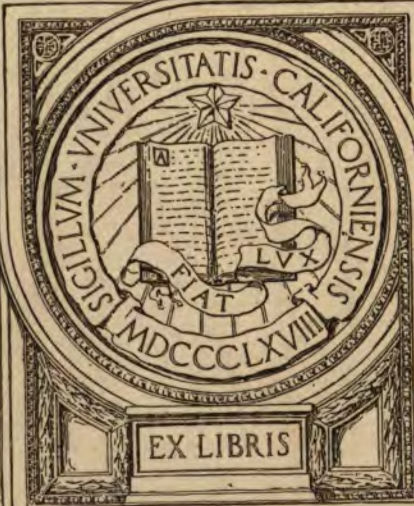
CLOVER...

...CULTURE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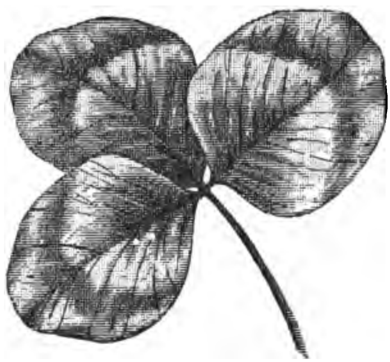
CLOVER CULTURE



BY HENRY WALLACE.

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PREFACE.

The scientific facts pertaining to agriculture, so far as they have been discovered, are scattered through many books and other publications, comparatively few of them being accessible to the ordinary farmer; the practical experience in the application of these facts, so far as known, is in the possession of the thousands of widely scattered farmers and largely beyond the reach of the public.

It has occurred to us that we might do some service to the farmers of the United States, and especially of the West, by collating as many as possible of the facts that are accurately and certainly known, and the experience of farmers over as wide a district as possible, on the one subject of "Clover Culture," and presenting them to the public in compact form, in language within the comprehension of every farmer and at an expense within the means of every man who grows an acre of clover. We began the investigation of the subject some years ago with the sole purpose of solving the difficulties encountered in obtaining satisfactory stands of clover on several hundred acres of land in western Iowa. Discussion of various phases of the subject through the HOMESTEAD has brought us hundreds of letters from farmers in many states who were meeting the same or similar difficulties, and the following pages are the condensed results of our study of the subject, of the experience of our correspondents, of our own experience and our observation both at home and abroad.

As such we submit it to the thoughtful reader.

The book is not written for the instruction of the scientist, nor is it intended as an exhaustive discussion of the subject, but to place in the hands of the practical farmer such information, both scientific and practical, as he needs on the subject under consideration. We have therefore, wherever possible, translated scientific terms into every-day English and have aimed to put the fodder in the rack where even the lambs can reach it. Such has been the aim; how far we have succeeded the reader must be the judge.

HENRY WALLACE.

THE CLOVERS AND OTHER GRASSES.

CHAPTER I.

In the very outset of our investigation of the subject of the clovers, it is important to notice the distinction between these and the other grasses. While in popular usage we apply the term grasses to all kinds of herbage that is summer food for the lower animals, botanically speaking clover is not a grass. The term grass pertains to plants with simple leaves, stems generally jointed and tubular, husks or chaff, technichally called *glumes*, in pairs and seeds single. A slight observation will show that the clovers do not belong to this class. The true grasses include all our commonly called grasses, the clovers excepted, and besides nearly all our grains, such as wheat, oats, barley and corn and also the sorghums. Clover belongs to the *Leguminosæ*, or Pulse familiy, and to the same family belong peas, beans, and vetches, sanfoin, lupines and many others among what are popularly termed grasses. It includes a large number of weeds such as wild indigo, wild peas, shoestring, etc., also a large number of shrubs such as the Wisteria, Carragana, Robinia, etc., and forest trees of which the locusts are the best known in the temperate zone and logwood and mahogany in the torrid zone. There are 6500 known species of *Leguminosæ*, it being surpassed by but one family, that of the *Compositæ*, to which belong the goldenrods, asters and sunflowers, and in the wealth of its products for the supply of human wants the family of the *Leguminosæ* surpasses all others.

The Clovers as a rule differ from the other grasses in their habit of root growth. Most true grasses throw out their roots horizontally, and while these often reach to great depths, much further than those who have not particularly investigated the matter believe, they penetrate to these depths only after having exhausted the fertility of the surface, and then in separate rootlets, while the cultivated clovers go down with a long, straight tap-root, some of them, as the alfalfa, reaching, under favorable circumstances, to a depth of eight or ten feet, and sometimes from fifteen to twenty, while three to four feet is by no means an uncommon depth to be reached by the ordinary red clover. The most striking difference between the clovers and the other grasses is in their power to increase the fertility of the soil, and in a way which has, until recent years, been unaccountable on any known scientific principles. This power is now believed to be shared by the entire family of plants called *Leguminosæ*, of which the best known cultivated varieties in America are peas, beans and the clovers.

This mysterious power of enriching the soil, while at the same time taking from it large crops of the highest feeding value, has been well known to practical farmers ever since agriculture had a history, and no doubt for a long time before. We find Virgil, for example, more than a century before the Christian era, singing in the first Georgic:

"At least, where vetches, pulse and tares have stood,
And stalks of lupines grew (a stubborn wood)
The ensuing season in return may bear
The bearded product of the golden year.
For flax and oats will burn the tender field
And sleeping poppies harmful harvest yield."

—*Georgic 1st*, *Dryden's Trans.*

The fact that good grain crops may be expected after a crop of Legumes was as well understood in those far-off days as it is now, and it is only in very recent years that scientists have been able to offer any adequate explanation. Flax seems to have had as bad a reputation as a soil robber as it has now, and we suspect our modern wise men know as little of the real reason as did the ancients. We find Virgil giving directions as to sowing the legumes in the following:

"Sow beans and clover on the rotten soil,

* * * * * * *

Vile vetches would you sow and lentils lean,
The growth of Egypt, or the kidney bean,
Begin when the slow Waggoner descends,
Nor cease your sowing till midsummer ends."

—*Ibid.*

The old poet had some notions about clover as food for dairy cows, for he sings:

> "If milk be thy design
> Bring clover grass."
>
> —*Ibid.*

It is a matter of history well known to all students, that the revival of English agriculture, which has made such wonderful development in all lines in the last century, was syncyronous with the introduction of clover and turnips, the clover enriching the soil in the material needed for the production of turnips, and the turnips furnishing the winter feed that has enabled Englishmen to bring to perfection their famous breeds of live stock. Nor need we go to a remote age, nor to foreign lands to notice this wonderful distinction between the clovers and the other grasses.

While it is generally conceded among intelligent farmers that exclusive grain-growing impoverishes the soil, and that grass culture must be resorted to in order to restore wastes of the soil robber, it is not generally known, as it should be, that this restoration comes almost exclusively through the medium of the clovers. Hence, we find that wherever farming is conducted on scientific principles, clover culture assumes a position of prime importance. At first, farmers are disposed to believe that grasses of any kind add to the fertility of the soil. In a measure this is true, but mainly true because they are grown in connection with some of the varieties of clover. The discovery that the recuperative power of the grasses lies almost wholly in the clovers comes to some farmers as a very great surprise, and often in connection with blasted hopes. How often have farmers who have sown their lands to timothy exclusively, and after mowing two or three years and then plowing them up and planting them to corn, been grievously disappointed in the results? It is a matter of common observation and remark that while timothy alone is a doubtful and uncertain crop, when sown with clover it yields abundantly and nearly as much timothy is grown with the clover as without and a fine crop of clover besides. The next year it will be noticed that while the clover is said to be "frozen out," but really dying out by the natural limitation of its life, the timothy grows most luxuriantly, and the faith of the farmers in this crop revives. The common explanation that clover keeps the land moist or that it keeps it loose, is wide of the mark. The true explanation is that clover feeds the timothy with nitrogen by means of its decaying roots. Farmers have also noticed how difficult it is to maintain a blue-grass sod for a series of years, unless it is accompanied by white clover. Blue grass maintains its selfish monopolizing policy for a year or two, but is compelled to yield sooner or later to the white clover and the two ever after grow together, for the simple reason that the blue grass, being a greedy nitrogen feeder, and always nitrogen hungry after the natural resources of the soil have been exhausted, is compelled to depend upon the nitrogen furnished by the white clover. If blue grass were used as a meadow grass, and the entire crop taken from the soil, it would be clearly seen to be as exhaustive of fertility as is timothy or grain crops. Every farmer understands that all kinds of grain or grass crops grow more luxuriantly when planted or sown with clover or on clover sod. This fact points out the clear and wide distinction between the clovers and the other grasses. All other grasses outside of the *Leguminosae*, the principally cultivated classes of which in America are the clovers, are great nitrogen feeders and always nitrogen hungry and, having no means of obtaining nitrogen except from the soil itself, are dependent either upon farm yard or artificial manure or the clovers for their supply, when once the virgin fertility of the soil in nitrogen is exahusted.

The most vital distinction, then, between the clovers and the other grasses is this: that the clovers, together with other varieties of *Leguminosae*, are able to obtain a supply of nitrogen, the most costly element of fertility, from a source quite independent of the stored fertility of the soil or of applied manure. It is important for the farmer to keep this distinction in mind in order that he may understand not only the reason why the cultivation of the clovers has always accompanied the introduction of improved farming, but also the bearing which their cultivation will have upon the development of the resources of the West, and in fact of the entire Nation.

The sources from which clover obtains nitrogen, the relation which nitrogen sustains to the other two great elements of fertility in the soil, potash and phosphoric acid, and the place which the clovers and other species of *Leguminosae* occupy of necessity in any cheap and practical feeding ration and their relation to the improvement of live stock as well as to the production of grains which will be demanded by the rapidly increasing population in America, will be discussed in the concluding chapters of this work. It is enough now to point out the facts which are clearly recognized by agricultural students and which have in the last few years been clearly demonstrated and for the first time really understood. Our object at present is to call the attention of our readers to the wide distinction betwixt the clovers and the other grasses, and to point out the fact that the cultivation of some variety of the *Leguminosae* is essential to any great improvement, either in grain production, the production of live stock or the conservation of the fertility of the soil.

DISTRIBUTION OF THE CLOVERS.

CHAPTER II.

If the statement in the last paragraph of the previous chapter be true that "the cultivation of some variety of the *Leguminosæ* is essential to any great improvement, either in grain production, the production of live stock or the conservation of the fertility of the soil," then the distribution of the legumes, and especially of the clovers, becomes a question alike of great scientific and practical importance. A crop that can not only supply itself with nitrogen, to a great extent independently of the nitrogen of the soil, but, by the decay of its roots and haulm supply other crops with nitrogen, is the very keystone of the arch of successful agriculture wherever its cultivation is possible.

The importance of the subject is greatly enhanced when we take into consideration the relation it sustains to the fertility of the soil, to growing crops and to the structure of all animals. Nitrogen, while the most costly and an absolutely essential element in soil fertility, in plant growth and in animal life, is one of the most abundant elements in all nature. It constitutes about four-fifths of the atmosphere, where it seems to be used merely to dilute the oxygen. It enters into no chemical combinations with it, but co-exists simply as a mixture, like sand in sugar. The process by which the free nitrogen of the atmosphere is transformed into the nitrogenous compounds of the soil has long been a puzzle to scientists, a puzzle all the more complicated and difficult of solution because it has been held until quite recently by all scientists and investigators that plants can not appropriate free nitrogen from the atmosphere. It is a striking fact, however, that all the sources from which either the nitrogen of commerce or that which enters into grain, grasses or the animal forms is drawn are either the sedimentary rocks, the remains of animal or plant life, the soil in which plant life flourishes, or, finally the atmosphere itself. The sedimentary rocks abound in animal and vegetable remains, and the atmosphere before rains, and especially after protracted drouths, contains available nitrogen in the form of ammonia which the rains bring down. It is evident that this latter form is a mere exhalation from decaying plant or animal life on earth, a supposition rendered still more evident by the fact that the amount of ammonia brought down by the rains is greater near large cities where decey is greater than it is in agricultural districts. Two methods alone have been suggested with any show of proof, by which the nitrogen of the atmosphere may be transformed into the nitrogenous compounds that make up the fertility of the soil—the one the combination called nitric acid, and believed to be a result of powerful electrical action in the air during thunderstorms, and the other the action of the legumes through the microbes in the tubercles on their roots. The last has been demonstrated to be a fact, but the exact way in which it is done seems to be as mysterious as ever. May it not be (and we put the question merely as a suggestion, never having heard it advanced by any scientific authority) that the supply of nitrogen for the support of the life of the plant or animal is mainly, if not wholly, obtained from the legumes which alone of all plant life have been clearly demonstrated to have the power to procure it, in a way not yet explained, from the free nitrogen of the atmosphere?

Speaking more particularly of the place of nitrogen in the animal economy, it, or rather the albuminoids, (the form in which the nitrogen is appropriated by the animal), forms the lean meat of all animals, much of the blood, the white and yolk of the egg, and is in fact the flesh-former and strength-giver of the animal economy. Potash, lime and the phospates enter into the bony structure, and to some extent into the flesh. Carbon is the main element of the fat, but without the albuminoids there can be no muscular formation, and hence no animal life. It is perfectly clear that the animal can receive nothing into its organization except through the food it consumes, and hence the flesh-forming element must be in the plant, the grass, the grain, or new milk fed to the young, and in the proportion adapted to the age of the animal—about one of nitrogen to four of carbo-hydrates in its youth, and in decreasing proportion after the muscular system has been built up. It will be seen, therefore, that the great problem of feeding lies in supplying nitrogen or albuminoids in this proportion, and consequently in supplying foods which in their combination have this proportion. On account of its relative scarcity to the elements that make up bone, or that keep up heat, it is always the most costly, and hence any plant or any class of plants that can draw supplies from the atmosphere instead of the soil becomes invaluable in the economy of the farm and the economy of nature. It is this fact that makes the distribution of the *Leguminosæ*, and especially of the clovers, a matter of such great importance in agriculture.

The *Leguminosæ* as we have seen constitutes a very large class of plants in all parts of the world, and in all conditions of soil and climate. It embraces some of the largest trees of the forest, especially in tropical countries, and, in the temperate zone, one of the most distinctive varieties is that of the locust, and the fact that the *Leguminosae* are able to procure nitrogen from the atmosphere explains what has doubtless been a puzzle to many readers, why grain crops can be grown close to a locust tree while they refuse to grow for rods around an oak, sugar tree or a walnut. They are found in all wild pastures, both in the shape of weeds and grasses. The wild indigo, the vetch and shoestring may be cited as prairie illustrations. If, as we have suggested, it is mainly through the *Leguminosæ* that the nitrogen of the air can be appropriated for the use of vegetable life, it will be clearly seen that the absence of the legumes would make plant life impossible. Whether this be true or whether science may yet reveal other hidden secrets of nature, showing that she is not limited to this class of plants, it is but reasonable to expect that they should have a wide distribution in every soil that is at all capable of supporting plant life. Without speaking of other leguminous plants, such as peas, beans, vetches and lupines that have been highly prized by agriculturists in all parts of the world, and in all ages, it is worth while to notice that there are in America more than forty native varieties of the clovers, in addition to those introduced since the settlement of the country, and that among these are species apparently adapted to all climates and to all varieties of soil, and all of them noted for being nitrogen feeders of other plants and restorers of the wastes created, in the first years of cultivation in every country, by the soil robber. The clovers in some of their varieties seem to be adapted to almost every soil where the plow can provide the means of human existence. Were nature as thoughtless as man, some portions of the earth would become a desert waste. She is ever aiming to build up and restore, and much of the skill and success in agriculture depends upon noting carefully her processes and working with her instead of at cross purposes.

As an example of this we might note the fact that the, Japanese clover, (*lespedeza striata*) sown by no human hand, spreads over the abandoned fields of the South and restores the wastes of the cotton planter, the robber of the Southern soils. The Bur clover, (*medicago deuticulata*) and half a dozen varieties of *trifolia* ,sown by the hand of Nature herself, gives richness to the pastures of California with its rainless summers; the alfalfa, (*medicago sativa*) makes the desert bloom like the garden of the Lord wherever the hand of man furnishes the life-giving water; the white clover, (*trifolium repens*) follows hard after the soil robber of the prairies and kindly binds up the broken-hearted land; the alsike camps in the sloughs and swales and along the bottoms, providing pasture for the bees while reclaiming the marshes; the white sweet clover, (*melilotus alba*), and the *Bokhara*, a closely related variety, take possession of the highways; the crimson clover, (*trifolium incarnatum*), flourishes all along the line between the cotton lands of the South and the distinctively corn lands of the North, while the medium red and the mammoth (*trifolium pratense*) pre-empt the carboniferous and calcareous soils wherever there is twenty inches of rainfall, mainly in the growing season. None of these ever take a foot-hold in the soil without enriching it and none ever fellowship with other grasses without increasing their luxuriance.

As this work is intended to be practical rather than scientific, for the guide of the farmer and not the instruction of the scientist, dealing in scientific facts and conclusions only in so far as it is necessary for the farmer to understand them in order to deal intelligently with clovers, we discuss the distribution of the clovers only in so far as it interests the American farmer. The mammoth and common red have a very wide distribution, and we group these together because they are not different species, as many suppose, but merely an early and late variety of the same species. This distinction is important, and because of the failure to note it carefully, many farmers have been led into serious error in their methods of handling mammoth, otherwise known as "pea-vine" or "sapling" clover. They regard the red as a species that produces two crops in a year, and seed only in the second crop, and the mammoth as a variety that produces seed in the first crop but furnishes none in the second. This is a mistake. The common red does produce seed the first crop wherever it has an opportunity of insect fertilization. We have cut on our own farms as much as three bushels of seed per acre from the first crop and from a thin stand, but ordinarily it is only the late blooms that become fertilized. This is owing to the scarcity of bumble bees, and to the fact that during the season of first blossoming there is an abundance of preferred bloom which prevents the Italian bees from visiting the clover. Farmers have abundant proof of this fact when they cut timothy for seed, in which they find more or less clover seed when the common red is grown with timothy. The mammoth would yield a second crop if the season were long enough. If a mixed crop of mammoth and medium red is cut by the 15th of June, or even the 20th, and the season is favorable, many plants of the mammoth will ripen seed, and if they are both cut by the 10th of June, a crop of seed may be expected from both. As proof of this we cite the fact that we have mown a meadow of mixed varieties for ten years and the mammoth in this meadow holds its own, which it could not do were it not annually ripening seeds. It has never, except on one occasion, been mowed prior to the 4th of July. The mammoth is simply a late-maturing variety of *trifolium pratense*, the botanical name for both, its season of growth being from two to three weeks longer for the crop than that of the medium red. This distinction will be more fully pointed out when we come to discuss the best methods of the management of each. These two varieties of the *trifolium pratense* have a very wide distribution, being co-extensive with the limestone and calcareous soils over the entire continent, limited on these only by the amount of rainfall. They grow luxuriantly on all the limestone soils of the Eastern and Middle states and refuse to grow with a profitable luxuriance wherever the rocks are deficient in the mineral elements peculiar to these soils. They reach far south on the Appalachian range, and their limitation by soil formation is most striking in Tennessee. They grow luxuriantly in Middle and East Tennessee, but whenever we pass west of the carboniferous formations into West Tennessee, they there disappear or fail to grow in desirable luxuriance. They may be found in North Alabama and Georgia, and even far south, wherever the peculiar geological formation of the Appalachian range appears, and they disappear with this formation.

The peculiar composition of the drift soil that covers the prairies of most of the Western states gives these varieties a very wide distribution. It is well known that most of these soils are not made *in situ;* in other words, they are not the result of decomposition of the rocks that underlie these states, although in many places modified by them. This drift is the result of the decomposition of rocks far distant and is mingled so thoroughly that scarcely any section may be found in the Western states in which there is not abundance of carboniferous or calcareous matter to develop a luxuriant growth of clover. The calcareous soils of the Missouri Valley, the deposit of the calcareous formations of the Upper Missouri, furnish material for the growth of clover in the greatest abundance.

We have for several years past been endeavoring to locate in crude outline the western limit of the medium and mammoth clovers. Without coming to any very definite conclusions and leaving the matter as yet undetermined, it is safe to say that in ordinary seasons these varieties may be grown successfully on fair soils as far west as the longitude 96° 40 m. west from Greenwich, and in favorable seasons there is practically no western limit; in other words, the limit is determined not by the structure of the soil, which on good lands is favorable for clover everywhere, but by the rainfall. Magnificent examples of common red and mammoth, white and alsike have been sent us this year from the extreme western boundary of Nebraska, longitude 102° 30 m., showing conclusively that the soil conditions are of the best on the edge of what is known as the desert, and all that is lacking is the rainfall. The northern limit of the growth of these clovers has not yet been determined. It is safe, however, to say that the reports of the destruction of these crops by freezing during the severe winters in many cases are the result of not understanding the nature of the plant, which is that of a biennial or short perennial and when used as a hay crop would naturally disappear at the second year whether the winters were favorable or unfavorable. *

The white, *trifolium repens*, has even a wider distribution than the mammoth and common red, (*trifolium pratense*),

* NOTE.—It is more than probable that under the name of common red clover we have several varieties of *trifolium*, some of which are biennials and some short perennials.

being able to grow on soils on which the larger varieties do not succeed and to grow on all soils in which they do.

The alsike, (*trifolium hybridum*), is distributed less widely, mainly because to grow a profitable crop it requires a much larger amount of moisture and it is especially valuable for wet lands where none of the other varieties succeed so well. It takes its technical name from the mistaken belief of the earlier botanists that it is a hybrid, or cross between the red and the white. This has long since been ascertained to be an error. The technical name is further objectionable because the term "hybrid" is properly applied only to the results of those violent crosses such as that of the ass and the horse, of which Nature forbids the reproduction. Alsike is preferred to the mammoth or common red, not only on wet sloughs, but on soils where it is believed that these varieties winter-kill. We are inclined to the belief that its preference in northern latitudes is due not so much to any peculiar ability to stand extreme cold, but to the fact that unlike the two former, it is perennial, and hence does not ordinarily perish at the end of the second year. The illustrations that will be furnished when we come to discuss the best methods of the cultivation of each will enable the reader to clearly distinguish these different varieties.

Alfalfa is the clover peculiarly adapted to the semi-arid regions and to the arid regions where irrigation is possible It is entirely true that it can be cultivated on any good corn lands, that are not underlaid with rock, hardpan or heavy clay, provided it is protected during the first winter in northern latitudes, but when thus grown is much inferior to the mammoth or common red in latitudes where these can be grown profitably, and hence its cultivation under these circumstances is not advisable. It is, however, to be preferred to any other in the regions of deficient rainfall, or where the rainfall, however abundant, in any given year, can not be depended upon for a succession of years. It has been grown very successfully over Central and Western Kansas, every county in the state but three reporting more or less alfalfa, and these counties lying in the eastern part of the state where red clover is so pronounced a success that farmers do not need to look further. The extreme length of its root enables it to go down in the years of sufficient rainfall to depths where it is in a measure independent of surface moisture, and the normal dryness of the climate furnishes the condition for curing it into excellent hay, a difficulty that is almost insuperable in sections of the country which enjoy an abundant rainfall in the months of June and July. It is therefore in the semi-arid regions the best of all substitutes for other clovers.

The great value of alfalfa lies in its adaptability to the arid lands of the mountains and the plains and the lands that have a winter rainfall and summer drouth as on the Pacific Coast. It is possible under these circumstances to cut three, four and even five crops in a single year, irrigation furnishing the moisture and the dryness of the atmosphere making the curing the crop entirely practicable. This will be more fully explained when we come to discuss the proper method of handling this crop.

Much has been said in recent years, and particularly by the Eastern press, of the value of crimson clover, *trifolium incarnatum*. This, unlike those previously mentioned, is an annual clover, the seed being sown in July or August and maturing early in the spring. It is therefore peculiarly adapted to the soils along the latitude of 40 degrees and south, and should not be attempted on the soils of the corn belt of the Northern states. Utterly valueless as it is in these soils, it is of very great value in its peculiar climate, as it can be sown in mid-summer, and removed in the spring in time for another crop. Its value as a forage plant is much inferior to any of the other clovers, and it is therefore adapted only for local cultivation in soils and climates specially suitable to its growth.

THE RED AND MAMMOTH CLOVERS.

CHAPTER III.

There is, perhaps, no agricultural subject in which the farmers, especially of the Western states, are more deeply interested than the cultivation of these two varieties of clover. In taking this deep interest they are but following in the wake of farmers in other countries. The cultivation of these clovers comes in everywhere, apparently, in the wake of the soil-robber. After lands have been exhausted of their virgin fertility, their owners begin to enquire how the lost fertility can be restored, and no means has yet been discovered so certain and reliable as the cultivation of red and mammoth clover. The Western states are now where the Eastern states were forty or fifty years ago, and where England was in 1633. In Sir Richard Weston's report on the Husbandry of Brabant and Flanders, published by Hartlib in 1645, we have some interesting statements as to the cultivation of clover at that time, both with regard to its object and methods, from which we quote as follows:

"It thrives best when you sow it on the worst and barrenest ground. The ground has to be pared and burned and unslacked lime added to the ashes. It is next to be plowed and harrowed; and about ten pounds of clover seed must be sown to the acre in April or the end of March. If it is intended to preserve seed then the second crop must be let stand until it come to a full and dead ripeness and it will yield at least five bushels per acre. Being once sown, it will last five years; and then being plowed it will yield, three or four years together, rich crops of wheat, and after that a crop of oats, with which clover is to be sown again. It is in itself an excellent manure."

The cultivation of clover seems to have spread as rapidly in England as it has in the Mississippi states of America in the last few years, for in less than twelve years, that is, before 1655, its cultivation, exactly according to the present method, seems to have been well known in England, and had also made its way to Ireland. The little change that has been made in the methods of cultivating clover in that country would seem to indicate that those early farmers had hit on about the right method. When a method does reasonably well, there is no inducement to change, and it is only when this method fails that farmers are forced to a more profound study of the principles involved. In the moist climate of England and of Flanders, and in the comparatively moist climate of the Eastern states, surface-sown clover, and especially when sown on winter wheat or rye, in the months of February or March, did reasonably well, but when it was tried on the lighter and drier soils of the West, and especially on spring grains, sown generally in April, the failures in securing a stand became very much more frequent. Farmers in these newer countries have, therefore, been compelled to get hold of the great principles that underlie the growth of clover in any and all countries and apply them to their own particular circumstances. Five things are essential to plant life: A soil that has all the elements of fertility essential to the life of that plant; that soil in a proper physical and mechanical condition, and in addition to these two, light, heat and moisture. No matter how fertile the soil, or how abundant may be the elements of fertility especially adapted to the plant, no plant will even germinate in utter darkness. For this reason clover bedded in a manure heap, with every element of fertility needed and with abundance of moisture and heat, will not germinate except where it lies near the surface and secures the proper degree of light. No matter what may be the light, moisture, or fertility, plants will not germinate at zero nor where the temperature is continually below the point of freezing. No matter how suitable the temperature, the sunshine or the fertility, they will not germinate without sufficient moisture, and no matter how completely all these elements are combined they will not make a profitable growth unless the soil is in a proper mechanical condition to meet the requirements of the plant. It is only by the proper combination of all these essentials that success is attained.

Of all the multitude of elements that enter into the composition of the clover plant, all soils have an inexhaustible quantity, with the exception of three or perhaps four. These are potash, phosphoric acid, nitrogen and perhaps lime. It is, however, very hard to find a soil so deficient in nitrogen that it will not grow clover. Clover has been grown in experimental pots of pure sand, from which every element of fertility has been washed out, and to which potash and phosphoric acid in their proper proportions have been added, and the only difference observable between their yield and that of similar plots rich in nitrogen, as well as the other elements, is during the brief period when the nitrogen in the seed has been exhausted and before the action of the microbes in the nodules or tubercles on the roots has been fully established. These experiments, of which we shall hereafter have much to say in detail, show conclusively that clover is less dependent on the nitrogen in the soil than almost any other plant, the only other exceptions in fact being other members of the *leguminosae*, to which order, as we have before said, clover belongs.

It will be noticed in the above extract from Weston that clover apparently did best on poor soils, a fact then inexplicable but which, it is well understood now, is not due to the poverty of the soil, but to its ability to supply itself with nitrogen, of which these soils are deficient, from the great source of nitrogen, the atmosphere. It is, therefore, one of the peculiarties of the clovers and one of their greatest merits, that they are less particular about the first condition of plant life,—the fertility of the soil—in nitrogen, than any other true grasses or grains. It is, therefore, almost impossible to find a soil in the Western states so far deficient in nitrogen that it will not grow clover, and it is almost as difficult to find one on our drift soils so far deficient in phosphoric acid, lime or potash. The question, therefore, as to whether the soil is rich enough to grow red and mammoth clover may as well be dismissed.

In the matter of the mechanical or physical condition of the soil, the red and mammoth clovers are as accommodating as are the other grasses. None of them require the garden culture demanded by most grains. They go on reproducing themselves in the pasture—where the plants are allowed to go to seed—year after year, and thi sself-seeding in the meadow or the pasture goes on successfully where careful seeding in the well-tilled field often fails. In fact, we have often seen clover sown on the wild prairie, when pastured closely with cattle or sheep, make a perfect stand while it almost completely failed when sown on spring grain, on improved land adjoining, in the best possible condition for the growth of the cereals. Why it is, we shall see when we come to speak more particularly of the conditions of light and moisture.

Nor is there any difficulty in growing these clovers on account of temperature. The season attends to that. The success or failure in growing clover depends on skill in regulating the mechanical condition so as to secure light and moisture.

The reader may learn much on this subject by examining the germination of clover seeds in an old stack of clover hay in May and June. He will find that on the outside, no matter how abundant the seed, it does not germinate, for the reason that while it has light and heat, it has no moisture. By lifting up the edge of the hay he will find that a certain distance inward it germinates freely, but beyond that a certain distance it does not germinate at all, simply because the proper combination of light, heat and moisture is not present. Success lies in getting the light and moisture in the soil in the combination supplied in the stack at the point where the germination is perfect. Given, then, almost any kind of soil that will produce a moderate crop of spring grain of any kind, how shall we secure a stand of clover that will hold against possible drouth for the first ninety days? This is the point to be considered in determining the very first question in growing these clovers,• the depth at which they shall be covered. After the first ninety days they are safe against anything except the extreme drouths. We are satisfied that nine-tenths of the failures in growing clover, about which we hear so much, and especially on the lighter soils of the West, depend upon the lack of proper covering in order to secure the conditions requisite for vigorous germination and the support of the life of the plant during the first three months of its existence. The management will, of course, depend upon the kind of grain crop in the soil. If it is intended to grow on land already in winter wheat and rye, the custom of sowing early in March can not well be improved. No matter how early it may be sown, it will not germinate until the season gives the right temperature. The freezing and thawing of the ground gradually imbeds the seed in the soil and growth is all the quicker because of the shallowness of the covering. Beginning at the commencement of the growing season, it is able to strike its roots deep in the soil and to stand any probable drouth in the earlier part of the year. Success will be all the more certain if the nurse crop is rye, for the reason that the narrow blades of the rye give the young clover plant plenty of air and sunshine. There are few soils and few seasons in any country, in which clover growing is practicable, in which a fine stand of clover can not be obtained by sowing on rye in March, and then pasturing off the crop with sheep, hogs or cattle. The best success is obtained by pasturing with the two former, and, if cattle are used, the lighter they are the better. Some little damage will be done the clover by tramping with heavy cattle, especially in wet weather, but we have found by experience that the advantages in securing the more perfect covering of the seed by treading are much greater than the disadvantages. Clover sometimes fails of a stand when sown on winter wheat, for the reason that a crust is likely to form on the top, especially if the month of March be dry, and the ground deficient in moisture and the seeds therefore do not become sufficiently imbedded. This may be remedied to a very great extent by harrowing the ground after the clover has been sown. In this way sufficient covering can be secured and the benefits to the wheat will far more than compensate for the labor. Success would be all the more certain if in a dry time a heavy roller were used, thus compressing the soil around the roots of the wheat as well as the seeds of the clover. It requires, however, a good deal of sound judgment and discretion to use the roller in a country subject to high winds.

When sown with spring grain, the problem is much more difficult. The season is necessarily later and care must be taken at all hazards to bury the clover deep enough to secure moisture, and not too deep to exclude light. Just how deep clover should be covered is a problem that can be determined only by the farmer himself. Everything depends upon the season and upon the nature of the soil. The lighter the soil and the drier the season the deeper must the seed be covered. Untold damage has been done to the clover interests of the Western states by the publication in works that are regarded as standard authority, and copied into the agricultural newspapers, of the depths at which clover germinates best and refuses to germinate. Prof. Flint in his work on *Grasses and Forage Plants*, quoting from a treatise on grass by the Messrs. Lawson, the noted seedsmen of Edinburgh, states that the red clover germinates best at a depth of from nothing to one-half inch; that half the seeds germinate from one and one-quarter to one and one-half, and that none of the seeds germinate when covered to the depth of two inches. This is no doubt true for the climate and soil of Edinburgh, and to some extent true in the moister climate of the Eastern states, but it is entirely misleading and false on the light soils and drier climate of the West. Acting upon this advice Western farmers have adopted the methods of surface sowing common in Europe and in the Eastern states and have been grievously disappointed. Clover sown on our own farms by this method has failed to germinate the first year, and sometimes the second, coming up as a full crop in the third year where the ground has been undisturbed, and that for the simple reason that the supply of moisture was deficient, for the lack of sufficient covering in dry seasons. The clover simply waited until there was sufficient moisture to secure germination. Mr. Jethro Tull, an English gentleman who wrote a book on Horse-Hoeing Husbandry, published in 1731, has a paragraph which incidentally refers to the depth of covering, which is worth quoting. Speaking of his experience in drilling plants in rows for the purpose of using the horse-hoe, he says: "I was formerly at much pains and at some charge in improving my drills in planting the rows at very near distances and had brought them to such perfection that one horse would draw a drill with eleven shares, making the rows at three and one-half inches distant from one another, and at the same time sow in them three different sorts of seeds which did not mix and these, too, at different depths. As the barley rows were seven inches asunder, the barley lay four inches deep. A little more than three inches above that in the same channels was clover; betwixt every two of these rows was a row of sanfoin covered one-half inch deep. I had a good crop of barley the first year; the next year two crops of broad clover, where that was sown; and where hop clover was sown, a mixed crop of that and sanfoin, but I am since, by experience, so fully convinced of the folly of these or any other mixed crops, and more especially of narrow spaces, that I have demolished these instruments in their full perfection, as a vain curiosity, the drift and use of them being contrary to the true principles and practice of horse hoeing."

It will be seen from the above that even in the moist climate of England clover succeeded well when covered almost an inch deep, and the practice was abundant, not on account of the failure to grow clover but because the narrow spaces between the drills of the different seeds did not allow the practical operation of the horse-hoe. In view of the importance of this question at the present time in the Western states, we requested Prof. Wilson, of the Iowa Experiment Station, at Ames, Iowa, to determine the depth at which clover grew best in the light soil of the College farm. He has kindly furnished us the results of this experiment, as follows:

"The College Experiment Station sowed red clover at different depths in the spring of 1892, to ascertain the effect on germination. The spring was late, owing to repeated rains that prevented seeding. The land used is a dark, sandy loam that had been in barley the previous year, and had been fall-plowed. Plots a rod square were used and the seeding was done on the ninth of April. A plot was sowed broadcast on the surface and raked in. A plot was sown in drills one inch deep. A plot was sown in drills two inches deep, and one three inches deep. The seed sown broadcast was above the ground and a good stand April 25th; that sown an inch deep was also a good stand April 25th; that sown two inches deep was through the ground only partly on the 25th of April, while that sown three inches deep was as good a stand as any on the 27th of April.

