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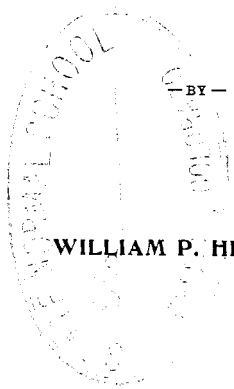
How Can We Maintain the Fertility of Our Colorado Soils?



—BY—

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HOW CAN WE MAINTAIN THE FERTILITY OF OUR COLORADO SOILS?

BY WM. P. HEADDEN.

This bulletin has no other purpose than to present to the farmers of Colorado some of the most patent facts relative to the maintenance of the productiveness of their lands. The writer has presented this subject repeatedly, either in lectures before Farmers' Institutes or bulletins, and particularly in the pages of our too short-lived *Agricola Aridus*. The presentation of this subject has, heretofore, apparently failed to attract the attention of our farmers, either because of the unskillful manner in which it has been presented, or because it was not opportune, the farmers not yet having come to a realization of the importance of the question, as one appertaining to their lands and to their prosperity. The time may be more auspicious for obtaining the attention of a reasonable percentage of the persons for whose benefit the Experiment Stations have their existence. It is in hope that this is the fact, that I present the following considerations, and not for the purpose of presenting any new results, or any facts which are not already well known.

OUR COLORADO SOILS ARE NOT INEXHAUSTIBLY RICH.

In the early days of Colorado agriculture, when the railroad land agent was endeavoring to induce homeseekers to settle on our prairie lands, it was, perhaps, pardonable to emphasize their virgin condition and to claim for them inexhaustible fertility. This fiction was soon dispelled by the plain facts, so plain that no one could misunderstand them. The magnificent yields of the first few years after the lands were brought under irrigation, were followed by rapidly decreasing ones, until they fell to one-half or one-third of their former weight or measure, and it became evident to the most obtuse that a remedy had to be found.

That this result would ensue, and that rapidly, was easily to be foreseen; the nature of our soils justified no other belief or expectation, and we now begin to apprehend that in our climate itself we have added reasons for the fact that the virgin fertility of our soils was of comparatively short duration when subjected to continuous cropping without fertilization.

Our soils on the eastern slope of the Rocky mountains are, for the most part, light, sandy loams. The heavier, clayey soils, derived largely from the disintegration of shales, especially of the Ft. Benton shales, are apt to come under the class of soils designated as gumbo, which, to use the language of an earlier writer, is inimical to vegetation. The soils derived from the strata of the Jura-Trias may be somewhat clayey, occasionally limey, due to the presence of calcite or ordinary lime stone, or to the presence of gypsum, the latter mineral being of common occurrence in portions of these strata.

ORIGIN OF OUR SOILS.

The origin of our soils may safely be ascribed to the breaking down of the rocks forming the mountains to the west of us. The mountains from which the material of the strata of the Jura-Trias were derived may not have been the present mountains, but the material composing them is so similar to that yielded by the disintegration of the Front Range, that there is no reason for discussing the possible differences in origin.

The rocks of the mountains are essentially granitic in character, and the sands and soils derived from their disintegration will naturally partake of this character, too. It is a fact that the soils from the foothills to the eastern part of the state are sandy or gravelly loams, in which the sands and gravel are composed of quartz and felspar grains, with some mica plates; in some places they may be coarser than in others, especially in river bottoms they may be finer, but we have everywhere the same general composition with but little variation, and this restricted to small sections.

The base of our soils, mineralogically, is very uniform. The fact that they are nearly all sandy loams tells us that these mineral grains still possess their mineralogical characteristics; they have been broken and ground to small sizes, but they have not been materially changed in their composition. The felspar, hornblende, augite or mica are the same rocks that form the mountain masses, only that they have been broken up into very small pieces. If we examine the red, clayey soils, corresponding to the Jura-Triassic strata, we find the same to hold true to a very great extent. The red sandstones of this formation show the same facts.

