possible brief excursions at the periods of mating and migrating, the gopher passes practically its entire life in its burrow. Indeed, it is a rare occurrence to find one abroad on any errand. They appear to. live solitary, each individual gopher apparently bent on having his world to himself, and each digging and taking care of his own dwelling. Doubtless where fields are so badly infested that tunnels cross and recross, more than one gopher may be trapped in the same runway. The female produces but one litter of young per year, yet because of her sheltered life raises enough of them that the species is constantly increasing.

The natural food of the gopher consists of succulent roots and such green vegetation as can be dragged from the surface into the burrow. The coming of alfalfa, with its deep-growing succulent roots has largely solved the question of food supply for this animal by providing it with an abundance easily accessible both in winter and in summer. Truly the conditions of the alfalfa-field are such as to render life easy for the gopher tribe.

Not only does the animal injure alfalfa by actual consumption of the roots, but by covering up a considerable portion (sometimes 20 per cent.) of the area badly infested, and by rendering the crop in fields so infested difficult to harvest.

Many methods of combating these animals have been tested at this Station, and poisoning has been found at once the quickest and most efficient. Shooting and trapping require too much time, and fumigation is inefficient. Pieces of potato, apple, and sweet potato, about the size of the end of the little finger, poisoned by inserting a few crystals of strychnine into slits made with the point of a knife, or raisins and prunes treated in the same way, and carefully introduced into fresh runways, have given excellent results. While these baits are as successful as any used, much time is required in their preparation, and the Station has therefore undertaken the manufacture and sale (at cost of materials and labor) of a poisoned syrup, one quart of which is sufficient to poison one-half bushel of corn. The corn is put to soak in hot water the evening of the day before the bait is to be used. In the morning the water is drained off, the requisite amount of poison poured over the corn and thoroughly mixed with it. Cornmeal may be used to take up the excess moisture, and the bait

PLATE 45. Alfalfa field showing gopher mounds.

is ready for use. Any citizen of the state is entitled to a copy of the formula according to which this syrup is manufactured and may make it for himself if he so desires. The Station sells the prepared poison for $1.10 per quart, delivered to the express or freight agent at Manhattan.

Whatever sort of bait may be used, success depends upon introducing it into fresh runways. Choose fresh-looking mounds and prod on the line between them with a wagon rod or sharpened broom handle to locate the runway ; or, failing there, prod about the freshest mounds. The sudden giving of the soil and the apparent looseness of the stick in it is sufficient to show that the runway has been located. Remove the prod and drop a teaspoonful of the poisoned bait into the burrow, leaving the hole open. Level the mounds with some sort of a drag, and as fast as new ones appear locate the burrows and put poison into them.

In case the area to be treated is large some sort of a special instrument for locating the runways is desirable. A very good one can be made from a spade handle by covering the pointed end with iron and fastening a foot-rest about fifteen inches above the point.

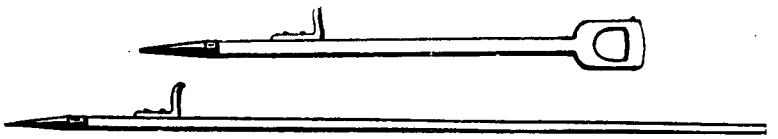


PLATE 46. Special tools for locating and opening gopher burrows.

By the use of the means just described the enterprising farmer can rid his land of gophers and keep them out of it. Once the farm is freed, the vigilance and prompt treatment necessary to keep it so will require but little time and effort.

No other creatures now attack the underground parts of alfalfa with sufficient vigor to demand attention, although moles and spermophiles, particularly the latter, may become injurious later.

INJURING STEMS AND FOLIAGE.

GRASSHOPPER.—In Kansas, even in the western part, it is not the notorious Rocky Mountain locust *(Melanoplus spretua* Thos.) but the home-grown species that do the most serious damage. Of the native species the differential locust *(Melanaplus differentialis* Thos.), commonly called the "big yellow fellow," and the two-striped locust *(Melanoplus bivittatus* Sand.) are most abundant, in the order named. Careful study has shown that the damage done to alfalfa comes mainly from individuals that have been hatched and grown right in the fields where they work. The "hoppers" begin to deposit eggs about September 10 and continue until cold weather. The female