The season was favorable to germination and growth of grass seeds. Rains were abundant during both spring and summer. On July 20th the four different plots were very similar, being about eight inches high and ready to cut for hay. That sown three inches deep was the most vigorous of any. The plots were hoed between the rows and kept free from weeds. Several other grasses were sown simultaneously with the clover that showed quite different results, but depth of sowing in this case raises no decisive objection to any of the depths at which the seeds were sown.

It may be well to state that the soil used is entirely free from any trace of clay, consequently it does not pack as much as some lands in the state, while it is not as loose a soil as the bluff deposit of the Missouri slope. Repeated experiments must be made to determine the effect of different depths of sowing in dry seasons. The indications so far, with the wettest season for some years, are that clover seed germinates as promptly at a depth of three inches as at a depth of one inch where the frost is out of the ground and the temperature is the same, and further, that there is no evident weakening of the young plants when the seed is sown three inches deep.

Contemporaneous with the foregoing it may be observed that the station sowed peas from three to five inches deep, and while the latter sowing was longer in coming up, yet at this writing, July 15th, there is no apparent difference in the vigor of the sowings."

For two years past we have called attention of the farmers of the West through the *Homestead* to this important matter, and their experience as reported from time to time largely pletely verifies the results of the experiment above quoted. The most successful clover growers in the West, and especially in the light soils of the Missouri valley, sow their clover with their spring grain and give it the same depth of covering. The almost universal custom is to cover either with the ordinary corn cultivator or with the disc cultivator, which in farm practice would give clover a covering of from one-fourth of an inch to two inches. The results of their experience, however, are not uniform, the failures being the exception, and success the rule. As an example of the very rare exceptions we give the following from Mr. George Geary, of Winterset, Iowa. In response to a letter of inquiry Mr. Geary writes:

"In the spring of 1892 I sowed a field to clover about ten days before sowing the oats. The oats were sown about the 3rd or 4th of April. It was disced twice, after the oats were sown and then harrowed twice. I can not tell how deep it was covered. The oats, however, all grew and none of the clover except at the head-lands, which were not so well cultivated, where a few plants appeared. On the head-lands the clover was not sown until after the discing was done. It was then harrowed and floated. After giving the matter full consideration I think the trouble was not in the deep covering, but because the clover sod had sprouted before the ground was cultivated, and this cultivation destroyed it. If this were not the case, some of it would have grown, no matter how deeply it was covered."

It is therefore extremely doubtful whether even in this case the failure of the stand in this field was due to the deep covering or to the fact that the clover had sprouted and was then destroyed by the tillage. It should be stated in this connection that many farmers who harrow in clover in corn stalks sow the clover seed a week or two in advance, and where the covering is not so deep as that practiced by Mr. Geary they have had good success. The advantage in sowing in advance is that it gives the clover time to take up moisture and swell and secures a quicker germination than when sowed with the oats or spring grain. In case of dry weather at the time of cultivation, it might prove hazardous.

Mr. Geary's farm lies on the edge of the timber and is, therefore, a much heavier soil than the prairie lands in the immediate vicinity. Besides, it rests on a very heavy bed of limestone, and the conditions of that farm are somewhat similar to the conditions on the heavy clay soils of the Eastern states. It is not, therefore, surprising that deep covering does not always succeed on that or like conditions even in the West. All this emphasizes the necessity of each farmer, no matter where his location may be, determining by actual experiment on his own farm the depth at which clover seed germinates best in an ordinary season. This will vary with the normal amount of rainfall in the spring months and the mechanical condition and character of the soil. The lighter the soil the deeper should clover be covered, and there are many parts of the West in which it should not be placed at less than two inches.

It must be remembered that in discussing the depths of covering at which clover does best, we are speaking solely with reference to land in cultivation in small grain, and not with reference to land in other grasses, whether wild or tame. A moment's reflection will convince anyone that deeper covering is required in soil in condition for the reception of small grains than in soil that is already compacted by the weather. For this reason clover requires a much shallower covering when sown on winter wheat or rye than when sown on newly cultivated land, on which spring grain has been sown.

We have devoted much space to the depth at which red and mammoth clover should be covered when sown with spring grain, for the reason that the proper depth of covering is one of the first conditions of success, and we are persuaded that most failures in growing these clovers have been due to the fact that farmers have not fully comprehended the first principles, and thus have failed to apply them to their particular conditions and circumstances.

Whether common red or mammoth clover should be selected for sowing depends altogether upon the rotation of crops that he has adopted and the objects for which the clover is grown. On good, rich land, where a crop of hay is desired, and where fall pasture is an important consideration, the common red is to be preferred. This is especially the case in regions where there are no insect enemies, such as the clover-root worm, the clover midge, the thrips or the clover hay worm. In the absence of these pests, if it is desirable to secure a crop of clover hay and the question of seed is less important than an abundant aftermath, we advise in every case to select the common red, as there are probably two or three varieties, different in the color of the blossom, in size and in maturity, and it would not be difficult by selection to develop a variety with pure, white blossoms, another with deep red and still others with minor shades, and with essential differences in growth and in the time of maturity. Possibly in the near future this may be done. These differences would seem to indicate that the mammoth was the original type, and that the different varieties of common red are simply variations from this type, the effect of soil and climate, or in other words, of environment.

As stated in a previous chapter, we regard the mammoth simply as a late-maturing variety of the red, and not a different species. The differences between them were regarded by Linnaeus as sufficient to justify a different classification, and he styled the common red, *trifolium pratense* and the mammoth *trifolium medium*. According to Prof. W. J. Beal, of the Chair of Botany in the Michigan Agricultural College, in his standard work on the grasses, page 346, the two species freely cross, and show all grades of intermediate forms. This would indicate that the distinctions are not so great as to justify the earlier classification. We have, therefore, in this work, where minute scientific accuracy is not the aim except in so far as it seems essential to the practical guidance of the farmer, treated them as different forms of one species, without presuming to settle the question as to whether the distinction heretofore made is scientifically correct or not. The original differences may be seen by comparing the illustrations on pages 28 and 29, as taken from Sudlow. It might, however, be somewhat difficult to find in any field o mixed Mammoth and common red clover two plants that vary quite as widely as the two illustrations.

On farms where the main object in growing clover is to increase fertility, where it is not essential to secure a crop of hay from every seeding of clover, and where it is desired to procure a reasonably certain crop of seed *as a money crop*, the mammoth should be preferred. The *mammoth may* also be used with advantage on thin soils, and *especially* at their first seeding, for the reason that on these soils it does not develop, to the same extent at least, the objection that is urged against it where on ordinary soils a hay crop is to be secured. This objection is that it grows so rank and lodges so early that the lower foot or eighteen inches of the stock becomes black and entirely void of leaves and that the stalk is so coarse that it is difficult to cure and is largely rejected by live stock. These objections do not apply where it is not desirable to secure a hay crop. Many farmers are so situated that they prefer to grow both in separate fields, the medium red for hay, aftermath and fertility, and the mammoth for securing with reasonable certainty a crop of seed. In this case they sow timothy with the mammoth and cut the first crop for seed, sometimes mowing or pasturing it off until the first weeks of June for the purpose of getting rid of the lower foot of the stalk and also for the purpose of securing more abundant stooling. A crop of seed is then taken about the 1st of September and the aftermath of timothy and clover is allowed to grow for the purpose of pasture. About two-thirds of the stalks of the mammoth clover die out the year after sowing, and the result is usually a very heavy crop the next year, about two-thirds timothy and one-third clover. The clover being at its best at the same time as the timothy, the crop of hay resulting is of a very fine quality, and comes in at a time when the best conditions are usually present for curing it in its best estate. It is very important, however, when growing timothy for seed to secure seed free from admixture with the common red and to sow it on soil not self-seeded with the latter variety.

In sections of the country where the insect enemies of clover are abundant it is advisable to discontinue the growth of common red for a time and take the mammoth in preference, with all its disadvantages. All the insect pests with which we are acquainted that infest the blossoms of clover, produce two broods in the season, the first at the time of the first bloom of red clover, and the second at the time of the second bloom. By using the mammoth the fly of these pests has no opportunity to deposit its eggs, and hence no second crop is possible on that field. This is likely to be a very important consideration in the West when the growth of clover is fully established.

While the mammoth is far inferior to the medium red as a hay crop, and therefore we do not advise its cultivation where a hay crop is the main object, it has very important advantages to the farmer who has exhausted the fertility of his land by long years of cultivation in wheat, corn, oats or *flax*, and who is not in shape either to buy live stock or to provide the shelter necessary to keep them at a profit. In such cases as this we advise the sowing of mammoth clover with every crop of spring grain, even though it be the intention to plow it up the succeeding year. The seed crop of mammoth clover is about as certain as any other farm crop, while the seed crop of the common red is one of the most precarious of crops, unless the first cutting be made at the right time. It is reasonably certain when the first crop is cut the last ten days of June. Under Western conditions this is not always, nor indeed usually, possible. It is also liable to be greatly injured by an early frost.

These objections do not apply to the mammoth which matures its seed crop about the 1st of September in the latitude of Central Iowa and Nebraska, and, owing to the high temperature of the season, can be cured rapidly and threshed easily. The yield is from two to six bushels per acre, which at present prices is equal as a cash crop to any other. The farmer, therefore, can by the use of mammoth clover restore the fertility of the soil for the time being without incurring the expense of investing in cattle, fences or barns, and to him it is invaluable. Where the object is pasturage, we would prefer sowing mixed seed in about equal proportions for the obvious reason that, plants being at their best about the period of bloom, the season of continuous bloom is prolonged, mammoth clover coming in bloom two or three weeks later than the common red. By using this method there can be a constant succession of clover bloom from May until frost. Keeping in mind these two peculiarities of the two different varieties, the reader will be able to determine for himself which is best adapted to the soil, climate and the character of his farm operations.

The question of the amount of seed per acre whether alone or mixed with each other, or with other grass seeds and the best method of sowing will be discussed fully in a subsequent chapter.

COMMON RED CLOVER. (*Trifolium pretense.*)

MAMMOTH CLOVER. (*Trifolium medium.*)

ALFALFA.

CHAPTER IV.

While the red and mammoth clovers are justly regarded as the sheet anchor of the farmer in the sections of country to which they are adapted, there is a point westward where, by reason of deficient rainfall, their cultivation ceases to be practicable or profitable. There is also a southern limit beyond which, by reason of the deficiency of lime in the soil and of the long continued summer heat, they cease to be reliable. We have before noted—so important does she seem to consider the clover family to the welfare of the race—that Nature provides some member of the family to meet the wants of almost every soil and climate adapted to either tillage or pasturage. This want is met to a very great extent, on the Pacific coast of America, in the mountain valleys, on the great plains, and on the Southern and along the Eastern Atlantic coasts round to where it meets the red clover, by the alfalfa. While not belonging to the same species as the ordinary clovers, it has the same general characteristics and economic values. It has the same three-cleft leaf and characteristic pea blossom, as will be seen by the illustration on the following page, the same power of assimilating nitrogen from the atmosphere, an even higher ratio of albuminoids to carbohydrates and therefore a similar feeding value. It is not a *trifolium* but a *medicago* and belongs to the same class as the bur clover of California and the western plains.

In its origin it antedates history. It has been traced back to the ancient kingdoms of Media and Persia and we have no doubt that when Nebuchednezzar was testing the value on Daniel and his companions of the legumes or "pulse," as food for young statesmen, alfalfa was growing luxuriantly on the royal farms on the banks of the rivers of Babylon. It was

ALFALFA. (*Medicago sativa.*)

brought to Greece during the Persian war about 470 B. C., thence to Italy; and it naturally followed the march of the all-conquering legions to France, Spain and Portugal. The Spaniards brought it with them to the new world and it soon became established along the La Plata and in Chili in South America, whence it was brought to California. Its very great value under irrigation having been recognized, it soon became established in the mountain valleys and on the plains. Of late years farmers are beginning to recognize its value as a substitute for clover on lands that are not susceptible of irrigation, and now it may almost be regarded as a maxim that where clover ends alfalfa begins, limited only in the practical application of the maxim to soils that have a sub-soil suitable for alfalfa.

Alfalfa has travelled under various names. While its botanical name is *medicago sativa* it is knownin European countries as "lucerne," from the city of Lucerne, in Switzerland, where it is largely cultivated. The Spaniard named it alfalfa, a name said to be of Arabic origin and this name has naturally followed the plant to the new world. It has some striking peculiarities, one that its stalk is very small in proportion to its root, the former growing under favorable conditions about two feet in length, the latter measured only by the distance to water. It may be anything from five feet to twenty feet.

It has been used for so many ages for the specific purpose of a meadow and forage plant that it does not adapt itself readily to pasturage, and in order to secure the best results, requires to be cut as a hay crop whether it be long or short, about the time one fourth of the flowers are in bloom, otherwise the stalk becomes woody and the value is very greatly reduced. It need scarcely be said that a grass cut with such an excess of sap is difficult to cure in a climate of great summer rainfall, and for this and many other reasons is not adapted to the soil and climate where clovers can be grown successfully. This difficulty of curing the hay is not the only obstacle in the way of its adoption by farmers who can grow the other clovers to perfection. It must have room to stretch out its roots and hence will not succeed on lands where the moisture is near the surface, for the same reason it will not succeed on lands that have a subsoil of heavy, impervious clay or are underlaid with rock. Requiring several years to attain its maxim of usefulness, it does not fit readily into the rotations especially the short ones which are so essential to diversified agriculture and of which the red and mammoth clovers are so integral and essential a part. It cannot endure cold winters in soils saturated with water or covered with ice during the winter season, and hence, while having a wider range than the ordinary clovers, it is almost as rigidly excluded from their domain as they are from the domain of alfalfa.

Alfalfa then has two leading uses, one, and the main one as a forage crop in the regions where irrigation is possible, and the other as a substitute for the ordinary clovers where they fail from lack of summer moisture. It is the peculiarity of arid soils and to a certain extent of the semi-arid, that the conditions under which they are deposited prevent the formation of heavy clays, thus removing one of the main obstacles to the growth of alfalfa. These soils have also comparatively rainless summers and therefore provide the conditions for curing with dispatch this clover which seems to have been designed especially for their benefit. The discussion of the growing of alfalfa naturally divides itself into two parts, its culture under irrigation and its culture as a substitute for other clovers, on soils and in climates where irrigation is not practicable and where the latter are not a reliable crop.

When it is remembered that over more than one third of the United States perennial grasses can be grown only by irrigation the importance of the position sustained by alfalfa will be readily recognized. It will grow steadily in popular favor when irrigated lands lose their virgin fertility, as they will in time, and when therefore it becomes necessary to find some method of restoring the wastes of the soil robber. The farmer on the plains and mountain valleys and on the Pacific coast will then be compelled to call on alfalfa to do for him what red clover does for the farmer in the Eastern states and on the prairies.

In the Pacific states and in the mountain valleys it is possible, by irrigation, to produce, on suitable land, from ten to fifteen tons of alfalfa hay per annum. This alfalfa hay has a higher feeding value than that made from any other known grass grown in the United States. This immense yield is secured in the southern sections by four or five cuttings during the season; the first crop is taken off early, the land being flooded immediately afterward and soaked to the depth of several feet. The alfalfa then grows with wonderful vigor and in a few weeks is ready to cut again, the extreme dryness of the atmosphere and freedom from summer rains rendering it possible to handle the crop and secure it in the best condition at almost any time during the season. In the more northern sections, fewer cuttings are possible and of course the yield is less per acre. The hay crop is taken when the plant is just coming into bloom and before the stems have been converted to woody fiber, to a great extent indigestible. When a seed crop is desired one of the latter growths is allowed to ripen, the yield sometimes reaching as high as ten bushels per acre.

While alfalfa is in the main a forage crop and its principle use that of a permanent meadow, it can be pastured with safety after it has become well established and its roots have penetrated to great depths. It is largely used in this way in connection with the ranches of the mountain states, furnishing, as it does by its last growth, a means of ripening the vast herds of cattle that have been carried through the summer on the wild grasses of the ranges. It has proven equally valuable on the great plains wherever there are suitable facilities for irrigation, or where by reason of the nature of the subsoil the roots can reach down in a year or two to permanent moisture. It is not at all uncommon, in regions where the sheet water or the underflow of the rivers of the plains, such as the Arkansas or the Platte, is within reach, to find alfalfa flourishing without irrigation after the second or third year, or, in other words, after the roots have reached a permanent supply of water.

In sowing alfalfa for cultivation under irrigation the soil must be well prepared. Alfalfa tolerates no slovenly culture. There being no heavy clays in this region and the under soil being, to a very great depth, as rich as the upper, this is a comparatively easy matter. The seed is usually sown broadcast at the rate of from fifteen to twenty pounds per acre and covered sufficiently to insure germination.

Should weeds threaten to smother the young plants they should be clipped, setting the mower high, and in this way the plants are allowed free access to air and sunlight. In order to prevent weed growth, alfalfa is sometimes sown in drills twelve or fifteen inches apart, and cultivated until permanently established. This is the English method of alfalfa culture.

A stand once secured, it lasts for many years with proper care and management. It must not however be either mowed or pastured until it has become well established. Sometimes, under very favorable conditions, one or two crops can be taken the year it is sown and the second season three, but it is better to allow, as in the case of the other clovers, a good start before making any demands on the crop. While alfalfa, like all the clovers, is a fertilizing crop and increases the supply of nitrogen in the soil, while at the same time producing an enormous quantity in the forage, it is not a suitable crop for poor, wornout land. It requires good land to start with. Arid and semi-arid soils nearly all have abundant fertility, (owing to the fact that they have not been subject to the leaching process, so far as nitrogen is concerned, inseparable from a sufficient annual rainfall,) to secure vigorous plant life, and therefore the main consideration is a proper mechanical condition of the soil and an abundant artificial supply of moisture. In soils that are not capable of irrigation the growth must be rapid in order that the roots may speedily reach permanent moisture and for this reason the land must be in good heart.

It is easy to see from the above statements what a veritable godsend alfalfa has been to the arid regions of America. When the irrigated wheat lands have lost their virgin fertility, which is only a question of time, its culture will be greatly extended. It will then be used as a rotation grass, as well as a source of hay and pasture, the rotation being of necessity a long one, on account of the number of years required to secure a crop that will give the best results.

Of late years farmers in the semi-arid regions are begining to realize the value of alfalfa as a substitute for the clovers usually grown on regions of sufficient permanent rainfall. It is not easy to locate on the map what, for the purpose of this work, should be called the semi-arid region, using the term as we do to describe the region west of the Missouri where the ordinary clovers cannot be grown as a reasonably reliable crop. We have in view that large region east of the Rocky Mountains where the methods of farming followed over the greater part of the Mississippi Valley, as for instance in the states of Iowa, Missouri, Minnesota and the eastern portions of Kansas and Nebraska, cannot be followed with success. This region may be said to be approximately bounded on the east by a line which, on the southern border of Kansas, begins near the 98th meridian of longitude west from Greenwich, and passing thence west of north crosses the Nebraska line near the 100 meridian and continuing in the same direction some seventy-five miles into that state, it changes a little to the east of north and thence extends into the Dakotas. In this region the limitations as to what crops can and what cannot be grown successfully, whether of grain or grass, have not been fully determined. It is quite clear that corn cannot be depended upon as a paying crop, and the same is true, as a rule, of the clovers and other grasses grown farther east. The experience of farmers has already determined their unprofitableness except in certain favored localities.

With these important crops stricken from the list, the entire aspect of farming changes. Other crops suited to the climatic conditions must be found, and even the methods of work to which the farmer has been accustomed in other localities and under other conditions, materially changed. There is no plant that gives promise of greater usefulness to the farmers of that region than alfalfa, and with a view to giving our readers the most reliable information on the subject we have requested Prof. Georgeson, of the Kansas Agricultural College, to contribute to these pages the results of his valuable experience and observation, which he has kindly consented to do in the following:

As has been noted elsewhere, alfalfa is a perennial plant. It sends its roots deep into the ground, and once established in a suitable soil, it will yield profitable crops for an indefinite number of years. Because of its deep rooting nature, it is less dependent upon the rainfall than almost any other farm crop. Its wonderful roots, which in some instances have been traced thirty feet deep, reaching down far below the influence of local showers and the solar heat, and pumping up moisture from below, sustain the plant in periods of drouth. This feature is greatly in favor of alfalfa for that region But what is more to the point, it has been proved to be a success both with and without irrigation in this semi-arid region—with irrigation producing magnificent yields, and on the uplands without irrigation, producing an occasional good crop of hay, and at all times better pasture than the native grasses afford. In Kansas there are instance of its successful culture in nearly every one of the western counties. Particularly is this the case in Ford and Finney counties, where efforts in this direction have been more persistent than elsewhere. Along the Arkansas valley in these counties it grows to perfection.

The prospect of alfalfa growing in the West may be studied under three conditions. First, under irrigation. This aspect of the case requires but little notice here. With irrigation, whether on upland or lowland, it is one of the surest as well as one of the most profitable crops that can be raised, and its successful culture is not at all problematical.

Second, on the lowlands without irrigation. Under this condition it is also grown successfully, as is testified by thousands of acres now in alfalfa in western Kansas. But the success, that is, the yield, varies with the situation. A very large proportion of the bottom lands in that region have a porous, sandy subsoil, through which the water of the streams percolate with ease for long distances, forming what is known as "sheet water." This water is, in some places, very near the surface, in others it is ten, twelve, or more feet below. On such lands, where the roots penetrate with ease to the water, alfalfa is successfully grown without irrigation.

Third, on uplands and without irrigation. It is especially this aspect of the case that commands our attention, because, at best, but a small fraction of the country is made up of valley lands of the above character.

There are a hundred acres of dry upland to one of bottom land. Land that is in itself very fertile, with a beautiful, gently undulating surface, but which is hopelessly beyond the reach of any system of irrigation, and which owing to the dry climate with an average rain fall of less than twenty inches, cannot be cultivated as farms are cultivated further east. Can alfalfa be grown here? The answer is a qualified affirmative. Actual trials in many places have demonstrated that alfalfa can be grown on these dry uplands, but the yield in forage is not to be compared with the yield in the lowlands. In the first place, the obtaining of a good stand is attended with more difficulties. If the rain in the early part of May is sufficient only to germinate the seed, but not enough to sustain the young plants till they get a foot hold, the stand will be light, and at times it may require two or more seedings before the crop is well launched. Again, the growth the first year is feeble, and nothing, either in the way of pasture or hay, can reasonably be expected from it the first season; no pasture, because it would kill the crop to turn the stock on it, and no hay because the growth is too light. The second, third and succeeding years it will yield increasingly good pasture, but it is only in favorable seasons that it will produce fair hay crops. Under the conditions named it is, however, a great thing for the plant to live and yield pasturage, for as pasturage it far exceeds the wild grasses both in quantity and quality. There is no better pasture for horses, hogs and sheep, nor indeed for cattle, except that it sometimes causes them to bloat. This upland alfalfa has one other good feature—it yields seed of superior quality, even though only in moderate quantity. Combining these features—good pasture, an occasional hay crop and a sure producer of good seed—and add to this its manurial properties, which, as we shall see, is by no means its least virtue, we have in alfalfa a better forage plant for the western plains than any other perennial that has yet been brought to our notice.

The claims here made are moderate. Oftentimes it will exceed the results here promised. In favorable seasons the crop may be started with ease even on the unbroken prairie. The Hon. R. P. Kelly, of Eureka, Kansas, who is a close observer and an accomplished scientist, informs me that he has seen a case in point which is worth noting here. On a large ranch in Meade county, about three hundred acres of creek bottom were sown to alfalfa. It grew well and yielded abundantly. On one occasion the crop was cut late, part of it having matured seed. This hay was fed to a large herd of cattle during the fall and winter, and for that purpose was spread over quite a large area of the adjoining slopes and upland. To the surprise of the owners, as well as to all others who subsequently saw it, the seed thus scattered on the prairie sod took root the following spring and made a good and permanent stand of alfalfa. Another almost identical case happened in another place and has been related to me by the owner of the pasture. If such accidents lead to success, what is to hinder the same results being attained with the judicious use of proper implements and a good supply of seed?

There are places where alfalfa cannot grow, regardless of climate. Wherever there is an impervious clay, the so called "gumbo," or a layer of hardpan, or rock within a few feet of the surface, it will be a total failure if on the uplands, and but a very indifferent success on the bottom lands. Likewise on the bottom lands, where the soil water stands too near the surface, or where it is overflowed for considerable periods, alfalfa should not be sown.

For successful seeding prepare a good seed bed by whatever means may be found most expedient In most cases I should prefer to plow in the fall; or, in sections of light soil with dry and windy winters, early in spring. Pulverize the surface well, and do not sow the seed in this elevated western region until the latter part of April, or the beginning of May. Late frosts are liable to occur here, and these sometimes nip the young plants severely if they germinate too early. On the uplands I would sow not less than twenty-five pounds of seed to the acre, and on the low lands, twenty pounds. Sow broadcast, either by hand, or with a grass seed attachment to a drill or disc harrow. Cover the seed well with some implement that suits the nature of the soil. If sown by hand the disc harrow, run shallow, will afford the best covering; then apply a heavy roller. On the uplands it should always be sown by itself. If sown with oats, barley, or the like, the young plants are apt to be killed by exposure to the sun after the "nurse crop" has been removed. On irrigated land there is but little danger of this kind, and the seed is generally sown with some spring crop. I prefer, in all cases, to sow broadcast. When young or newly cut the ground is not then so exposed to the scorching sun as when it stands in rows.

The first year is always the most precarious period. No stock should ever be allowed on it that year and care should be taken that it is not choked out by weeds. To kill these run over the ground two or three times with the mower during the season and set the finger-bar high, especially the first time, to avoid injuring the young plants. On the uplands a second year of this treatment may occasionally be necessary. When pastured, care should be taken that it is not over-stocked; for, if in addition to a drouth and a weary search for water on the part of the roots, it is kept grazed to the ground, the crop will be brought to an untimely end. It makes one of the best pastures for hogs imaginable, but for the good of the crop they should not be put on till it is thoroughly established. They should be prevented from rooting by ringing their noses and they should not be kept on long enough at a time to injure it.

For hay the crop should be cut every time it comes in bloom, no matter what its height may be. It does not grow any taller after it begins to bloom, and if allowed to go to seed it will drop its leaves, and, moreover, will make little or no growth after that for the rest of the year. Cut it when about one-fourth in bloom. The hay is very brittle, and the leaves, the best part of it, break off easily in handling. To diminish this waste it must be cured with care. The best practice is to rake in the afternoon what has been cut in the forenoon, put it into good sized cocks and let it cure there thoroughly before it is stacked. If the crop is light and the sun strong, the rake may follow soon after the mower. If dried too much in the swath, there will be little besides the dry stalks left when the crop is raked. To keep alfalfa hay well the stack must be covered, or it must be housed. It does not shed rain well and a single soaking rain will cause it to mould and spoil. Growers of alfalfa in western Kansas prefer, for these reasons, to dispose of the crop as soon as possible after it is secured. It sells usually in the towns to local consumers for about $3.00 a ton. Some of it is baled and shipped to other points, but the frieght rates are so high as to make this impracticable, unless it can be sold to unusual advantage. On low lands, or when under irrigation, the fields are usually cut three times and sometimes four during the season. It is a usual practice to take two crops of hay and to let the third crop go to seed. Sometimes, however, an early frost will catch this crop before the seed matures, and, of course, blast the prospects of seed. So, to make it sure, the second crop is often taken for seed. The seed can be threshed and cleaned on an ordinary separator. The yield on the bottom lands is reported to have fallen off in late years. When first started the alfalfa crop frequently yielded from ten to twelve bushels of seed to the acre; now it is said to average only between five and seven bushels. This is for the vicinity of Garden City. On the uplands the yield is nearly as good. There is a large demand for the seed from seedmen and it sells at from $3.50 to $4.00 per bushel, and these prices are likely to remain stationary for some years to come until the supply has been largely increased. At present the increase in demand is equal to the increase in production.

As regards its nutritive qualities there are but few other plants that can compare with alfafa. Red clover is the best known and most universal leguminous crop. For the sake of comparison I quote the following analyses of the two from Wolf's tables. The figures refer to the digestible nutrients in each case:

	Red clover. Quality very good.		Alfalfa. Quality very good.	
	Hay.	Green. In blossom.	Hay.	Green. In blossom.
Crude Protein	8 5	1.7	12.3	3.2
Carbohydrates	38.2	8.8	31.4	8.1
Fat	1.7	0.4	1.0	0 3
Nutritive ratio	5	5.7	2.8	3.1

It will be here seen that alfalfa, either as hay or green, contains more of the most valuable nutrient (protein) than red clover, and the nutritive ratio indicates that it is nearly as narrow. The figures speak for themselves. Further argument on that point is unnecessary.*

What place, then, can alfalfa take in western farming? It is grown with excellent success on the bottom lands and under irrigation. It can be grown, and is grown, with comparative success on the uplands. But this is not all. As a fertilizing agent of the soil it is fully equal, if not superior, to red clover. It is a nitrogen gatherer of the first magnitude, and its habit of growth renders it peculiarly efficient as a renovator and enricher of the soil. The long roots draw up ash elements from depths where no other crops could feed, and store them until, by their decay, they again give them up to succeeding crops. By their penetration into the subsoil it is on their decay rendered more porous; it is aereated more perfectly than by other crops; the water will drain through the soil better for the openings they leave and thus store more water below which can again be raised more easily through the capillaries they have formed. These are all beneficial features.

Alfalfa, however, has some drawbacks. Owing to the fact that it takes so long to develop its full powers it can never take the place in a short rotation that clover occupies farther east. For that purpose we must look to some other leguminous crop which can thrive in that region, and it seems probable that the soy bean will meet the want. But alfalfa can be used in a longer rotation. If it is allowed to stand five years and then plowed under, it will have served for pasture or meadow at least three or four years and at the same time will have developed a large root growth for the benefit of the soil. Many would hesitate to break up a good alfalfa field, but by breaking up a portion and seeding an equal portion every year the acreage could be maintained, and there would be no loss of feed. I should consider this the safest practice. It will not do to allow the soil to lose fertility. Our western farmers must resort to renovating crops of some kind, and, used in this manner, alfalfa will answer the purpose. If, in the course of a few years, farmers in the section of country above described, find themselves tilling an exhausted soil in addition to the precarious circumstances which now mark the situation, their lot will

* It should be remembered, however, that it is customary to cut alfalfa when one-fourth in bloom, while red clover is usually cut for hay after it is full bloom and one-third or more of the heads have turned brown. It should also be remembered that the relative supply of protein decreases rapidly in all plants after blooming has commenced. Unless these facts are borne in mind the above comparison is in danger of misleading.—*The Author.*

be hard indeed. But this need not happen. They have already discovered that land which has been in alfalfa far out yields adjoining land of equal original fertility. And I already hear of instances where comparatively young alfalfa fields are broken up to be followed with wheat because of the increased yields they afford. This is right and should be encouraged. While permanent and exclusive stock farms with alfalfa the main if not the only crop will of course be numerous, and while stock raising must always be a prominent feature of agriculture in that region, the vast majority of the farmers must engage more or less in mixed husbandry. They must grow wheat, barley, oats, Kaffir corn and such other crops as will prove to be certain and profitable, and this system leads to certain exhaustion of the soil and consequent ruin of the farmers unless some renovating crop keeps up the balance of fertility. Eastward clover is that crop; in the West alfalfa can and doubtless will take the same function, if not exactly in the same manner at least with the same result.

The above from Prof. Georgeson so completely covers the ground in the territory and under the conditions indicated that every reader who knows the character of his soil and subsoil can determine with reasonable accuracy at once whether it will pay him to grow alfalfa. We have recently made a careful personal investigation of the conditions in the territory indicated, and our observations coincide with the conclusions of Prof. Georgeson in every particular. It is our object to make this work a reliable guide to the farmer in growing clovers best adapted to his own particular soil and climate; and for this reason we have supplemented our own studies and observations with the experience of other men who have made the growing of the clovers a matter of special study and experiment in the several sections of the West. We have no doubt that there are very considerable areas of country east and south of the district indicated in which it will pay to grow alfalfa without irrigation. In fact, subject to the conditions of subsoil indicated by Prof. Georgeson, we believe it may be regarded as a maxim that where clover ends, alfalfa begins. The Creator has made no mistake in providing leguminous plants for every country where he intended the farmer to prosper.

In traveling over Kansas and Nebraska for the special study of the problem of growing the clovers, we were impressed by the failures of many alfalfa growers because of the lack of reliable information as to the best methods of growing alfalfa, under their present conditions. With a view of giving the reader of the far West definite and reliable information on this point we requested Prof. C. L. Ingersoll, of the Nebraska State University to contribute to these pages the results of his wide observation and special studies on the subject of alfalfa under irrigation. Prof. Ingersoll has special qualifications for this work. He was for five years connected with the Colorado Experiment Station, and during these five years made alfalfa under irrigation a matter of special study and experiment. He has kindly consented to give the reader the benefit of his knowledge and experience. In the following pages he so completely covers the ground that the reader in this district, whether in Nebraska or the states further West, who carefully studies and follows his instructions, can scarcely be said to be experimenting with the plant:

The subject of alfalfa culture in the United States has received great impetus within the last fifteen or twenty years because of its peculiar adaptation to culture in the more arid regions, and the excellent results obtained. The plant itself is not a modern one, but has been cultivated for several centuries. It is perennial, and when once successfully established in a soil, will remain and grow vigorously for years. In this respect it is quite unlike its congener—the red clover, which usually lasts but two, or at most three years without reseeding. On this account the alfalfa is, therefore, of special value.

The plant has been known by the Spanish name, alfafa, rather than by its French name, lucern, because it has come to us by the way of South America and California, where, with a Spanish speaking population, it would naturally be called by its Spanish name. Its botanical name is *Medicago sativa*, and it is supposed to have been raised by the ancient Greeks and Romans to some extent, as long ago as the Christian era. Indeed the name *Medicago*, applying to the genus, is derived from the Greek word signifying forage or forage plant. Other persons have supposed that the name was derived from the Province of Media, where it was supposed to have been cultivated in early times. Some of the Roman writers have memtioned it in their writings. In its introduction into America, it seems first to have found its way into the countries of South America, where there is little rainfall and where irrigation has been practiced to some extent. From these countries and especially Chili, it has found its way into some parts of Mexico, and also into Southern California, from which place it has spread into the states and territories lying to the eastward and reaching as far as the Missouri river. Agriculture in these regions on account of the physical conditions occasioned by lack of rainfall, must be carried on almost exclusively by means of irrigation, and while varied crops could be grown successfully, it was with difficulty that good stands of grass or the ordinary clover could be obtained under this system. In alfalfa, then, those farmers seemed to have secured the plant with all the conditions necessary to supply them with forage. They found that it was a plant easily raised, provided proper care were used to put the soil in proper condition, that it grew thrifty, that it maintained its hold upon the fields, was strong and did not kill easily by winter exposure. They found that a given area would produce a much larger cutting of forage of good quality, than one set of grasses or ordinary clover. Although they were liable to be prejudiced against it because of the prevailing systems in the East, they soon found that alfalfa was valuable in flesh producing compounds, and that animals soon learned to love it and thrived upon it. They also found that it was an excellent milk producer, and that when fed to sheep it produced a good quality of wool. All of these things combined to induce farmers of this region to forego their former experiences, and to learn, as it were, the new agriculture, with alfalfa as *the* forage plant as the basis.

