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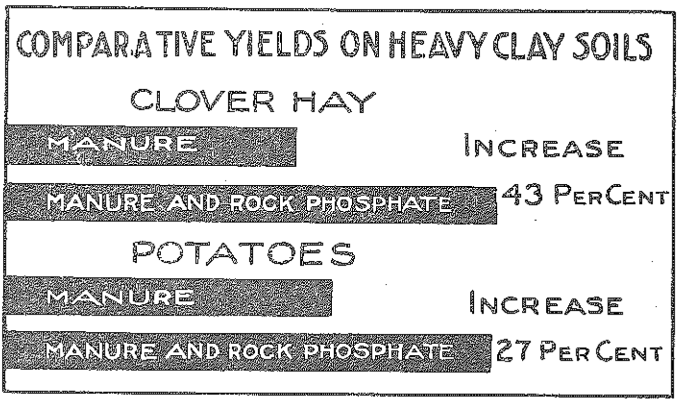

Heavy clay soils respond quickly to the application of rock phosphate supplementing manure. The lack of phosphate often limits the yields on these clay soils.

THE MANAGEMENT OF HEAVY CLAY SOILS

BY

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DIGEST

The Area of Heavy Clay Soils in Wisconsin comprises about 3,000,000 acres, which, when properly managed are very productive and adapted to a great variety of crops. The tendency of these soils to pack and thereby require special cultivation to assure good tilth makes good management of special importance. These clay soils should be plowed only when in proper moisture condition since a single plowing when too wet will leave a bad effect for several years. An abundance of vegetable matter near the surface is necessary.

Pages 3 to 5

The Drainage of Heavy Clay Lands is of prime importance since these soils naturally retain moisture and puddle easily if worked when wet. Surface water must be thoroughly drained away and not allowed to stand on clay fields. Tile drainage is very effective and experience at several points in the state has shown that the returns from tile drainage will pay for this improvement in a few years.

Pages 5 to 11

The Crops and Rotations for Clay Soils must be chosen with special view to the character of the land. Clover and timothy grow abundantly on clay and small grains including oats, barley, and wheat are well adapted to such land. The rotation on clay fields should include clovers, small grains and tilled crops such as corn, potatoes and rutabagas. A four or five year rotation is generally recommended.

Pages 11 to 14

To Maintain Fertility on Clay Soils it is necessary to add considerable vegetable matter by turning under an occasional second crop of clover or other legume as well as by using all available manure. Clay soils rarely contain much humus even in the natural state. The supply of phosphorus is also limited and should be increased by the addition of phosphate fertilizer supplementing farm manure.

Pages 14 to 17

The Management of Heavy Clay Soils

A. R. WHITSON AND E. J. DELWICHE.

The soils of Wisconsin include many varieties with a wide range of crop adaptations and special requirements. While none of the clay soils are as heavy as frequently occur in the southern and western states, nevertheless, they require special treatment in several respects. The most extensive class of clay soils which is at all heavy is that known as the heavy red clay, which occurs along the southern shores of Lake Superior, in the valley of the Fox River, and to a much less extent along the shore of Lake Michigan. The total area of this type is estimated at 3,000,000 acres. Smaller areas of moderately heavy clay soils occur in other sections of the state. When properly managed, these soils are very productive, their very fineness giving them a large water-holding capacity which adapts them especially to small grains and grasses. The largest areas of this clay are located where there are climatic conditions favorable to these crops.

The management of these heavy clay soils presents some special problems which are discussed in the following pages. Among those of a physical character, the fineness of these clays give them a tendency to cake and to require more than the usual amount of labor in cultivation. Their lack of sufficient surface and under drainage renders them cold and wet in the spring and their rather general lack of sufficient amount of vegetable or organic matter is a disadvantage. The chemical analyses so far made indicate some deficiency in the total amount of phosphoric acid and if this proves to be generally true these soils will require the use of phosphate fertilizers, to a moderate extent at least. The methods of treatment here recommended are chiefly based on the results of studies on this soil conducted on the sub-station farms at Superior and Ashland during the past five years.

CLEARING NEW CLAY LANDS.