Such are the salient, mineralogical characteristics of our soils. The mineral which can furnish the potash is a felspar, orthocluse, which yields slowly to the decomposing action of water and air, and to some extent, to the action of the roots of the plants. The total amount of potash in our soils is from two and one-quarter to two and one-half per cent. of the weight of the soil. A comparatively small portion of this, however, exists at any given time in such form as to be readily taken up by plants. Before this can take place, the

felspar must be altered and the potash brought into another form, or, in other words, it must be prepared for the use of the plant. In our virgin soils, this preparation had, to a certain extent, taken place, but this supply of prepared, available potash was quickly used up, and the magnificent crops of the first few years gave place to poor and unremunerative ones.

The phosphoric acid in our soils is also furnished, certainly in a large measure, by the felspars. A sample of this mineral, just as it was broken from the granite of which it formed a part, contained more phosphoric acid than some of our soils. The amount was below the minimum considered necessary to a fertile soil, but was equal to or greater than the amount found to be present in sixteen out of fifty-five samples of soils representing the different counties of this state.

The same facts pertain to this substance, regarding the extent to which it is prepared to be taken up by the plant, or, as it is generally expressed, its availability, as to the potash.

OUR SOILS NOT RICH IN POTASH AND PHOSPHORIC ACID.

The average Colorado soils, as represented by a considerable number of samples from almost as many portions of the state, are not very rich in these elements of plant food, potash and phosphoric acid; that is, the amount of potash taken up by dilute acids is very moderate indeed, while the total amount of phosphoric acid is comparatively small, only about one-tenth of the samples analyzed showing two-tenths of one per cent. or more, and about one-third of them as much as one-tenth per cent. or more. This statement, unlike the one relative to potash, has reference to the total amount of phosphoric acid present, because dilute acids extract the whole of it from the soil.

THE NITROGEN IN OUR SOILS.

This element may be considered as having been furnished wholly by the agency of animals or plants. It is the most variable plant food in soils in general, depending, also, to a considerable degree, on conditions of climate, which are of less effect in the cases of potash and phosphoric acid. There are the same questions of availability regarding the nitrogen as regarding the other two plant foods mentioned. But assuming that a fairly productive soil contains about one-tenth per cent. of nitrogen, nearly all of our soils would measure up to this standard, but only a comparatively small number of them would have a considerable excess above this, less than one-third of the samples analyzed showing as much as two-tenths per cent. of nitrogen.

The statements made in the preceding paragraphs pertain almost exclusively to virgin soils.

These, then, were the conditions under which our agriculture began. It is a well known fact, that the farmers very soon began to feel the need of doing something to keep up the yield, particularly of the cereals, because this was the first class of crops raised.

THE COST OF GROWING CROPS.

In these early days the soil bore the burden or cost of raising the crops, and the farmer made no estimate of this; even now he seldom takes this factor into account. A ton of alfalfa, perhaps one of his cheaper crops, is charged with the rent of the land, cost of irrigating, cutting and stacking. There is seldom any question as to whether the ton of alfalfa has cost the land any of its fertility or not. The time has already arrived when these questions of cost in soil fertility must be taken into account. I have taken alfalfa because it is our popular forage plant, and very justly so. I shall use figures in this calculation which I published ten years ago, but they are the same facts, just as true as they were then. The cost of the ton of alfalfa in soil fertility will be best understood if we consider it to have been sold off of the ranch. With the ton of alfalfa hay, cut when the plants were in half bloom, there would be sold fifty-five pounds of potash, ten pounds of phosphoric acid, and fifty-two pounds of nitrogen, some of which, however, came from the atmosphere. I do not know how much of it really came from the air and how much from the soil, but I will assume that one-half of it came from each, and we will use the trade values for these substances as given for 1904. The fifty-five pounds of potash, at 5 cents per pound, is worth $2.75; the phosphoric acid, in cotton seed meal, etc., is quoted at 4 cents, and the 10 pounds in the ton of alfalfa is worth 40 cents. Considering that one-half of the nitrogen is obtained from the soil, we will have 26 pounds of nitrogen to charge against it at 17 cents per pound, or $4.42, a total cost in soil fertility, which would have cost, bought in the market in 1904, $7.57. As it may be better understood by some, I will express it as the cost of raising four tons of alfalfa hay per acre, which would be $30.28.