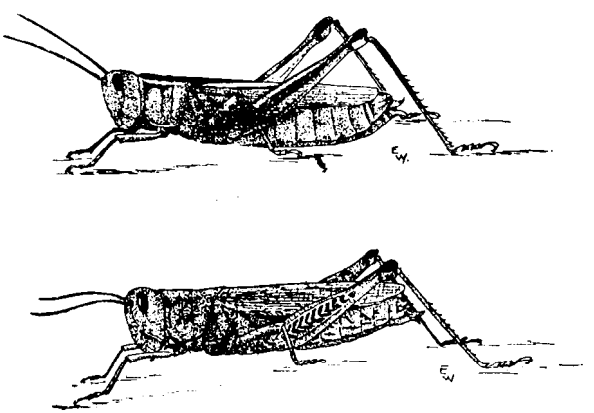


PLATE 47. Upper figure, two-striped locust *(Melanoplus bivittatus* Sand.). natural size. Lower figure, the differentia1 locust *(Melanoplus differentialis* Thos.), natural *size.*

digs a hole in the ground with her tail, extending it as far down as her abdomen will reach, then deposits about 100 eggs, neatly arranged and glued into one mass. She then packs the earth in over them. There they remain throughout the winter, but with the coming of warm spring weather they hatch and the young come to the surface, where they feed on alfalfa all summer long. They reach full size the latter part of summer, then pair and lay the eggs that are to produce the next year's brood.

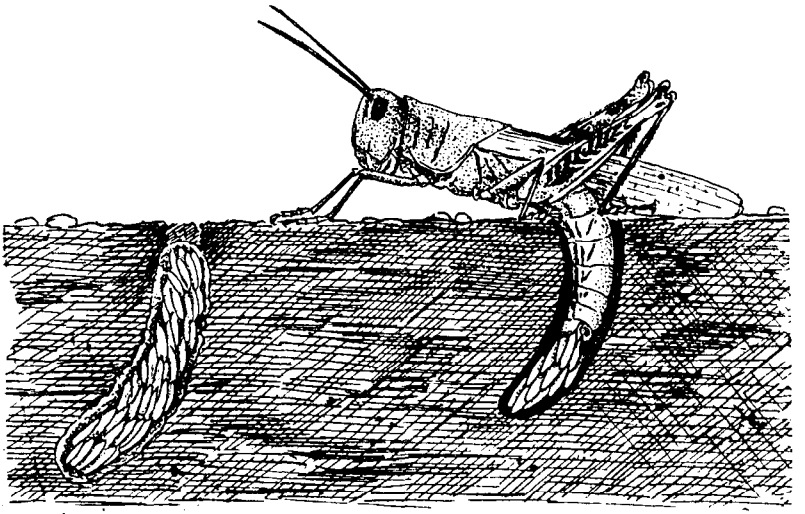


PLATE **48. The way the female grasshopper places her eggs.**

During the egg stage. is the best time to attack the grasshopper, because methods can then be used which will not only destroy a large portion of the eggs but will actually increase the subsequent cuttings of alfalfa and destroy the native grasses. We refer to disking. When the disks are set to cut down three or four inches, a large portion of the egg-packets will be broken up and turned out, so that, being exposed to natural enemies and inclemencies of the weather, vast numbers will, be destroyed. Of course, disking will not kill those eggs deposited along roadsides and fence rows. For the destruction of locusts hatching from these, the "hopper-dozer" should be employed. Essentially, the "dozer" consists of a shallow, high-backed pan mounted upon runners sufficiently high that its bottom will scrape the tops of the crops to be

protected, and filled with water covered with a film of kerosene. It should be used as soon as the hoppers are noticed in abundance, and during the warm part of the day, because they are then most active. Of course there are other methods of destroying "hoppers," such as poisoning, crushing with a roller, burning or driving, but these require a combination of special conditions to render them practicable.

WEB-WORMS (small green, black-dotted, web-spinning caterpillars appearing in June, July and August and binding up the plant with webs).-The web-worms *(Loxostege sp.)* have proven very serious enemies to alfalfa in this state. They have been reported as injurious during the months of June, July, and August. The eggs are laid on the food plants and the tiny "worms" begin feeding, as they grow constructing webs, beneath which they feed in safety. Usually the grower does not notice the trouble until his alfalfa plants are covered with webs and are seriously damaged. The first brood ordinarily becomes noticeable in June, gets its growth, and goes into the ground to pubate. The moths emerge in early July and lay eggs for the destructive July brood. There are probably three broods of these worms in Kansas, the last passing the winter in silk-lined cocoons in the soil.