Clearing the land of underbrush, small stumps, and dead timber as a rule is not a very expensive process. In most cases this can be done on "cut-over" land for from $5 to $7 an acre. To rid the land of large pine stumps is not so easy a matter and frequently the cost of removing such stumps exceeds $20 an acre. On clay lands, blasting the stumps with dynamite, judiciously used, is the most economical method of treating them. The amount of explosive to use for a single stump cannot well be told beforehand. Much depends on the size of the stump as also on the condition of the ground when the blasting is done. As a rule, much more effective work can be done when the ground is wet than when it is dry. It requires considerable experience to use dynamite economically, and ordinarily the inexperienced settler will find it profitable to employ a professional stump blaster until he has learned the art himself.

In developing a clay farm, it is advisable to get clover started as soon as possible if it does not grow naturally in the locality. After burning the brush and dead timber, it is a good plan to go over the land with a spring tooth harrow or disc and sow the clover. The clover helps to keep brush and weeds down, adds nitrogen to the soil, and furnishes hay or pasture. As a general rule, the stumps will blast out more easily if given a few years' time to rot after the timber is cut. Besides, considerable revenue can be obtained from the land from the pasture or hay it affords.

The best available time for breaking new land is usually in June, after the spring work is finished and before haying begins. At this time the brush and weeds are well started and thus are more easily destroyed by cultivation. Another opportune season is in the fall, particularly on land which is fairly free from brush. If the land has been broken in June it should be seeded to winter rye late in August or in early September. The next spring, sow clover in the rye. The rye is harvested in July, and the clover is allowed to grow. In most cases the spring sown clover will afford good pasture at a time when wild pastures are apt to be scanty. The rye furnishes grain and also considerable straw for bedding and feeding. As soon as clover is once started the rotation of crops can be established.

Care should be taken not to let cattle graze young clover during wet spells, for that may result in the clover winter-killing the following spring. In the spring of 1907 considerable clover was killed in this way.

PLOWING HEAVY CLAY LANDS.

All working of the heavy clays should be done only when the soil is in proper condition, that is, when it is dry enough not to puddle when worked. A single plowing when too wet will have a bad effect for three or four years. The same is true of harrowing and cultivating to a somewhat less extent. Depth of plowing is a matter needing study. While it is desirable ultimately to have the furrow slice deep, six or seven inches, it should be deepened gradually. The bacteria and other organisms which are active in producing fertility are much more abundant near the surface and the vegetable matter on which they act in the new clay soils are largely confined to an inch or two of the surface. When these new soils are plowed deep this layer of organic matter and bacteria is covered so deeply as largely to prevent the access of air necessary to their proper action. For this reason it is important that the first plowing should be rather shallow and that it should be deepened gradually, a half inch or so each year. Disking a sod before plowing aids in getting good contact between the surface soil and the subsoil.

DRAINAGE OF CLAYS IMPORTANT.

The drainage of heavy clay lands deserves much attention, for the yield of crops obtained on such soils is very largely proportional to the degree of drainage. This soil, being naturally retentive of moisture, puddles easily if worked when wet, thus preventing the entrance of air in the ground. The excess of water also prevents the soil from warming up early in the spring, and thus retards the planting of seed and its germination after being planted. The bacteria and other organisms which prepare the nitrogen of the soil for the use of the higher plants cannot do their work well in a wet or puddled soil. They must have air and a comparatively high temperature in order to do their best work.

METHODS OF SURFACE DRAINAGE.

The surface water which accumulates after heavy rains and in the early spring from the melting snows should not be allowed to remain on the ground long. Hence the importance of having a good system of surface drains or ditches to carry away this superfluous water. Generally speaking, on heavy clay good outlets for ditches can be had without much trouble or expense.

The land should be plowed in narrow lands leaving dead furrows about 30 feet apart. The open furrows are cleaned out and the water from them flows into a ditch on the side of the field. By this means, very little surface water will stand on the field after heavy rains. When the outlet to a dead furrow is not good a cut may be made from it to the next dead furrow. By this system, deep cross ditches, which interfere with the use of farm machinery, are largely avoided. When the land is plowed in the fall, the dead furrows are filled and new furrows opened about 15 feet from where the old furrows were. This system of surface draining has given satisfaction on the substation farms at Ashland and Superior during the two past seasons. In some cases, in addition to those dead furrows, it is necessary to run small ditches following the lines of the natural drainage so as to carry the water to a creek or gully.