The sugar beet is a crop which is now grown on a large scale in several sections of the state. The crop harvested in this immediate neighborhood in 1904 was 80,000 tons. What was the money value of the phosphoric acid, potash and nitrogen removed from the soil by this crop at the current prices of these substances, *i. e.,* 4 cents per pound for phosphoric acid, 5 cents per pound for potash, and 17 cents per pound for nitrogen. These are the values adopted by some of the Eastern Experiment Stations and would be too low for our market. The 80,000 tons of beets would contain 331 tons of potash, worth $31,100; 71 tons of phosphoric acid, worth $5,680; 160 tons of nitrogen, worth $54,400; a total of

$81,180 for the crop, a trifle over one dollar per ton. In other words, had the farmers of this immediate neighborhood who sold their sugar beets to the local factory, been compelled to pay the market prices for the potash, phosphoric acid and nitrogen removed from their lands by the beet roots taken to the factory, it would have cost them $81,180.

These examples serve thoroughly well to emphasize the fact that there are other items of cost in raising a crop, even of alfalfa, than those previously mentioned, *i. e.,* land rent, labor, etc., and to show that the cost in the diminished fertility of the soil may be a very important item.

Our farmers can no longer afford to treat this subject with indifference or utter neglect, as they have done in years past, and as they do to a considerable extent even at the present time. We have shown that the soils are by no means inexhaustibly rich; even our virgin soils are not. In fact, none of them are more than moderately rich in the essential elements of plant food.

CLIMATE AND FERTILITY.

Our climate does not seem to be especially favorable to the formation of that form of organic matter known as humus, which favors the retention of nitrogen until it can be converted into a form fitted for its taking up and assimilation by the plant. The moderate supply of plant food, our climatic conditions which favor the complete destruction, the burning up of the organic matter in the soil rather than its humifaction, and every other condition which tends to lessen the fertility of our soils, admonishes us to vigilance in the preservation and enhancement by every means within our power of the intrinsic value of our lands, which is their power to produce.

This view is supported by the experience of ranchmen or farmers throughout Colorado, and while it is in perfect agreement with the theoretical views held regarding the fertility of the soil and its durability, it is simply a plain matter of fact not fully appreciated as yet, but one which is coming to be more and more generally acknowledged, even by the most careless and indifferent.

The necessity of carefully considering this question cannot be too strongly urged upon all classes of our agricultural population. This will undoubtedly seem a self-evident fact, even a trite one, to many persons, but a very little observation of the practices of our farmers will convince any one that it cannot be repeated too often.

CAN WE PROFITABLY REPLACE THE PLANT FOOD REMOVED?

There is a very important question confronting us, *i. e.,* can we, by any available means, restore the plant food removed by our crops, sugar beets, for instance, at such a cost as will permit us to make a

reasonable profit? The question of our being able to maintain the fertility of our lands is one thing, but the question of its cost is another. It is clear that the returns, either in the present or in the immediate future, must not only pay the cost of maintenance of the fertility, but must permit of a profit. It must, in other words, be accomplished in some business way which must be approved by an increased prosperity.

The means at our disposal with which we may endeavor to meet this question are such as other communities possess, but the questions of costs and local conditions, and perhaps methods or practices dependent upon the latter, may prevent us from availing ourselves of some means which, in other places, have been very efficient. I wish that I could emphasize the fact that the Colorado farmer, while he may avail himself of the observation and experience of others, must solve his own agricultural questions, the maintaining of the fertility of his soil and the earning of profits for himself.