Alfalfa is adapted to all the soils found upon the slope of the mountains in the above mentioned region, such soils as a whole being made up of the disintegrated rocks of the region lying above them. In the erosion of the rocks, and in the distribution of the material we find considerable variation, for, in the first place, the rocks vary somewhat in character and hardness.

It is not usual to sow this crop upon prairie land broken for the first time, although this is sometimes done. The best results are usually attained when the land has been cultivated in two or three crops, such as wheat, barley or oats, and then to have the land well prepared the following spring for the seed bed. In ordinary cases we are to suppose a depth of plowing varying from five to seven inches. Great depth of plowing, however, is non-essential, as the roots of the plant penetrate in ordinary soils to many feet in depth, the plant having one well marked taproot which thrusts itself downward into the soil and largely sustains it, while the lateral roots that are thrown off are few in number and only contribute a small portion to the nutrition of the growing plant. One might suppose that it would be labor wasted to plow the ground again after a crop, unless he were to raise another crop of grain, but it has been ascertained that the best way to secure a nice even stand of alfalfa under irrigation is to raise it without other crops. This may seem like losing the use of the land for a season, but the farmer will find that he is well repaid in the end by the strong and better growth of the alfalfa during the year, making it strong to pass the first winter. Therefore, where best results are expected, the ground should be plowed in the early spring or late in the previous fall, and as soon as danger from frosts is passed, in April or May, the seed bed should be carefully prepared. This must be done by repeated harrowings and the use of the roller or a plank smoothing arrangement, so that there is a well pulverized seed bed of one to two inches upon the surface. The ground should be moist, or at least moist enough to sprout and grow the seed successfully without irrigation. If there is not this degree of moisture in the land, it should be irrigated before the seed bed is prepared. As alfalfa seed is about the size and has the same appearance as red clover, it can be sown in approximately in the same manner, either broad-cast or drilled, but more seed is generally used than of red clover. Various quantities are stated as being used by successful farmers in the arid region, and with equally good results. One of the finest fields the writer has seen was prepared as above stated, and the seed drilled in about one inch in depth in two directions, making cross checks, using twenty-five pounds of good seed per acre. The field produced one of the finest stands of forage that we have ever seen.

Alfalfa will grow at almost any elevation below 7,000 down to sea level; above that the winters seem too severe and the nights in spring or early summer too cold and frosty for the plant to thrive well. The number of cuttings of forage which alfalfa produces is marvelous. In northern Colorado and this parallel extending east and west at an elevation of 5,000 feet, the usual number of cuttings in a single season is three, while in exceptional seasons, four and even five cuttings have been made. In southern Colorado and northern New Mexico, four, five and six cuttings are quite usual, and the yield at each one of these is as great as the yield of good meadow grass. If the total growth of the plant during one season were taken, it would be found to vary from nine to fifteen feet in length; this varies, of course, with the soil, local circumstances, latitude and the elevation above sea level; in this case we are supposing a proper amount of water for irrigation.

The irrigation of alfalfa is comparatively easy after the young plants are started, but sometimes the ground, if not well sloped and smoothed, will tend to wash and some of the seed will be covered too deeply by soil which is conveyed in other places, and in other cases the entire seed and soil may be washed away. Much care, then, and labor must be used in order to prevent this condition of thing and have a free and equal distribution of the water upon the field. The second irrigation, a few weeks later, will be much easier, while the third irrigation will usually cost little or no effort. The water should be turned upon the alfalfa, after the first year, as early in the spring as it can be obtained from the canals, and the growth of the plant will thus be pushed very early and an accordingly larger growth made. The experience with reference to later irrigation varies somewhat. Some good farmers prefer to turn the water upon the field just before it is ready to be cut, and then as soon as the soil has become reasonably dry to commence the haying; others prefer to make the hay and turn the water immediately upon the stubble. Both methods have their adherents and advocates, and both obtain equally good results as far as our observation extends. It is usual to irrigate at least once for each cutting; sometimes an extra irrigation would be valuable if the weather be extremely hot and dry. A late irrigation just before the ground freezes is desirable to give moisture for winter.

We have alluded to the yield of alfalfa as a forage plant. It is no unusual thing to take six or eight tons of forage from a single acre, and that upon large areas, so that a man who has a comparatively small area well set in alfalfa is master of the situation as far as forage is concerned. We must remember that in this region corn cannot be successfully raised in large quantity; and if alfalfa is to be the great forage plant in this region, it must successfully take the place of corn in the agriculture at low elevations. The amount of forage which it furnishes per acre gives us the first great factor in this comparison and makes it especially valuable. The farmers of Colorado especially have found alfalfa to be a very strong nutritive plant for feeding, and in some instances it has been used successfully in the fattening of beef steers for the market without the addition of a single ounce of grain ration. We have seen the fattening of nearly one hundred and fifty in one bunch that was conducted in this way, and the animals brought the highest price in the Denver market. Perhaps a statement of the composition of the alfalfa plant at this point might not be out of place. The green alfalfa contained 39.11 per cent. of dry material and 60.89 per cent. of water. The alfalfa hay contained 9.59 per cent. of water, 11.90 per cent. of ash, 3.85 per cent. of fat, 12.87 per cent. of albuminoid nitrogen, 18.01 per cent. of crude fiber and 43.78 per cent. of nitrogen free extract

This was for alfalfa cut when the bloom was half turned, showing that it was rapidly ripening. Experiments at several of the experiment stations in the United States have shown that this is the proper time at which to cut grasses and clovers in order to have them retain the greatest amount of nutritive qualities. Alfalfa, like other clovers and grasses, should be carefully cured for hay. As the leaves are somewhat smaller than those of other clover, and the climate of the arid region is excessively dry, it should be secured before the hay has cured too much so as to prevent the breaking off of the leaves and leaving the hay largely of bare stems. A very little experience will teach one what is best in regard to this. Again, if the plant stands too long and becomes too ripe, the seed begins to form and there is too much woody fiber in the stalk, and much of it is quite indigestible, even when eaten by stock. It is customary in many places, however, to cut one crop of hay, then to take a crop of seed and to pasture for the remainder of the year. In cases of this kind we have known three tons of good hay to be secured, and eight bushels of fine seed per acre, beside the pasture. It is thus readily seen that a plant, which, under irrigation, will produce such results as those mentioned, is extremely valuable to the farmer who practices irrigation, and that in the agriculture of the west, at an elevation of from 2,500 to

7,000 feet, there is no other plant we know of that can take its place.

We have often been asked what was our opinion relative to alfalfa for the state of Nebraska. We have always replied that it would be valuable for a large portion, if not for all the state. If a line were to be drawn from Sioux City, Iowa, southwest, passing through Grand Island, in Hall county, extending to the south line of the state, all lying west and northwest of that line would, in our opinion, be benefitted by raising more or less of this plant for forage. In the more eastern and southeastern counties, the propriety of its general growth might, perhaps, be questioned; but even there, in small areas for special purposes, it might be valuable. In many places farmers have made the mistake of sowing this plant upon low ground, where it was but a short distance to water. It should be grown where its roots would be obliged to go some distance for water and where there is no impervious sub-soil. When grown with too much moisture the plants turn yellow, having a feeble, sickly appearance and usually die in one or two years. The same appearance is found when the roots of the plant cannot penetrate shaly sub-soil. In summing up this whole matter of alfalfa growing, we believe that no single plant has been introduced in the western part of the United States that is of such great utility and value as alfalfa.

WHITE AND ALSIKE CLOVER.

CHAPTER V.

White clover sustains the same relation to permanent pastures on dry calcareous or carboniferous soils, and alsike on pastures of slough, marsh or other wet lands, that the red and the mammoth sustain to the meadows in the carboniferous soils in the northern and western states that have rainfall of twenty inches and over, and that alfalfa sustains to the deep, sandy or other light soils in the Pacific states and territories and other arid or semi-arid regions where irrigation is possible. The relation is not merely that of a source of an abundant supply of pasture and forage on the one hand or of hay and forage on the other, but each is a hand-maid, a help-meet, as a source of nitrogen to whatever other grasses, non-leguminous, may be associated with them. There is no true grass that we know of that will not flourish better and produce more abundantly when associated with the clovers, whether in the pasture or in the meadows.

It is unnecessary for us to enter into any detailed description of the white clover nor is any illustration needed to identify a plant so widely spread and generally known. It is called *trifolium repens*, or the creeping three-leaf plant, because of its creeping habit of growth. Its deficiency in length prevents it from being of much value as a meadow grass, although the analysis of its hay shows it to be equal, if not, indeed, superior, to either the red or the mammoth clover. It differs from the red and mammoth in many particulars.

FIRST. It is perennial; that is, it grows from the same root year after year, while the others are for the most part, biennial that is, growing two years, or at most short perennials, which they are said to become if prevented from flowering by continued pasturage, and thus last for three or four years. It is probable that there is ground for the statement made by English botanists, and at which we have hinted in a previous chapter, that there are at least two varieties known as the common red clover, one of which is strictly a biennial and the other a short perennial. Another point of difference is that when the creeping vines of white clover are allowed to grow long, they throw out rootlets along the vine which give it an ability to stand prolonged summer drouths better than the red or mammoth varieties with their longer tap roots.

White clover seeds abundantly, the seeds growing four and sometimes six in a pod. It secretes a great abundance of nectar and being easily fertilized by the common bee, and therefore independent of the bumble bee, it yields a far more certain crop of seed. It is a common saying among farmers that white clover never fails to produce a seed crop. When we come to examine the ash of the plant and compare it with red clover, the white contains nearly twice as much phosphoric acid, nearly four per cent. more lime, and potash in the proportion of two to five. It will therefore flourish on soils that are deficient in potash, while it requires more phosphoric acid than the red clover. Both, however, by reason of the bacteria in the nodules or tubercles on their roots, obtain their nitrogen to a very large extent from the atmosphere.

The history of white clover is somewhat obscure. It is probably indigenous to the Eastern states of America, and is said, on what authority we do not know, to have been domesticated, by cultivating the seeds of the wild plant, about the beginning of the last century. It is recorded of a farmer in one of the Eastern states at that time that he "sowed the wild white clover which holds the ground and decays not." In Sir John Norden's Surveyor's Dialogue, printed in 1607 and re-printed in 1618, we find the growing of "clouer grasse or the grasse honey suckle (white clover) with other hay seeds" advised. This would indicate that it is probably indigenous to England, and that the attention of the farmers was called to its merits a hundred years earlier in England than in America. It precedes the introduction of red clover from Europe almost fifty years. It is not, so far as we have observed, indigenous, that is a natural product of the soil, to the West. It seems to have come in as did blue grass (*poa* *pratensis*), with the introduction of lawn grasses into the villages, and from this it spread with the blue grass in all directions following naturally the main traveled roads, and especially the ridge roads that meandered over the unbroken prairie. We have usually observed blue grass gaining a foot-hold, where the prairie grass had been tramped out, three or four years in advance of the white clover; and after the white clover had become established in connection with the blue grass, it always retains its footing. These two grasses seem to be united by a marriage bond stronger than that of squire or clergy, and one which no court has sufficient jurisdiction to dissolve. There are two obvious reasons for this close and intimate relation between blue grass and white clover. The blue grass needs the white clover to supply it with nitrogen which it requires in large quantities, and the period of growth of each is such that neither interferes seriously with the other. The blue grass has thrown up heads and blossoms and its seed is well on the way to maturity before the white clover is ready to make its push for the occupancy of the ground. The latter then has the field mostly to itself until the blue grass is ready to make its fall growth, hence, in mid-summer farmers sometimes claim that the white clover has taken the blue grass and are disposed to mourn over the fact. An examination of the same field in the fall will show that blue grass occupies the ground almost wholly and they are disposed to wonder where the white clover has gone. It is for these two reasons that these plants are found inseparable in the permanent pasture.

The place for white clover is in the permanent pasture. It should never be sown in any pasture that is not intended to remain undisturbed for three years or more, and it should be as far as possible carefully excluded from all meadows and from lands intended for rotation of five years or less. The reason need scarcely be stated. If sown on lands that are intended for meadows, it will very soon crowd out timothy and the larger clovers, and thus greatly reduce the yield of forage. It is liable to spring up every year in lands cultivated in corn or other tillage crops, and hence becomes a weed, comparatively harmless, but at the same time useless, while the amount of nitrogen it may supply in its brief life as a weed among cultivated crops is not worth mentioning.

Like most other good things, and we might add good people, it has its faults. In the earlier part of the season cattle take the larger clovers and other cultivated grasses in preference, probably on account of some particular flavor which they prefer. This objection, however, is speedily overcome as the season progresses, and it is never found that a crop of white clover is necessarily wasted. Another and more serious objection is that in certain seasons, and particularly during the months when the seed is ripening, it is believed to slobber stock, particularly horses and occasionally hogs, the so-called salivation being believed to be produced by the supposed pungent character of the seeds. It is, however, extremely doubtful whether the white clover is justly blamed for this result. If the salivation is produced by the seeds there is reason to believe that the seeds of the other clovers are equally to blame. It is at least possible that the slobbering is due to wild plants in the pasture. The whole subject should be thoroughly investigated by the various Experiment Stations. It is worthy of notice, however, that whatever may be the objections of farmers on this question, they always disappear with the first season of real drouth. The same objections made to this plant ten or fifteen years ago from the State of Iowa now come to us from Kansas and Nebraska where it is being introduced as a grass essential to the permanent pastures. It might be well to remark that in Scotland where it has been grown for nearly three hundred years, many of the best authorities claim that the proportion of white clover in a good permanent pasture should be kept up to twenty or thirty per cent. of the total grasses. This fact shows the high favor in which white clover stands where it has been cultivated the longest. Farmers, therefore, in the newer parts of the West should not hesitate to sow it, and more especially as but little seed, a pound or two per acre, is all that is necessary. This will not only seed the ground in a year or two, but the seeds will be carried by birds and live stock into all parts of the farm and adjoining farms, and will spread over the adjoining country until it ceases to be necessary to seed at all, even where a stand in connection with blue grass is desired. The seeds are about one-third the size of those of the red and mammoth clover and hence the small amount per acre above suggested.

When it is desired to sow white clover as a part of the permanent pasture, it is always best to sow it with as great a variety of grass seed as possible, and the mixture should include varieties that will for the first year or two give an abundance of forage. If we were making a permanent pasture in which white clover was expected to bear a prominent part, we would sow red and mammoth clover in about equal proportions, the usual amount of timothy, more or less blue grass, and, south of latitude 42, more or less orchard grass, and on all wet lands and sloughs in dry lands, we would sow alsike clover. The reason for this suggestion is that the blue grass, which forms a prominent part in all permanent pastures where it does well, can not be expected to be ready to completely occupy the ground inside of three years. During this time the land should be producing to its full capacity and hence should be occupied by the larger clovers and other grasses which can afford less resistance to the growth of blue grass than white clover would if a full stand were sown with it. This subject will be more fully discussed when we come to speak in detail of grass mixtures suitable for different rotations and parts of a rotation.

In sowing the smaller seeds such as blue grass and white clover the depth of covering which is so necessary for the larger clovers in a light soil and a dry climate is not required. It is not safe, however, in the drier and lighter soils to trust to surface sowing, and white clover, while it grows when seeded naturally on the surface, yet has the advantage of the freezing and thawing of the soil in winter to enable it to imbed itself in the soil. This imbedding on land under tillage, such as is necessary for grain crops can be secured by the use of a common smoothing harrow and it were better still if this were followed by a light brush harrow, or, where the conditions are suitable, light rolling.

One of the varieties most recently introduced into the West is alsike or Swedish clover, (*trifolium hybridum*,) an illustration of which will be found on the following page. Its botanical name (*hybridum*) was given by the early botanist, Linnæus, who believed it to be a cross or hybrid between the white and the red. This, however, has long since been discovered to be a mistake. It is a distinct species, native over a large part of Europe, and is believed to have been first cultivated in Sweden, deriving its name from the village of Syke in that country. It was first introduced into England in 1834 and into Germany in 1854, where it is said to be largely grown not only for its forage but also for the seed. Our attention was first called to it some ten or twelve years ago. We instructed the tenant on one of our farms to sow some fowl meadow grass, (*poa serotina*) on a small patch of wet bottom land, and to sow a small quantity of alsike for experiment on a piece of dry, corn land. Instead he sowed the two together

ALSIKE. (*Trifolium hybridum.*)

on the wet land, and the seed of the fowl meadow proving worthless and so reported, we paid no further attention to the plot until a year later, when, driving near it, our attention was called to the hum of the bees apparently among the slough grass surrounding the patch. We found on examination that the alsike was growing luxuriantly and was a favorite with the bees, and it then occurred to us that we had thus accidentally found the grass for wet sloughs that would not, at the prices of tile in that locality, pay for drainage and yet should be made productive in some way. We therefore began sowing alsike as an experiment at the heads of sloughs and learned, after the experience of a year or two, that an excellent stand could be secured by burning off the slough grass in the fall, sowing the seed in March and then mowing the slough early in June in order to allow the alsike abundance of air and sunlight. We have ever since recommended it through the *Homestead* and it is now sown quite extensively especially east of the grand divide in Iowa, and where our farmers find it difficult to secure a profitable crop of anything else from the sloughs so common in the Mississippi Valley.

Alsike differs from both the red and mammoth and the white. It grows, when supported by other grasses, taller than the red but not so tall as the mammoth and is more slender in the stalk, more succulent and hence makes even better hay. It has fuller heads, on long stems and intermediate in size between the white and red. It differs from the white in its habits of growth, the stalks when lying down not throwing out rootlets at different points, and hence it is unable to stand extreme drouth, and does not succeed well on the drier lands. It partakes in its root growth somewhat of the habits of both the red and the white, throwing down, in connection with its main root, similar, but not so long as the red, a number of fibrous roots. Its seed differs in color both from the white and the red, but in size is similar to the white. Like the white it is a perennial. It spends its main strength on the production of the seed crop and throws up but little aftermath in dry ground or in a dry season. It is, therefore, peculiarly adapted to marsh lands, swales, sloughs and bottoms subject to overflow, succeeding in lands of this character better than any clover as yet introduced, but on the whole inferior to red or mammoth for lands capable of regular cultivation, or what in the west are termed "corn lands," and inferior to the white on the high, dry soils. Like all the clovers it does best on calcareous or carboniferous soils. Like the white, when once introduced, its seed stays in the ground. In the fall of 1891 we plowed under a bottom field of alsike. On account of continuous rains in the spring of 1892, corn planting was necessarily delayed and by the 10th of June the entire field was covered with a rank growth of alsike that had grown up from the seed that had been lying in the soil. We have known lands that have been overflowed for a sufficient length of time to destroy all the tame grasses, covered, after the waters had receded, with a vigorous growth of alsike, the seeding of former crops. The value of alsike, therefore, lies in its adaptation to lands, whether bottom, marsh or slough, which on account of lack of drainage or possible drainage facilities, are not capable of cultivation in regular rotation and will not produce profitable crops of other tame grasses. On lands of this kind it is not at all difficult to secure a stand on the following plan: First; burn off, the fall preceding, all wild grasses that may have grown on the land. In March of the following year sow from four to five pounds of alsike, mixing the seed with sand so as to secure an even cast. Then either pasture closely or else early in June mow off whatever grass may be growing on it, first leveling the ant hills and removing whatever obstructions to the mower that may exist. This will secure light and air to the young plants and the entire crop of alsike and wild grass may be mown in the fall as a grass crop. The next year, unless either the land or the season be very wet, but little will remain save the alsike, which may be used either as a hay crop or for seed. The effect of seeding in this manner will be somewhat surprising. On wet lands where the coarser varieties of slough grass grow, the growth of the alsike will be accompanied by the decay of the roots of the coarser grasses, they being smothered out by the rank growth of the alsike. This will have the effect in time of allowing the water to sink away that has heretofore been held by the mass of roots of the wild grass, and especially if the land be pastured after the first and second year's mowing, the entire surface will be compacted by the tramping of cattle, and if a slough, the water confined to the center. It will then be possible in the course of two or three years to sow white or red clover or blue grass, the result of drier conditions. In fact, we know of no way of reducing the width of a slough and limiting it to a narrow channel so effective as sowing with alsike and treating in the manner above indicated.

We are not advised as to the climatic range of alsike clover. Manifestly its cultivation is not practicable in the drier Western states, nor is it likely to be very popular where dry draws take the place of sloughs. The fact that it was first cultivated in Sweden indicates that its northern limit will be beyond that of the red and mammoth clovers. It is worthy of experiment as far South as the carboniferous and calcareous soils extend, and anywhere in the region covered by the drift when there is sufficient moisture. It is not likely to be in favor in the Eastern states, nor do we recommend it on well-drained soils anywhere, as under these conditions red clover or mammoth would be preferable. Within the limits indicated, farmers who allow their wetter lands to grow up in coarse slough grass or their sloughs to become an eye-sore either through lack of ability or unwillingness to drain, will find it greatly to their advantage to sow them to alsike, thus drying and narrowing them and preparing the way for blue grass, t mothy and other clovers.

Wherever farmers keep Italian bees, which everyone should for the purpose of fertilizing red clover if not for the purpose of procuring the one pure sweet, distilled by Nature herself, they should sow or induce their near neighbors to sow a few acres of alsike clover even on lands that will produce a greater crop of red or mammoth clover. As a honey plant it probably has no superior. In addition to this it should, whether on dry or wet land, form an ingredient in the mixture for hog pastures, if for nothing else than for the sake of greater variety and more continuous bloom. When sown with other grasses, it should be given the same covering suggested in the former part of this chapter for white clover. It is, as will be seen from the above, a special-purpose grass. The illustration on page 50 will enable our readers to identify it readily.

MINOR VARIETIES OF THE CLOVERS.

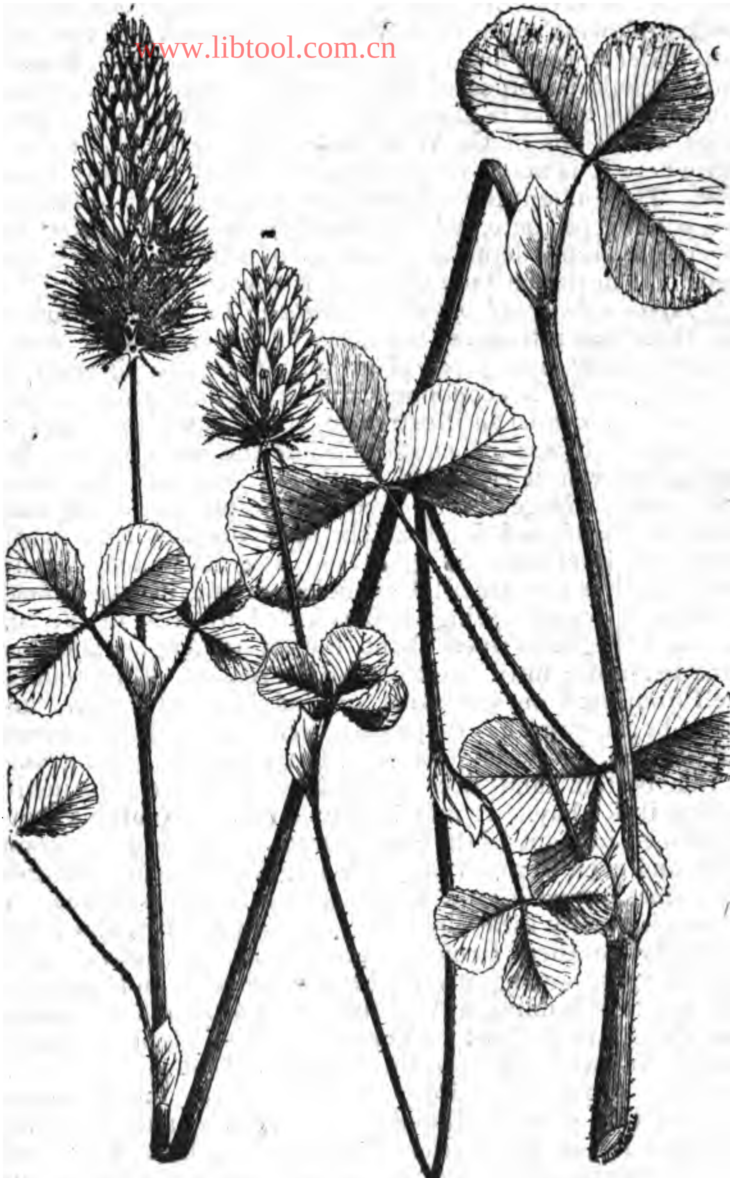
CAHPTER VI.

While the red and mammoth clovers (*trifolium pratense*) the alfalfa (*medicago sativa*) the white or Dutch clover (*trifolium repens*) and the alsike (*trifolium hybridum*) are the clovers most valuable in the eastern, northern and north-western states, there are a number of other varieties of no little local value. Some of these will grow in what is usually known as the "corn and grass belt," but being inferior to the varieties just mentioned, are properly neglected or regarded as weeds. Of these is the *melilotus alba*, commonly known as sweet clover, which can be found growing in gardens, whence it escapes to the highway, vacant lots, especially in cities, and to neglected fields. A sub variety of it is known as Bokhara clover. It grows to the height of six or eight feet on good land when not cropped, and its only value, on lands that will grow red or mammoth clover profitably is as bee pasture. For this purpose it will pay apiarians to sow it along the roadsides or in the vacant corners and other neglected lands. In the drier portions of the West and in the South this clover has very considerable value. It is proving a valuable forage plant and also one of the renovating crops greatly needed in some of the more southern states. An illustration of this variety will be found on next page. Trials at the Mississippi Agricultural College and by planters in that state seem to have established this fact beyond question. Like all the other clovers it has the capacity of appropriating nitrogen from the atmosphere and thus enriching the land and preparing it for the profitable production of other crops. Where it has been found impossible to grow the better varieties of clover it is worthy of trial, and experiment stations in those states where the better varieties are not a success should make a still more careful and thorough investigation of its merits.

SWEET CLOVER. (*Melilotus alba.*)

Scarlet or crimson clover. Within the last few years a good deal has been said in the eastern and southern papers with reference to scarlet or crimson clover (*trifolium incarnatum*) an illustration of which may be found on next page. This is sown in midsummer or early autumn, and blooms, in the latitude to which it is adapted, early in May. It grows from twenty inches to twenty-eight inches in height, and is harvested in time to prepare the ground for another crop. It has a long slender head brilliant scarlet in color and yields large crops which can be cut from the tenth of May to the first of June, according to the latitude. The Delaware Experiment station has recently been carrying on experiments with a view of determining the value of this crop and reports that it yields easily eight tons of green fodder per acre, if cut between the 5th and 10th of May, that its roots run down four feet in favorable locations and that it is superior to the ordinary red or mammoth clover in two respects: 1. Its ability to flourish on relatively poor soils. 2. Its capacity for growth during the fall, spring and in open winters. It also reports that it can not be seeded with winter grain owing to the fact that it grows when winter wheat or rye seem dormant and as the result, one crop or the other would be destroyed. It is specially valuable for soiling and for plowing under as a green crop instead of rye. European writers mention five varieties of this clover, differing to some extent from each other in their relative powers to withstand winter conditions, and it may be that some variety may yet be introduced that will be able to withstand the rigours of a northern winter. Until this is done the crimson or scarlet clover must be regarded as a crop especially adapted to the southern and border states. We tried it one year, on our own farms in southern Iowa, sowing after harvest on wheat stubble, and the next spring we failed to find a single stalk that had survived the winter. Similar experiments were made at the Iowa Agricultural College, and in Illinois in the latitude of North Missouri, so that any variety known in America must be regarded as adapted only to the latitudes of the southern border states. Having the same power of appropriating nitrogen from the atmosphere, it will no doubt prove of great value where its cultivation is practical, and especially to truck farmers who after the removal of their crop can sow the land to clover and plow it under or use it for hay and turn the roots in time for a profitable crop on the same land next season.

Our object in experimenting with it was to ascertain



SCARLET OR CRIMSON CLOVER. (*Trifolium incarnatum.*)

whether the Western farmer could sow it in his corn fields at the last plowing or on the stubble after harvest and turn the crop under in time for a crop of corn the next year. If some variety could be procured that would endure the northern winters this might be done, and it would then prove of great value in sections of the West where corn is the leading crop and where it is necessary to supply nitrogen at a very cheap rate. The amount of seed necessary is from fifteen to twenty-five pounds per acre, which should be sown broadcast and covered the same depth at which red or mammoth clover succeeds best in the latitude where it is sown.

Japan Clover, (*Lespedeza striata.*) In some unknown way there was introduced a variety of clover into the South Atlantic States from Japan about forty-five years ago that has proved of no little economic value, known as Japan clover, (*Lespedeza striata*,) an illustration of which will be found on next page. It was little noticed before the late civil war, but during the war it extended south and west and has spread rapidly over a large district of country, especially along roadsides, in abandoned fields and in open woods. Like nearly all clovers in climates of great and long continued summer heat, whether the rainfall be deficient or not, it is an annual, growing up every spring, and is killed by frost in the fall. The seeds begin to ripen about the 1st of August and continue to mature until the close of the season. It reproduces itself from seed on the same ground year after year, and hence by mistake has frequently been regarded as a perennial. It will grow on poor soils, but prefers clay, and only on rich bottom lands does it obtain size sufficient to justify cutting it for hay. It may be found in the situations above mentioned in many of the Southern states, driving out broom sedge and even Bermuda or Johnson grass in some localities, but it does not withstand drouth so well as the Bermuda. It is likewise easily killed by frost. It has proven a great blessing to the Southern farmers, a good Samaritan, providing its own charges, sowing itself wherever there is an abandoned field and thus binding up the broken-hearted land. It ranges from the Atlantic Coast to Tennessee, Mississippi, Alabama, Georgia and as far West as north-eastern Texas.

It is scarcely possible to over-estimate the economic value of this plant to the Southern farmer, and it is only since the recent discoveries of the power which all clovers and all legumes possess of fixing nitrogen in the soil by appropriating it from the atmosphere and storing it in the soil

JAPAN CLOVER. (*Lespideza striata.*)

that its value has become fully understood, even by the most intelligent farmers. Any plant that will of its own accord restore the wastes of the soil, robber must grow in popular estimation year after year. It should be sown at the rate of half a bushel to the acre and covered to a depth sufficient to give it the same degree of light, heat and moisture which it secures when self-sown on uncultivated fields or commons. It must ever be borne in mind that all seeds on loose, well-cultivated soils require a deeper covering than when self-sown on unplowed land.

Bur Clover. (*Medicago denticulata.*) This clover is next in economic importance, and grows largely in California. This, too, is a foreigner, which was early introduced in that state, and has given itself a wide distribution, having spread over the lower lands in the southern and central counties and on some of the high lands as well. It has also been tried with success in some parts of Texas and Mississippi. We have seen thousands of sheep feeding in mid-summer on lands in California apparently almost as bare as the highway. The sheep seemed to be in good condition, and by inquiry we found they were feeding on the seeds of the bur clover. The seed remaining begins to grow with the winter rains and hence this clover furnishes a winter pasture in the leaves and a summer pasture in the seeds. The only objection that can be made to it as a forage plant for sheep is that the seeds being in the form of burs, (hence the popular name,) injures the market value of the wool to a greater or less extent. Bur clover, like the white, of the northern states, has a growing mate in the *alfilaria* (*erodium cicutarium*), pronounced al-fi-la-res, the local name being stork's bill, pin clover, pin grass and filaria. The alfilaria is neither a grass nor a clover, but belongs to the geranium family and the two grow together for the same reason that white clover and blue grass are a wedded pair, bound together by a tie which no court can dissolve, the bur clover evidently supplying the alfilaria with nitrogen.

A closely related variety of bur clover (*medicago maculata*) is found in Western Nebraska, and no doubt over other portions of the plain region. Nature is careful in her distribution of the legumes, and especially of the clovers, and provides some variety of this invaluable plant for almost every soil and climate.

Besides the foreign species above enumerated, there are in the United States some forty species of native clovers, most of them belonging to the Pacific Slope and the mountain region, and a few belonging to the southern states and the plains. These clovers are mostly annuals. We give the following description of the most prominent of them taken from the report of Dr. Geo. Vasey, botanist of the Department of Agriculture for the year 1886, with illustrations showing the varieties described, which will be found at the conclusion of this chapter:

TRIFOLIUM FUCATUM.

This is one of the largest and strongest growing of our native kinds, and is found on the Pacific coast. Under favorable circumstances it attains a height of two or three feet. The stem is decumbent, smooth, thick, and juicy. The stipules at the base of the leaf are half an inch to an inch long, ovate, broad, and clasping the stem. The leaves are trifoliate, with stems or petioles three to six inches long; the leaflets vary from roundish or oblong to obovate, thickish, strongly veined, three-fourths of an inch to an inch and a half long, and with numerous small, sharp teeth on the margins. The flower heads are large (one to two inches in diameter), larger than those of the common red clover on naked peduncles (stems), which are longer than the leaf-stalks (sometimes five to six inches long). There is a conspicuous green involucre surrounding the base of the flower head deeply divided into seven to nine ovate, entire, and pointed lobes, which are about half as long as the flowers. The heads contain comparatively few flowers (about eight to ten), but these are about an inch long, thick and inflated, the calyx about one-fourth as long as the carolla, which varies from pink to purple in color. Mr. S. Watson, in the "Botany of California," says of this: "A common species in the Coast Ranges and in the foot-hills of the Sierra Nevada, through the length of the State—in some places very abundant and affording good pasturage." It would seem very desirable that this species should be given a fair trial in cultivation.

TRIFOLIUM MEGACEPHALUM (Large-headed clover).

A low species, seldom reaching a foot in height, but robust and with strong, deeply penetrating roots. A number of stalks usually proceed from one root, but these stems are unbranching, somewhat hairy, and terminate with a single large head. The leaves mostly proceed from the base of the stem, there usually being but one pair on the stalk near the middle. The lowest leaves are long-stalked, and with five or seven leaflets instead of three, as in most clovers, but the upper ones are sometimes reduced to three leaflets. The leaflets are an inch long or less, somewhat wedge-shaped or obovate and blunt at the apex, and with very fine, sharp teeth on the edge. The stipules at the base of the leaves are large, mostly ovate in form, and sharply toothed or deeply cut. The heads are mostly terminal, about one and one-half inches long, on a naked peduncle, and without an involucre. The flowers are large, purplish, about an inch long, and very compact and spicate in the head. The calyx with its long, plumose teeth, is half as long as the corolla. This species grows in the mountain region of California, Oregon, Washington Territory, Nevada, and Montana. It is not as large as the common red clover, but experiments are needed to determine its possibilities for pasturage. Its large, showy heads and its peculiar leaves would make it an interesting ornamental species.

TRIFOLIUM INVOLUCRATUM.