A system of plowing to improve drainage, which is used to a considerable extent in this country, in Canada, and elsewhere, is to plow in wide lands, say six or eight rods, in width, always turning the land in the same direction. In course of time a considerable slope is established, together with a deep dead furrow to collect the surface water. The open, dead furrows discharge into a main ditch or stream at the lower end of the field.

One objection to using this method of draining is that a high ridge is gradually built up, on which the crop matures earlier than in the rest of the field, thus interfering with the harvesting of grain crops. Another objection is in having a deep ditch which cannot well be crossed with heavy machinery. On the other hand, the first system of surface drains described has the objection of having a large number of small dead furrows. While these are not very objectionable when crossing with machinery they mean some loss of land.

Whichever system is used, it should be planned and carried out in the most effective way. The important fact to remember is that in order to farm successfully the flat clay lands with most crops it is necessary to provide some practical system of surface draining.

TILE DRAINAGE FOR CLAY SOILS.

The value of tile drainage in removing surplus underground water from heavy clay soils has been repeatedly demonstrated, nevertheless, there is quite a prevalent opinion that the red clay soil is so tenacious that water will not percolate through it and drain out. Experiments with tile drains at the Ashland and Superior sub-stations farms during the past five years disprove this idea. Two separate systems of tiling have been established on red clay, one at each of these places.

EXPERIMENTS AT SUPERIOR SUB-STATION.—In the Fall of 1905, about seven acres of low land were tile-drained on the Superior

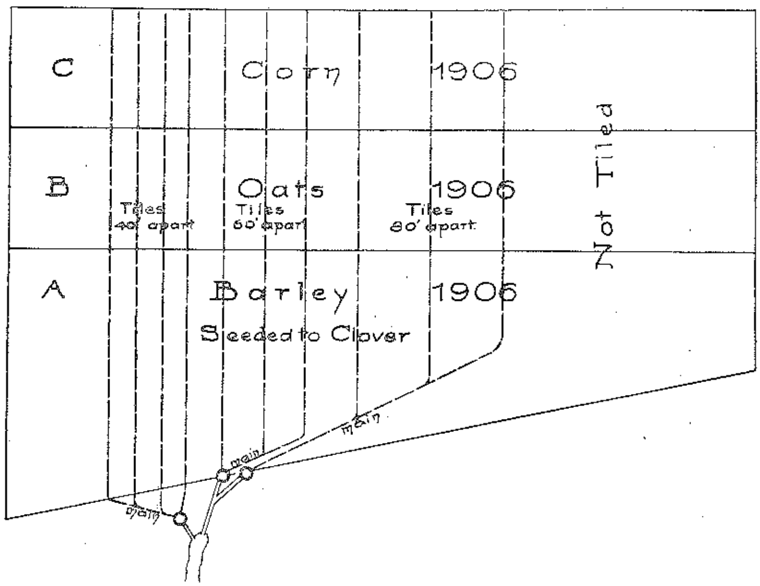

Figure 1.—Plan of the drainage experiment field at Superior, showing method of testing with three crops under various conditions.

Sub-station farm. The land is stiff red clay and originally was very wet and swampy. In fact, the field never produced crops of any account before it was drained. The tile was laid at three different distances apart, namely, at 40, 60 and 80 feet. One object is to determine, if possible, what distance most economically drains the land. Measurements by means of hook gauge and automatic register have been taken for three seasons for this purpose. The data obtained will be published in a later bulletin. It is not the object of this bulletin to discuss these experiments which are of a more or less technical character, but rather to give here the results obtained with different kinds of farm crops.

As shown in Figure 1 the land is divided into three parts each to be in a different phase of a three year rotation. Three classes of crops have been raised every year, namely, a grain crop, clover, and cultivated crop.[1] In general the crops have been much benefited by the underdrains in spite of the fact that surface drains

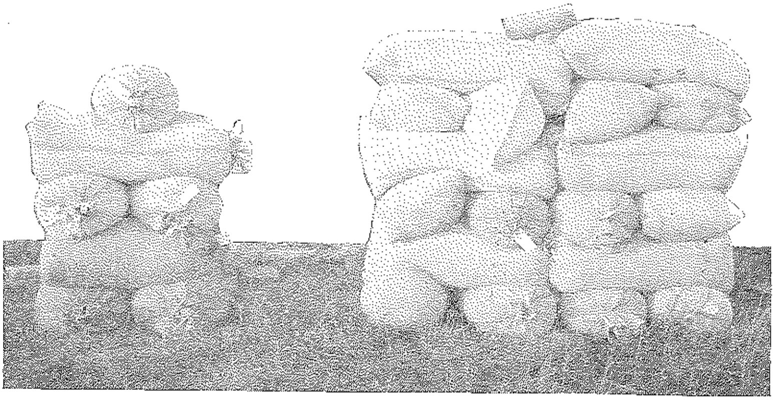

Figure 2.—Yields of barley from equal tile drained and undrained areas at Ashland. The yield was almost tripled by tile draining the land.