Colorado is not a sea-board state and its agriculture cannot look to the products of the sea as a means of restoring the waste of its lands. Among its varied mineral resources there has not as yet been found phosphorite, apatite, or other rock phosphate, or any salt of potash in such quantity as to permit of its use in agriculture; its packing house industry is too small to supply any quantity of waste or by-products nearly adequate to supply the elements of fertility which we are annually using up. Our manufacturing interests are producing no by-products, such as phosphatic slags, to which we can have recourse. In regard to our sources of nitrogenous fertilizers, we are no better off. Our coke industry might be made to yield us some in the form of ammonia salts, our packing industry a little in the form of dried blood and other forms, but these are all insufficient to supply an amount nearly equal to our actual consumption.

CAN WE USE POTASH SALTS?

If we use German or Stassfurt salts as a supply of potash, we must realize from its use a sufficient return to pay for its production, preparation, marketing and delivery to us, together with the profits put on by the producer and dealer, and leave a margin of profit for the farmer who uses it.

Can the Colorado farmer profitably use these? The answer depends upon two things: First, upon the price that he must pay for the potash. This, of course, depends upon the actual cost of the salt, including transportation, and the modesty of the profits realized by all of the interested parties. Second, upon the increased productivity of the soil, considering the total increase in both quantity

and quality of crop, whether it is produced during the season of its application or later.

The writer does not know of any series of experiments showing conclusively that the Colorado farmer can make a profit by using this salt on general crops, and will certainly be pardoned, if he does not find some sympathy, in entertaining a serious doubt regarding the feasibility of our using this salt for maintaining the supply of potash in our Colorado soils.

CAN WE USE SUPERPHOSPHATES AND CHILI-SALTPETRE?

The preceding considerations apply to the questions relative to phosphoric acid, whether it comes from Canadian apatite, or phosphatic rock from Tennessee, South Carolina or Florida. They also apply to nitrogen, whether it is in sodic nitrate from Chili, or in dried blood, meat, etc., from the packing houses of Chicago. I have assumed throughout that the trade would by every means, consistent with a reasonable business proceedure, for it is always entitled to a legitimate profit which no one ought to begrudge, endeavor to make the use of such fertilizing materials profitable in order to extend their business.

It, however, seems to me to be a serious question whether we can, with any hope of realizing a profit, look to these means of maintaining or restoring the fertility of our soils, except perhaps in a few special cases as, perhaps, in market gardening in the vicinity of our larger cities.

BETTER PRACTICE REGARDING BARNYARD MANURE.

In the past, even up to within a very few years, not more than three or four years ago, but little or any use was made of the manure accumulating about our towns and the corrals where hundreds of animals had been fed. Within the past year it has been possible for us to find piles of manure five, ten and even twenty years old, which have lain there just as they were piled when the corrals were cleaned out.

At the present time this is one of the most important and, at the same time, available means for the maintenance of the productiveness of our fields, *i. e.*, the careful husbanding of all the products of the farm which can economically be converted into a fertilizer—say into barnyard manure.

Our former practice was, in cases where the alfalfa was fed upon the ranch where it was grown, to neglect the refuse or perhaps haul it out to dump it in some boggy place; if it were sold off of the farm no further account was taken of it—another crop would grow. So little appreciation of this subject, which is of the very greatest importance to the agriculture of this section, has heretofore been evinced, that it has been possible, within the three years last

past, to obtain at the corral a four-horse wagon load of well-rotted manure for a consideration of twenty-five cents. This time is past, it lasted altogether too long.

WHY SAVE THE BARNYARD MANURE?