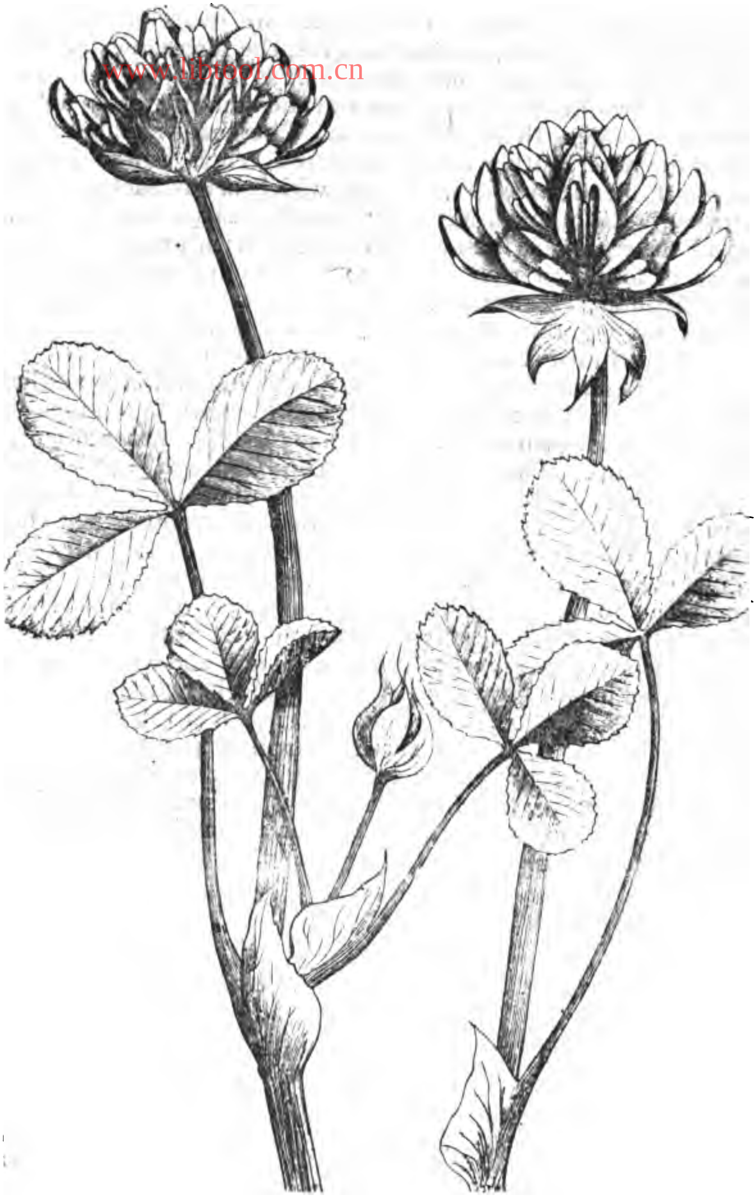
This is an annual species, presenting a great variety of form, but under favorable circumstances reaching one and one-half or two feet in height and of vigorous growth. The stems are usually decumbent and branching below, very leafy, and terminating with one to three heads on rather long peduncles. The leaves are on stalks longer than the leaflets, which are in threes, one-half to one inch long, of an oblong or obovate form, smooth, and with very fine, sharp teeth on the margins. The stipules are large, ovate, or lanceolate, and usually much gashed or deeply toothed. The heads are long-stalked, about an inch long, the purplish flowers closely crowded, and surrounded with an involucre, which is divided into numerous long-toothed lobes. The flowers are half to three-fourths of an inch long, slender, with a short, striate calyx, the teeth of which are very slender, entire, and pointed, and little shorter than the corolla. This species has a wide range of growth in the western part of the continent, prevailing from Mexico to British America through the mountain districts. Under cultivation it would probably produce a good yield of fodder, but has never been subjected to experiment so far as known.

TRIFOLIUM STOLONIFERUM (Running buffalo clover).

This is a perennial species, growing about a foot high; long runners are sent out from the base, which are procumbent at first, becoming erect. The leaves are all at the base, except one pair at the upper part of the stem. The root leaves are long-stalked, and have three thinnish obovate leaflets, which are minutely toothed. The pair of leaves on the stem have the stalk about as long as the leaflets, which are about one inch long. The stipules are ovate or lanceolate, pointed, and entire on the margins, the lower ones nearly an inch long, the upper ones about half as long. There are but one or two heads on each stem at the summit, each on a peduncle longer than the leaves. The heads are about an inch in diameter, rather loosely flowered, each flower being on a short, slender pedicel, or stem, which bends backward at maturity. Each flower has a long-toothed calyx about half as long as the corolla, which is white tinged with purple. This species is found in rich, open wood-lands and in prairies in Ohio, Illinois, Kentucky, and westward. It is smaller in size and less vigorous in growth than the common red clover.

TRIFOLIUM CAROLINANUM (Southern clover).

A small perennial clover, having much resemblance to the common white clover. It usually grows from six to ten inches high, somewhat pubescent, the stems slender, procumbent, and branching. The leaves are trifoliate, on petioles of variable length. The leaflets are about half an inch long, obovate, wedge-shaped at base, and somewhat notched at the summit. The stipules are nearly as long as the leaflets, ovate or lanceolate, and slightly toothed above. Each stalk has usually two long-stalked heads, proceeding from the upper joints. The roundish heads are from one-half to three-fourths of an inch in diameter, without an involucre, and with numerous crowded, small flowers on slender pedicels, which become reflexed in age. The long lanceolate teeth of the calyx are slightly shorter than the small, purplish, pointed corolla. The pods are ususlly four-seeded. This species occurs in all the Southern States and in Texas. It is too small to be valuable for fodder, but is worthy of trial as a constituent of pastures in the South.



(*Trifolium fucatu m.*)

LARGE HEADED CLOVER. (*Trifolium megacephalum.*)

(*Trifolium involucratum.*)

RUNNING BUFFALO CLOVER. (*Trifoliuu stoloniferum.*

SOUTHERN CLOVER. (*Trifolium Carolinanum.*)

PRACTICAL CLOVER GROWING.

CHAPTER VII.

In previous chapters we have described the general range of the clovers, and discussed somewhat in detail the varieties usually grown in different sections of the country. In this we take up the best methods of practical management. These methods will vary in different localities, often in the same neighborhood, and on the same farm. The first question for the farmer to decide is the variety or varieties he can use with profit in his latitude and longitude, and in connection with the system of farming which he has adopted. While it is well for the enterprising farmer to experiment with new varieties, but always on a small scale, it is folly to devote any considerable part of his farm to a variety that has not been found entirely reliable and reasonably well adapted to his section of the country and to his system of farming. By "entirely reliable" we do not mean a variety that will grow well enough in an occasional wet year, or that will survive an unusually mild winter, but one that can be depended upon from year to year as a part of a regular rotation. While latitude and longitude must always be taken into account, the rainfall, the rotation and the nature of the soil must be considered as well.

The next thing to be determined is the object in view in growing clovers. If the object is to secure hay and fall pasture, and store up fertility for future crops of corn and other grain, his reliance in all sections where it is a sure crop, must be on the common red clover. If his object be mainly fertility in connection with a cash crop of clover seed, then the mammoth should have the preference. If the object be pasture as an ultimate end, to be grown year after year, on the same land, and always ready to be plowed under for a corn crop, should circumstances seem to justify it, then he can use to advantage in the North, both the red and the mammoth; and, if his lands are unusually moist, the alsike. If he wishes to lay down his lands in permanent pasture, not to be broken up for an indefinite number of years, he can use all these and the white clover in addition. If he is located in sections where the above varieties are not reliable, and he wishes a permanent clover meadow, or a crop for summer soiling, his main reliance must be alfalfa, provided always that he has a soil that is not immediately underlaid with impervious clay, gumbo, hardpan or rock. If he has land under irrigation there is no forage plant that will take the place of alfalfa as a permanent meadow. If he resides in the mountain or Pacific coast states and cannot irrigate his land, he must use the annuals native to that region; if in the extreme Southern states, his main reliance must be on the Japan, and if in the border states, where the winters are sufficiently mild, he can use to great advantage the crimson. Bearing in mind the uses and fitness of each variety, every farmer must make a selection for himself.

The object in view in growing clovers having been clearly determined and a judicious selection made after a thorough study of the resources of the country and of the particular farm, the next practical question is the determination of the mixture to be used, either of the clovers by themselves, or in connection with other grasses. Much harm has been done by the recommendation by seedsmen and some agricultural papers, of grass mixtures selected on purely theoretical grounds, and without reference to the wants of either the section of the country or the individual farmer. Many of the mixtures seem to have been taken from English works, and are frequently made up of grasses which have generally failed wherever tried in the Western states, and where they have succeeded, have proved inferior to the grasses and clovers in common use that have been demonstrated, after years of experience, to be extremely valuable. All mixtures that contain English rye grass, Italian rye grass, sheep's fescue, crested dog's tail and such like grasses, should be rejected, as there are few sections in the West in which these grasses will stand either the extreme cold of winter or the extreme heat of summer. The recommendation to sow orchard grass, red top or meadow fescue should be well considered before purchasing the seed. These three latter grasses are valuable in their place, but only in certain locations and under certain conditions, which will be hereafter described. Always keeping in mind the fact that no mixture can be prescribed that will fit every modification of circumstances, and that all proposed mixtures must be taken only as general suggestions to be modified by local conditions, and sometimes by the price of the various seeds, we venture to recommend some mixtures that will be found to be valuable to farmers, especially in the corn and grass belts of the West. There are many farmers whose great aim in growing clover is to increase the waning fertility of their soil. They have not reached the point where they are prepared to engage in what is called in a vague way, "diversified farming." They have neither the capital nor the experience that would justify them in engaging in stock growing to any very great extent, and are depending upon the sale of grain for shipment to the great markets, to lift the mortgage on their land, usually given for purchase money. This accomplished, they are ready to build barns, fences, sheds, plant groves and sow a diversity of grasses and invest in improved stock. To these we suggest the sowing of mammoth clover alone on every crop of spring grain. If this is sown at the rate of twelve pounds per acre, and covered as directed in Chapter III, it will, in all ordinary seasons, in a clover country, make a stand that will furnish pasturage for the limited stock on the farm during the fall months, or if fenced in common with the corn fields, will make the corn stalks (which are seldom used by this class of farmers except for pasture), doubly valuable as a winter feed. The crop can then be plowed under the next spring in time for corn. The cost will not ordinarily be more than $1.00 or $1.25 per acre, part of which will be covered by the fall pasturage, and the rest by an increase of two bushels per acre in the corn crop. Without definite experiments to guide us, and judging from the returns of corn from clover roots that have been allowed to mature a seed crop and then turned under, we should not expect a smaller increase than from eight to ten bushels per acre the next year. It is much better, however, after a stand has once been secured, to allow the crop, after a reasonable amount of fall pasturing, to stand another year, and then to take a crop of seed the next season after pasturing it, where it is practicable, into June and then fall-plow for corn the next year. Our experience justifies us in estimating the increase in the next corn crop at from fifteen to twenty-five bushels per acre the first year, and not quite so much the second. The soil will then be left in better condition as regards fertility than before the first clover was sown. The crop of mammoth clover seed, under these conditions, is much more certain than that from the common red, and an average yield would be somewhere in the neighborhood of three bushels per acre, provided always that it is all secured.

Another class of farmers, who have given more attention to stock growing and have their farms fenced in separate fields, desire more or less tame hay as well as fall pasture. For these we recommend the mixture described below. If the rotation they have adopted be such that they can allow the land to rest two years in grass, we would sow a mixture of ten pounds of common red clover and eight pounds of timothy, sown with spring grain and covered to the depth that is found best in the soils of the neighborhood, as explained more fully in Chapter III. The first year the stand will be mostly clover, and if it is desired to secure the seed crop, this should be mown, in the latitude of central Iowa, before July 1st. If for any reason there should be a failure in the seed crop, the second growth or aftermath will yield a large amount of fall pasturage, except in seasons and localities of very extreme drouth. The next year timothy will take the lead, most of the clover having died the previous winter, and that which survives being, for the most part, plants from seed that, for some reason, did not germinate the first year. Under these circumstances, an ordinary season seldom fails to produce a large crop of timothy, due to the fact that it finds an abundant supply of all the elements of fertility in the decaying roots of the clover that perished the previous winter.

Under ordinary circumstances the land should then be plowed for corn, although if it has been pastured off after the second crop has had a chance to reseed the ground, the previous year, clover is likely to assert its supremacy the following year. If it does the field can be kept as a permanent meadow, in many sections at least, for an indefinite number of years, each second crop contributing its quota of seed. We have this year taken the eleventh crop from part of a field managed in this way, and the yield has been larger, both in clover and timothy, than from the first year's sowing. Where the intention from the first is to establish a permanent meadow of this kind, we advise in all sections where orchard grass (*dactylis glomerata*) does well, to sow it with the previous mixture at the rate of half a bushel per acre, mixing the seed with sand or road dust to secure an even cast, sowing after the clover and timothy have been covered, and covering the orchard grass with a brush harrow. Orchard grass does well, as a rule, south of the latitude of central Iowa and Nebraska, and has a westward range much further than clover. How far north this mixture can be used depends very much on the nature of the exposure and the protection furnished by groves, windbreaks and other grasses. The reasons for adding orchard grass to this mixture are two: First, It is about the only grass that will be fit to cut for hay at the time the common red clover is at its best estate. Second, We know of no grass, except clover, that will yield such an abundant aftermath. If, therefore, the amount of timothy above suggested be lessened and orchard grass added, the result will be, wherever this grass does well, an amount of fall pasture that is surprising to farmers who do not know the capabilities of a soil well set in the best grasses. However, where orchard grass forms any considerable portion of the sward, it should not be plowed up except after a term of years, for the reason that the seed is expensive, and the grass being a perennial or growing from year to year from the same root, should be used as long as its usefulness continues.

By using clover in any of the ways above suggested, it is possible to keep up the fertility of the soil for a great length of time, depending upon the amount of phosphoric acid and potash that are available, or that may become available by the disintegration of the primary rock of which all soils are largely composed. As to how long it might require to exhaust the potash and phosphoric acid on the drift soils of the West no one is yet competent to express an opinion. This, however, should be distinctly understood, that if the crops grown with the aid of clover as well as the clover itself are removed from the soil and no manure returned, the land will become permanently exhausted and cannot be restored to its wonted fertility without the costly, hazardous and uncertain experiment of the use of commercial fertilizers.

As clover itself is a large consumer of phosphoric acid and potash the first symptom would likely be that the soil would refuse to grow clover and become, in popular language, "clover sick." This, however, is not a proper use of the term, the true clover sickness being a disease that affects the clover in the fall of the year and after it has made a vigorous growth during the spring and summer months. We wish, therefore, to impress with the utmost clearness and distinctness on the mind of the reader this fact, that he cannot go on forever obtaining large crops by the use of clover unless he restores to the land, in the shape of barnyard manure, or in some other way, the mineral elements which it, as well as the other crops, have removed from it.

As proof of the value of the clovers, sown and managed as above described, we have only to point to the cornfields grown on clover sod in any year, and especially in wet years, in any part of the country, but particularly in the West, as compared with corn grown on like land after other crops and treated in all respects similarly. The natural drainage formed by the partially rotted soil renders earlier planting possible, the decaying roots furnishing an abundant supply of nitrogen in the best condition for the use of the plant; and the result, in the worst corn seasons, is a crop that cannot fail to be largely profitable. There is, however, no surer way to exhaust permanently the fertility of the soil than to continue the process we have outlined above without restoring in some way the potash and phosphoric acid that have been removed by this stimulating process.

Where it is desired to use the clovers in connection with the other grasses as a permanent pasture, a different mixture should be adopted. If the land has been in cultivation, and it is desired to sow the grass seed with spring grains, we suggest the following mixture:

Red Clover	5 pounds
Mammoth Clover	5 pounds
Timothy	6 pounds
Blue Grass	6 pounds
White Clover	1 pound

The principles laid down in Chapter III should be observed with regard to the depth of covering, the moist soils requiring shallower, and the light and dry soils a deeper covering. As the object in the permanent pasture is to secure as far as possible a constant succession of fresh grass and of bloom, it would be well to add to, or substitute in part for the above mixture any other grasses that are known to do well in the particular locality. For example, we would add, in the latitude of southern Iowa, 3 or 4 pounds of orchard grass. On wet lands we would leave out half the red and mammoth clovers and substitute five pounds of alsike. Where red-top does better than timothy, as it does in some of the southern states, or better than blue grass, as in some of the extreme northern, we would reduce the timothy and blue grass and substitute red-top in part. In a pasture seeded as above, the orchard grass will furnish the first bite, so desirable in the early spring, the blue grass coming next, followed by timothy and clovers. After maturing seed the blue grass will rest while the clovers are making their most vigorous growth, but will revive and take full possession of the field when the clovers are taking time to ripen their seed crop. The disposition of blue grass and white clover to usurp full possession of permanent pastures renders it somewhat difficult to retain the red and mammoth. The difficulty may be overcome by scarifying the surface with a disc harrow and then sowing the seeds of the red and mammoth clovers, or by scattering manure containing these seeds on such pastures during the winter season. On some soils especially adapted to clovers, these retain their place in the permanent pasture much longer than on others, and in all pastures there is a constant contest among the grasses themselves for the supremacy.

Where it is desirable to seed rough lands in prairie grasses to permanent pasture, the following mixture, per acre, may be used with advantage:

Red Clover	8 pounds
Blue Grass	7 pounds
White Clover	1 pound

This should be sown before the frost leaves the ground in the spring, the wild grass having been burned off the previous autumn. It should then be pastured heavily, preferably with sheep, calves or hogs, in order to check the growth of the wild grasses and allow the cultivated varieties air and sunlight. The tramping of the soil will insure covering, and, unless the ground be excessively wet, will not materially injure the young plants of the cultivated grasses. The pasturing should be as close as possible the first year, but in the second year the red clover should be allowed to produce seed and thus re-seed the ground. For some reason we have never succeeded so well on these pastures with mammoth clover as with the common red. Where a large acreage is to be seeded it is not practicable usually to pasture with either sheep, hogs or calves. In that case yearling or two-year-old steers should be used, and enough should be turned in to keep the wild grass very short during the entire summer. The only difficulty in this method of seeding is that the best results in securing a speedy transformation of the wild into the tame pasture require more cattle to the acre than is profitable for their owner.

We are not prepared to say how far West of the Missouri the method of seeding with a nurse crop will prove successfu on account of lack of summer moisture. It has proved a failure under drier conditions than prevail east of the Missouri, and Nebraska and Kansas farmers have resorted to the method of cutting the prairie sod with heavily loaded disc harrows, and then sowing grass seeds as above described. We are inclined to think that the rule will hold good that wherever the tame grasses require to be sowed alone without a nurse crop the wild pastures will require to be disced in order that the grass seeds may secure an early and rapid growth to enable them to withstand the coming drouth.

In practical clover management the amount of moisture that can be confidently expected must always be borne in mind. While in the entire country east of the Missouri and for some distance west, it is entirely practicable to sow the grass seeds with spring grains, it is unsafe, as a rule west of that river. If they are sown with oats especially the growth is necessarily limited, the plants are delicate and "spindling," and when the nurse crop is removed the hot sun is almost certain to greatly weaken, if not entirely destroy, the stand. This is true to some extent with the oats crop in Iowa and Missouri, and especially during the excessively hot seasons. The rule, therefore, west of the Missouri, except in unusually moist soils, should be to sow grass seeds as a crop by themselves. The ground should be carefully prepared, clover and timothy seed covered to the depth usually given to oats or spring wheat, and the tame grasses allowed the full use of the ground. The weeds will spring up with the young grasses and these should be mowed off once or twice during the summer, if necessary, setting the mower somewhat high thus allowing the young plants to have the full measure of sunshine and air. By this method it is possible to grow the tame grasses far beyond the limit set by public opinion, based on previous experience, and by the methods usual in localities where the moisture is more abundant. This necessarily involves a change in the rotation which will be discussed more fully in the next chapter.

It will be found, however, that wherever the clovers can be relied upon as a permanent crop, they can be grown quite successfully without a nurse crop.

There is a point west of the Missouri where the growth of red, mammoth, white and alsike clover is so uncertain that alfalfa should be used as a substitute. Just where this line is has not yet been determined by actual experience. It is not a line marked out by degrees of latitude or longitude,—the determining factors are the geological formation of the soil and its capacity to hold moisture and rainfall. We are inclined to the belief that the ordinary clovers can be used with success east of a line running from Norfolk, Nebraska, to Kearney, and south to the Republioan, east along that river and south to some distance west of Topeka. It will be found by practical experienoe that they can be grown in many places west of the line indicated. Where these can not be grown, alfalfa is the best substitute among the grasses yet discovered. It is grown without irrigation quite successfully on all soils west of this line that do not rest on hardpan or rock, and while it cannot take the place of clovers in rotation, it is the best substitute among the grasses yet discovered. It is probable that on many of these soils west of the line indicated, and possibly in some places east of it, the soy bean will prove a better crop, especially in view of its adaptation to rotations, than either the clovers usually grown or alfalfa.

Under the present conditions from ten to twenty per cent. of the lands east of the Great Divide in Iowa comprising sloughs, swales and bottoms are too wet for cultivation, and the time for tile drainage has not yet fully come. In the course of a few years farmers will realize the importance of tile draining all these sloughs. In the meantime mnch can be done to render them profitable by the use of alsike clover. The method of sowing is similar to that recommended in the case of prairie lands which it is desirable to seed without plowing. Whatever grass may be upon the land of the previous year's growth shonld be burned off in the fall, and these lands, whether sloughs, swales, or bottoms, annually wet or subject to overflow, should be sown to alsike before the frost leaves the ground in the spring, at the rate of about four pounds of seed per acre. As it is not ordinarily practicable to pasture these lands, especially sloughs which meander through cultivated fields, the mower should be run over them after first leveling the ant hils with a spade, and thus the rank growth of slough grass kept under control. This will give the alsike air and sunlight and ordinarily secure a fair stand the first year. The second year the entire crop of alsike and slough grass may be cut for hay; or, if desirable, threshed for seed. The effect of this method will be, in a year or two, to greatly decrease the size of the slough and dry out bottom lands, the decay of the roots of the wild grasses allowing the water to sink away, and where it is practical to pasture them, especially with heavy cattle, the compression of the soil by their weight will narrow the slough, and when this process has been begun it is practicable to sow the red, mammoth and white clovers. In this way the unsightly sloughs which disfigure a great part of the Western country, may be converted into meadows, to the profit of the farmer and a great improvement in the appearance of the farm.

CURING CLOVER HAY.

CHAPTER VIII.

The problem of curing clover hay at its best estate, where the acreage is large and the weather uncertain, is one of the most difficult and perplexing that awaits the solution of the practical farmer. The problem is to evaporate at the least expense of labor the large water content in clover, when cut when it should be, with the least possible damage to the hay, either from excessive drying, from rainfall or from dew. Analyses made at different times and places and collected and published by the Department of Agriculture show that clover before bloom has from 61.2 to 82.7 per cent. of water, with an average of 72; in bloom, from 47.1 to 91.8 with an average of 72.7; after bloom from 61.1 to 74.2 with an average of 68.2, the average of all analyses giving a minimum of 47.1 and a maximum of 91.8 and an average of 70.8. Analyses of clover hay cured before bloom give a minimum of 6 per cent., and a maximum of 31.3, with an average of 20.6; in bloom a minimum of 9.4, a maximum of 26.7, an average of 20.9, while the average of all analyses, numbering some thirty-eight of clover hay, give a minimum of 6 and a maximum of 31.3, with average of 15.3.

Mr. W. H. Heileman, under the direction of Prof. Wilson, of the Iowa Agricultural College and Experiment Station, located at Ames, Iowa, has taken samples of clover as nearly as possible in the best condition for cutting for hay, has analyzed samples of it when cut, has cured the rest into hay in the proper condition for storage, and analyzed the different samples, and also like samples of hay thoroughly cured in the mow, with the following results:

Total moisture in a sample of clover in its best condition for cutting, 75.90. The total moisture in sample of well cured hay, 16.62. Moisture in clover hay after being in the barn twenty days, 12.22. From this it will be seen that the amount evaporated in the process of curing was 58.28 per cent., and that an additional amount of 4.40 was lost in the barn in twenty days. In other words, after losing in the process of curing 58.28 per cent. of the original moisture, 26.48 per cent. of what remains is lost after storage in the mow for twenty days. On the basis which these figures furnish, 100 pounds of green clover cut at the proper season and cured in its best estate, will make 41.72 pounds of hay ready for the mow. Twenty days after storing it will weigh 37.32 pounds. The shrinkage probably continues in a variable, but gradually decreasing degree for a considerable time longer, the variation depending on the season and the average humidity of the atmosphere which surrounds it.

It will thus be seen that the problem before the farmer in making hay is to get rid of about 60 per cent. of the weight of the clover by evaporation in the sunshine and wind, and to do this with the least possible expense, and least danger of damage from scorching by the sun, from rainfall or dew. The problem in the Eastern states, where the crop is small, labor plenty and barn room abundant, and where there is little necessity for the use of special machinery, is a comparatively easy one. Under these circumstances, the clover can be taken in its ideal condition, that is, when about one-third of the heads are turned brown and nearly every stalk in bloom, and can be converted into ideal hay with but little risk of exposure to sun, rain or dew. By the use of the mower an hour or two in the afternoon or evening, a sufficient amount of the crop for the next day's operations can be cut down. By stirring it once or twice with the tedder in the morning it will part with sufficient of its water to enable it to be placed in cocks. These can then be covered with hay caps made either from ducking, muslin or wood pulp, and allowed to remain until they go through the sweating process, whether that be two days or a week. A hay day can then be taken, the caps removed and the crop stowed away in the barn. The first crop treated in this way, a crop of seed in the fall from the common red clover is reasonably certain.

The conditions are widely different, however, in the West. There the crop is usually large, running as a rule from forty acres to several hundred on a farm, and machinery specially adapted to the work becomes a necessity on account of the magnitude of the crop and the high price of labor. It is by no means difficult to secure a crop of clover hay under these conditions, provided it be allowed to stand until the heads are nearly all turned brown and the stalks have parted with a large amount of their water content; but the hay is by this delay very seriously damaged in quality. With the ordinary farmer hay is hay, and, hay made in its best estate, is regarded as but little superior to hay made from clover which has become largely woody fiber and therefore to a great extent indigestible. The farmer has no means of determining the food value of this hay, nor of comparing it with clover hay made in its best estate. He notices that some seasons his cattle eat a very large amount of it, and at other seasons a comparatively small amount, with about the same final apparent result in thrift, but he attributes this difference in the spending quality to the temperature, or to the previous condition of the cattle and other stock, whereas it may lie almost wholly in the difference in the nutritive value of the hay fed, due to the time of cutting and manner of curing. We know of no experiments covering this ground, and hence are obliged to fall back on certain well-known principles, namely, that all grasses after they have passed their bloom, with the possible exception of timothy, develop woody fiber very rapidly, and that this woody fiber is to a very great extent indigestible and hence useless. Corn fodder cut when the ears are glazed as compared with corn fodder cut when the blades are brown furnishes an example of the change that goes on in clover. It is, therefore, an easy matter to make clover hay in the West, provided it is allowed to stand until half its nutritive value is lost; it is often a very difficult matter when cut with the maximum of nutriment in the plant. It is as near that point as possible when in full bloom. On account of the difference in the blooming period in any one field, the central heads of the stalk or branch blooming first, and the later and earlier varieties being grouped under the one term, red clover, the farmer is obliged to allow about one-third of the heads to turn in order to get the maximum of bloom.

In dealing with clover, it must always be borne in mind that it is a wonderful evaporator of moisture. That is the habit of its entire life. All close observers are familiar with this fact, that no matter how thoroughly saturated the soil of the clover field may be by recent rains which the magnitude of the crop will not allow to run off, it soon becomes dry, and that solely through the enormous evaporation from the leaves.

This habit of its life clings to it in death. When mown, it evaporates its water so rapidly that in a short time under a hot sun and in a dry wind the leaves, the most valuable part of it, are dried to the point where they crumble to pieces in handling. The problem before the farmer is to avoid this crumbling, and at the same time secure such an amount of evaporation from the stalk that it is in condition to go into the barn. The destruction of the structure of the leaf by too rapid drying destroys its power to evaporate water from the stalk, and hence it is possible to have the leaves dry, almost charred, in fact, and their evaporating power destroyed, while the stalk may yet remain full of sap. When clover is very heavy, say three tons of cured hay to the acre, it is not an uncommon thing to see the leaf structure on the surface of the swath destroyed, while the underlying grass is almost as green as when it first felt the edge of the sickle. To avoid this we regard as the essential point, the very key to the situation in the curing of clover hay. The leaves must be preserved, not merely for their own sake, but for their use in evaporating the juices or sap of the stalk. It is this consideration that makes the use of the tedder so imperative when clover hay is cut when it should be to secure the best quality of hay, and at the same time a reasonable chance for a seed crop.

It must be remembered that the only practical agencies which the farmer can use for the ev poration of the surplus moisture are the sunshine and the wind, and the whole problem lies in exposing to the fullest extent the fresh-cut grass to the sun and wind so as to secure the requisite amount of evaporation in the shortest possible time, and in the best part of the day. It must never be forgotten that while clover parts with its moisture readily, the evaporating power of its leaves being usually great, it absorbs moisture with almost equal readiness. A heavy swath of clover lying on damp ground will keep green for days, especially if the atmosphere is heavily laden with moisture, which it sometimes is even in the hottest weather. We have had it after two days of hot sun so dry on the top of the swath as to be seriously damaged, while the bottom was almost as green, to all appearance, as when first cut. It absorbs dew like a sponge and in fact begins to take up water from the air in a day when the atmosphere is full of moisture, long before the dew begins to form. Much of the damage to clover hay arises from the failure on the part of the farmer to comprehend this wonderful power of the clovers to absorb as well as evaporate moisture. On the other hand, it must be remembered that the damage to clover whether in the stack or barn comes nearly always from the outside moisture, whether in the form of rain or dew or absorbed from an atmosphere loaded with moisture. We do not undertake to explain why it is that the juices of the plant are comparatively harmless even when somewhat in excess, but such we take to be the fact.

With these preliminary statements we are prepared to describe what we regard as the best practical method of managing clover, cut in its best condition and under circumstances prevalent on the average western farm. The mowing should be done as far as possible in the evening, say after four o'clock. A wide-cut mower, say six or seven feet, will enable the operator to cut down a comparatively large acreage, and especially if he runs the machine quite late in the evening. The time of the man, team and mower is worth a great deal more an hour after sundown than in the heat of the day. Clover is not damaged in the least by being cut with the dew on or slightly wet and the heat of the sun from four until six is seldom sufficient to render clover cut during these hours liable to damage even if wet with dew or rain in the night. The first work in the early morning should be to start the tedder, one wide enough to take two swaths, and drawn by a span of fast-walking horses. The more directly upwards the tedder tosses the hay, the better. This shakes off dew or rain, and leaves the mass in the best possible shape for the circulation of the air and most exposed to the action of the sun. A good tedder with a team of this kind can cover a large amount of ground in a few hours, and by repeating the operation, in good weather, clover can be fit to go into the barn in the afternoon.

We cannot describe in words the amount of dryness necessary for safety in storing hay. This can be learned only by experience. When a stem of hay is taken in the hand and tightly twisted and no moisture is observed on the outside of the stalk, it is generally safe to store it. This, however, is conditioned somewhat upon the amount of moisture in the atmosphere, and only experience can tell the exact ideal condition. This condition being attained, in the best judgment of the manager, the work of storing away should be done as quickly as possible. It is here that the hay loader becomes valuable, inasmuch as with a good loader a ton can be placed on the wagon in from fifteen to twenty minutes and removed in much less time with a horse fork and hay sling. By this method of handling the hay, the labor of cocking it, or raking it into windrows, the expense of hay caps, etc., are avoided: Where the crop is light, say one and one-half tons to the acre, it is necessary to use the hay rake for speedy loading, and under these circumstances the second tedding may be omitted and the hay loaded out of a small windrow.

It requires nice judgment to know what to do with hay partially cured that has been caught in a heavy rain. In the West storms are frequently accompanied with such high winds, and the down-pour is so heavy that hay anywhere near cured, if put in a cock, will be soaked to the bottom. If caught in a windrow or bunched it is in a worse condition, when thoroughly wet, than if it were scattered on the ground. It will need to be shaken out before storing away, and every time hay is handled after partially cured and then soaked, it is seriously damaged. We have seen it in hot weather with the atmosphere laden with moisture, utterly ruined in twenty-four hours in the windrow. The best way is to keep the work well in hand and the loader well up with the work, so that but a small amount of hay fit to go into the barn or shed can be exposed to threatened rain. It is almost as easy with improved machinery and an adequate force to put hay in the barn or shed as it is to put it in cock, and when once in the cock and completely soaked, it is about as well to let it stand until it dries out of itself. Half its value will be lost in the handling and if allowed to stand till winter it is likely to be no worse. In a matter requiring as sound judgment and prompt action as curing clover hay, no minute directions can be given. Experience will best suggest details. It should be borne in mind that the damage which hay in the process of curing receives from rain, is proportionate to the stage to which the curing process has been carried. The more thoroughly it has been cured, the more damage it receives from the same amount of rain. The less it is handled after being once wet, when partially cured, the less ultimate damage will result. It is almost impossible in ordinary seasons to secure a crop of clover hay in the best condition without the use of barns or hay sheds. If the farmer is to wait until settled weather before commencing to stack and hasten the rounding out and covering of the stack when a cloud appears on the horizon, his work must necessarily be greatly hindered. All farmers cannot have expensive barns, but it is possible for every farmer who has twenty acres of clover hay to build a hay shed that will hold his crop, and by facilitating the process of harvesting it, pay a good interest on the investment and a much larger interest in the way of protecting the crop after it is harvested. The damage to clover hay in the stack under the most favorable conditions is not less than twelve per cent. in the first three weeks, even if in that time there should not have been a drop of rain. This arises from the heating of the hay, (which is unavoidable) the deposit of the ascending moisture on the outside of the stack during the night and the consequent bleaching of the entire outer surface. The loss from this cause has been quite fully investigated by some of our Experiment Stations, and we think that in stating it at twelve per cent. we are making a very conservative estimate. It is possible to erect a hay shed that will hold fifty tons of hay, without cattle shedding around it, for $100. With this the farmer does not need to wait for settled weather and can stow away a load whenever it is cured. The advantages are none the less in feeding it out in the winter. There is no waste in stacks partially used, no stack bottoms wet with rain or snow, no loss in hauling from the stack to the feed yard, and we therefore urge every farmer who wishes to make or feed hay economically to provide himself with one of these useful buildings.

We have emphasized the importance of the use of the tedder. There are years when it will not be needed, as, for example, when by reason of the lateness of the season the corn cannot be laid by in time to secure a hay crop in the best condition, or when by reason of the lack of hay weather the crop is cut late, or when the crop is light or too large to secure it at its best, but we strongly urge every farmer who wishes to secure a crop of clover hay that will feed out satisfactorily, to provide himself with one of these useful implements. After several years' experience we would not undertake to secure a large crop of heavy clover at the proper season without one. We know of no implement that will so well secure thorough and even curing of the hay and guard against both the over-curing that leads to the loss of the leaves and the wet, uncured bunches that do so much to set up destructive fermentation in the mow and induce, under certain conditions, spontaneous combustion in the barn.