were provided on the tiled and untiled land. Figure 2 shows the effect of tiling on barley. The pile of sacks to the left being from the drained field and that to the right from undrained land. Table I shows the height and stand of corn for different degrees of drainage for the season of 1906.[2]

TABLE I.—GROWTH OF CORN ON TILED AND UNTILED LAND AT SUPERIOR, 1906.

	Untiled land.	Distance between laterals.		
		80 feet.	60 feet.	40 feet.
Average height of corn	4 feet	5 feet.	5.6 feet.	5.8 feet.
Average stand	25 per cent.	40 per cent.	80 per cent.	95 per cent.

EXPERIMENTS AT ASHLAND SUB-STATION.—In the fall of 1906, a field containing a little less than six acres was tiled at Ashland. The land for the most part was

[1] The results obtained during 1906 and 1907 have been published in the 23rd and 24th Annual Reports of this station.

[2] For a more complete discussion of tile drainage, see Bulletin 199, of this Station.

very wet and in the natural condition timothy hay would not grow on the greater part of it. Sedges grew on at least half of the field. Another field of about the same area, and possessing about the same degree of natural drainage, was used as a check on the tiled land. Exactly the same kind of crops were grown,

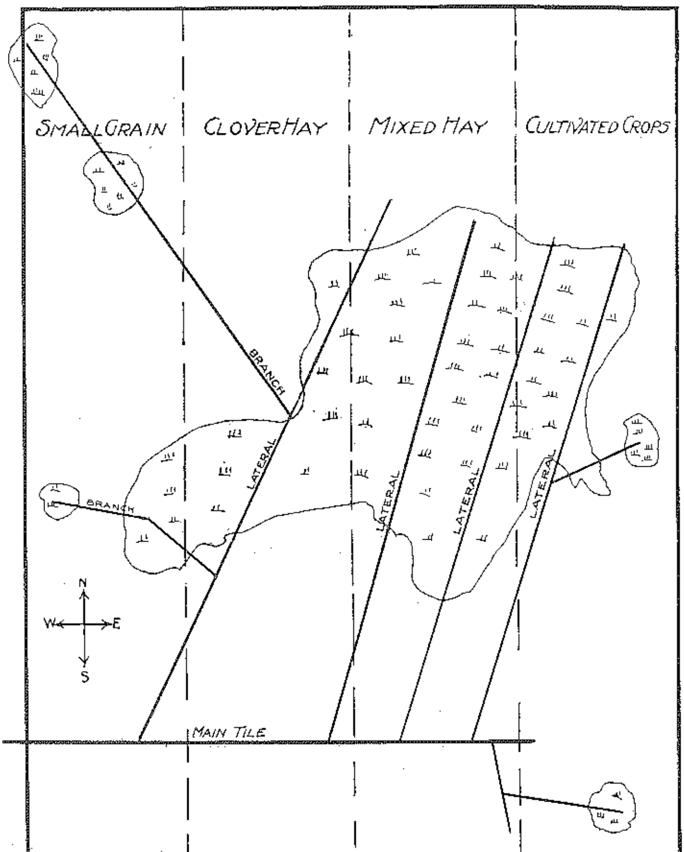

Figure 3.—Plan of tiled field at Ashland showing method of growing four crops on the drained and undrained areas.

and the same treatment was given to the two fields so far as possible. Surface drains were provided in both cases.

This land, both tiled and untiled, had been in meadow for ten or twelve years, and consequently was in a poor state of fertility. This was especially true of the higher and better drained parts.

The effect of draining was very marked in 1907, due principally to the fact that the tiled land could be worked considerably earlier in the spring. The differences ranged from 25 to

100 per cent in favor of the tiled land. In 1908 the effect of tiling was not so marked, as the unusually dry weather permitted of better drainage on the untiled land.