I intentionally chose alfalfa as an illustration to show that it cost a great deal to raise a crop, which I endeavored to make evident by converting the elements of fertility into their respective money values, which for a four-ton crop of alfalfa, per acre, amounts to $30.28, assuming that only one-half of the nitrogen present in this amount of alfalfa hay was obtained from the soil. I realize that it is difficult for the average ranchman to appreciate this fact, for it represents money value which he has never had represented in his bank account, nor has he ever seen the materials in mass, nor can he miss them from the place whence they have been taken. They are, nevertheless, no longer there, but have been embodied in the hay and removed with it. There is less plant food by this much in the soil than there was before.

It costs less, not in the labor of plowing and preparing the seed bed, or of irrigating and harvesting, but in soil fertility, to grow a ton of wheat, or oats, or rye straw, still it cannot be grown except at a cost, and after it has grown and produced its crop of grain, it still has a value which is of too much importance to be permitted to, in any degree, go to waste. Thousands of tons of this material are left in the fields where stock has access to eat what it may, but very large quantities of it are removed before the next plowing by the ready means of the match, whereby the nitrogen and the organic matter, both beneficial to our soils, are dissipated in the atmosphere, while the ash constituents would have been far more valuable if applied jointly with the other constituents of the straw. The glow of the burning straw pile is, even in this year of 1905, not an unusual sight. This, too, has been a wanton waste of fertilizing values which the future will teach us to utilize in a rational way.

Cattle feeding in the vicinity of Fort Collins has given place to lamb feeding, at least, to a large extent. The number of lambs which have been or are being fed in this immediate neighborhood during this season, the winter of 1904-1905, is about 250,000 head. In order to get a clear idea of the important bearing of the question of barnyard manure upon our agriculture, I will estimate the manurial value of the voidings of 250,000 sheep, using conventional but conservative data.

First, we will assume the feeding period to be 100 days; second, we will take the daily consumption of alfalfa at three pounds; third, we will assume the manurial value of alfalfa hay to be $11.90 per ton; fourth, that the voidings of the sheep contain 95 per cent. of the manurial values of the hay; fifth, that no corn has been fed.

On these assumptions, the total weight of hay consumed will be 37,000 tons, with a manurial value of $431,300. The voidings equal 95 per cent. of this value or $409,735. I do not mean to say that this full value can be realized or that no losses will occur, but it is a fact that if our community should desire to purchase the amounts of potash, phosphoric acid and nitrogen contained in the voidings of these 250,000 lambs for 100 days, each lamb consuming three pounds of alfalfa per day, it would cost them not less than $409,735.

Is it feasible to preserve the whole of the voidings? Very nearly all, and the straw, which is still burned in considerable quantities, could be used to good advantage as an absorbent and would thereby be converted into an excellent form for application as a manure. We know that no one man in the community would reap the benefit of this great value, but the community as a whole should. While I have singled out the sheep feeding as an example, the principle applies to every individual, whether he keeps only one horse or a cow, or is a feeder on a large scale. Everyone ought not only to try to preserve and utilize all of the barnyard manure naturally produced on his farm, but he ought to use every practicable means to increase the amount. While this is particularly applicable to the farming districts, it applies in a less degree to the towns and cities as well.

In using barnyard manure which is produced upon the farm, we preserve, in a large measure, the plant food originally present, but we do not add any to the total originally present; on the contrary a little goes off of the farm in various forms—in the increased weight of the lambs, in the case which we have already used as an illustration. The exception to this statement is in the case of the nitrogen, provided alfalfa, clover or pea-vine hay has been fed, when, owing to the fact that these plants obtain a considerable portion of their nitrogen from the air through the agency of certain organisms, we may actually return more than we took away from the soil with the crop.

The use of barnyard manure is preeminently a method of maintaining the fertility of the land, but is in a measure a method of increasing it by improving the conditions of the soil; also by adding organic matter, and in our case by increasing the supply of nitrogen.

GREEN MANURING.