The destruction of many barns from mysterious and unknown causes since the introduction of clover culture in the West renders a discussion of the subject a fitting conclusion to a chapter on curing clover. Too many of these barns have been destroyed by fire to allow the farmer to regard the problem of spontaneous combustion as of interest merely to the scientist or perhaps to the manufacturer. While it has long been known that spontaneous combustion is liable to occur in heaps of rubbish containing oil and other carbonaceous matters in a state of minute distribution, it has been steadily held by the majority of scientists that under no circumstances is the spontaneous combustion of clover hay possible. The mysterious fires that have occurred in barns, sheds and stacks have been regarded as the results of accident, or the farmer's pipe, or the nibbling by mice of matches dropped out of the boy's pocket as he was tramping the hay in the mow. As late as the summer of 1889, Professor Sanborn, one of the highest authorities on such questions, in answer to an inquiry in the *Breeders' Gazette*, of Chicago, said:

In fact, I never knew before this case, of a barn burning where either lightning, coal oil lanterns or satisfactory evidence of incendiarism —generally for insurance—was not the easily inciting cause. Hay or fodder that is green enough to ferment will pack closely in a mow by its very weight, and as it heats it settles closer and closer, of course excluding the circulation of the air, except it be by a very slow movement. As the hotter part is the center of the mow, it will be seen to be very doubtful whether air, always essential to flame, will be present in amount sufficient to produce flame. I doubt whether spontaneous combustion of hay or corn fodder is possible.

We had, ever since our attention had been called to the matter, held to the same view. There are frequently mysterious things connected with fires, and the occasional loss of barns from no apparent cause seems to us no more mysterious than dozens of cases of fires in cities.

During the month of September, 1889, we received a letter from Mr. H. R. Leaming, of Wyoming, Iowa, of which we quote the important part:

Enclosed find a sample of clover hay put up in June, on the third day after cutting, in a barn that would hold a hundred tons. It became so hot that it could not be held in the naked hand, and tons of it are completely spoiled. Farmers are in a panic here about their hay. Stacks and barns are taking fire and they do not know what to do. Fifty tons of hay burned within one-half mile of my own farm last night, from its own heat. This hay was watched as it was expected to burn, and there was no question as to its cause. One barn, two miles east of here, was emptied of its hay day before yesterday, that was already on fire in the inside of the mow and kept down by water till it was hauled out to the field. After being hauled out it took fire and burned completely up.

The letter in full may be found in the *Homestead* of October 1st, of the year named, and furnishes clear and convincing proof of at least more than one case of spontaneous combustion. About the same time two cases were reported, one from Gilman, Hancock County, Iowa, and one from Manchester, Delaware County, Iowa. In the Manchester case the barn was the property of Mr. L. G. Clute, and was insured in the Farmers' Insurance Co., of Cedar Rapids, Iowa. The adjuster of the company makes the following statement in the Cedar Rapids, (Iowa) *Gazette:*

The barn was 60x100 feet, the mow being 40x90, and about 30 feet deep, containing nearly 500 tons of hay. Early in haying season green clover had been put in one bent, and ever since it had been heating until at last it took fire by spontaneous combustion. When discovered, there was in three chimney holes, as the neighbors called them, a blue blaze springing out over each, some two or three feet under the roof. The fire was located far beneath at the depth of thirty feet. . . . . This blue blaze was gas, and the depths beneath were a gas well on a small scale. One hundred and three neighbors collected to fight the fire and worked two days and nights to save the hay. Thirteen out of the one hundred and three succumbed to the effects of the gas and had to stop work, one being so violently ill as a result that he is not likely to recover.

We have from time to time received accounts of the spontaneous combustion of clover hay, but the above embraces nearly every distinct feature. The first phenomenon is excessive heating in the center of the mow or stack; then the formation of funnels through which gas escapes at a temperature high enough to cook eggs in a few minutes, corroding at the same time the shell and the lining or membrane which encloses the egg, sometimes followed by flame and sometimes not. Instances often occur in which the combustion has been arrested, and in the heart of the stack may be found a mass of charcoal.

We sent a sample of this charcoal taken from the mow of Mr. C. H. Seager, of Gilman, Iowa, whose barn was burned in the fall of 1889, to Prof. Sanborn, asking his opinion of this new evidence of spontaneous combustion, and we quote a part of his reply, as follows:

"All preconceived views of the matter are puerile before facts. The charred material looks much like matter burned in an air insufficient for full combustion. Charring does not imply flame, but rather the contrary. The heating of green food in the mow is due to a ferment and not to direct oxidation in the old sense of the word, or in the sense that wood is burned. Will the ferments (low plant life) thus produce self-destruction or carry fermentation forward until it becomes oxidation? Fermentation ceases with loss of moisture, and flame will not occur where it is abundant. I confess I never saw such charred material as you have forwarded to me. While it does not follow that combustion need be the result, I confess to the belief that the circumstances do not warrant the denial of the possibility of it, at least by me, with the evidence before me. I hope that you will obtain the views of the highest biological authority in the country, for the question is an interesting and important one."

In the state of Iowa in 1889, there were not less than one hundred cases of spontaneous combustion, all having the same general features, and for some reason the large majority of them, in fact, all with a few exceptions, occurring in the north part of the state. Was it because the farmers in that part of the state had less experience in curing clover hay, and hence cured it too green, or was it because the low plant life which is the cause of the heating in clover hay and other forage was more abundant in that section than in other parts of the West?

Mr. J. W. Bopp, of Hawkeye, Iowa, who investigated nearly fifty cases of spontaneous combustion, reported that in all cases they occurred when the hay was in bays over twenty feet deep. In all, or at least nearly all the instances, the hay was put in damp, either from rain or dew, or with wet bunches interspersed, the result of attempting to cure a heavy crop without the use of the tedder. In most cases into which we have enquired, the hay was placed on timbers that furnished an opportunity for the moderately free access of air underneath. In one notable case at Marshalltown, Iowa, a stack put up when the hay was in bad condition, took fire and burned. Horses running in the field had eaten well into the sides, for some reason preferring this stack to other stacks in the same enclosure, that were put up in the best condition. In the *Homestead*, of February 5, 1889, Mr. Luman Edwards, of Henry county, Illinois, reported two cases occurring in 1886, one at Cambridge, and the other at Kewanee, of that state. Since the public agitation of this subject, we have received numerous letters from farmers, notably from Englishmen, giving their experience both in America and in Europe, all corroborating the facts already stated. The only wonder is, that the theory of the scientists, that spontaneous combustion of clover hay was impossible, had not been utterly exploded long ago. In the light of the facts above given it is utterly untenable. Since the numerous cases of spontaneous combustion in Iowa and elsewhere have occurred, the subject has been investigated by Prof. Burrell, of the University of Illinois. His conclusions are as follows:

"In the first place, it may be said that spontaneous combustion is certainly and definitely known to occur in some substances. One of the requisites in most cases for this is that substance shall be in a state of minute subdivision, in order that a very great surface may be presented for oxygenation, and that the slowly accumulated heat shall not be car-
-d away by conduction. Thus oils containing a large portion of hydro-
like common lubricating oil, have no tendency to ignite at ordinary
eratures when kept in bulk, but when cotton waste is smeared with

the oil and thrown into a heap of some considerable size, fire is very liable to occur from the heat generated within the pile. In this condition slow oxygenation of the oil takes place, favored by the comparatively enormous oil surfaces presented to the air included within the mass, while at the same time escape of heat is prevented by the non-conducting quality of the substance. As the heat accumulates, chemical combination takes place with still greater energy, the stored heat favoring the process, and the process constantly contributing to increase the degree of temperature. If now, the supply of air continues sufficient, as it will be when the mass is sufficiently porous, and the physical conditions are such as to continuously retain the generated heat, the time will come when the temperature will be raised high enough to enkindle the mass. Should an abundant supply of fresh air suddenly reach this over-heated and inflammable material an outburst of flame may result.

"Just the same result has been known to occur in many other substances, as charcoal still having condensed within its pores the inflammable gases separated in the process of manufacture, and reduced to a pulverized state; bituminous coal containing sulphur, and stored in very large quantity.

"Now what of moist vegetable substances? Commonly we should infer that moisture would prevent combustion. In order to burn, such things must be dry. Hay in a barn is no exception to this rule. In fact, if spontaneous combustion does occur in a haymow, you may be assured that the igniting portion is dry at the time. What takes place before combustion is possible? At best it is hard to make all conditions such that spontaneous combustion can occur. Hence one requisite is very inflammable material. Green grass or partially dried grass cannot possibly ignite in this way. In truth such material has not the slightest tendency o become warm on its own account. Familiar as the phenomenon is, green vegetation thrown into a heap does not spontaneously heat. If there were any way of keeping living organisms out of such a mass there would be no generation of heat whatever. Green stuff would keep cool just as certainly as the most thoroughly dried material. But under all ordinary conditions, minute living things are abundant on grass when ever cut and collected. They must have moisture to live. When, however, moist nutrient material is present, they do possess the peculiar power of forming what we call fermentation. In this process heat is one of the results, the chemical changes being fairly equivalent to, though not identical with those of combustion. Under favorable conditions the degree of temperature due to these organisms may rise until it becomes injurious to their physiological functions, *when it can rise no higher*. If the mass still continues moist, no other means are known whereby this temperature can be increased through any internal combinations or changes whatever. Spontaneous combustion is an impossibility. Hence, no silo filled with material containing water enough to keep moist through the fermenting process can possibly burn. The upper limit of temperature for these micro-organisms is pretty definitely ascertained, viz. about 145 degrees Fahr. is about the upper extreme if the bodies are immersed in water. The micro-organisms referred to, are minute plants, and though not killed by temperature fatal to grass and beans, are just as effectually prevented from development at a given degree of heat. Now 145 degrees Fahr. is scalding hot, but it lacks a long way of being sufficient to ignite such fairly combustible matter as dry hay. In other words, heat due to fermentation by living organisms is never sufficient to cause the ignition of vegetable matter, whether moist or thoroughly dry.

"Let us see, however, what else occurs. As true fermentation progresses, water is consumed as well as the nutrient material in which the destructive process occurs. Along with the carbonic acid formed, there is separated a considerable amount of free hydrogen, the inflammable substance of common illuminating gas. If now, the water supply becomes exhausted, the micro-organisms die, or at least their activity ceases and fermentation stops. If there is any further rise in temperature it is not due to fermentation, but to the spontaneous oxygenation similar to that which occurs in cottón waste. Such oxygenation can only occur, as was before said, when the body is porous enough to admit the air, and rise of temperature can only take place when the generated heat is prevented from escaping. The greater the mass, the more favorable the condition for this last. The dryer this mass, the more inflammable it is, and the more pronounced becomes its nön-conducting quality in regard to heat. It may be said by some that little moisture, as in the case of coal, favors spontaneous combustion; but this is only true when by some chemical action the hydrogen of the water is liberated, a process not likely to occur in heated herbage.

From this it may be inferred:

1st. That spontaneous combustion of stored vegetable matter may occur.

2nd. That this can take place only when a considerable number of conditions are favorable at one and the same time.

3rd That just enough moisture to allow very active fermentation to proceed for a time and then become exhausted, is one of these conditions.

4th. That great bulk and exposure to heating effects of the sun (as under an unventilated roof) with the above (3rd.) may be considered seriously dangerous.

5th. That contrary to this no such danger threatens silos as usually filled, however hot the material seems to become."

CLOVERS IN THE ROTATION.

CHAPTER IX.

No permanent system of advanced farming is possible without the adoption of some kind of rotation of crops. In the very nature of things the operations of the farm can not be conducted profitably by the growth of but one crop. There are, it is true, temporary conditions, as for example, when the country is new, land cheap and farm machinery at hand adapted to large operations, under which, for the time being, farming can be conducted on the ranch or bonanza system, as for example, the growth of wheat at the present time in the Dakotas. These conditions last but for a brief period, as is evidenced by the constant removal of farming operations of this class to newer and cheaper lands of the farther west. Profitable farming, under ordinary conditions, requires the employment of labor, whether of the farmer himself or hired help, for the entire year, and hence sooner or later must come diversity of crops, and, later still, systematic rotation. No instance has yet occurred in the history of agriculture where the land has been of such natural fertility that it could endure continuous cropping in any one variety of grain. The constant demand made on the soil by one crop for potash, phosphoric acid or nitrogen, speedily exhausts it of one or all of these essential elements of fertility. No matter which is exhausted, the land, for the time being, becomes barren. Nature, it is true, does not allow of complete exhaustion, but when the exhaustion of any one of these elements has gone so far as to prohibit the growth of *paying* crops, the land, so far as commercial purposes are concerned, is exhausted. The exhaustion of the nitrogen is usually first, for the reason that this most costly element is more easily washed out of the soil by rains during that part of the summer season when it is not covered with some kind of growing crop. There are other reasons, in addition to the failure in the supply of nitrogen, that prevents continuous cropping by the same plant. A notable instance of this is the refusal of even the best corn lands in the West to grow profitable corn crops in succession for very many years. The corn-root worm (*Diabrotica Longicornis*) in many portions of the West begins its operations in a small way the first year. The damage is more noticeable the second and third years, and wherever this pest has made its appearance it usually reduces the crop below what should be regarded as a paying basis.

Long continued growth of successive crops of winter wheat on the same land gives every opportunity for the increase of the Hessian fly, which lays its eggs in the volunteer crop that springs up after harvest. The smuts, rusts and other fungus diseases multiply rapidly when a large acreage of spring and winter wheat is sown in the same vicinity, and especially when sown repeatedly upon the same lands. It is only a question of time when Nature comes in with her imperative command, "Rotate or cease to grow profitable crops."

A rotation, to be profitable, must embody several distinct features. It must comprise crops that mature in different seasons of the year in order that the labor of the farm may find profitable employment. This is imperative. It should consist of crops for which the ground can be prepared and the planting done at different periods of the year. It should consist of crops that draw as far as possible on different elements of fertility in the soil, and if possible, of some crop which restores the elements of fertility which have been exhausted by other crops. It should embrace both grain crops and forage crops. And finally, it should consist of one or more cleaning crops; that is, crops that either smother out weeds or furnish ample opportunity for destroying them in the cultivation demanded, for other reasons, by the crop. For the above reasons, rotations wherever adopted should contain as far as possible grain crops, grass crops and hoed crops, by the latter being meant such crops as require tillage in some form during their period of growth, as for instance, corn and potatoes in America, and potatoes, turnips, mangels, beets, etc., in Europe. As all ordinary rotations must necessarily contain shallow rooting crops, such as wheat, oats and corn, they should also contain deep rooting crops, such as the clovers and what are known ordinarily as root crops.

Having thus described the general features of desirable rotations, it remains to inquire how far the clovers meet the wants of the farmer who is selecting a profitable rotation for his own land, his own tastes and his own market.

As a cleaning crop the clovers surpass all of the so-called hoed crops in America. While hoed or cultivated crops, such for example as corn, potatoes, mangels, beets, etc., afford abundant facilities for the destruction of weeds that germinate prior to July 1st (cultivation being then for the most part suspended by the conditions of the crop as well as the necessities of the farmer) clover smothers out these as well as the weeds that germinate later, which are usually as destructive as those which germinate in the spring. A weed once sprouted and then smothered is as completely destroyed as when it is killed by the use of the plow or the cultivator. Farmers often find that corn lands that have been kept scrupulously clean until July 1st, are foul with smart weed, hog weed, cocklebur and other no less noxious weeds, and that there is no method of destroying them after cultivation has ceased except by the generally impracticable method of hand weeding. The longer land is continuously in corn, the more foul under ordinary circumstances does it become. especially in the Western states. No matter how foul land has become, it is comparatively clean after it has been in clover even for two years. As a deep-rooting crop the clovers have no equal, especially the red, mammoth and alfalfa.

In supplying the nitrogen upon which all the grain crops draw to such an extent, the clovers are invaluable and the more so, because, as we have before stated, they alone of all the crops in general cultivation in America have the power of obtaining their supply of nitrogen from the atmosphere. It is true that beans, peas and other legumes have the same power, but their cultivation is too limited to enter largely into rotation crops. For the reasons above given, the clovers form an essential part of the rotation in every part of the world where advanced systems of agriculture have been established.

The only objection to the clovers, where it is practicable to grow them in America, is that the care of the first crop to some extent interferes with the cultivation of corn and the harvesting of the grains. It is one of the standing regrets of foreign writers on agriculture that clover can not be grown either in Great Britain or on the Continent except as a part of a long rotation, and hence short rotations have to be abandoned. Fortunately as yet, it can be grown in any desired rotation in most parts of the United States.

It is possible to form an indefinite number of rotations by the use of the red, mammoth and alsike clovers. The tendency in all countries is to begin with a short rotation and to extend rotations as agriculture becomes more diversified. Farmers usually begin in the new countries with the crop for which the land is best adapted and which brings the best cash price, and continue with that until compelled to alternate with some other crop. The bulk of new lands in the corn regions are planted in corn year after year, and when corn begins to fail alternated with oats, spring wheat or barley. The difficulty with any of these rotations is that they draw excessively on the stored fertility of the soil, and especially of the nitrogen, and the first move toward the adoption of a better rotation is the introduction of clover. The rotation then stands:

1. Corn; 2. Oats, barley or spring wheat seeded in connection with clover. Where a good stand of clover is secured the crop can be turned under and again planted to corn with manifest advantage. This is the shortest rotation possible. A manifest improvement on this rotation is:

1. Corn; 2. Oats, barley or spring wheat sown with clover; 3. Clover meadow and seed crop.

This makes a 3-years' rotation and the meadow can be turned under and again planted in corn. This is perhaps the best rotation possible where the aim is to get the largest possible amount of immediate cash crops from the land, and at the same time secure a large amount of hay for consumption on the farm. It involves plowing the ground but once in three years, oats and other spring grains being cultivated in without plowing. The seed crop, if the mammoth variety is used, is ordinarily a paying crop, and if the manure is returned to the meadow after the seed is taken off, there is no reason why fertility should not be kept up for an almost indefinite period.

Where the farmer is engaged more largely in livestock production, and especially where he has no permanent pasture in connection with his corn lands, the following is an improvement on the above rotation:

1. Corn; 2. Oats, spring wheat or barley, sown to clover

and timothy; 3. Clover and timothy meadow; 4. Pasture.

If the manure is carefully saved and returned to the pasture before plowing under for the next crop of corn, lands under this rotation should increase in fertility from year to year.

In latitudes where spring wheat is a failure and barley unprofitable on account of climatic conditions, the following rotation may be used to great advantage:

1. Corn; 2. Oats; 3. Winter wheat sown to timothy in the fall and clover the following spring; 4. Clover and timothy for meadow; 5. Pasture.

This can readily be changed on strong lands to a six-crop rotation by taking two successive crops of corn. In this rotation the land is plowed but twice, once for corn and once for winter wheat, if the six-year course is not adopted.

Some Missouri farmers have adopted the following rotation:

1. Corn; 2. Oats sown with clover; 3. Clover meadow; 4. Wheat sown with timothy; 5. Timothy meadow: 6. Pasture, upon which manure is applied.

This rotation would be improved by sowing the wheat to clover as well as timothy. Here again we have but two plowings in the rotation, or one in three years. The clover meadow, it the conditions of the ground admit of early plowing, furnishes one of the best possible preparations for wheat, while the wheat furnishes the best opportunity for securing a stand of timothy, and the pasture following the timothy gives an excellent opportunity for the application of manure to be plowed under in the fall as a preparation for corn the first course in the succeeding period of the rotation.

In sections west of the Missouri where the tame grasses can not be grown successfully with a nurse crop, we venture to suggest the following rotation:

1. Corn; 2. Mammoth clover; 3. Wheat; 4. Mixed clovers and orchard grass; 5. Meadow; 6. Pasture; 7. Pasture.

The objections to this rotation are that two years out of seven there is no money crop. The objection has much force, and yet we believe that the increased returns from the other five years will much more than make up for the apparent loss of the crops of the two years in which the grasses are being established. We suggest that the mammoth clover be sown on corn stalks as early in the spring as practicable. When a stand is obtained, the crop could be turned under in August in time to prepare the ground thoroughly for a wheat crop;

or, it could be pastured with advantage during the months of July and August. The land being in excellent heart the fourth year should furnish a fine crop of mixed clovers, and orchard grass, which would during the fall months afford a large amount of pasture. We make the above suggestion merely as a matter worthy of trial, not only at the experiment stations, but in a small way by the farmers themselves. Should the soy bean meet the expectations of those who are best acquainted with its value, it could be substituted for the mammoth clover. The soy beans could be removed in time for a wheat crop, leaving the land in excellent condition for seeding without plowing, and thus one year's loss of the use of the land be avoided. The reason for using orchard grass is that it succeeds admirably, even on quite dry soils far west of the Missouri. It furnishes in connection with clover a very superior aftermath, but the cost of the seed is so great that it should not be plowed up for at least two or three years after sowing.

Some Minnesota farmers have adopted with great advantage the following rotation:

1. Corn; 2. Barley; 3. Spring wheat; 4. Oats sown with clover and timothy; 5. Clover and timothy meadow; 6. Pasture.

This rotation has resulted in a very great increase of the fertility of the land for the time being, but lands must be very fertile indeed to endure four grain crops in succession without the use of clover.

We have given these examples of rotation in use in different parts of the West, not for the purpose of discussing the subject of rotations, but to show how essential clover is to any rotation that will secure large crops and at the same time conserve the fertility of the land.

A rotation specially adapted for locations where winter wheat is a reliable crop, and where potatoes by reason of market facilities are profitable, is,

1. Clover; 2. Potatoes; 3. Winter wheat.

This in many respects is an admirable rotation. In fact it fulfills all the requirements of an ideal rotation. Clover turned under early in the fall, say in August or September, forms the very best preparation for a large and profitable crop of potatoes. The clover being in itself an admirable cleaning crop, the culture of potatoes is an easy matter. There are comparatively few weed seeds to germinate and give trouble, and these can be easily kept down in the cultivation of the potatoes. It besides furnishes in available form and in great abundance the elements of fertility which the potato needs. The potatoes in turn can be removed from the ground in time for a crop of winter wheat, with or without plowing, preferably without, as the potato ground furnishes the solid bottom for the seed bed, with loose, mellow soil on top. Wheat can be planted on this with a press drill as early as desirable, and speedy and vigorous germination will follow. Winter wheat, again, is one of the best nurse crops for clover. We do not see why the fertility under this rotation should not remain almost constant, and, if top dressing of manure is applied with the clover, why it should not increase from year to year, the clover increasing the supply of nitrogenous compounds and the slow disintegration of the minute particles of rock, of which the soil so largely consists, keeping up the supply of potash and phosphoric acid. We advise farmers situated in the winter wheat regions where potatoes are a profitable crop to adopt it.

CLOVER IN FEEDING RATIONS.

CHAPTER X.

No practical work on clover culture would be complete without a clear and definite statement of the use and value of the different varieties, both as pasture and forage, in the feeding ration needed for different kinds of stock under different conditions and circumstances. American farmers are but beginning to discuss this important matter, and the more expensive the various articles of stock feed become on account of the higher price of land and labor, the more important and indeed essential it will be to learn how to feed them to advantage, and with the least waste, whether of the clovers or other parts of the ration. The problem is usually regarded as too abstruse and difficult for the practical, every-day farmer. While there are many difficulties connected with this problem, and even those best informed on the subject have much to learn, the elementary principles are simple enough. It is obvious from a moment's reflection, that every part of the animal frame must be derived directly or indirectly from the plant. No animal can live on air alone, or upon the soil on which it treads. In the story of the creation we are told that the herb yielding seed and the tree yielding fruit were created before either man or animal was formed to consume them. This is simple enough. While the frame of the animal is mostly carbon and nitrogen, both elements of the air it breathes, there is no possible way in which they can become part of it except through the medium of plant food. The flesh and food-forming elements of the animal must first appear in the plant. The plant is the medium through which the materials existing in earth and air become adapted to the life of the animal. The most costly element in all food, either of the animal or the plant, is in the form of nitrogenous compounds of different kinds, which we group under the one term, nitrogen. Some writers call it protein, some albuminoids, but all three mean practically the same thing, the flesh-forming elements of the food. The atmosphere which the animal breathes is four-fifths nitrogen, which is the base of all these compounds, and yet the animal inevitably starves to death unless it has a supply of these compounds of nitrogen through the plant, or in case of carnivorous animals, through the flesh of other animals, or insects which has in turn been derived from the plant. The same remarks apply to the carbonaceous, that is, the elements that are consumed to maintain the animal heat, and that are stored away in the system as fat, and also to the mineral elements which make up bone. Of whatever the animal frame may consist, whether bone, flesh or fat, it must have been fed into it either in the plant or the milk of its dam or the flesh of other animals, and therefore must come through its food. While carbonaceous substances compose by far the largest part of animal food and animal forms, it has been very clearly demonstrated that the animal fed on purely carbonaceous food, such as sugar or starch, will speedily starve, no matter how abundant the food; and it has been as clearly proved that foods having an excess of nitrogen when fed to herbivorous animals will sooner or later produce disease and death. It seems that when carbonaceous elements are lacking the system can use nitrogenous compounds for keeping up the animal heat, just as for lack of coal we may burn wood in the stove. But the carbonaceous elements can not be used for the purpose of building up either the muscular system, or the skeleton, commonly called by scientists, the osseous or bony system. It is therefore evident that much of the success in stock feeding depends upon supplying these elements as nearly as possible in their proper proportion, feeding nitrogenous food in the proportion in which it is required for growth and repair of waste, carbonaceous foods in the proportion in which they are needed for keeping up the animal heat and finishing the animal for the shambles, and furnishing mineral elements in the proportion needed for the growth of the osseous system.

In compounding feeding rations, as in every thing else, Nature is the best teacher. She emphasizes in the most emphatic way the necessity of a balanced ration. She provides in the milk for the young of each race, a ration composed of the materials in the due proportion that each needs, and man soon finds out that if he interferes and takes away the carbohydrates or the albuminoids, as for example the fat, from the milk in the shape of cream, or the albuminoids in the shape of cheese, the young fail to reach their proper development, pine away or perhaps die. The skim-milk calf, for example, unless the balance is kept up by means of cheaper fats, is always a sorry looking object. The whey calf fares still worse, because the subject of a greater robbery, but neither of them fares very much worse than the calf, the milk of whose dam is too rich in fats. Nature insists on a balanced ration, and can not be prevented from taking her revenge on those who violate her laws. When either albuminoids or carbo-hydrates, or in other words, nitrogenous or carbonaceous compounds are fed in excess of the wants of the animal, the surplus is wasted. It is worse than wasted, for digestion has meanwhile gone on, and the system having no use for the digested matter beyond its capacity to assimilate, can do nothing else than void it. This is a waste, not merely of the animal food, but of the animal forces. For example, the animal at a certain stage of its existence demands a ration composed of 1 of albuminoids to 6 of carbo-hydrates, which we express as follows: 1:6, and if fed corn exclusively, having, let us suppose, a ratio of 1:9, or 1 of albuminoids to 9 of carbo-hydrates; then one-third of the carbo-hydrates is clearly wasted. If, however, to this corn ration be added bran or oil meal in quantities sufficient to make a ratio of 1:6, then is the corn fully utilized as is also the added food.

The western states have a great excess of carbo-hydrates, an excess rendered all the greater by the continuous shipment abroad of wheat and oil meal and livestock, and rendered all the greater locally by the shipment of livestock to the great cities and wheat to the great milling centers. It therefore stands in need of a fodder rich in albuminoids to balance up the too carbonaceous corn stalks and straw that are left for feed on the farm. It also needs a ration having albuminoids in excess for finishing stock for the feed lot in order to avoid the expense of providing albuminoids in the form of bran and oil meal. To meet the first want the clovers furnish an ample supply if properly handled. The second want which is supplied in other countries by peas, beans and turnips, will doubtless be met in time, by some legume adapted to the climate and soil, possibly the soy bean. Great as is the value of the clovers in supplying nitrogen to the soil, they are scarcely less valuable as a source of albuminoids with which to balance up our excessively carbonaceous foods. In order that the reader may see the value of the clovers for this purpose, we give the following tables, showing the amount of dry organic matter and also of digestible albuminoids, carbohydrates and fat that are required by different animals and of the same animal in different stages of its growth, and when fed for different purposes:

TABLE I.—Pounds Per Day Required for 1000 Pounds Live Weight.

	Total dry organic matter. Lbs.	Digestible constituents: Albuminoids. Lbs.	Carbohydrates. Lbs.	Fat. Lbs.	Total nutritive matter. Lbs.	Nutritive Ratio.
Oxen at rest in stall..........	17.5	0.7	8.0	0.15	8.85	1:12.0
Oxen at medium work.......	24.5	1.6	11.3	0.30	13.20	1:7.5
Oxen at hard work..........	26.0	2.4	13.2	0.50	16.10	1:6.0
Horses at light work........	20.0	1.5	9 5	0.40	11.40	1:7.0
Horses at medium work.....	21.0	1.7	10.7	0.60	13.00	1:7.0
Horses at hard work........	24.0	2.4	12.5	0.80	15.70	1:6.0
Milch cows..................	24.0	2.5	12.5	0.40	15.40	1:5.4
Fattening steers, 1st period..	27.0	2.5	15.0	0.50	18.00	1:6.5
Fattening steers, 2d period..	26.0	3.0	14.8	0 70	18.50	1:5.5
Fattening steers, 3d period..	25.0	2.7	14.8	0.60	18.10	1:6.0
Sheep, wool producing, coarse	20.0	1.2	10.3	0 20	11.70	1:9.0
Sheep, wool producing, fine..	22.5	1.5	11.4	0.25	13.15	1:8.0
Fattening sheep, 1st period..	26.0	3.0	15.2	0.50	18.70	1:5.5
Fattening sheep, 2d period..	25.0	3.5	14.4	0.60	18.50	1:4.5
Fattening swine, 1st period..	36.0	5.0	27.5		32.50	1:5.5
Fattening swine, 2d period..	31.0	4.0	24.0		28.00	1:6.0
Fattening swine, 3d period..	23.5	2.7	17.5		20.20	1:6.5

TABLE II.—Pounds Per Day Per Head.

Age—mos.	Average weight.	Total dry organic matter. Lbs.	Digestible constituents: Albuminoids. Lbs.	Carbohydrates. Lbs.	Fat. Lbs.	Total nutritive matter. Lbs.	Nutritive Ratio.
GROWING CATTLE.							
2 to 3	150 lbs.	3.3	0.6	2.1	0 30	3.00	1:4.7
3 " 6	300 "	7.0	1.0	4.1	0.30	5.40	1:5.0
6 " 12	500 "	12.0	1.3	6.8	0.30	8.40	1:6.0
12 " 18	700 "	16.8	1.4	9.1	0.28	10.78	1:7.0
18 " 24	850 "	20.4	1.4	10.3	0.26	11.96	1:8.0
GROWING SHEEP.							
5 to 6	56 lbs.	1.6	0.18	0.87	0.045	1.095	1:5.5
6 " 8	68 "	1.7	0.17	0.85	0.040	1.060	1:5.5
8 " 11	76 "	1.7	0.16	0.85	0.037	1.047	1:6.0
11 " 15	82 "	1.8	0.14	0.89	0.032	1.062	1:7.0
15 " 20	86 "	1.9	0.12	0.88	0.025	1.025	1:8.0
GROWING AND FATTENING SWINE.							
2 to 3	50 lbs.	2.1	0.38	1.50		1.88	1:4.0
3 " 5	100 "	3.4	0.50	2.50		3.00	1:5.0
5 " 6	125 "	3.9	0.54	2.96		3.50	1:5.5
6 " 8	170 "	4.6	0.58	3.47		4.05	1:6.0
8 " 12	250 "	5.2	0.62	4.05		4.67	1:6.5

These are German tables and the weights do not in all cases correspond with those customary for stock of like ages in this country, but this does not affect the principle the tables are here adduced to illustrate.

To show how inefficient our non-leguminous grains and grasses are to meet the requirements of the above tables, we give the digestible nutrients shown by the analyses of the non-leguminous grains and fodders that are grown in the West, and that form the staple of the food of our livestock:

	Albuminoids. Per cent.	Carbohydrates. Per cent.	Fat. Per cent.	Nutritive Ratio.
Corn	8.36	64.81	4.74	1: 9.3
Oats	8.46	46.11	3.94	1: 6.5
Barley	9 64	60 77	1.86	1: 6.7
Rye	8 37	63.16	1.09	1: 7.8
Timothy hay	3 67	41.25	1.03	1:12.7
Red top	4.13	44.76	0.94	1:11.3
Orchard grass	4.66	43.07	1.08	1:10.4
Blue grass	6.42	41.96	1.17	1: 7.1
Hungarian grass	3.87	49.68	1.22	1:13.5
Barley hay (seed in milk)	5.24	44 82	1.18	1: 9.0
Oat hay (seed in milk)	5 07	43.89	1.31	1: 9.2
Corn stover	2.41	34.48	0.47	1:14.7
Sowed corn fodder, very good, field cured	3.00	40.00	0.93	1:14.0
Oat straw	1 44	42.62	0.66	1:30.0
Rye straw	1.14	37.55	0.59	1:34.0
Wheat straw	1.29	37.70	0.40	1:29.0
Corn fodder, green	1.19	10.87	0.31	1: 9.9
Sorghum, green	0.80	12.26	0.28	1:16.0
Rye fodder, green	1.77	13.38	0.39	1: 8.0

In order that the reader may be able to compare the nutritive elements in the non-leguminous grains and forage with the elements contained in the legumes, and thus form an adequate idea of the difference in the proportion or ratio that exists between the albuminoids and carbo-hydrates of the two classes, respectively, the following table showing the digestible contents of clovers and other leguminous plants, is appended:

	Albuminoids. Per cent.	Carbohydrates. Per cent.	Fat. Per cent.	Nutritive Ratio.
Red clover, full bloom	11.72	40.17	2.75	1:3.9
White clover, in blossom	11.27	40.56	2.56	1:4.2
Alfalfa, in bloom	11.65	41.05	1.02	1:3.7
Beans, ripe	22.58	57.76	1.87	1:2.7
Peas, green, dried substance	14.13	65.98	1.51	1:4.9
Soy beans	31.14	27.48	15.59	1:2.0

It will be readily seen that with certain ends to accomplish, as for example, the growth of the pig from fifty pounds weight to a hundred, where a ratio of from 1:4 to 1:5 is required, and with no feed on hand except corn with a ratio of 1:9.3 (see table 3.) and a deficiency in bone material, besides, there can be but one result: the frame becomes deficient in bone material and the pig fine in bone, chuffy and small; and no amount of corn fed, even with its attendant waste, can properly develop its form. It becomes, under excessive corn feeding a globe of fat, fit subject for every disease and a source of continual disappointment to its unwise owner.

If a horse is to be kept for hard work, involving great waste of muscular tissue, and it is fed solely on corn, which is deficient in material adapted to supply the waste, it is clear that it must be fed much more corn than under other circumstances would be necessary. Hence, the preference for oats as feed for work horses, and of corn as a food for fattening mature cattle or hogs. In the last case, the waste of muscular tissue is slight, while the end in view is the storing away of surplus fat in the system. For this nothing is better than corn.