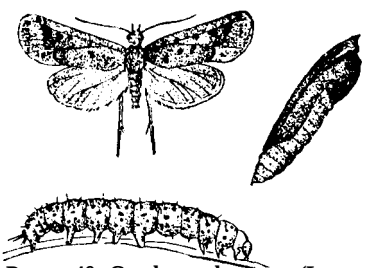


PLATE 49. Garden web-worm *(Loxostege similalis* Gn.) Larva. pupa and moth. Moth 1.5 times natural size.

This insect would also be reduced by the practice of disking recommended for grasshoppers. When they appear in limited patches they should be killed by spraying the plants with arsenate of lead at the rate of three six pounds to fifty gallons of water. The spray must be applied with sufficient force to break the web and poison the places where the worms feed.

If, however, they are generally distributed through the fields in sufficient numbers to menace the crop, it should be cut and the worms destroyed before they can become fully grown and go into the soil. The grower will thereby reduce the danger of later trouble from these insects and get another crop more quickly.

PLATE 50. Army-worm moth *(Leucania unipuncta* Haworth). Natural size.

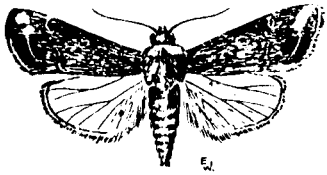


PLATE 51. Fall army-worm moth *(Laphygma frugiperda* Hw.) 1.4 times natural size.

ARMY-WORM (variable but usually dark-gray or dingy-black caterpillars marked above with three narrow yellowish longitudinal stripes and on each side with a slightly broader and darker one) .—Our correspondence files clearly indicate that occasionally the army-worm *(Leucania unipuncta* Haworth) becomes a menace to alfalfa-growing by stripping the foliage from large areas. Except for the fact that it passes the winter in the soil as a half-grown caterpillar its life-history is almost identical with that of the fall army-worm *(Laphygma frugiperda* Hw.) and the means of combating applying to that insect and to the web-worm are quite as efficient for this one.

FALL ARMY-WORM (caterpillars much like the true army-worm but distinguished by being slightly more hairy, having larger and more prominent black tubercles, and by the presence of a white inverted V on the forehead) .—This insect usually becomes noticeable during September. In Nebraska it has been. so destructive to alfalfa as to get the name of "alfalfa worm." The worms spin no web but simply crawl up the stalks and devour the leaves. During September of 1907 they appeared in several parts of this state in sufficient numbers to receive notice in the press. We gave close attention to the subject at Emporia and Topeka. In both places the worms damaged the alfalfa in spots. At Emporia the spots were scattered through the fields, nearly all at some distance from the edges. This means that, instead of the worms coming from the surrounding grasses, they were hatched and grew where they did their damage. By September 14 most of the larvæ? had entered the soil to a depth of from one-half to one and three-fourths inches, where they transformed to shining, light-brown pupae, and by September 28 the majority had emerged as moths. It is thought that these insects pass the winter in the soil as pupæ

and produce three broods during the summer. It is the second brood that becomes noticeable on alfalfa during September. When the fall army-worms appear in a field they should have the same treatment as has been advised for web-worms.

PLATE 52. Fall army-worm caterpillar. 1.4 times natura size.

Should either the fall or true army-worm assume the army habit and march from adjacent grasses into alfalfa, barriers and poisons should be used. The best type of barrier is a narrow, steep-walled ditch. The wall nearest the field to be protected must be as nearly vertical as possible, so that the worms cannot readily crawl up. If deep post-holes are dug in

PLATE 53. Front view of head of the fall army-worm. Greatly enlarged.

PLATK 54. Front view of the head of the army-worm. Greatly enlarged.

the bottom at intervals of ten feet the worms will collect in them and may easily be destroyed by kerosene or crushing. By spraying a narrow strip of the crop just ahead of the worms with arsenate of lead, or dusting it with Paris green, and liberally distributing poisoned bran-mash, the advancing horde may be checked and eventually destroyed.

CUTWORMS (plump caterpillars one and three-fourths to two inches long when fully grown, of dull brown, gray or greenish hue, generally marked with longitudinal stripes, oblique dashes, and dots, with head and following segment reddish brown and horny) .—These insects, among which the variegated cutworm *(Peridroma saucia* Heubn.) is most common, occasionally do serious damage to alfalfa. Our correspondence indicates that they damage the crop during late spring, principally in May, but they might well appear throughout the summer. The variegated cutworm is a wide feeder, working on field, garden and greenhouse plants as well as on the foliage and fruit of trees. It passes the winter as a larva in the soil, emerging from winter quarters in the late spring.