The next best method is probably that of green manuring, and for this purpose we have no better plant than alfalfa. I know that there are some who may think it too big a sacrifice to turn under a good growth of alfalfa for the sake of its manurial effect upon the soil. The writer has a great deal of sympathy with this view, but it is not well supported by any facts which we can produce. There seems to be no plant which could be grown here for this purpose.

Crimson clover is, so far as I have seen, a failure with us; red clover is by no means a pronounced success, though it will grow; pea vines do not make a sufficiently early growth. Some of the vetches might be better, but they, too, are not early enough. Rye might be used if we aimed at adding succulent organic matter, which would easily decay, but would add no nitrogen or other fertilizing substance.

In green manuring we take nothing away from the soil, nor do we use the crop grown for any other purpose, but simply return it to the soil in its succulent and easily fermentable condition, together with the total content of plant food which it has gathered from the soil. The effects produced may be marked, but they are not due to actual addition of plant food, as in the case of the addition of mineral manures, but are due to the availability of the plant food contained in the crop, the effect of the fermenting material upon the soil and probably to the humus substances produced.

I have stated that alfalfa is our best plant for this purpose. It is out of the question to use this plant for this purpose, except in some systems of rotation, which is, under all circumstances, advisable, whether the last crop is to be potatoes or sugar beets. I am not prepared to even suggest what rotation will prove to be most advisable; some of our practical men can work that out in detail.

I fully appreciate the fact that a good plantation of alfalfa which will yield 3 1-2 to 5 tons of alfalfa hay per acre, is a valuable asset on a farm, but some of our people are coming to realize that it is a good thing to plow under, too, though it is not the easiest task to perform, especially when it is in full growth in the spring time.

ALFALFA OUR BEST PLANT TO USE AS A GREEN MANURE.

There are several considerations which lead me to think this the best plant which we possess for this purpose.

Our soils are only fairly rich in nitrogen, and an addition of this element from time to time is very advisable. Alfalfa is an energetic gatherer of this substance, largely from the atmosphere, the young alfalfa shoots being relatively very rich in this element. There are but few plants, even among the legumes, by means of which we can add nitrogen to the soil so cheaply as by means of alfalfa.

Alfalfa is not only an energetic gatherer of nitrogen from the atmosphere, but it is also an energetic gatherer of other plant food from the soil, so much so that a ton of alfalfa hay made from plants cut in May before any blossom buds had appeared, contained about 60 pounds of potash, equivalent to 111 pounds of the pure sulfate of potash, and whose value would be $3.00 at the price prevailing last year, while the nitrogen in the same would be worth $8.50, nearly.

EFFECTS OF ALFALFA DUE TO DEEP FEEDING.

I will here digress a little to discuss a fact which I have made rather prominent and one which may seem to some as an objection to the alfalfa. I have stated that the alfalfa plant is an exceptionally heavy feeder, which I have shown to be the case by showing that the market value of the food constituents removed from the soil by one ton of alfalfa hay, assuming one-half of the nitrogen to have been derived from this source, was $7.57 at the prices which potash, phosphoric acid and nitrogen commanded in 1904. Some persons have before now asked me how it is possible to harmonize this fact with the observed improvement produced by putting land down to alfalfa for a few years.

Both facts are well established, *i. e.*, that a piece of land which once produced 50 bushels of wheat per acre and had been so far exhausted that it would produce only 18 bushels, may be so far restored in its fertility by being put down to alfalfa for a few years as to produce 35, 40 or even more bushels per acre.

In the meantime it is very probable that an average yield of four tons of alfalfa hay has been cut annually. This land was no longer able to produce 50 bushels of wheat per acre, which, with the straw, would require not more than 143 pounds of potash, phosphoric acid and nitrogen taken together, but it would very probably yield four tons of alfalfa hay during the season, which would re quire 469 pounds of these ingredients. The alfalfa crop of four tons per season removes a trifle over three times as much of these elements of plant food as a fifty bushel crop of wheat, together with its straw, and that from soil which has been so far depleted of its supply of plant food as to no longer yield more than eighteen bushels of wheat.