The term "pigs in the clover" has become a synonym for abundance, while feeding an exclusive corn diet without clover to growing pigs is everywhere condemned by good farmers as unprofitable, and hence in their experience is a waste of corn. How to avoid this and like wastes by the use of clover is the problem now under consideration.

In the early stages of their growth, all grasses have a large amount of nitrogenous compounds. The dry matter, for example, of clover cut when from three to four inches high, approximates the nutritive value of oil meal, hence a pasture of mixed grasses in May and the early part of June forms an almost ideal ration. As these grasses mature, the proportion of carbonaceous compounds or carbohydrates increases relatively. Clover alone contains a sufficiently large proportion of nitrogen to make it valuable in balancing up rations. We now inquire how this clover can be used to balance up the carbonaceous foods, and that, too, by any farmer who has even a general idea of the different elements in the supply of food at his command.

Nearly every farmer in the West has a field of cornstalks which he wishes to use to the best advantage. Many farmers are not prepared to build silos and many others have not the labor at their command at a price which they believe justifies them in cutting up the corn and using it as fodder. It requires labor to handle the grain and fodder after husking and to return the stalks to the field in the shape of manure. In the greater part of the United States this will pay. There are portions, however, where the cornfields are very large and the supply of stock limited where as yet this method of saving fodder is not believed to be profitable, and the question before us now is, how these stalks can be used to the best advantage. Corn stalks in their best estate, before bleached by rain, and the leaves in which, with the husks, most of the nitrogenous compounds are found, have a ratio of 1:14.7, a very wide ratio it will be seen, which becomes wider, that is, the proportion of carbohydrates to albuminoids becomes greater, every day after it is exposed to the weather. It is entirely practicable for most farmers to have in the same field a clover meadow, and to allow the second crop or aftermath to remain untouched until after the corn is husked and the cattle are turned into the corn field. This clover aftermath or second crop has, before being damaged by winter's rain or frost, a ratio of 1:2.3. This ratio becomes wider during the winter season, but it does not widen as rapidly as that of the corn stalks.

It is now plain to be seen that by using this second crop for pasturage in connection with corn stalks, a very great saving may be made for stock cattle or milk cows or horses, by allowing them to consume both together, the excess of albuminoids in the clover balancing the excess of carbohydrates in the corn stalks, and together making a fairly good winter pasture. No argument is needed by any farmer who has once tried this method. Nor is it alone in the balancing up of the ration that the benefit consists. There is very little danger of compaction of the stomach where cattle have free access to this clover aftermath, nor is there any danger from bloating from the clover.

Every farmer who is extensively engaged in growing wheat, oats or barley has, at his command, a large amount of straw which is either burnt (a wasteful habit which can not be too strongly condemned) or stacked and allowed to rot on the fields, or perhaps used for bedding. This has a ratio of 1:29 in case of wheat straw; 1:30 in case of oats; 1:34 in case of rye, with a probable average ratio of 1:32. The stock require a ratio of say 1:8. It will be seen that if the animal is to increase in size and weight or even repair the waste of muscular tissue, it must consume a very large amount of the straw to get sufficient for the purpose. This straw has to be wet with a large amount of water, the water has to be brought up to blood heat and then the greater portion of the carbohydrates is wasted. This explains why cattle fed on foods of this kind exclusively wear themselves out in the winter by trying to digest a great deal more than the system can assimilate. This waste may to a great extent be avoided by stacking the straw in a clover field where the aftermath has been allowed to stand, and allowing cattle free access to both. Where this is not practicable, the waste can be avoided by feeding clover and straw alternately, or by cutting and mixing both and making a complete ration by the use of bran or oil meal.

For example, clover hay has a ratio of 1:5.6. (We are speaking now of clover hay in its best condition cut when the heads are not more than one-third brown and properly cured. The feeder usually knows how far his hay varies from this standard whether by late cutting or defective curing. It should be noticed in either case that the departure from the standard will be in the loss of the albuminoid or protein elements and therefore the less efficiently will it balance up a corn ration.) The farmer has steers on feed, and wishes to get the best results from his corn. This has a ratio of 1:9.3, and should be brought down to a ratio of 1:5.5 or 1:6.5. He can do this by feeding oil meal, shorts or bran, but he can narrow this broad ration of corn to some extent by feeding clover hay for roughness. How far he can narrow the ration will depend on how much clover hay he can induce his cattle to eat in the uncut state, and this no one can determine but himself.

When labor becomes cheaper in the West and land and its products dearer, there will be a much greater opportunity than now to use clover in the feeding ration. Clover hay will then be largely cut and mixed with ground food and there is scarcely any limit to the methods in which it can be used in this way. It will enter largely into the ration for dairy cows in connection with other forage and the various cereals. Although it is impossible to make an ideal milk ration by adding clover hay to the corn and corn fodder upon which so many cows are now fed, yet every pound of clover that is added to these foods improves the ration. The ideal balance for milk should be one pound of albuminoids to each five and four-tenths pounds of carbohydrates. Good clover hay as usually cut has a ratio of 1:5.6, and is of itself substantially in the right proportion, but the corn is 1:9.3 and the corn stalks 1:14.7. If the last two were fed in equal weights the ratio would be 1:12; if the three feed stuffs were fed in equal weights the ratio would be 1:9.8, which, although still far from the ideal requirements, is much more nearly right than the corn and fodder without the clover. Substitute bran for half the corn and the ratio would be still further narrowed to 1:8.5, or substitute oil meal for half the corn and the ratio of the mass would be narrowed to 1:7.5.

Timothy hay has a wide ratio of 1:12.7, and every farmer knows how the addition of clover improves it. The reason is that the ratio, that is, the proportion between the albuminoids and the carbohydrates, is narrowed. Equal weights of timothy and clover hay cut as described will have a ratio of 1:9.15. If to such mixed hay corn is added the ratio will not be much disturbed. If an equal weight of corn and bran in equal parts be added the ratio of the whole ration will be 1:8, and if the grains fed be half corn and half oil meal the ratio of the whole will be 1:7.1. If the mixed hay be added to an equal weight of oats the ratio of the mass will be 1:7.8, whereas timothy and oats alone in equal parts would have a ratio 1:9.6. These examples are given merely to illustrate the manner in which clover hay may advantageously narrow the ratio of other feed stuffs. Corn ensilage may in like manner be narrowed with clover. Alone it has a ratio of about 1:11, but if an equal weight of clover hay be added the ratio of the whole will be narrowed to 1:8.3. A careful study of the tables on pages 101 and 102 will suggest other combinations of clover hay suitable to the live stock of the farm.

Where alfalfa hay is grown the hay can be used even to better purpose than clover, for it is customary to cut it at an earlier stage of growth, when if well cured its ratio is about 1:2.8. It is the more valuable because in the district in which alfalfa is grown there is a very great supply of carbonaceous foods which require, for use for the highest profit, to be balanced up with a more albuminous food. Some horse breeders in the Eastern states have become so impressed with the value of alfalfa as a producer of muscle that they send yearling colts to the alfalfa districts of Kansas in order that they may be grown largely on alfalfa pasture and alfalfa hay. This may seem a mere conceit, but it is not impossible that they may have more facts to sustain them than is apparent at first sight. It is in entire harmony with feeding principles. While many farmers see at a glance the value of the various clovers in the ration the number will greatly increase as land and its products increase in value and the science and practice of compounding balanced rations which is yet in its infancy becomes completely understood.

INSECT AND OTHER ENEMIES.

CHAPTER XI.

It is a peculiarity of all cultivated crops that when grown abundantly over a wide district of country, they become infested with many diseases and are attacked by a large number of insect and other enemies. The more useful the plant, the greater the variety and number of its foes. It may therefore be reasonably expected that whenever the culture of clover becomes established in any state or section and is in such high favor with farmers that a large acreage is in cultivation, insect enemies will appear, increase and multiply.

Prof. J. A. Lintner, in the Report of the New York Agricultural Society 1881-2, page 190, gives a list of no less than seventy-one species of insects in Europe which infest the clover plant. In the same volume, pages 192 and 206, he gives the names of some sixty species that have been known to attack clover in America, and some eight or ten other species have since been discovered by other entomologists. A recent bulletin of the Ohio Agricultural Experiment Station gives the names of eighty-two that have been discovered up to 1885. It will thus be seen that the clovers have as many enemies as a saint. Many of these species are not peculiar enemies of clover, as, for instance, the grasshoppers and various butterflies, and, hence, will not be discussed here, while others do comparatively little damage. We confine our attention mainly to those peculiar to the clover, which have infested the clover fields in some parts of the country, and may in all.

One of the minor pests is the clover leaf midge, (an illustration of which is presented on the following page) which deposits its eggs in the folded leaf of the white clover, and has, in some instances, been found on the red, though not yet, we believe, on the alsike. It is described by Prof. Riley in the Report of the Department of Agriculture, 1879, page 197. Where it has begun its operations, the eggs will be found on the leaves, on the dividing line in each leaf, and their presence may be suspected when the leaves are folded up. On unfolding these leaves, from one to twenty whitish, pale orange maggots may be found, similar to, but smaller, than those of the clover-seed midge, which will be described in Chapter XII. It was first described by the German entomologist, Dr. Leow. The length of this midge is about .059 of an inch. When matured it forms a white, delicate cocoon, in the folded leaflet, inside of which may be found the pupa, pale orange in color. The perfect fly is very similar to that of the clover seed midge, the main difference being that the antennae, or feelers, of the leaf midge have fourteen instead of sixteen joints. It is not likely that this will ever become a serious pest, inasmuch as the exposed condition of the eggs leaves them open to many enemies, and renders them especially liable to be infested by parasites. When working on the red clover it will be found in the form of a gall on the undermost leaves.

THE CLOVER LEAF MIDGE.

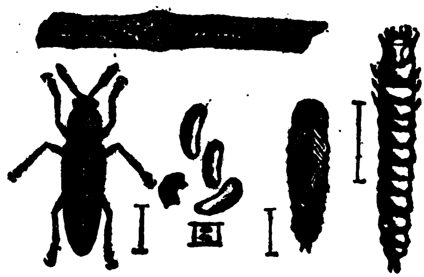
A much more serious pest is the clover root borer, (*Hylesinus trifolii*), Mueller. This was first noticed in New York in 1878, and described by Prof. Riley at some length in the report of the Commissioner of Agriculture for that year. As the name implies, it belongs to an entirely different family, and is closely related to the common bark beetle, which is often found under the bark of both evergreen and deciduous trees, deciduous trees being those that shed their leaves in the fall. The illustration on the following page will enable our readers to identify the beetle in three of its stages. In the illustration *a* represents the affected plant with the maggot feeding in the root, *b* the maggot highly magnified, *c* the pupa, and *d* the full-grown beetle. The eggs are whitish and oval, the larvæ white with oval head and the beetle black and about .08 of an inch in length. The female appears in the spring, bores a hole in the crown of the root, eating out a pretty large cavity, in which she deposits the eggs. These are hatched in about a week, and the maggots first feed in the cavity made by the parent for their accommodation. When somewhat grown, they begin to burrow downward, following out the different branches of the root. The pupa is formed in a smooth cavity, generally at the end of one of these burrows, and may be found there in the fall. This, of course, greatly weakens the plant, and it is not able to produce a seed crop; hence, where farmers find clover after the first cutting in the fall not producing seed heads, they may suspect the presence of the clover root borer. A very slight investigation will discover the presence of the pest. The stalks pull up easily and sometimes push before the mower. Thus, the borer, as will be seen from the above description of its habits, affects only the second year's crop, as the first year's crop is not sufficiently advanced to allow the female to deposit her eggs, there being no crown or sufficient root development for the support of the young. The only known method of avoiding the ravages of this pest is to plow up the field and plant it to corn, a remedy not applicable, however, in fields where clover is growing as part of the permanent pasture. From its habits the clover root borer cannot be distributed as rapidly as the clover seed midge. It prevails, however, over a large part of the country, having been abundant as far west as some counties in northern Iowa, for some years. Fortunately, the farmer does not suffer any serious loss by being compelled to plow up his clover field at the end of the second year, the main loss being the deficient yield of the affected plant and the failure of a seed crop. In many places where it has appeared, this singular fact has been noted, that while they may ruin whole fields one season, the borers may be quite rare the next. This would indicate either that it has some parasite enemies, or that they are destroyed in great numbers while hibernating in the ground in the winter, or that the old plants have been destroyed and sufficient young ones have come forward from self-seeding to maintain the stand.

THE CLOVER ROOT BORER.

Another insect that affects clover injuriously is the flavescent clover weevil, (*Sitones flavescens*) Allard. In the month of October, 1885, Mr. F. M. Webster, then of Lafayette, Indiana, special agent of the Department of Agriculture, discovered that the foliage of white clover, and also of the alsike on the grounds of the Purdue University, at Lafayette, Indiana, were seriously injured by an insect enemy, and he described and reported the insect to the Department, the description being published in the annual report of 1886, pp. 580-2. The injury was done mainly to the leaves of the clover, and consisted in cutting a circular disc in the center of the leaf, and also circular spaces from the margins, in some cases leaving only the leaf stalk and the backbone of the leaf, or the bases of the mid-veins. This he identified as the flavescent clover weevil, (*Sitones flavescens.*) The insect had been previously described by Dr. Lintner, of New York, and also by Dr. Riley, of the Department of Agriculture. It is one of the beetles, and has a wide distribution, being quite frequent in the Atlantic states, and in Indiana, Illinois and Minnesota. The beetles are described as rather timid, and drop to the ground on the slightest disturbance, hiding among the leaves and rubbish, and, therefore, it is difficult to discover them in the act of feeding on the leaves. The peculiar circular marks which they make are due to the habit of the insect when feeding, of moving simply the head and neck, the body remaining stationary, much after the fashion of a cow with her head between a barb wire fence and reaching as far as her tongue will enable her to take in the herbage.

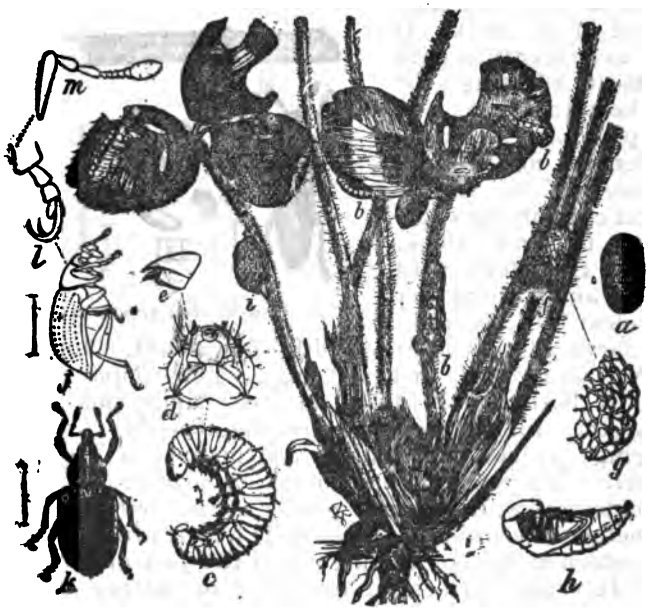
These beetles appear in the spring of the year, about the time the first tender leaves make their appearance, and carry on their depredations throughout the summer. The eggs are deposited in July and August, and the deposit continues until cold weather begins. The larvæ hatch out about two days after the eggs are laid, and pass the winter in the larval stage, pupating or undergoing their final transformation in the spring, and after remaining about twenty days in this stage, emerge as adults, thus completing the cycle. This pest was discovered in 1891, as being quite abundant at Ames, Iowa, and a full account of it may be found in Bulletin 14, for August of that year. While as noticed in Indiana and further east, they infest mainly the alsike and white clovers, they seem to be partial to red clover in Iowa. It is not probable that this insect will do very serious damage, and it is likely common, its ravages being mistaken for those of grasshoppers. Prof. Osborn describes it as little less than one-fourth of an inch in length, about one-tenth of an inch wide, with a faint light brown stripe running the length of the head between the eyes, and dimly discernable on the wing covers.

Clover Stem Borer, (*Languria Mozardi*,) Fabr. In his report to the Department of Agriculture for 1879, Prof. J. Henry Comstock, entomologist of the Department, describes a new clover pest then recently discovered, called the Clover Stem Borer. The accompanying illustration will enable the reader to identify the eggs, larvæ, pupa, the adult borer and also the manner in which the eggs are laid in the stalk. It seems to be identical with an insect affecting the fall wheat in Kansas and perhaps other sections, and hence is not peculiar to clover. The female lays her eggs in June, according to Prof. Cook, piercing the stem with her jaws and pushing her eggs clear into the pith. The larvæ feed on the pith downward, forming a burrow about six inches long. The pupa is formed at the bottom of this burrow and shortly afterwards the fully developed beetles begin to appear, emerging from the hollow stems from August to October. There is but one brood each year. The beetle hibernates and waits until the plants are in their full vigor in June before depositing her eggs. It will readily be seen that the Western method of cutting clover the last of June or the first of July, and then either pasturing or cutting the second crop for seed will give small chance for this pest to increase. Recent discoveries, however, have shown that a stock of the borers may be kept up indefinitely, from the fact that it lives on quite a number of plants besides clover. It has been found in the sweet clover, in wild thistles, wild lettuce, yarrow and in timothy. It has, however, several parasites, and there is but little danger of it ever becoming a destructive pest.



THE CLOVER STEM-BORER.

Clover Leaf Beetle, (*Phytonomus punctatus*). This, like many of our destructive insects, is stated by Prof. Cook to be an imported species, common in Germany, prevailing in Canada since 1853, appearing in New York in 1881, and later, in 1884, at Buffalo, N. Y. It appeared in northeastern Ohio in 1891, and recently near Cincinnati, Ohio. The following illustration will give our readers an idea of the beetle at its work, in which *a* represents the egg enlarged; *b, b, b, b*, represent the different stages of their growth feeding; *c*, the young larvæ; *d*, the head from beneath; *e*, the jaw enlarged; *f*, the cocoon reduced in size and meshes of the same; *g* and *h*, the pupæ; *i*, the beetle, also reduced; *j*, side view of the beetle, and *k*, a dorsal view of the same, slightly reduced from the natural size; *l* and *m*, foot and antennæ enlarged. For the illustration the public is indebted to Dr. Riley. From a descrip-

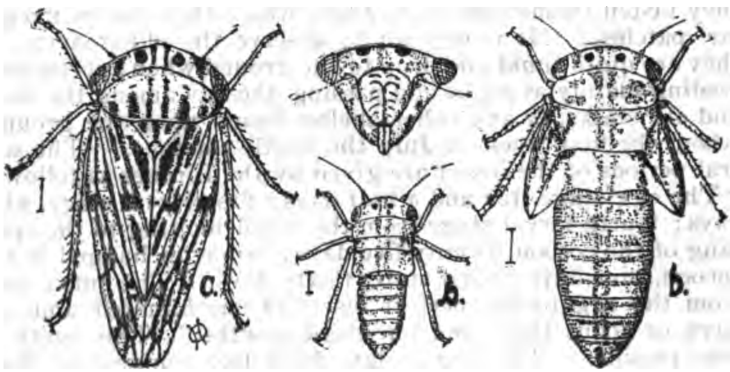


THE CLOVER LEAF BEETLE.

tion by Dr. Lintner, State Entomologist of New York, we condense as follows: It measures four-tenths of an inch in length, is oval in form, brown in color; the beak is short, broad and blunt. The wing covers are clothed with short, yellowish brown hairs, the egg is a long oval and about twice as long as wide, pale yellow, smooth when first laid, but becoming greenish yellow before hatching. The larvæ hatch out in about a week from the time the egg is laid. They are pale in color, with a dark head, which subsequently becomes greenish. The body is deeply wrinkled, and when it rests clings sidewise to the leaf in a d position. The eggs are deposited in the latter part ummer by beetles which appear in July and August.

The larvæ appear in September, change to pupæ in October, and emerge as beetles in November. Some of them lay their eggs from which the larvæ hatch and hibernate while quite small within the old clover stems. Others hibernate as beetles and lay their eggs the following spring. The young larvæ are seen as early as April, feeding on the clover, but their ravages do not become marked until May or June. They feed first on the folded young leaves, and attach themselves to the under side of the leaf, while later they fasten themselves to its edge, which they eat in irregular patches. It is difficult to observe the older larvæ, as they are quite timid and drop to the ground when approached, feeding mainly at night and passing the day among the roots and old stalks, or any other shelter found upon the ground. About the first week in July the beetle emerges. The several periods of the insect are given by Dr. Lintner as follows: "The egg stage, ten and a half days; first larval stage, nine days; fourth larval stage from the third molting to the spinning of the cocoon, twenty-five days; larvæ unchanged in the cocoon, nine days; pupa state, thirty days. The entire time from the egg to the perfect insect is one hundred and one days, or about three and one-third months." This beetle is very prolific. The female lays from two hundred to three hundred eggs in the clover stem, which it usually punctures for that purpose. The larvæ, or worms, are constitutionally hungry and consume every part of the plant above the surface of the earth. The beetles are described by Prof. Cook as doing very serious damage in June or July, thus completing the work of destruction begun by the larvæ. Inasmuch as these beetles are waterproof, they may be expected to spread very rapidly along streams, and once introduced are liable to become a very serious pest unless they fall a prey to their parasitic and other enemies. Paris green would no doubt destroy them as it does other insects, but it is not a practical remedy under western conditions, nor with field crops. It is probable that no better thing can be done than to plow up the infested clover fields in May and plant them to corn. It is to be sincerely hoped that the insect will not appear in the West.

The clover leaf hopper (*Agallia sanguinolenta*). Of the numerous minute leaf-hoppers that affect different crops, this is one of the very abundant and widespread species. It appears to be quite distinctively a clover feeder, for, while it occurs on other plants and doubtless at times feeds upon them, it shows decided preference for this as its staple food. The life history has been worked out by Prof. Osborn and is in brief as follows: The adult insect hibernates and may be found in sunny places in early spring, or, for that matter, at any warm spell during the winter. It is about one-eighth of an inch long, and is shown in the figure at *c* much enlarged, the line at the left being a little longer than the actual length of the average specimens. It is broad in proportion to length, and is marked with numerous dark blotches and stripes. The adults pair during April and the females deposit eggs in the leaves of clover and probably also in



THE CLOVER LEAF-HOPPER.

(*Agallia sanguinolenta*), *a* larvæ, *b* pupa, *c* adult, *d* head in front; all enlarged, size lines a little too long.—(After Osborn).

the petiole and perhaps also near the ground in the crown. The first larvæ appear during the month of May, though egg deposition lasts for some time and larvæ of this first brood may be appearing for some weeks. Some of them mature, producing the adults by early in July, and these deposit eggs which produce a second brood of larvæ, and it is possible that the earliest maturing of these might produce a third brood, but the bulk of the insects are doubtless included within two broods. Remedial measures for this pest are not readily applied and the only reccommendation that seems feasible at present is to use the flat "hopper-dozer," or "Tar Pan," which has been proven at the Iowa Experiment Station to be so effective in killing the leaf-hoppers in pastures and meadows. It will also serve to diminish their numbers greatly to burn over the old grass, along fences and other places where the insects hibernate, during late fall or early spring. The "Tar Pan" could be best used in summer, directly after the cutting of the first crop of clover.

Clover hay worm (*Asopia costalis*). Heretofore we have treated of insects that feed on clover roots and the clover stalk, and it now only remains to treat of the clover hay worm, leaving those that infest the seed to be considered in Chapter XII. The clover hay worm, (*Asopia costalis*), Fabr., belongs to the same family as the moth that infests bee hives and the moth common in meal. The illustration herewith given will enable our readers to identify the worm. In it, as described by Prof. Cook, 1 and 2 represent the larvæ suspended by threads of their own spinning, 3 represents the cocoon, 4 the chrysalis, 5 the moth with wings spread, 6 the moth at rest, and 7 the larvæ concealed in a case of silk which it has spun. The eggs are laid on the clover. The larvæ work in a silken case and thus often mat the hay into a great mass. They may be seen in summer working on hay, but more usually in February or March, when stacks and mows may be fairly alive with larvæ. They often crawl into the stack to protect themselves from the cold. The color of the larvæ is dark brown, the cocoon is white and the chrysalis yellow, the moth purple with a silken luster and it has two bright spots on the wings. Prof. Riley described the insect at an earlier date in the 6th Missouri Report. Prof. F. M. Webster, of Wooster, Ohio, special agent of the Department of Agriculture, in "Insect Life," (volume 4, numbers 3 and 4, November 1891,) paid a visit to the farm of Prof. W. I. Chamberlain on April 27th, 1891, for the purpose of investigating this worm at work. The hay was in an open stack and was damaged twenty per cent. It was found that the majority of the larvæ could be killed by re-stacking the hay and dusting it with two pounds of powdered pyrethrum, mixed with ten pounds of flour, to each ton of hay. A number of larvæ were taken from this hay and placed in breeding cages. They continued to feed on the dry hay for a considerable time, the pupa being first observed on May 25th, and moths beginning to issue on June 12th. The eggs appeared to be laid on the heads of growing clover and about July 1st the young larvæ appeared. It would seem from this that the eggs may be deposited on the plants in the field and thus the larvæ

THE CLOVER HAY WORM.

be drawn to the stack or mow, and also that the eggs may be deposited in the stacks early in August. The only remedy we can suggest for the destruction of this pest, should it appear, is to burn up all the old stacks of hay left over from the preceding year, to remove all old hay from barns, and to thoroughly cleanse all sheds and barns where the pest has become established.

The clovers, however, suffer seriously from other than insect enemies. They are subject to a peculiar kind of rust, (*Uromyces trifolii.*) This rust is a fungus or low form of plant life, without chlorophyll, or the coloring matter of plants, and without roots, stems, or leaves, which derives its nourishment from the clover plant. It is, therefore, a parasite and is reproduced by spores which float in the air, and when placed under proper conditions, germinate and develop on the leaves of the plant. This clover rust has appeared but recently in the West. It was first reported on white clover in Iowa by Prof. Arthur in 1884 and seems to be more widely distributed than is generally supposed. Prof. Underwood reported it in the vicinity of Syracuse, N. Y., in 1888. Dr. Roland Thaxter reported it near New Haven, Conn., in the annual report of the Connecticut Agricultural Experiment Station in 1889, page 175. In Bulletin No. 15, Cornell Agricultural Experiment Station, Prof. Dudley reports it as common about Ithaca, N. Y., and in August, 1890, it was reported in the Monthly Review of the Iowa Weather and Crop Service as common at Ames, Iowa, where Prof. Pammel reports that it has been unusually severe during the past summer. This rust usually appears on the rowen or second crop, and it would be an interesting investigation to ascertain whether it affects clover when under hard conditions, such, for example, as an exceedingly wet and hot year, or when plants are weakened by previous drouth or by insect enemies. It is difficult to suggest any remedy short of plowing up the field, but it is not likely that it will do any serious damage where clover is grown in short rotation. Where there is much affected clover in a permanent pasture, burning over the field late in the fall would, no doubt, prove advantageous.

In this connection attention should also be called to the violet root fungus, (*Rhizoctonia medicaginis*), which, in parts of Europe, is a serious pest. The fungus covers the roots with a violet mould. Plants affected with this disease wilt suddenly and then die. The disease spreads in circular areas. It also affects alfalfa, in fact, has been reported on that host by Mr. Webber, in Nebraska. (Flora of

Nebraska, page 76). Carrots and mangolds are also affected Some of the clover sickness referred to by European writers is undoubtedly due to the abundance of this parasite in the soil. Everyone should be on the lookout for this fungus If found, it should be exterminated at once. Rotation with corn and oats for a number of years has been very effective

The clovers, however, are subject to a very much more dangerous, though, fortunately, as yet an uncommon parasite, the clover dodder, (*Cuscuta epithymum*). The dodders belong to the morning glory family, and are near relations to the common bind-weed, the morning glory, moon flower and sweet potato. The genus *Cuscuta*, or dodder, contains upward of a hundred different species, forty-four of which have been found in America, and thirty-nine of these are found in no other part of the world. They occur on various native plants such as smart weed, goldenrod and sunflowers. The reader, passing through a slough in the fall of the year that has been allowed to grow up to weeds, common to such locations, may have noticed a vine of reddish or yellow color, closely entwined around some weeds and which, on examination, has no connection with the ground. This is one of the dodders. Dodder grows from seed and if it finds no suitable plant upon which to take hold, dies. If, however, it reaches a stalk of clover or alfalfa, the clover dodder pierces the bark with small and short rootlets which are called suckers or haustoria, and then lets go of the ground and lives from the plant, like a worthless son-in-law, who finds it easier to live off his wife's parents than to make a living for himself.

The dodders contain little, if any, green coloring matter in the minute scales on the stems, which are their substitute for leaves, or in the stems themselves, and, hence, cannot assimilate, that is, make starch out of raw material as the ordinary green leaves do, but must derive their nourishment entirely from the plant upon which they live. They are, therefore, essentially parasitic. The stems of the dodder are small and fleshy, orange or reddish in color, and are twisted around the stalk of the host, or plant on which they feed. At the base of the flower and at the joints of the stems may be found minute scales which are rudimentary leaves; but the plant in its present stage of development has no need of green leaves, as it finds food already prepared in the host plant. The reader will find, on the following page, an illustration of this detestable parasite, by referring to which he can follow the description herewith given the more readily. The flowers appear in clusters around the stem,

THE CLOVER DODDER. (*Cuscuta Epithymum.*)

soon forming a capsule, which contains four seeds. The capsule does not split into lobes, but opens by a transverse circular line. Each seed contains a thread-shaped embryo, which is spirally coiled in the albumen. The albumen is the nourishing material stored up in the seed outside of the embryo or germ. This embryo is dependent for its development upon the albumen stored up in the seed. The number of flowers in the cluster range from ten to twenty, and the seeds are of a pale gray color, difficult to detect with the naked eye, and, hence, the rapid spread of the parasite. As an example of the difficulty in detecting these seeds, we notice the report of the Delaware Experiment Station on a sample of alfalfa sent for examination, as follows:

The purchaser remarked that it was one of the purest samples of seed he had ever seen, and an examination proved this fact, the proportion of impurities being only four-tenths of one per cent. mainly dirty; but a close examination revealed the presence of *Cuscuta*, or dodder seed, at the rate of seven hundred and twenty to the pound. This seed, when sown at the rate of fifteen pounds to the acre, which is about one-half that generally sown in Germany, would furnish nearly eleven thousand *Cuscuta* seed to the acre, or enough to give one seed every two feet, in drills two feet apart. The sowing of this much *Cuscuta* seed upon an acre of land, would, at the least, be a dangerous procedure, and might result in a total destruction of a crop in the course of two or three years. Every precaution should be taken against the introduction of this parasite into the state. In Germany its presence has proved a national calamity, and well nigh forced German farmers to abandon the growth of clover. The flax dodder, according to Ledoux, broke up the culture of flax in North Carolina and paved the way to cotton culture. In Germany the fight against the *Cuscuta* has been vigorous, but the enforcement of stringent laws and the sharp eye of the German government over the quality of clover and alfalfa seed has done much to reduce this evil.

It will be seen from the above what untold damage might be done to the clover interests of the West by the introduction of this seed. When the seed falls to the ground it usually remains dormant until the following spring, when the embryo begins growth by sending one end into the soil, and with the other sends up a stem, turning from right to left, or contrary to the sun's apparent motion. If it is in reach of a clover plant it seizes it by means of its sucker-like points, which it at once throws out and then goes on fastening itself to the foster plant and others in the vicinity. It then lets go its hold on the ground. Dodder is an annual and therefore can be destroyed before it has ripened seed, and should be in every case where it is observed. The best method we know of to get rid of it is to cut the infected portion close to the ground and then burn it. The mowing, however, should be as close as possible, inasmuch as the dodder flowers quite low. Where seed is suspected it should be sifted carefully through a seive, the seed being but half the size of clover.

Our attention was first called to this parasite by the receipt of a sample from Mr. J. N. Downing, of Hall Town, Missouri, with the statement that it prevailed largely in his district and was introduced in seed shipped in during the previous spring. It has been reported elsewhere in Missouri and Canada. The sample was submitted to Prof. Pammel, of Ames, Iowa, and also to Prof. McBride, of the Iowa State University, from whose replies, published in the *Homestead* of October 18, 1889, and from Bulletin No. 8, of the Colorado Experiment Station, the above description has been taken. Subsequently we received a package of dodder on clover from the southern part of Iowa, which, however, on examination by Prof. Bessey, of the Nebraska Experiment Station, was pronounced to be a native dodder, different from the *Cuscuta epithymum*, and which had adopted the bad habit of living on clover instead of its natural host. Bulletin No. 8, of the Colorado Experiment Station, above mentioned, reports three species of parasite on alfalfa in that vicinity. These are the *Cuscuta epilinum*, or the flax dodder, *Cuscuta Gronovii*, a species abundant in wet, shady places from Canada to the Rocky Mountains, through Minnesota, Iowa and Texas, and also parasitic on the great rag weed (*Ambrosia trifida*,) and other members of the sunflower family. This is the most common of all the species and is frequently found in Iowa, especially about Ames and Des Moines. Fortunately for the West, although the various dodders are generally distributed, they do not usually attack cultivated plants. We have mentioned most of the spots certainly known to be infested with clover dodder. We have dealt with the subject thus fully, in order to warn our readers of the danger of trifling with it wherever it appears, as nothing but the most prompt and vigorous measures will be efficient in dealing with this parasite.

CLOVER SEED AND ITS INSECT ENEMIES.

CHAPTER XII.

While some clovers are grown for pasture and fertility, others for pasture, seed and fertility, others for seed and fertility, and still others for hay, seed and fertility, it is important in every case that the plant should seed abundantly. Even if the farmer never takes a seed crop, it is important to him that the plants should bear more or less seed every year. Many clovers being annuals, others biennials and still others short perennials, it is important that the stand should be mantained by self seeding; everything, therefore, that bears upon the seed crop is of interest to every clover grower.

A full crop of clover seed of any of the varieties is the result of the harmonious co-operation of man, nature and insects. Nature must provide the soil and a fitting season, man must do his part in preparing the soil, sowing the seed, and, so to speak, superintending the work, while the insects must perform the indispensable work of cross fertilizing the seed, a work which they can depute to neither man nor nature. In order, therefore, that the farmer may act intelligently and co-operate with nature and his insect friends, it is important that he should know something of the process of insect fertilization of the clover plant.

To give the reader full and accurate information on this point, we have requested Prof. L. H. Pammel, of the Iowa Agricultural College, at Ames, Iowa, to explain in detail the method by which red and mammoth clover are pollinated, and the part which various insects play in this important work. This he has kindly done in the following:

In order to understand the method of pollination, we must have a clear understanding of the parts of the flower. The clover flower consists of two kinds of organs, known as the essential and non-essential. The essential are absolutely necessary in the production of seed. The non-essential, which surround the former, consist of two sets of modified leaves, the outer known as the calyx. This is green and made up of an enlarged lower portion which bears five bristle-shaped lobes. Next to the calyx is the colored part of the flower, known as the corolla, or, in common language, the blossom. It is made up of five parts known as petals. Flowers, like clover, in which the petals are unlike in size, are known as irregular, and many irregular flowers need insects to carry the pollen. In some flowers both calyx and corolla are absent, but in no case can seed be produced where the stamens and pistil, the essential parts of the flower, are absent The stamens occur next to the corolla, while the pistil is found in the center. The corolla of the clover floret* consists of the following parts: An upper, larger petal known as the bearer, two lateral petals known as the wings, and two lower petals resembling the keel of a boat, which are united and are commonly known as the "keel." The keel contains the ten stamens, each stamen consisting of an anther, at the end of which is attached a thread-like affair known as the filament. But in the case of clover the filaments are united to form a tube, the anthers containing the pollen. The pistil is also found in the keel. The expanded portion contains the undeveloped seeds. The narrow neck is known as a style, the tip is the stigma. The color of the clover flower is especially attractive to insects. The honey which the insect seeks is contained in the tube formed by the union of the fine, thread-like bodies or filaments.