Figure 3 shows how the tiles are laid. The laterals are about 70 feet apart, and are not laid in as regular order as at Superior, but more in the order of what is sometimes called the "natural" system of tiling. The depth varied from 1.8 feet to 3.5 feet.

On this land a four year rotation was established. The crops run in order as follows: Clover, one year; mixed hay, one year; cultivated crops, one year; and small grain seeded to clover, one year. The diagram indicates the crops grown on the land in 1909.

The results obtained with tiling during five seasons at Superior, and four seasons at Ashland are summarized in Table II.

TABLE II.—EFFECTS OF TILE DRAINAGE, ASHLAND AND SUPERIOR, 1906, 1907, 1908, 1909, 1910.

(a) *Cultivated crops.*

Crop.	Number of crops.	Amount of increase.	Per cent of increase.	Value of increase.
Rutabagas	3	74.3 bushels	33.0	$26 00
Turnips	2	25.3 bushels	13.5	6 40
Potatoes	5	33.5 bushels	35.8	17 90
Corn (grain)	2	13.3 bushels	67.0	6 65
Sugar beets	2	1.91 ton	29.0	9 55
Cabbage	1	2.2 ton	39.0	17 60
Average				**14.07**

(b) *Grain and hay crops.*

Crop.	Number of crops.	Amount of increase.	Per cent of increase.	Value of increase.
Clover hay	3	0.29 ton	20.0	$2 90
Barley	4	5 bushels	29.4	3 00
Oats	1	8.29 bushels	76.0	4 15
Wheat	2	1.3 bushels	7.0	1 30
Average				**2.84**

On examining Table II, given above, it is evident that the greatest value of increase has been with cultivated crops, the highest being with rutabagas. The average value of increase for all cultivated crops tried is $14.07, and for grain crops, $2.84. Under present conditions, when tile has to be shipped from comparatively long distances, the cost of tiling, including labor, will be about $30 an acre. This is based on the cost of tiling at

Ashland. This shows over 25 per cent. on the investment of $30. At 6 per cent. the interest is $1.80, deducting this from $8.42, the average annual increase of crop value per acre due to tiling, we have $6.62 left to go toward paying the cost of tiling. At this rate it will take approximately five years to recover the entire expense of tiling, including interest on the investment.

For raising truck crops on land near a city, it is especially desirable to tile. This will apply to such crops as potatoes, sweet corn, cabbage, rutabagas, strawberries, and the like. Where potatoes are raised, more than half of the cost of tiling will be recovered in one season. (See Table II.)

Although we believe that all the heavy clay lands would be benefited by underdraining, we do not wish to say that all such lands need to be tiled for profitable cultivation. The fact is that there is a great deal of high and well drained clay land in the northern counties which will and does raise good crops of hay, grain, etc., without drains. What has been said applies to the *wet* clay lands, where in the natural state no true grass grows, but where sedges form the greater part of the vegetation. As has been explained, most of the land where these experiments were carried on is of this character. It is well to bear in mind, however, that practically all farms in the heavy clay belt possess areas where underdraining would be of great benefit.

CROPS AND ROTATIONS FOR HEAVY CLAY SOILS.

One of the essentials to success in farming anywhere is the ability to adapt one's methods and operations to the conditions of soil, climate, and market that obtain in a given locality. Perhaps the most common cause of failure in a new country is the lack of understanding of these factors, or of the ability to correlate them in the general farm practice. The system of cropping to be adopted, and the crops to raise, as well as their disposal, will vary much in passing from a light sand to a heavy clay. It is the farmer's business to study and understand all these conditions so as to get the greatest possible returns for his efforts, and at the same time improve or maintain the fertility of his soil.

Clover grows abundantly on the clay lands, as do field peas. Clover is one of the best feeds for dairy animals and sheep, having about one and a half times the value of timothy for feeding purposes. Peas furnish a good deal of straw for fodder, and yield good crops of grain. Yields of nearly 40 bushels per acre have been obtained on clay land at Ashland. The grain may be sold as seed or fed to bacon hogs or to sheep. Clover seed may be obtained from second growth clover. In 1908 on the Ashland farm two and a half tons of hay were obtained from the first cutting and four and a half bushels of seed from the second cutting of medium red clover. Alsike clover yielded five bushels per acre on the Superior farm in 1907. Farmers co-operating with the station have obtained almost as good results.