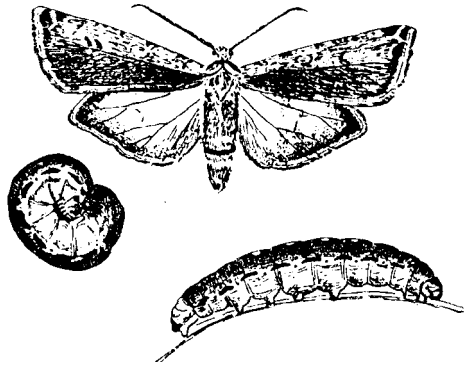


PLATE 55. Variegated cutworm *(Peridroma saucia* Heubn.) Larvæ and moth, natural size.

The second generation of worms appears in July and August, and a partial third generation in the fall.

Doubtless the disking recommended for grasshoppers would destroy many of the over-wintering larvæ. In case the larvae appear over limited areas during the spring and summer it would be quite possible to kill them with poisoned bran-mash or by spraying the alfalfa with arsenate of lead at the rate of three to six pounds to fifty gallons of water. The bran-mash may be prepared by mixing forty pounds of wheat-bran with two pounds of some arsenical compound (white arsenic or Paris green), pouring over the poisoned bran two quarts of cheap molasses which has been previously mixed with one gallon of warm water, stirring the mixture thoroughly and adding enough water to make a stiff. mash. It should be scattered in heaping tablespoonfuls about the infested patches. Of course, alfalfa sprayed with poison could not safely be used for hay, and the only purpose in applying such treatment would be to prevent the worms from spreading to other parts of the field.

BLISTER-BEETLES.—Occasionally certain blister-beetles, particularly of one species *(Epicauta lemniscata* Fab.), become sufficiently abundant to defoliate large patches of alfalfa. Such injuries have been reported to this station mainly during the month of July. The blister-beetles have a complicated life-history, during one stage of which the young grubs feed exclusively on grasshopper eggs. It is therefore to be expected

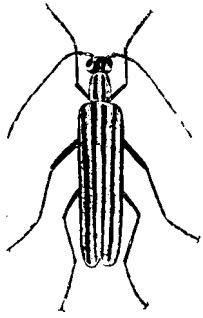


PLATE 56. Three-lined blister-beetle (*Epicauta lemniscata* Fab.) 2¼ times natural size.

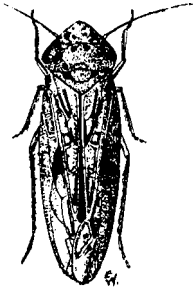


PLATE 57. Leaf-hopper, frequently found damaging alfalfa (Deltocephalus sp.) 8¼ times natural size.

that any method which will destroy grasshoppers will also reduce the numbers of blister-beetles.

LEAF-HOPPERS (small green or gray insects that, when disturbed, hop and fly swiftly about among the plants) .-Several species of these insects appear to do serious damage to young alfalfa. These leaf-hoppers, usually called gray or green flies by growers, do not consume the stems or foliage but, thrusting their beaks into the leaves and tender shoots, suck the sap. When they are abundant the leaves turn yellow and the plants make no growth. Perhaps the most efficient method of destroying them lies in the use of a "hopper-dozer" of special type. As these insects are small and cannot jump very high, the dozer should run on the ground with the front edge turned up only enough to avoid scraping up the soil. It should be coated inside with coal-tar, because this substance will neither slop nor spill, yet is quite sufficient to hold and kill leaf-hoppers.

MOUND-BUILDING PRAIRIE ANT.—This ant constructs the gravel-covered mounds, each surrounded by its bare circular area, so well known to residents in the western part of the state. It is found throughout Kansas west of a line running across the state through Belleville in Republic county and Oxford in Sumner county. Its mounds are small and scarce in the eastern border but become larger and more plentiful westward.

The ants clear away the vegetation from a small area and construct their mound near its center. They excavate an

PLATE 58. External view of a nest of the mound-buildlng prairie ant *(Pogonomyrmex occidentalis* Cresson).

extensive series of chambers and connecting galleries that reach far down into the earth, in many cases ten or more feet. Above the excavations they pile the mined soil, cementing it together to form a mound ranging from a few inches to two feet in height, itself honeycombed with chambers and passageways. A layer from one-half to one inch in thickness over the top of the mound is composed of coarse particles. The sides of the mound thus constructed are pierced by from one to three or more funnel-shaped openings.