When an insect like the bumble-bee lights on the flower, it uses the keel and wings (the latter being attached to the tube containing the nectar) as a resting place, its weight pressing the keel down and causing the pistil and stamens, the latter being somewhat shorter than the pistil, to come in contact with the underside of the bee's head. The insect is certain to leave some of the pollen from another flower on the stigma. The honey is obtained by the insect thrusting its proboscis into the united filaments of the stamens, which has a slit on the upper side to give place for a free tenth stamen. Self-pollination, or pollination of the flower from its own stamens, is not excluded, as the insect leaves the flowers. Does self-fertilization occur? Charles Darwin (Cross and Self-Fertilization, page 361) says: "One hundred flower heads on plants protected by a net did not produce a single seed, whilst one hundred heads on plants growing outside, which were visited by bees, yielded sixty-eight grains weight in seed," making a total of 2720 seeds for the one hundred heads. Mr. Sirrine (Bulletin 18, Iowa Agricultural Experiment Station, page 90) found that when pollen of the same flower was used, no seed set. Prof. Cook (Bulletin 26, Division of Entomology United States Department of Agriculture, page 87) found that in ten heads of white clover from which insects were excluded, no seed set. In a similar pot of ten heads not protected from insects by gauze, seeds set. In ten heads of red clover covered, no seeds set; in a similar pot not covered, seed were produced. Prof. Beal, in Grasses of North America, pages 325-328, inclusive, also shows the inability of clover to self-fertilize. It is well known that before the introduction of the bumble-bee into Australia and New Zealand, clover did not set seed, but since the British Government introduced the bumble-bee in 18[illegible]4, clover seeds are produced. They have since multiplied with remarkable

* The heads of red and mammoth clover are made up of from twenty to sixty flowers or florets, each separate in their structure and together forming what is ordinarily known as the clover blossom.

rapidity. According to Thompson (Insect Life, volume 4, page 157) they have so greatly increased that he asks whether they may not become a serious pest to the apiarist, as they work on all sorts of cultivated flowers.

In order to reach the honey an insect must have a tongue from .3543 to .3937 inches (9 to 10 millimeters) long. The honey lies from .2755 to .3937 inches (7 to 9 millimeters) deep. Any insect sufficiently heavy to press down the keel can pollinate the flower. Bumble-bees are, of course, the common pollinators. Prof. Osborn informs me that he has observed two common species (*Bombus Pennsylvanicus* and *B. fervidus*). My friend, Mr. Robertson, records several more. The honey bee can, no doubt, pollinate red clover, as they often collect pollen. I have taken an interest in bees for many years, and have given some attention to red clover and honey bees. The following paragraph from a paper published in 1888 may be of interest:

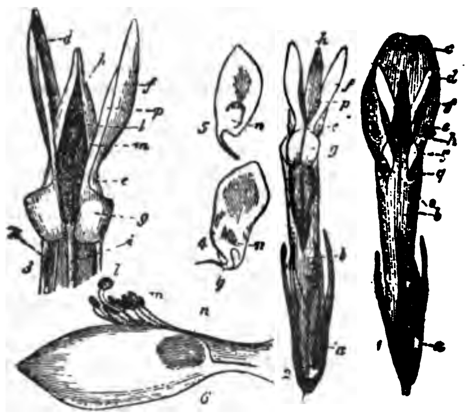
"In the summer of 1883, in the vicinity of La Crosse, Wisconsin, I noticed large numbers of honey bees on the flowers of red clover. In many cases they were actively collecting pollen, but in some cases honey, through perforations in the corolla made by some other insects. Herman Mueller says the honey bee 'usually visits the red clover only for its honey, which its proboscis is not able to reach in the legitimate manner—yet I have now and then seen hundreds of honey bees on a patch of red clover, all busy collecting pollen.' Here at Ames I have seen red clover visited by several butterflies, especially the large red butterfly (*Danais archippus*), cabbage butterfly (*Pieris rapae*), the yellow butterfly (*Coleus philodice*), also *C. eurytheme*, and a fly (*Bombylius*). Red clover is adapted especially to bees, but Dr. Hermann Mueller of Germany, and Mr. Robertson, of Carlinville, Illinois, record a large number of butterfly visitors. Thirteen out of twenty visitors belonging to the butterfly family were observed in Illinois. There is no question that they do occasionally pollinate red clover and effect cross fertilization. Mr. Robertson writes: 'Bumble-bees depress the keel so that their heads and proboscides are well dusted with pollen, but butterflies can insert their thin tongues without depressing the keel, and even if they get a little pollen on their thin proboscides, it is apt to be wiped off by the closely approximated tin of the petals, which close the mouth of the flower."

Th. Pergande expresses the belief that different species of thrips, which are found in many kinds of flowers, may effect cross pollination (Psyche, volume 3, number 100, page 381). Prof. Osborn informs me that two kinds of thrips are common in clover blossoms, *Thrips tritici* and *Phloethrips-nigra*, but these certainly cannot generally effect cross fertilization.

Can the honey bee effect cross fertilization in mammoth clover (*Trifolium medium*)? It probably can do so as it does in the common red. I have not studied the flowers of mammoth clover carefully, but so far as I can see, the flowers of the forms in the College collection are about the same size as red clover. One form has much smaller heads and the flowers are also somewhat smaller, but I am inclined to think that mammoth clover is pollinated principally by bumble-bees.

The work of honey bees in fertilizing white and alsike clover is well known; in fact, they can easily accomplish this. One other thought suggests itself to me in this connection. I believe it is generally supposed that the second crop of clover produces more seeds than the first. This I think is due to insects, there being a much larger crop of bumble-bees at the time of the second bloom than at the first.

Our readers, even those who have the least familiarity with scientific terms, will, with the foregoing explanation, be able to understand fully the structure of the blossom of red clover, and the method of pollination with the further aid of the illustration herewith presented. Figure 1 in the illustration represents the floret, or one of the minute flowers of which the clover head is made up, separated from the head, and viewed from below. Figure 2 represents the same flower with the larger petal stripped off and viewed from above. The calyx of which Prof. Pammel speaks is marked *a* in figures No. 1 and 2 in the illustration. Immediately above it is the corolla, or what is usually called the blossom, marked *b*, made up of five parts known as petals. The bearer or vexillum is the upper, larger petal, marked *c* in figure 1, while *e* represents the lower border of a wing or small petal bent outwards, *f* its outer surface and *g* a pouch swelling at its base. The lower petals form what is described by Prof. Pammel as the keel or carina, and in figures 1, 2 and 3 are marked *h*. Figure 5 represents the right half of the carina or keel, from without, while figure 4 represents the right wing or side petal from within, the claws in both being broken off short. Figure 6 represents the pistil, *l*, and stamens, *m*, without which no flower can exist, and, hence, called the essential organs. They are found emerged from the depressed keel. It will thus be seen that gravitation of itself would cause the pollen from the stamens to fall away from instead of towards the pistil, or part to be fertilized. This explains why insect fertilization is necesssary. Let us now see how a bee fertilizes clover. It clings with its fore legs to the wings, or lateral petals, resting its middle and hind legs on the lower part of the flower, the keel and wings are drawn down to the stamens and the anthers are thrust up against the underside of the bee's head as described by Prof. Pammel above. In going to another flower it carries the pollen with it and places it on the vital parts of the second plant, thus producing cross-fertilization.



THE RED CLOVER BLOSSOM.

It follows, therefore, that everything which favors the increase of bumble-bees is of advantage to the clover grower, and it need not be said that their nests should be protected instead of ruthlessly destroyed. It will also be seen, in view of what has been said as to the ability of the honey bee to fertilize red and mammoth clovers while gathering pollen if not honey, that it will inure to the advantage of every farmer to keep a few hives of bees, always selecting the Italians, as larger and the more industrious. In fact, while we have seen the Italians and their crosses working on mammoth clover year after year, we have very rarely seen the native or black bee engaged in this useful work. It would be well worth all the cost involved, if the Department of Agriculture were to import some of the giant Asiatic bees for the purpose of securing, by means of a cross on our native bees, a variety with sufficient weight of body and length of tongue to enable it to perform the office of the bumble-bee in fertilizing the red and mammoth clovers. If the produce of these could be again crossed with the stingless bee of South America, the result would be what might well be called the "granger's bee," or the "clover grower's delight."

As stated in Chapter III, the mammoth clover is too late in maturing to furnish both a hay and a seed crop. The seed, must, therefore, be taken from the first crop, as it is usually termed. It is desirable, however, to use some method of getting rid of the lower twelve inches of the stalk on account of the great bulk of the crop. Where it is possible, this should be pastured off. The stock may be allowed free range of the field up to June 10th, in the latitude of central Iowa, in ordinary seasons. It is better to let the crop be well started and then put on enough stock to eat it down closely. This will not only reduce the amount of haulm to be handled, but also thicken up the stand by favoring branching. Some farmers practice mowing about the 10th of June. This, however, requires to be done with a good deal of sound judgment, as sometimes the growth is so rank by this time that there is danger, if rain should follow immediately, of the cut clover smothering out the plant, or at least allowing the weeds to get the advantage of the clover.

Clover should be cut for seed with a reaper of some kind, when ripe, that is, when all the heads are turned brown or black. The most convenient implement is the old-fashioned self-raker. When this is not available some farmers use the ordinary binder, removing the apparatus for binding the sheaf and substituting the flax attachment. The cost for the flax attachment is about five dollars. This is said to throw the gavels with the clover heads up and therefore in the best shape for drying. Others remove the binding apparatus, leaving the deck board and dropper, and bolting on the latter a three-inch board of the same thickness, extending eighteen inches to the rear. They then bolt a piece of iron half an inch wide, a quarter of an inch thick and eighteen inches long, on the rear end of this dropper and at right angles to it, bending in a semi-circle upward to the driver's seat and to the end of which they attach a small rope or cord bringing it up through a small pulley fastened on the top of the machine and above elevating rollers and extending to a treadle on the foot board in front of the driver's seat. Wood pieces are put in in lieu of the iron parts that have been removed with the binding apparatus. In this way the clover can be cut and dumped in such gavels as seems best. Where the stand is thin it can be cut with the ordinary mower and raked in small windrows, taking care to rake it only when slightly damp, especially after it has had two or three days of hot sun.

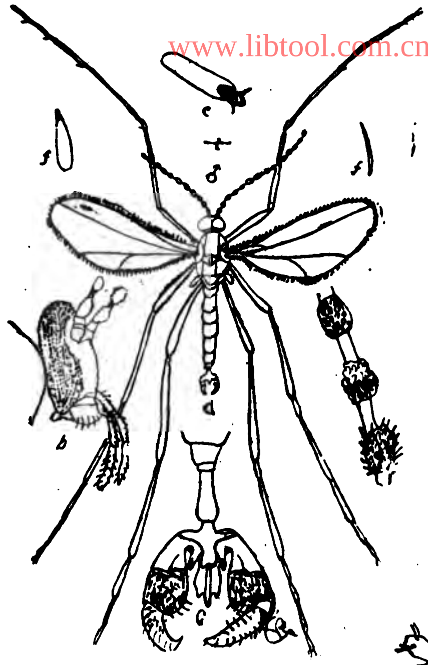
The threshing should in all cases be done with a huller where one can be obtained. The hulling attachments, while often the only practicable means of getting the seed, leave much of it in the straw and chaff, and when these are used it will pay to thresh the chaff the second time. Whenever the growing of clover seed has been established, threshers will find it profitable to procure hullers, and in good seasons will do a very profitable business.

The seed crop of the common red clover comes from the second growth. It is not true that the first crop does not seed. The only reason that the seed does not materialize is the lack, in most seasons, of insect fertilization, due to the time of cutting. To insure a good crop of seed the first crop should be removed not later than the first week of July, although when the autumn is peculiarly favorable a crop of seed can be grown on cuttings as late as the middle of that month. The method of handling is the same as that mentioned above in the case of mammoth clover. With both it is a mistake to allow the clover, after being cut, to lie in the gavel longer than is necessary for easy threshing. If a huller cannot be secured it should be stacked and well covered and allowed to remain until the cold winter weather.

The seed crop of the alfalfa is taken from one of the last cuttings and the white and the alsike from the first. No special directions need be given as to the threshing of either of these, as they all thresh readily. Great care, however, should be exercised in handling them after cutting, as the seed in all shells out quite readily.

If insects are essential to the pollination and fertilization of clover seed, they also play an important part in its destruction, and one of the most difficult problems in growing clover seed is to escape the ravages of insects that prey upon the seed. We, therefore, conclude this chapter with a description of the habits and life history of two of the most dangerous clover seed pests, having described in the previous chapters the insects that prey upon the leaf, the root and the hay after it has been cured.

The most dangerous, perhaps, of these is the clover-seed midge, illustrations of which will be found on this page. In explanation of these illustrations, after Riley, and for the purpose of more



THE CLOVER-SEED MIDGE (MALE).

readily indentifying the midge, should it appear in any field, we call the attention of our readers more particularly to figures 1 and 2 herewith given. Figure 1 represents an enlarged back view of the male, with scales stripped off in order to show the structure more clearly; *b* represents the eye, the palpi and the basal joints of the antennæ highly magnified; *c* represents the male organ highly magnified; *d* represents the highly magnified antennal joints;

FIG 2

THE CLOVER-SEED MIDGE (FEMALE).

e represents a tarsal claw, and *f* forms of scales. Figure 2 shows an enlarged view of the female, with ovipositor by which it deposits its eggs, extended; *b* represents the head more enlarged; *c*, the tip of the ovipositor highly magfied, and *d* a great enlargement of the antennal joints. In figure 3 *a* represents the maggot or larva enlarged and from the under side, while *b* represents the head drawn out and more highly magnified. With this explanation the reader will be able to determine for himself the presence of this pest.

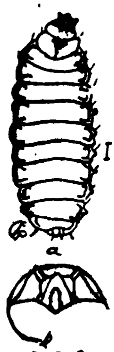


FIG 3

THE LARVA.

There are two distinct insects that pass under the common name of clover midge. The one, the clover-seed midge, (*Cecidomyia Leguminicola*, Lint.), the other the clover-leaf midge, (*Cecidomyia trifolii*, Leow), which lives in the folded leaves of white clover and sometimes of the red. The first, which is now under discussion, affects only the seed, and seems first to have been observed in America by Prof. J. A. Lintner, in 1877. The larva was described briefly in 1878 in a report on some of the injurious insects of the year, to the New York State Agricultural Society. Prof. Riley, of the Department of Agriculture, observed it in 1878 and described it in the annual report for the Department of Agriculture for that year. It was observed by Prof. Forbes in Illinois in 1879, and since that time has extended over almost the entire clover growing region of the United States, with the exception, perhaps, of southern and western Iowa and the region beyond the Missouri. The eggs of the midge are so small that it is almost impossible to see them without very good eyes, their average length being .01 of an inch. They are described by Prof. Riley as being "long, oval in shape, their length three times their breadth and one end slightly larger than the other. Their general color is pale yellow and an orange streak is more or less apparent according to the age of the embryo." The female simply pushes the eggs down between the hairs which surround the seed capsule of the floret or minute flowers of which the clover head is composed, which stage of development occurs in central Iowa in the latter part of May. In other words, the egg is deposited before the bloom appears, but after the head is formed. By the time the larvæ are hatched, the mouth of the floret is open, and the maggots or larvæ work their way throgh the mouth of the flower down to the seed.

The larvæ or maggots hatched from the egg seem to vary much in color, some being bright orange red, others white and occasionally with a tinge of pink. Some are smaller than others, the greatest variation being in the males. It is these maggots that do the damage, feeding upon the clover seed, while yet in the dough state, and issuing, when they have completed their growth, in the last part of June, from the head, to undergo their second transformation in the soil. The sight of these larvæ or maggots leaving the clover is said to be an interesting one. The head, which one moment seems destitute of animal life, becomes the next fairly swarming with the maggots. From nearly every closed floret one emerges, wriggles violently and works its way out and falls to the ground.

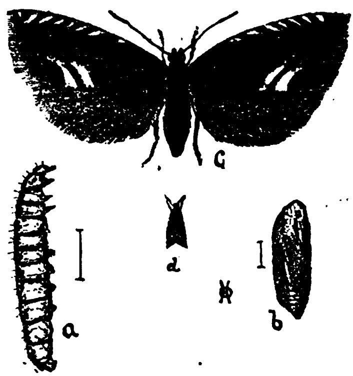
It should be stated in advance that insects of this kind exist in four stages, the egg, the maggot or larva, the pupa, in which stage the insect passes through its transformation, and to outward appearance to the superficial observer is dead, prior to assuming the fourth stage, that of the perfect fly. It will, therefore, be understood when we speak of larvæ that we refer to the maggot stage, and of pupæ to the stage in which the insect passes through its final period of transformation. This insect is, in the latitude of central Iowa, two-brooded, while in the more southern latitudes it is supposed to be three. After the insect has taken on its pupal stage, which is said to last about ten days, but no doubt varies, it emerges as a fly, and after mating, is ready to lay a second crop of eggs in the second crop of clover, hence, it will be readily seen how vast are the means of multiplication.

There are but two methods known of combating the clover-seed midge. The first is that of cutting the first crop, whether in the meadow or in the pastures, before the first crop of the midge leaves the head. To make this method effective, it would have to be done, not merely on one farm, and all parts of it, pastures as well as meadows, but on all the farms of the neighborhood. It is very difficult, if not impossible, to induce farmers to co-operate in this way, however much their interests might require it. The second method, which is almost equally as difficult, is to abandon for the time being the use of the common red clover, and sow mammoth in its stead. This variety, as stated in preceding chapters, comes in bloom some two or three weeks later than the common red, and matures its seed crop about the time the second crop of the common red is in bloom. The midge so far has not been able to time its visits so as to make the mammoth the medium for producing the second crop. This method, suggested by the well known periods of the appearance of the midge, seems to have been found entirely practicable in Ohio and eastern states where the midge has fully established itself. It is important to use very great care in procuring seed, as the midge is likely to be carried in the seed and planted where it will develop and form a new starting point for this pest. Clover seed should never be purchased except after being examined with a strong magnifying glass. With or without a glass the best way of detecting it is by running a handful on white paper, and if the maggots are in the seed they will be easily recognized. Where they are found the seed should be rejected, although they would probably be destroyed by the hot water treatment known as that of Jensen for smut; viz., steeping the seed just before sowing, first in water at a temperature of 120 degrees, and then afterward in water of the temperature of 135 degrees. Although we have never tried this on clover seed, oats has been found to endure this temperature for fifteen minutes. Miss Eleanor Ormerod, of St. Albans, Eng., formerly consulting entomologist of the Royal Agricultural Society, states that the midge has been found in American seed exported to England, and emphasizes the necessity for the greatest watchfulness in purchasing clover seed from any locality known to be infected.

Like most other insects when they multiply in great numbers, the clover-seed midge seems to have its parasites. Prof. Riley, in his report to the Commissioner of Agriculture, to be found in the Report of the Department of Agriculture for 1879, page 196, describes two parasites which work on the midge and greatly reduce their numbers. The first is a chalcid, called *Eurytoma funebris*, belonging to the same family as the joint worm fly. This parasite, which is very minute, undergoes its transformations within the seed, and gnaws an irregular hole through the seed large enough to let it out shortly after the time when the maggots have left the seed to go into the ground. An examination of an infected field by Prof. Riley on the 20th of June showed that five-sixths of the seed had been destroyed by the midges, and that four-fifths of the midges had been destroyed by this parasite.

Another parasite, belonging to a different family, called *Platygaster error*, (Fitch,) has been found working on the midge in New York. Instead of undergoing its transformations entirely within the seed, the parasite stays with the midge, goes with it into the ground and emerges as a full-grown parasite from the cocoon of the midge. Prof. Beal in his work on grasses, p. 391, states that the larva (of the fall brood, of course) has been found in seed on the market, and that this explains the rapid distribution of this insect. This emphasizes the importance of farmers procuring their seed, wherever it is possible, from the growers and from men of well known reputation whose fields have not been infected by the insect.

Another clover pest, well known in the East, and which has become somewhat common as far west as Iowa, is the clover-seed caterpillar, (*grapholipha interstinctana*, Clemens.) These caterpillars now seem to be quite widely distributed, having first appeared in New York, Pennsylvania, Washington and Michigan prior to 1885. They were first noticed in very great numbers at Ames, Iowa, the last of May, 1891. The following description is taken mainly from Bulletin No. 14, Iowa Experiment Station, August, 1891. The moths increased from the time they were first observed until the 3d of June, and on the 25th of June an examination of one hundred and seventy-seven heads showed ninety-one heads infested by the caterpillars of the moth and eighty-six not infested. At this time many larvæ were full grown and some were spinning their cocoons. The hay was cut at this date and an examination of forty-eight clover heads taken from scattered bunches showed two-thirds of them infested, while of forty-two heads from a different field, cut two days earlier, only three were found infested. The accompanying illustration, original with the Iowa Experimental Station, will enable our readers to identify this pest; *a* represents the larva, or caterpillar; *b*, the pupa, or larva undergoing its transformation to a moth; *c*, the moth, all these greatly magnified, while *d* represents the moth in its natural state. The larvæ are dirty white and the pupæ a light brown, while the moths are small, brown and often nearly black, with white lines and dots marking the wings. The larvæ are about one-fourth of an inch long, while the moths are from one-third to two-fifths of an inch, with wings expanded. The damage done by this insect is by eating into the florets or small flowers, of which the clover head is composed, and later into the seed vessels of the florets, causing the flowers to dry up and the seeds to shell from their receptacles like chaff. Inasmuch as the track of the larvæ is uniformly from



THE CLOVER-SEED CATERPILLAR.

the base of the blossom or floret upward, and the young larvæ are found almost invariably near the base, and beginning their work on the florets there, it would seem that the eggs are deposited at the base of the floret. In working upward they usually form a spiral track around it.

The second brood were observed at Ames, pairing during the last week of July, and by August 5th the larvæ were found in great numbers. This rate of growth would seem to indicate that there are three broods per year in the latitude of Iowa, and possibly, though not probably, four.

Since the foregoing was written, Bulletin 19 of the Iowa Experiment Station has been issued, containing the results of careful investigations during the season of 1892, by Mr. H. A. Gossard, assistant entomologist, who has given special attention to this species. This investigation shows that the insect is three brooded in Iowa; that moths appear in late May or early June, deposit eggs in June in the involucre of the clover head or in the florets, and larvæ occur in heads of clover in latter part of June. When the clover is not in bloom, eggs may be deposited in the crown and the larvæ work on other parts of the plant. Pupation occurs in late June or early July and moths appearing during July deposit eggs for second brood. These mature and produce moths for third brood in early September, and caterpillars of this generation, the third brood, become partly grown and hibernate; pupating in spring and producing the first brood of moths of the following season.

The remedies recommended are: 1st, rotation of crops, not keeping clover on same ground over three years, and only two if the field becomes badly infested; 2d, that seed for new crop be planted on land as remote as possible from old clover fields; 3d, that infested fields from which seed is desired the following year be pastured in fall to clean up all late growth and leave the field free from vegetation in the fall, and that no manure be applied at the time to furnish places for larvæ to hibernate; 4th, that clover infested during the spring be cut as early as practicable, while larvæ are in heads, handled as carefully as possible to prevent shaking larvæ from the heads, and stored in stacks or barns, where the larvæ are found to perish; 5th, when ready to change from clover to another crop, plow under some time in October, November or early in spring, burying the larvæ as deeply as possible, and roll or harrow to pack the surface.

Several parasites have been reared at Ames, and these will assist in reducing numbers under ordinary conditions.

THE CLOVER ROOT TUBERCLE.

CHAPTER XIII.

In previous chapters we have assumed certain facts, namely, that the clovers of all kinds fertilize the soil while at the same time furnishing, in the crop, a very large amount of nutritive material of the richest quality; second, that the fertilizing material furnished by the clovers is in the form of nitrogenous compounds which we have grouped under the general name, nitrogen, and third, that this surplus of nitrogen is obtained from the atmosphere through the medium of the tubercles or nodules on the roots of the clovers, eighty per cent. of the atmosphere being nitrogen, and therefore furnishing an inexhaustible supply.

Having assumed these facts so frequently and stated them so confidently, it is but due to the reader that we should give, in as brief and concise a manner as possible, the reasons for this frequent assumption and confident statement. The fact that clover adds materially to the fertility of the land on which it is grown, notwithstanding the heavy drains it makes upon its resources, is too well known to need argument. The fact that this fertility is mainly in the form of nitrogenous compounds might well be suspected from the fact that all kinds of grain which make heavy drafts on the nitrogen in the soil do better after clover than following any other crop, and has been very clearly proved by analyses of soils in pots on which clover has been grown, the analyses having been made both before and after growing the clover, and in a way which precludes any material errors.

The fact having been ascertained that clover does in some way obtain a supply of nitrogen, under certain circumstances, quite independent of the supply in the soil, the interesting and important question arises, how does it obtain it? It was at first supposed, and quite naturally, that it obtained it by means of its long tap-root, but, while it does no doubt in this way restore a certain portion of the nitrates that have been washed down by rains into the subsoil, the amount has been found to be very inconsiderable compared with the entire amount obtained. It was next supposed that the supply was obtained from the nitrogen in the form of ammonia in the atmosphere. This ammonia, washed out, as it is, by rains, would be equally available for any other plant, and hence, so far as root action is concerned, in no way aids in the solution of the problem. The same remark applies to the small amount of nitric acid that is known to be formed in the atmosphere by electrical action.

The question has arisen, whether the clovers do not obtain their supply of nitrogen from these two last sources through their leaves. To test this matter clovers have been grown in pots with access to air alone that had been washed by being passed through water, thus removing the nitric acid or ammonia, and the result was precisely the same as in the case of similar pots grown in the open air. Every other means of determining the source of nitrogen in the clovers having failed, attention was directed to the tubercles in the roots.

If the reader will pull up a stalk of any of the clovers, during the growing season, he will notice on the roots, sometimes on the smaller and sometimes on the larger, certain knots, warts or protuberances. These are the tubercles, a somewhat unfortunate name because associated with disease, but so definitely associated with them that it is useless to attempt to change it now. He will notice that the healthier the plant and the more vigorous its growth, the more of these tubercles will be found, and he will fail to find anywhere a healthy stalk of clover, during the period of vigorous growth, without these tubercles. It was this apparent connection between the number and size of the tubercles and the vigor of the plant that led Prof. Helriegel, of Bernberg, Germany, to investigate, in 1883 and the years following, the cause of the tubercles on the legumes and also the relation they sustain to the plant. As early as 1862 he had been conducting certain elaborate experiments for the purpose of determining whether, other things being equal, the magnitude of crops was proportionate to the supply of certain essential elements of fertility in the soil. He had no difficulty in determining that in the case of the cereals, such as wheat, oats and barley, the magnitude of the yield was proportionate to the nitrogen in the soil; no nitrogen, no crop; a certain amount yielding practically the same crop, and the crop increasing with the increase of nitrogen; but he soon discovered that certain other plants were, under certain circumstances, almost entirely independent of any nitrogen in the soil. He saw to his surprise, as far back as 1862-3, clover and peas growing in a crop of pure sand and producing a full crop of seed, while in other years, and apparently under the same conditions, they starved to death. He discovered that when clover and peas, growing in the most barren soil, had abundance of tubercles they prospered, and when the tubercles were wanting, death ensued. He then began a series of most elaborate experiments, conducted with the greatest care, to discover under what conditions the clovers and other legumes were thus independent of soil nitrogen, and from what source other than the soil they obtained it. It is due to the thoughtful reader that we should detail at some length the nature of these investigations.

For a soil material to be used in his investigations, Prof. Helriegel selected fine quartz sand, such as is used in the manufacture of glass. This was washed twice and boiled in concentrated muriatic acid three times for the purpose of removing completely every vestige of fertility. As culture vessels, he used cylinders of white glass of different sizes, each having a hole in the bottom for drainage. Pieces of quartz that had been washed carefully and then heated red hot were put in the bottom to afford air drainage. Upon this was placed a thin layer of unsized wadding and on this the sand, which after fertilization in a porcelain vessel was crumbled into the culture vessels under slight pressure in order to secure the proper degree of porosity and density. The seeds to be used for this purpose were selected with extreme care. From a large number of samples the very heavy and very light were excluded. The remainder were then sprouted between folds of blotting paper, and if there was developed any defective root or abnormal growth it was rejected, the object being to secure even results. Fourteen vessels thus prepared were sown to barley and fertilized with commercial fertilizers, containing potash and phosphoric acid, but no nitrogen. Nitrogen in the form of nitrate of lime was then given in the following proportions: No. 1, .0336 grains; Nos. 2, 3 and 4, two-thirds of the amount; No. 5, one-half the amount; Nos. 6, 7 and 8, one-third of the amount; Nos. 9, 10 and 11, one-sixth of the amount; No. 12, one-twelfth, and Nos. 13 and 14, none. At the end of the first week after sprouting the plants were exactly alike; no difference whatever could be noted. A few days afterward, or as soon as the reserved nutriment in the seed was about exhausted, Nos. 13 and 14 began to fail. For a few days after this no perceptible difference could be noted in the growth of the other plants. No. 12 then dropped behind and a few days later Nos. 9, 10 and 11, and, after a short interval, all the others up to No. 1 could be identified by their appearance, so that in a month from the time the first plants appeared the row of pots showed clearly which had received the larger amounts of nitrogen. This was manifest not merely in the height and general vigor of the stalk, but in the number of shoots or stools put forth. No. 1 put out five shoots or stools; Nos. 2, 3 and 4 put out four, one only of them bearing a head; No. 5, from three to four, one bearing a head; the remainder from one to two, but all failed to head. Later on, however, the main stalk consumed the side shoots to build itself up. The next lower also consumed their earlier-formed parts in their effort to develop heads. The results of this experiment with a non-leguminous plant are only what might have been expected, inasmuch as it has been repeated over and over again and always with the same result, namely, that within certain limits the yield of the cereals or non-leguminous plants is dependent upon the amount of nitrogen in the soil available for the plant.

Having thus demonstrated that the cereals were absolutely dependent upon the amount of available nitrogen in the soil, Prof. Helriegel conducted a series of elaborate experiments with the legumes, of which we give one typical case. Fourteen pots were selected, identical with the others, the soil material, the manner of filling and the fertilizers being precisely the same. No. 66 having the same amount of nitrogen as No. 1 in the barley experiments, and Nos. 77, 78 and 79 corresponding in amount to Nos. 13 and 14 of the barley table, or, in other words, with no nitrogen. The plants all came up well and evenly, and there was no difference in the pots up to the end of the second week. The third week there was a difference not only in growth, but in color. Those that had no nitrogen were somewhat higher and of a somewhat greener color, while those that had been fertilized with nitrogen were darker, and the more nitrogen, the darker. The fourth week a difference in the development began to appear. Pots 77, 78 and 79 fell back, showing signs of nitrogen hunger. The new leaves were smaller and they seemed to be formed by pumping out and drying up of the lower leaves. The numbers grew normally and by the end of the sixth week the whole row of experimental pots very accurately reflected in their condition and appearance the of nitrogen each had received. During the seventh week the picture very suddenly and decidedly changed without any apparent cause. No. 77 continued to be in a starving condition, but two plants in 79 took courage and a little later, two in 78 followed the example. Their sickly green color gave place to a healthier, new leaves grew stronger and broader and without consuming any of the earlier developed leaves. From this time on they made rapid growth and by the eleventh week they had overtaken those abundantly supplied with nitrogen and passed many of them. From this time on there was no relation or correspondence whatever between development and the quantity of nitrogen supplied, while the harvest bore the same general result, and subsequent analyses showing, in some cases, plants containing less nitrogen than had been given the vessel in which they grew, in others more, and in some large quantities of nitrogen where none at all had been given. On this Prof. Helriegel says:

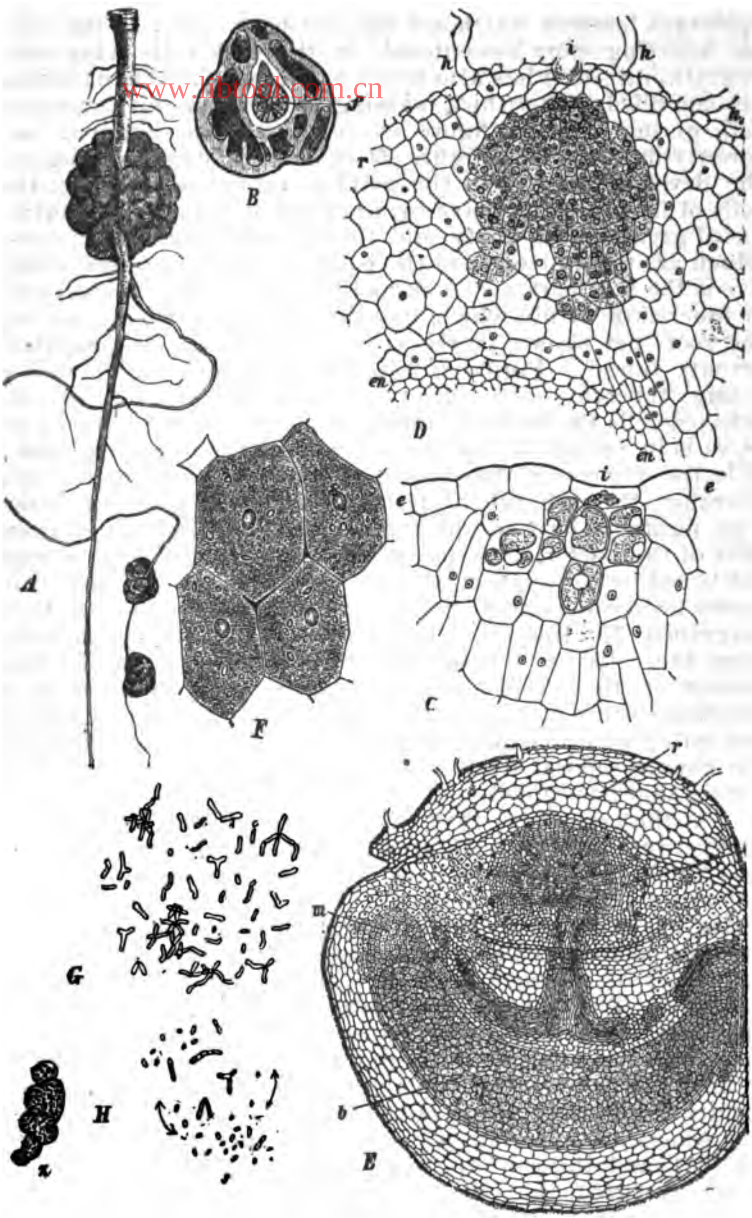
> Three years of this kind of experiment demonstrated two facts clearly, first, that the legumes had found a source of nitrogen somewhere else than in the soil, and that, second, they might or might not thrive even though the soil was amply supplied with nitrogen in a form rendering it available for other plants—in short, while the harvested plant contained abundant nitrogen, whether the soil had or had not contained any, seemed to have no connection with or influence upon the amount contained in the plant. Chance seemed to rule. The thriving pea vine two months old might fail utterly, although supplied with abundant nutriment in the shape of complete fertilizers, or it might do well with one from which nitrogen had been wholly omitted The first inference was that the pea had some source from which to provide nitrogen other than the soil, or, rather, some peas had and others, apparently under precisely the same conditions, had not. What was the source? And why could some plants draw on that source and others not?