I would not be too sure that I can fully explain this great difference. It is, however, no less certainly a fact than it is that such land will again produce wheat at a very greatly increased rate after it has been in alfalfa for a few years.

While I may not explain the facts in the case, I will suggest some things which are apparent. The root systems of the two plants are entirely different. The wheat plant has a fibrous system which, under favorable conditions, may penetrate the soil to a depth of four feet, but the conditions obtaining in our soils are not favorable to their attaining this depth. It is a fibrous system, one admirably adapted to gathering sustenance for the plant from rich, mellow ground, especial at no great distance from the surface, but not to penetrate hard soil to more considerable depths.

The four feet mentioned as the maximum depth to which the wheat roots may penetrate, is probably very much deeper than they, in fact, penetrate our soil, unless it be in very exceptional cases.

The alfalfa has a simple tap root system, at the best only

slightly branching, but able, in our soils to attain to a depth of from 9 to 12 feet, even through soil so firm that a pick is necessary in order to remove it. The largest, most branching portion of this root system is at the point of its greatest depth or nearly so. This system is marvelously free from fibrous roots, though under special but easily explained conditions there may be a fair abundance of what may be termed fibrous roots. For our present purpose we may waive the question of the relative ability of these two plants, the wheat and the alfalfa, to obtain food from sources which may yield it slowly or with great reluctance, and simply consider the amount of soil which they respectively lay under tribute, considering that the whole of the soil from the surface to the maximum depth attained by the respective root systems is involved. Using this assumption as our basis, we see that no part of the soil would be laid under a relatively heavier tax by the alfalfa than by the wheat, because the alfalfa feeds to a depth at least three times as great as the wheat plant. Our assumption, however, is not justified by what we know of the roots of the alfalfa, which form a cone-shaped system whose base is from 9 to 12 feet from the surface. The first few feet of the root may consist of a single tap root and cannot possibly come in contact with more than a small fraction of the soil reached by the smaller roots of the deeper portion of the system. The larger portion of the tap root near the surface, even if it is as active in gathering food as any other portion of the root system, can only gather a comparatively small portion of the food used by the plant. This justifies us in using the term so frequently heard, characterizing the alfalfa as a deep feeding plant. These considerations also justify the popular expression that the alfalfa rests the land, meaning, of course, that portion of the soil previously exhausted by the wheat. The correctness of this assertion is not in the least affected by the apparently contradictory fact, that a four ton crop of alfalfa hay removes from the soil a trifle over three times as much plant food as a fifty bushel crop of wheat, including the straw.

There are some interesting facts relative to this question, and while certain reservations ought to be made, we can still, with a fair degree of accuracy, state that the alfalfa obtains its food very largely below the depth to which the wheat root can penetrate. This explanation may not be a complete one, but it answers two questions which are frequently asked: First, Is alfalfa a heavy feeder? To which the answer is, yes. Second, How does it rest the soil? To this we offer the following answer: By feeding below the depth had in mind by the questioner.

EFFECTS OF ALFALFA DUE TO OTHER CAUSES.

We will now turn to some other facts which cannot be omitted

in considering the question of alfalfa as a green manure. Alfalfa is not a plant which can be sown in late summer or early fall with the expectation of obtaining a growth of desirable material to plow under the following spring. We can only use it as a green manure at the end of a rotation in which the alfalfa is one of the crops, and involves a longer rotation than can advisably be used under Eastern conditions, consequently it is necessary to take other factors into the account.