The entire colony, consisting of a limited number of males and fertile females (queens) and, in large nests, of an immense number of workers (sterile females), lives and reproduces within these ever-dark chambers and galleries. During summer, when the weather is clear, the workers go into the field between eight and nine o'clock in the morning. They return to the nest about noon and remain there until the hottest part of the day is past, then come forth and work until evening. On cloudy days they do not return at noon. Just before sundown a small force of workers collects little pebbles and

other coarse particles like those of which the gravelly roofing is composed, and stop up the openings so carefully that one must look a long time to discover their location. On the approach of a storm a large force is employed and the gateways are closed in haste, but when it has passed they are reopened and the ants return to their work.

The ant colonies are too few to seriously decrease the yield, although occasionally they will destroy the alfalfa on from one to two per cent. of the total area of a badly infested field. Their claim to rank as alfalfa pests lies principally in the increased difficulty of harvesting the crop when they are present.

Extended experiments have shown that the ants can most easily and efficiently be controlled by fumigating the nest with carbon bisulfid as follows: Set fumigation only when gateways are open ; invert a galvanized iron vessel, such as a common wash-tub, over one or more of the openings, covering as much of the mound as possible ; firmly pack soil over such holes as the tub will not reach; introduce under the tub and near the holes a shallow dish containing from one to three ounces (depending on the size of the nest) of carbon bisulfid ; set the tub down and quickly pack soil about the rim, making it as nearly air-tight as possible; allow to stand for five hours. The forming vapor, being heavier than air, sinks downward and comes to fill every chamber and gallery, destroying all the occupants.

Caution.-It must be remembered. that carbon bisulfid is as explosive as gasoline and must be used with equal care.

INJURING THE HAY.

CLOVER HAY WORM (medium-sized, dark-brown caterpillars, each segment of which is ringed with a band of darker brown). This insect is very fond of and devotes its entire attention to the various clover hays. The caterpillars usually appear toward the bottom of the stack in early spring, the hay which they infest having a moldy appearance due to the numerous fine silken threads they spin as they crawl about through it. It is badly cut up and rendered unfit for stock. This insect may be held in check by never stacking clover hay for two successive seasons in the same place, clean-

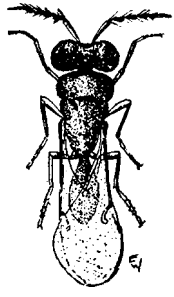


PLATE 59. Clover-seed chaicis (*Bruchophagus funebris* How.) 15.6 times natural size.

ing out the mow each spring so that no old hay will be left over in the barn until the new comes, and never putting new clover hay on top of old, either in stack or in mow. The worms in the hay can, if sufficient care and trouble be taken, be killed in the stack or mow by fumigation, but here preventive measures are most satisfactory.

INJURING THE SEED.

CLOVER-SEED CHALCIS FLY (tiny four-winged black "flies," whose grubs feed singly upon the forming tissue of the seeds, undergo transformations and emerge as adults through little round holes in the seed-coats).—This insect formerly devoted its attention to the seed of Red clover, but of recent years has shown a liking for alfalfa. At this Station, in 1907, it destroyed almost 50 per cent. of the seed from one of the seed-breeding experiments. The female inserts her eggs in the young seed and the tiny grub consumes the growing tissue. The insect comes at a time when its work makes no noticeable difference in the appearance of the head. The life-history of the clover-seed chalcis fly is so incompletely worked out that no reliable measures can now be suggested to prevent its damage.

PLATE 60. Work of clover-seed chalcis larvæ in alfalfa.

CONCLUSION.

When we call to mind that the grasshopper passes the winter in the soil in the egg stage, the web-worm, army-worm and cutworms remain in the soil over winter as larvæ the fall army-worm as a pupa, that the blister-beetles are dependent upon a supply of grasshopper eggs for food during one necessary stage, it is plain that thoroughly stirring the soil with a disk-harrow (preferably the spike-toothed kind) just after the frost is out of the ground and before the plants begin to grow, or, better still, in the late fall just before the ground freezes, if such a proceeding would not injure the plants, will go far toward controlling the insects enumerated. During the summer, when these insects are in the field or when the alfalfa is attacked by clover hay worms, leaf-hoppers, mound-building prairie ants or pocket gophers, the grower must resort to measures especially fitted to destroy the enemy in question.