It is impossible for us to give details of all the experiments undertaken to answer these two questions, for they cover upwards of 200 pages of Prof. Helriegel's work, of which we aim to give our readers only the substance. One cannot read them without admiring the patience and intelligent discriminations of the investigator, without admiring also the methods of true science which seeks to narrow downward gradually by experimental proof until one by one the facts are set aside as demonstrated, all bearing one way and leading up to one inevitable conclusion. As stated above, it was first discovered that plants that did well without nitrogenous fertilizers had tubercles on their roots; those that did not do so well, had fewer, those that did not do well at all, had none, or nearly none. The connection between the presence of tubercles on the roots of the legumes and the capacity to obtain nitrogen, where there was none in the soil, could not long remain unsuspected, and numerous, long and carefully conducted examinations only served to confirm the investigator in the certainty that tubercles and power were closely correlated. Tubercles and power was the law, while also no tubercles and no power was also a law. There was no visible cause for the tubercles. What was more natural for the scientist than to suspect an invisible cause. Recent discoveries in other fields suggested that probably the tubercles were of bacterial origin. To determine this, wadding, which lets in air, but strains out bacteria, was placed over the pots. The result was that no bacteria could get in, hence, no tubercles were formed, hence, no nitrogen was taken up, hence, no thrift in the plant. Nitrogen hunger, nitrogen starvation, was nature's answer to the question of the experimenter.

Pursuing his investigations further, Prof. Helriegel found that some pots left uncovered thrived, others did not, and none covered with wadding did. The scientific inference, therefore, was that whether they throve or not depended on whether bacteria found an entrance by chance. Another equally clear inference was that the ground where clover, beans, peas and other legumes had grown must be full of it. This was readily tested by placing soils in which these plants had grown in the vessel with water, and after the sediment had all settled to the bottom, and the water had become clear, decanting carefully so as to take nothing but the clear water. He then watered the plants that were drooping from nitrogen hunger, and straightway every plant thus treated developed tubercles and acquired the power of securing nitrogen, when there was none in the soil in which it grew. He then took of the same water and sterilized it by boiling to kill all the bacterial life, watered the plants with this, protecting them by wadding from accidental bacterial inoculation, and the result was that no tubercles were formed, no power to take up nitrogen was developed and there was no thrifty growth.

The illustration on the following page will aid the reader in securing a clearer comprehension of what occurs as root tubercles are developed in the legumes. It is taken from the *Lehrbuch der Pflanzenphysiologie*, by Dr. A. B. Frank, professor in the Agricultural High school at Berlin.

Figure *A* in the illustration is a root of the lupine on which are several root tubercles. Figure *B* is a section of a root tubercle; at *f* is seen the central woody-fibrous cord and around it, within the root bark, the fleshy parts of the bacterial tissue. Figure *C* shows the first stage of infection, which precedes the formation of the tubercles; *e*, *e* is the



TUBERCLES ON THE ROOT OF THE SUPINE.

epidermis beneath which are the root-bark cells; in the cell *r* the infecting spore has entered; in the bark cells lying next beneath, infection has also taken place, and they have thereby become filled with a thick, shining protoplasm, with enlarged cell germs. This figure is magnified one hundred and seventy-five times. Figure *D* is a more advanced stage of the development; *i* was the point of infection; beneath, the cells of first infection have by a process of cell-division, introduced greater complexity and formed other infecting cells, which are themselves upon the point of further sub-division; *r*, *r* is the root bark; *h*, *h*, *h* rootlets; *en* is the endodermis, or inner skin within which lies the fibrous or woody part of the root, not shown in the cut. This figure is magnified seventy times. Figure *E* is a cross-section of a root with a young tubercle. By means of a further increase of the infected cells the bacterial tissue *b* has been formed, which at *m*, *m* is in process of further development through division; *f* is the fibrous or woody cord of the root from which run branches through the bacterial tissue; *r* is the root bark. The figure is only slightly magnified. Figure *F* is from cells of the bacterial tissue, whose contents are clouded and thickened by being filled with masses of bacteria. The cell germs are visible and a few starch granules. The figure is magnified 230 times. Figure *G* is a number of bacteria from the cells of *F* magnified 1090 times. Figure *H* is a cluster of the *Rhizobinum leguminosarum*, produced by a gelatine culture of the bacteria; in the center is seen a few of the latter within which clusters are visible. At *s* is seen the cluster separated; at *z* the zoogloa state composed of a cluster that has united,

At the same time that Prof. Helreigel and others were prosecuting these investigations, Prof. W. O. Atwater, then of Middletown, Connecticut, was performing the same important service for America. In 1881 he instituted a series of experiments which were repeated in 1882, and brought positive evidence of the acquisition by peas of large quantities of nitrogen from the air during their period of growth. The investigation was unavoidably interrupted until 1885, when four other series of investigations revealed large losses of nitrogen during germination and early growth in all cases where root tubercles were not formed.. The results of the experiments of the first series were reported to the American Association for the Advancement of Science for 1881, and those of the first and second series together were reported at the meeting of the British and American Association for the Advancement of Science in 1884, and in detail in the American Chemical Journal, volume 6, page 365 (February, 1885). The question for study in the first series was: Will peas grown under normal conditions acquire any considerable amount of nitrogen free or combined from the air? When the subject was resumed in 1885, it was to obtain an answer to the two following questions: What effect has the addition of soil infusions on the formation of root tubercles, and is there any definite relation between the quantity and the number of root tubercles and the quantity of atmospheric nitrogen obtained by the plant? We cannot follow the experiments in detail. Suffice it to say that they were conducted with sea sand, thoroughly washed and boiled and the methods adopted were almost identical with those adopted by the German experimenters. They covered, as in the German experiments, the cereals as well as the legumes, and the conclusions to which Prof. Atwater arrived were, that the cereals could not obtain nitrogen from the atmosphere, while the legumes could and did. His conclusions may be summed up as follows: That the leguminous plants in general are able to secure large quantities of nitrogen from the air during their period of growth; that there is scarcely room to doubt that the free nitrogen of the air is thus acquired by the plant; that without root tubercles there was in no case any large gain of nitrogen, and that with them there was uniformly more or less gain, and that the greater the abundance and number of root tubercles the larger and more vigorous the plants and the greater the amount of atmospheric nitrogen acquired. Still further, that the connection between the root tubercles and the acquisition of nitrogen is clearly demonstrated, but that the relation of the bacteria to the root tubercles and to the acquisition of nitrogen, and in general how the nitrogen is obtained, are questions yet to be solved. In conclusion Prof. Atwater says:

This subject has a wider significance than what has been said above implies. The future welfare of our race, material, intellectual and moral, depends upon the food supply, or, in other words, upon the product of the soil. This in turn reduces itself essentially to a question of phosphoric acid, potash and nitrogen. Enough of the first two for an indefinite time to come is assured in the deposits of phosphates and potash salts already discovered, but the probability of a sufficient supply of nitrogen has been questioned. This costliest of the fertilizing elements escapes from our soils into the air and into the sea, and is taken away by crops, and not completely returned. Artificial fertilizers promise to meet but a small fraction of the coming demand. If, as has been urged, the exhaustless stores of the atmosphere are not available to plants, the outlook is dark enough. But if the farmer may use his crops to gather it, without money and without price, we may dismiss our solicitude. With the assurance that plants obtain nitrogen from the air, the fear of starvation for the over-populated earth of the future may be ignored. That research will bring the brighter answer to this problem, there seems to be most excellent reason to believe.*

In 1891 we visited the celebrated Experiment Station conducted by Sir J. B. Lawes, of Rothamstead, England, the oldest and in many respects most complete experiment station in the world, and found that not only had this distinguished experimentor and his scarcely less distinguished assistant, Dr. Gilbert, full faith in the capacity of clover and other legumes to obtain nitrogen from the atmosphere, but that their experimental grounds furnished ocular demonstration of the truth of this theory. A large number of plots had been sown with the clovers, peas, beans, lupines and other legumes, and fertilized more or less with nitrogen, while each alternate plot on the same kind of soil, to which no nitrogenous fertilizers had been applied, was sown with the same plant. In very few cases could we detect the slightest difference in the plant, visiting them as we did at the period of their greatest luxuriance, showing conclusively that though much nitrogen might be applied, the legumes found it easier to assimilate the nitrogen in the atmosphere than that in the soil. We found the leading scientific agriculturists in Belgium and Scotland holding firmly to the same belief, so that the capacity of the legumes to supply themselves with nitrogen from the atmosphere is not a theory held by a few men here and there, but is now the accepted belief of the agricultural world, and is regarded as among the very greatest discoveries of the age.

The results, both scientific and practical, of the above investigations demonstrate that clover receives its nitrogen, not from the soil in which it grows, except in the earlier stages, perhaps, but from bacterial action in the tubercles found on the root of the clover plant, and that all the legumes, such as beans, peas, etc., derive their nitrogen in the same way. It leaves, however, the precise method in which the bacteria obtain the nitrogen from the only source possible, the atmosphere, still unsolved. It, however, explains some things which have sorely puzzled practical clover growers who never heard of these investigations. It goes far toward explaining why it is that when clover is sown on new lands, the plants seem to take on a vigorous growth for a week or two and then dwindle away and die. This was our experience for some years in sowing clover on new lands, both on the raw prairie and in cultivated fields, and we have no doubt it

*A detailed account of Prof. Atwater's experiments may be found in the second annual report of the Storrs School Experiment Station, Storrs, Connecticut, published in 1889.

has [illegible] the experience of many others similarly situated. Until we became acquainted with these investigations we had despaired of finding the solution of the mystery. It explains, also, why occasional plants flourish, especially on portions of the field where the wild legumes grew. If allowed to remain and mature seed, the clover gradually spreads all over the field, securing in time a perfect stand. As no subsequent trouble was found in seeding these fields, there can be but one conclusion, viz., that the bacteria were present only in such spots in the field as had grown wild legumes, and that they multiplied readily and extended all over the field. We might state that recent investigations in Germany have shown that it is necessary to inoculate or leaven certain fields or portions of fields with the microbe of lupines, a leguminous plant. The readiness with which clover grows on gravelly points on which nothing but prairie grass ever grew, when covered with manure from cattle, and especially horses that had been fed on clover hay, suggests that inoculation with the microbe is fully as essential as the sowing of clover seed.

We have felt that it was due to the reader, before closing this volume, to state briefly the facts contained in this chapter, which have been established by the most rigid scientific investigation, in order that they may see that in assuming in almost every chapter of this work that clover is not dependent upon the nitrogen of the soil for its growth, we are making no bald, unsupported assumption, but one that has been demonstrated with almost mathematical precision, and which is now held by scientific men in all countries where science has attempted to aid the farmer in his work.

CLOVER CULTURE---THE WAY OUT.

CHAPTER XIV.

If the assumptions of the earlier chapters of this work be correct, and the facts stated and the conclusions drawn in the previous chapter prove that these are not mere assumptions, but demonstrated facts and established verities, clover culture becomes a problem of the first magnitude, not only to the individual farmer wherever he may be located, but has important bearings on the commercial and financial interests of the entire nation.

If it be true, as the concurrent testimony of the ablest and most reliable scientific investigators in the world with one voice affirm, that the legumes are, to a great extent, independent of soil nitrogen and supply themselves in preference from the atmosphere, why should the farmer in the Atlantic and Middle states invest his hard-earned dollars in nitrogen in the form of nitrates, costing from ten to eighteen cents per pound, when he can, through the medium of the tubercles on the roots of the legumes, draw on the limitless, inexhaustible supply of nitrogen that floats over him daily in the atmosphere. The Connecticut Experiment Station estimates that no less than half a million dollars are expended annually by the farmers of that small, non-agricultural state, for commercial fertilizers, more than one-third of which is for nitrogen. Why this waste? The market gardener must, per force, purchase his nitrogen in the form of nitrates, dried blood, or in some other condensed shape, because he cannot wait for the two years which the clover plant requires for its perfection. He must have immediate results. Nor can he tolerate any vegetable matter in the soil not thoroughly decomposed. He can use nothing that will interfere with the cultivation of the smallest and most delicate plant. It is different, however, with the farmer. He can employ a rotation in which the clovers of some kind form a prominent part that will supply him with available forage, and also diversify his crop, while storing his soil with the fertility needed in the future. Two years ago one of the ablest scientists in Europe said to a convention of Scottish farmers, in substance, that it was folly for them to invest pounds, shillings and pence in nitrogen where they could grow clover and other legumes. In view of the recent discoveries to which we have alluded in the previous chapter, it is high time for some one, in whose judgment they have confidence, to tell the eastern farmers the same truth. If, for any reason, the clovers cannot be grown, other legumes, such as beans and peas, can. A soil is poor indeed that will not grow beans, and the fact that a comparatively barren soil will grow paying crops of a food rich in nitrogen, itself should suggest to the practical farmer that when the scientists affirm that beans, so rich in nitrogen, are largely independent of the soil for their supply, they are but confirming the experience of his life-time. In fact, the most that scientific investigation has done in recent years is to explain the paradox of twenty centuries, viz: That the clovers and other legumes, while furnishing a large supply of nitrogenous food, at the same time actually increase the supply of available nitrogen in the soil. When stated as a distinct and separate proposition, it seems incredible. When offered as the rational explanation of an agricultural paradox, it solves a mystery that has puzzled the student of agricultural science for centuries. The eastern farmer who has spent large sums annually for nitrogen in the form of commercial fertilizers, cannot do a wiser thing than to investigate this subject and learn how he cannot only reduce the expense of cultivating his land, but successfully undertake to restore abandoned lands without beggaring himself to purchase nitrogen. Clover culture, however, means far more to the western farmer than it does to his co-laborer in the Atlantic and Middle states. He has at least two great and distinct advantages, his soils are not made up from the decomposition of the rocks of the immediate locality. In many districts in the eastern states the soil is deposited *in situ*; that is, it has been formed by the decomposition of the rocks lying immediately over or under it. Some of these may be rich in potash and poor in phosphoric acid, and others rich in the latter but poor in potash. The sub-soils of large portions of the western states are the result of glacial action, and are covered by the great northern drift in which the elements derived originally from the primary rocks are so thoroughly commingled that it is difficult to find a soil destitute of the two great inorganic elements of fertility, potash and phosphoric acid. Hence, the important question with him is how to obtain a supply of nitrogen commensurate with the supply of potash and phosphoric acid in the soil. He has another very great advantage. His soils are not, except in rare cases, so far exhausted by long cultivation of their potash and phosporic acid that they refuse to grow the clovers. They are not, therefore, said to be "clover sick." He can proceed to draw on them at once to the limit of their supply in nitrogen, because he can count with confidence on an abundance of potash and phosphoric acid which are so essential to the growth of clover. He has still a third advantage, viz: That while many eastern soils heave out the clover during the late winter and spring months by purely mechanical action, his soil, when properly drained, holds the clover plant during the entire period of its natural life.

If, however, he postpones the use of clover and other legumes until his soil is exhausted of its natural supply of potash and phosphoric acid by continuous cropping with the cereals and grasses that are wholly dependent upon soil nitrogen, his condition will be practically hopeless. He cannot purchase commercial fertilizers of any kind at present prices at the sea-board, paying in addition freights and profits, and then pay freights and profits on his products back to the principal markets. When this exhaustion has taken place it is too late to grow the legumes, for these are as dependent on potash and phosphoric acid as are the cereals on nitrogen. When his soil is thus reduced to the condition of some of the soils of the eastern states, he may as well give up the struggle.

The fact, attested by the experience of clover growers in many thousands of cases, that a good crop of clover roots adds to the ordinary crop from fifteen to thirty bushels of corn per acre the first year, and almost an equal amount the second, and to all other crops in a corresponding proportion, should teach the western farmer that his soil needs mainly nitrogen, or, rather, that his soil is more deficient in nitrogen than in either potash or phosphoric acid. The best way agricultural chemists have found of analyzing a soil is to interrogate it with various commercial fertilizers, and find from the varying yield, what great element of fertility is lacking. The farmer interrogates his separate fields in the same way, when, side by side with a crop grown on clover roots, he plants corn, wheat or flax on a similar soil that has been cultivated some years and gives both plots the same culture and care. The almost uniform answer of the soil in such cases is, "I am hungry for nitrogen." If, however, he will by the culture of clover and other legumes, fill his soil with nitrogen and conserve the potash and phosphoric acid by carefully husbanding the manure made on the farm, he can maintain for an indefinite period the fertility of his farm and be in a position to meet successfully the inevitable competition, whether from his neighbors, his own countrymen or the grain growers of the civilized world. The nation that can grow the great cereal products and transport them to the world's markets at the smallest cost will eventually dictate the price of bread.

It is supreme folly for any man or any class of men to say that his lands are inexhaustible. Many times in the history of agriculture has that claim been made, and as often have those who have made it been brought to confusion by the dire event. All that is needed to exhaust the fertility of any soil for any cereal crop is to keep on growing that crop year after year. It is quite true, as has been affirmed by Sir John B. Lawes and other thoroughly scientific investigators, that it is not possible to exhaust completely the capacity of any land for the production of any one crop provided the soil is good to begin with. Nature loves fertility and hoards it as a miser does his gold. She parts with it slowly and reluctantly, and as soon as she has allowed man to exhaust it to the point where he cannot grow paying crops in competition with better soils, and has thus driven him from his land, she at once begins the work of soil restoration.

The strict and accurate truth is that any soil may by continuous cultivation in the cereals be so far exhausted of its nitrogen or other elements of soil fertility, that the crops grown on it are no longer profitable. When it reaches this point of exhaustion and the farmer can no longer make a living on his farm, it is for him practically exhausted. What we mean, therefore, by soil exhaustion is not the complete removal of one or all of the great elements of fertility, but the reductions of any one of them to a point where the soil will not produce paying crops. Sir John B. Lawes has for nearly forty years grown continuous crops of wheat on the same land without manure, equal, even in late years, to the average crop of the wheat-growing world, but it has been done, by a system of thorough tillage, hand-hoeing and weeding, which if done on a commercial basis would reduce the owner to beggary.

We desire to reiterate what has been said in preceding chapters, that the most complete exhaustion of the soil, paradoxical as it may seem, may be accomplished by the use of the clovers. If by supplying nitrogen in the clovers and continually drawing on the potash and phosphoric acid, which the clovers do so largely, the farmer practically exhausts the land of these, he must then either resort to expensive commercial fertilizers or throw his land into the hands of mother Nature to nurse it back through long years, or it may be centuries, to the condition to which as a foolish and unskillful cultivator he has found it a fit subject for his robberies.

The Western farmer has now reached a point where, willing or not, he must elect to do one of three things: 1. Continue his present robbery of the soil by continuous growing of grain for sale in the world's markets and thus selling his land by piece-meal. 2. He may by supplying nitrogen in the clovers and returning nothing in the form of manure rob it more completely and reduce it to a more hopeless barrenness. 3. He may draw on the winds of heaven by means of the miracle-working tubercle in the roots of the clovers, and then by the judicious use of the manure made on the farm in various ways restore the potash and phosphoric acid, trusting to the gradual disintegration of the rocks of which the soil is composed to keep up indefinitely their supply.

The folly of the first course is as supreme as it is conspicuous. The farms all over the West that have been rented on one-year leases to croppers attest that folly so completely that he "may run that readeth it," and "the way-faring man, though a fool, need not err therein." Heretofore millions of the best acres in the West have been cultivated by farmers who confessed themselves pilgrims and strangers, and like Abraham of old, though in a far different sense, said they were seeking a better country and would find it as soon as they had, to use their own expression, "skinned" or "taken off the cream" from the lands they occupied. These are the soil robbers who plant neither orchards nor groves, around whose homes are no flowers, on whose porches are no vines to shade their wives from the summer's sun, and who expect as soon as their robberies are completed to find in the farther West another piece of virgin land to despoil. It is time for this class of farmers to understand that the limit of the corn lands of America has been definitely marked out, as fixed by their Creator; that these lands are all out of the possession of the Government and are nearly all in cultivation, and that while there is a large amount of wheat lands as yet untouched by the plow, they are in capricious and uncertain climates, subject to the vicissitudes of doubtful rainfall, hot winds and destroying insects, or else yield up their natural fertility only by irrigation. Capitalists can no longer buy the finest lands in townships and counties, rob them of their fertility by continuous wheat growing on the bonanza plan, and find in the newer West fresh lands to impoverish. The migration of these bonanza farmers westward must now cease. A farmer who wishes a permanent home for himself and a heritage for his children must buy it soon. The tabernacle of the wilderness must give place to the permanent structure in a land not divided by lot but selected by purchase. The soil robber must henceforth be content with robbing himself and wasting in advance the patrimony of his children.

If, however, he makes the second election and sees in the recent discoveries of agricultural science an opportunity by clover culture to rob his lands more completely than before, by selling in a distant market the elements of fertility in his land, he should know that in this way he will reduce his land to a degree of barrenness impossible under former conditions. He may by clover culture become thus penny wise and pound foolish. He may adopt the specious though fallacious maxim that "tillage is manure," without stopping to think that improved tillage by increasing the yield will only the more speedily exhaust, by the magnitude of the crops which it furnishes, the fertility of the land. He may draw upon the great bank, the atmosphere, for his supply of nitrogen, and if his drafts be properly drawn, signed and sealed by the clover-root tubercle, they will not go to protest, but when he draws upon the soil for potash and phosphoric acid, he will get the quick response, "Protested—no funds." Every farmer owes it to those who are to bear his name, to leave the acres that have fed him, richer if possible than he received them from the hand of Nature or a previous purchaser, or if he fails to do so, he cannot with truth have the honorable title of "a good farmer" engraved on the marble that is intended to perpetuate his memory.

The only wise choice is the third one above mentioned, viz., to grow clover, feed stock, husband carefully the farm-yard manure and restore it to the land without waste. He must necessarily dispose by the sale of his live stock and grain of more or less of the great elements of fertility. Nature, however, is ever struggling to maintain it by the gradual decomposition of rock material of which the soil was first formed, and if he works with her he will be entitled to a well earned reputation for agricultural wisdom. If better methods of tillage hasten the decomposition of the primary rock, it only increases his supply of home-made fertilizers by the careful husbanding and diligent application of which he is ever restoring to the land its own. The future prosperity of the Western farmer depends, more than on anything else, on whether he elects the part of wisdom, and the prosperity of any section or of any community depends upon the number of farmers who make this choice.

It cannot have escaped the attention of thoughtful students of agriculture that in any country that is really prosperous for any great length of time the farmers have settled down to a system of mixed grain and stock growing and the cultivation of the tame grasses that are so essential to success in this line. The ranch system so long dependent wholly on the wild grasses may endure for a time, or as long as these grasses are abundant and free to all, so to speak, "without money and without price," but it should be noted that even the ranchman is turning to alfalfa. Nor should it escape the notice of the thoughtful that among the grasses that form these cultivated pastures the legumes have always had an important place, and that the failure of clover in any nation except as part of a long rotation has always been regarded as a great calamity.

Circumstances will compel the Western farmer to adopt the same methods. He has, however, a great advantage over all the farmers that were before him. They grew the clovers because they found by experience that they increased the value of all subsequent crops, but did not know how or why. Their farming was on the principle of "cut and try." The modern farmer is now in the position of the tailor who has a rule by which he can cut and be reasonably sure of a fairly good fit. He knows, or at least may know, that by the use of clover he can store up nitrogen in his soil for a crop of wheat, corn or flax following. He knows what plants can obtain nitrogen from the atmosphere and what can not, why timothy always does well after clover, why blue grass flourishes with white clover as a growing mate, and can thus plan his rotations and his seed mixtures with intelligent foresight, as a painter mixes his paints and plans his work, knowing beforehand very nearly what will be the result.

The Western farmer has been placed for many years in a peculiarly trying position, and that largely through no fault of his own. In the last thirty years a vast empire has been opened up west of the Missouri. Its fabulous wealth has been advertised over Europe and America by railroads interested in its settlement. Population has rushed in, fully imbued with the idea that unlimited acres of inexhaustible fertility were to be had for a song. Payments for the land, for the improvements and for living expenses had to be made from crops of ready sale at cash prices in the world's markets. These bulky products had to be hauled from five hundred to seven hundred miles to the nearest water line and from a thousand to fifteen hundred miles to the seaboard, and that, too, as soon as gathered. Paradoxical as it may seem, the pioneer farmer as a rule has not been able to build granaries to store the products of his land. The result has been two-fold—exclusive grain farming in necessary violation of the well established principles of successful agriculture the world over, and the glutting of the markets of the world with cereals to an extent that has produced acute and severe distress among grain farmers everywhere. A cry of distress, both in years of shortage and abundance, has been heard in every part of the United States in which the improved grasses have not been contiguous to the grain and cotton field. Meanwhile the American farmer, by reason of his fertile soil, improved machinery and skilled agricultural labor, is crowding the British, the Russian and the Hindoo farmer to the wall, and while suffering himself, is inflicting more severe suffering on farmers in other parts of the world under less favorable conditions.

We have outlined these existing conditions, not to make the broad claim that clover culture is the panacea for all the ills to which agricultural flesh is heir, but to show that the evils of a false system can be remedied only by a return to a correct one, and this cannot be done successfully without the introduction of the legumes, and especially of the clovers. What the American farmer needs at present is something that will enable him to maintain cheaply the fertility of his soil, especially in nitrogen, the most costly and at the same time the least stable, of all the elements of fertility in all soils. The potash and phosphoric acid will remain locked up in various soil compounds until it is needed by the plant, but the nitrogenous compounds, as soon as converted into nitrates, the form in which they are assimilated by plants, are liable to be washed out by rains. He needs a system of farming which will enable him to condense his freights by feeding his products on the farm, and shipping them in the form of live stock, butter, cheese and wool, and he needs besides a home-grown forage, rich in nitrogen or albuminoids that will enable him to use to the best advantage the carbonaceous food products which exist in such super-abundance in the West. In this lies the "way out" for the western farmer. We do not by any means affirm that he is not suffering from other evils. We know, for example, that he pays more than his proper share of taxes; that he is the victim of trusts and combines, and that in many localities he is compelled to pay exorbitant freights and excessive rates of interest. We do mean to say, however, that where a system of agriculture has been adopted for any great length of time, these evils diminish in their intensity or disappear altogether. In fact, it is the one-sided system of agriculture adopted in many parts of the West that has rendered it possible to form some combinations and extort usurious rates of interest. In this correct system of agriculture wherever established, the tame grasses must form an essential and indispensible part, and chief among these grasses will always be found the legumes, and especially the clovers.

The "way out," if it be a main travelled road leading to the city of refuge and not a by-path leading into the forest or a morass, must provide for retaining soil fertility and especially nitrogen. As we have before shown, there is no present way by which that can be done effectively and at the same time economically except by the intelligent use of the legumes. Theorists may speculate as they please, but when the available fertility of any soil, whether of the farm or the district, is so far exhausted that it will not produce paying crops, as it will be in time by continuous cultivation of the non-leguminous plants, it matters very little what political party is in power, or what the rate of taxation or transportation, or what kind of currency may be in use. The "way out" for the western farmer that does not provide for the conservation of nitrogen and its increase, at least to the measure of the supply of the other elements of the fertility in the soil, will lead him into worse trouble than he complains of now. It is for the reason that it furnishes the farmer with clear, definite and precise information on a matter of the first importance that we regard the discoveries of Helreigel, Wilfarth and Atwater as among the greatest of the present age. If this important element of fertility cannot, by reason of deficient rainfall or some other climatic or soil conditions, be furnished by the red and mammoth clovers, then resort must be had to alfalfa, and where this cannot be grown, the supply of nitrogen must be secured by the use of some other legume. The "way out" must be sown with legumes.

It is not enough, however, to have a supply of fertility in the soil. There must be some way of using to advantage the products furnished by this raw material provided by nature and husbanded by man. No country ever became permanently rich which was burdened with the trasportation of crude products to a consumer from a thousand to five thousand miles distant. It matters little how cheap freight rates may be, for the obvious reason that competitors are likely to have them as cheap. Freight rates by rail can be reduced about as much in one part of the world as in the other, for the reason that the reduction is the result of inventions in which the whole world shares. Water freights are practically equal with each other, and, hence, it is not the cost of freight, but the fact that freight must be paid, and that, too, by the farmer, that makes hard times in any country that must find a customer for its bulky or heavy products in a far-distant market. The "way out" must, therefore, suggest a method by which the farmer can convert these bulky products into some more compact and available form. The introduction of the clovers and other cultivated grasses at once reduces the acreage of the cereals and paves the way for successful stock growing, which, in turn, furnishes a means for condensing freights.

It requires no prophet to forsee what would be the immediate result if half the lands now in cereals in Kansas, Nebraska and southern Dakota were successfully sown to clovers next year. There would be an immediate, though temporary reduction in the yield of cereals which would at once be felt in prices, demand for improved stock to suit the improved conditions, and a decrease in the amount of freights furnished the railroads. It is quite true that a large amount of the corn grown in these states is condensed by feeding to stock brought in from the ranges. This system, however convenient or profitable it may be for the time, leads surely and speedily to the soil exhaustion of these states. The feeding is done on comparatively few farms and by men who are feeders rather than farmers, and thus a few acres are enriched at the expense of the many. When farmers in these states adopt the method of farming half the land and seeding the remainder to tame grasses, where these can be grown, they will be able not only to maintain the fertility of their soil, but place themselves in the position which farmers the world over occupy, wherever agriculture is permanently prosperous.

Nor are we advocating any new or untried policy. Corn is grown in nearly every state in the Union, and yet there are but seven corn surplus states, or states that grow an amount beyond their home requirements, and the surplus produced by two of these is comparatively small. This policy has been largely adopted in all the states east of the Missouri. As the grasses and legumes travel westward, elevator properties on the lines of the railroads leading to the great grain markets first decrease in value, then stand empty and finally are burned up or torn down.

The progress of clover and grass culture may be noted even in the political discussions, and especially those that grow out of agricultural discontent. These discussions move west with the tame grasses. The granger legislation of 1873 affected Illinois, Wisconsin, Minnesota and Iowa, while that of 1889 affected only, to any great extent, the states west of the Missouri and south of the Ohio rivers, or, in other words, the grain and cotton growing as distinguised from the grass growing states. No less significant is the fact that the so-called granger legislation of Iowa in 1884-88 had for its object, not the cheapening of rates on crude products, but the cheaper distribution of its own products within that state.

It will be seen that the culture of the clovers and other grasses is far reaching in its consequences. In urging it as we do, we are on main traveled roads. We point to the experience of all farmers in all countries for the last hundred years; we point to the fact that where once introduced it has never been abandoned, until the soil refused to grow clover; we point to the fact that where it is once established, land uniformly advances in price, and the rate of interest as uniformly falls; we point to the fact that where it is once established diversification of industry naturally follows. For example, the great dairy interest is confined almost wholly to the regions where the clovers and other tame grasses have proved a success. Creameries have been built by the score in advance of the grass and clovers, and only in rare instances have they succeeded beyond the white, red and crimson of the clover fields. While it is true that there is a natural limit to the tame grass belt, it is also true, and we call attention to the well known fact, that the clovers have a wider Western range than any of the other cultivated grasses, and, as we have already shown, where clover ends, alfalfa begins. Where, by reason of the unsuitable subsoil, it is impossible to grow alfalfa, other legumes, such, for instance, as the soy bean, will be found to take its place. The necessity of the introduction of some legume that will supply the place of the clovers and alfalfa in semi-arid regions is so urgent, or will be in a few years, that every clime will be searched by enterprising farmers and experiment stations to find something that will meet the want. The right plant will be found when it is needed, just as the right man appears in every great crisis of a nation.

Again, any "way out," especially for the Western farmer, must provide some method for utilizing the great surplus of carbonaceous food products that exists on his farm. Western states have a very great surplus of this carbonaceous food. Corn, their great crop, is highly carbonaceous, and straw, cornstalks and sorghum still more so, and the ordinary tame grasses, outside of the clovers, scarcely less. No one of these, nor all of them together, can be fed exclusively to young and growing stock, or to milk cows, without great waste of the food. The young grasses alone furnish a balanced ration, but only for a brief period of the year.

The continuous waste that goes on for eight months in the year becomes so enormous that no section can compete with other sections blessed with albuminoids with which to balance up rations. Oats is about the only stock grain that in itself comes near being a balanced ration, and in default of the legumes farmers are compelled to use oil meal, cotton-seed meal and wheat bran in order to feed their carbonaceous rations without waste. The clovers come in to meet the requirements with nitrogenous compounds, drawn not from the soil beneath, but from the air above, and not only store nitrogen in the soil by means of their roots, but in the form of hay and pasture supply this much-needed want. Eastern farmers who travel through Western Kansas and Nebraska and Dakota and other wheat-growing sections and see the great mass of straw given to the flames each year are accustomed to declaim against the thriftlessness of the Western farmer. He is at least as wise as they, for experience has taught him that cattle will eat themselves poor by trying to live on this carbonaceous food, and that for him its main value is in its ash, which he therefore distributes as wisely as possible by heading his wheat and burning his straw. If, however, he can grow clover or alfalfa to balance up this excessively carbonaceous food, the straw becomes at once a mine of wealth.

English wheat growers are this year, in many cases, getting more for their straw per acre than for their wheat, for the reason that they can use it economically and without competition, whereas in the growth of grain they are compelled to compete with the whole world.

In the arid regions of the plains, the mountains or the Pacific coast, the word alfalfa has a charm second only to gold and silver, because it furnishes in the form of hay a ration that improves or balances up every other forage with which it is fed. As the subject of feeding rations becomes better understood through the greater number of analyses of western grains and grasses and carefully conducted experiments with balanced rations, the legumes will be rated at a much higher value than they have been in times past. Stock growers will even find that it will pay them to grow the legumes solely as a means of stopping the great waste that is now going on by the enforced use of rations too highly carbonaceous to meet the wants of the animal economy.

A system of farming that will at once conserve and increase the fertility of the soils of the West, that will, by diminishing the amount of the acreage in cereals and increasing that of the grasses, reduce the cost of labor fifty per cent., and that will stop the waste of foods now going on, will at least indicate the "way out" that can be followed with safety and profit. The extended use of the clovers and other legumes will provide such a system, and for this reason we urge it upon the attention of every farmer. Other nations and the majority of our states have already adopted such systems, ignorant of the recent discoveries that have made the way plain, safe and easy. It devolves upon the Western farmer to say whether he will be guided at once by the experience of practical farmers in the past and by the light that science has shed upon the subject, or whether he will continue to waste the fertility of the richest heritage that Providence has ever bestowed upon a people, and reduce to comparative barrenness the fairest land on which the sun shines.

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