We have assumed that our alfalfa has yielded four tons of hay annually and we have removed from the soil a total of 469 pounds of plant food in the form of potash, phosphoric acid and nitrogen, or 369 pounds, considering that only one-half of the nitrogen came from the soil. The loss in making alfalfa hay ranges from 20 to 66 per cent.; in other words, a four ton crop of hay gathered, represents, even under the most favorable conditions, five tons cut, not counting the stubble. This ton lost is composed of leaves and the fine stems, portions richer than the average sample of hay in nitrogen and ash constituents, and representing a total of 117 pounds of plant food. This, owing to our practice of irrigating after each cutting, especially after the first and second cuttings, is almost wholly incorporated into the soil, for the moisture will facilitate its decay and the strong stubble will prevent its being washed away to any considerable extent. The stubble proper is not considered in the preceding statement, on account of which we are justified in increasing this amount, 117 pounds, to 150 pounds, which alone is as large an amount of plant food as is required to raise a fifty bushel crop of wheat. It is further to be remembered that, as we have assumed one-half of the nitrogen added came from the air and the rest of the substances from portions of the soil beyond the reach of the wheat plant, the amount of plant food added is practically a clear gain.

So far two important points have accrued to our soil by simply being put down to alfalfa, a practical resting of the surface soil, which would be still further benefited, as I firmly believe, if we could give our alfalfa a cultivating, and, second, by an addition of plant food. These are not the only points which we will gain if at the end of our rotation we turn under a good growth of succulent alfalfa, rich in nitrogen and potash. Our soils need organic matter, but coarse manure or such as has been firmly matted do not readily pass into decay under our conditions, but the green alfalfa ferments easily, exercising a very beneficent influence upon the soil, not only adding its own available plant food, but possibly acting quite vigorously upon the soil itself, greatly improving the mechanical as well as the chemical conditions. Some of our farmers have already discovered that these things are facts and do not hesitate to turn under a fine growth of alfalfa, though some still look upon it as a doubtful practice.

Some other facts at which we have arrived are of interest in this connection, *i. e.*, the actual manurial value of the stubble. On an acre of alfalfa taken to the depth of six inches it is worth, estimated in the same manner that we have estimated the manurial value of the hay, not far from $20.00 per acre, while the roots below the depth of six inches possess a value of $16.00, or the stubble and roots together have a value of about $36.00 per acre. It may be a rather difficult task to turn under a growing crop of alfalfa in middle or late spring, but it is also difficult to correctly estimate the great manurial value of the excellent material thus added to the soil; it is certainly very much in excess of the figures given above .

There is still another respect in which alfalfa is probably our best crop to use as a means of benefiting the soil. It has been intimated, though not explicitly stated, that our soils are often very firm at shallow depths, so much so that it is very probable that scarcely any cultivated plant may be able to reach the greatest depth to which it can and would feed under ordinarily favorable conditions. A good stand of alfalfa, say three years old, will probably have 500,000 plants to the acre, or more than ten plants to the square foot, every one of which penetrates the soil to a depth much greater than the usual feeding depth of such plants as potatoes, beets, wheat, etc. They not only in this way open up the soil to the attack of less vigorous roots, but fill these channels with a supply of plant food, accompanied by a mass of organic matter that by its decay may bring still more plant food into available form.

This subject of preserving and even of increasing the fertility of our soils cannot be too strongly urged upon the attention of our agricultural population.

While our soils contain a large amount of potash in the total, due to the presence of the potash felspar, the amount of the available potash is not extraordinarily large, and that locked up in the felspar is only slowly becoming available, too slowly to replace that removed by crops. Our soils are poor in organic matter and only fairly well provided with n rogen. Our climate does not favor the formation of humus, nor do our soil conditions as a rule. The best means at our disposal to meet these conditions and to maintain our good yields are, I believe, to husband all the material available for conversion into well-rotted barnyard manure, our alfalfa, all of which should be fed, if possible, on the farm which grows it, being of great value for this purpose. All of the straw, while of itself not of very great value, can be used to good advantage and should be so used.

Our alfalfa is an excellent plant to turn under as a green manure, but owing to facts which are evident to every ranchman, this involves a certain rotation of crops, at the end of which a good, vigorous growth of alfalfa can profitably be added to the soil.