During the last few years peas have sold for from $1.50 to $2.50 per bushel. The cost of production is not much greater, if any, than that of barley or wheat. It will be readily seen that such a crop is a very profitable one to raise. However, it should be borne in mind that although peas thrive best in a cold climate and on moist soil, they are very sensitive to standing water. Hence, the necessity of providing good surface drainage.

Small grains like oats, barley and wheat do exceptionally well on red clay land. Yields of wheat of from 20 to 30 bushels per acre have been obtained without any special effort at manuring. Where the land had received special care, spring wheat has yielded over 30 bushels per acre. We think that in a four year rotation wheat may safely be raised on red clay land, providing, of course, some provision is made to restore the phosphorus carried away when grain is sold. This may be done by buying bran, feeding it to dairy cows and applying the manure to the land. As mentioned before, rye is an especially valuable crop to sow on new land. Barley and oats can be grown with success. Barley does best on soil that has been under cultivation for some years, and which contains a good supply of available plant food. When sown after some cultivated crop like corn, potatoes, or rutabagas, yields of from 30 to 45 bushels may be expected. Oats do well, and do not require as rich soil as barley, but in some seasons are likely to rust. A good crop of wheat was grown the second year after breaking on low land on the Douglas County Poor Farm, where only surface drainage was supplied.

Cultivated crops should be grown in every rotation scheme if the best results are to be obtained. On the sub-station farms at Ashland and Superior, potatoes, mangels, rutabagas, turnips and corn have been grown with success. A fine field of smut nose flint corn was grown in 1908 on clay land at Ashland. This was given a dressing of ten loads of manure per acre.

Most of this corn matured and it furnished a goodly quantity of forage per acre. We believe that corn for silage purposes can be raised on most of the land in the northern belt.

Mangels, rutabagas, and turnips grow well and are of much value as a means of supplying succulent feed for dairy cows and sheep during the winter months. While it is not advisable to

Figure 4.—Potatoes yield well on the red clay soils of Northern Wisconsin under proper management. This field at Ashland yielded at the rate of 150 bushels per acre.

try extensive potato raising on heavy clay lands, every farmer can and should raise his own potatoes, and if located near a good market he can profitably raise some for sale. In 1907 yields of over 180 bushels per acre were obtained on the Superior Sub-station farm. In 1908, owing to unfavorable weather conditions, the yield was not so satisfactory, but still considerably above the average. In 1909 an average yield was obtained and in 1910 the average for Ashland and Superior was 320 bushels per acre. The quality of the potatoes was very good. Figure 4 shows a field of potatoes on red clay land at Ashland.

A four or five year rotation seems to work best on heavy clay land. The first year may be small grain, such as rye, oats, barley or wheat, seeded down to clover, with a little timothy mixed in it. The second year clover, the first cutting being cut for hay and the second left to grow for seed. The third year, mixed clover and timothy. The sod is manured either before plowing in the fall or on the plowed land in winter. The fourth year the land is put into cultivated crops as explained above. In this scheme of crop rotation, one-fourth of the land is in grain, one-fourth in clover, one-fourth in mixed clover and timothy, and one-fourth in cultivated crops.

MAINTENANCE OF FERTILITY ON CLAY SOILS.

There are three things to which the farmer on heavy clay soils in Wisconsin must give attention in order to maintain fertility. They are humus, nitrogen, and phosphorus. Or, since humus includes nitrogen, we may say humus and phosphorus are the substances to be supplied. Nearly all of these soils were originally covered with forest growth and under such conditions a rather limited amount of humus is developed naturally. The chief supply of organic matter under such conditions is from the leaves of trees, but these falling to the surface decompose rather quickly and have no way of becoming mixed through the soil itself. The large amount of humus or organic matter found in prairie soils is produced there by the decomposition of the very fine roots of grasses which form practically all the vegetation of these sections.

In a wooded section there is relatively little humus in the soil. On the other hand, such soils after being cleared are extremely well adapted to the grasses and clovers and it is therefore not difficult under proper management to increase their supply of humus. Moreover, fineness of the clay lessens the rate of oxidation of the raw fibers and this further increases the tendency to form humus. Humus is helpful on such soils in improving the texture as well as in furnishing the supply of plant food material by its decomposition.

The most important element coming from humus is nitrogen. While this is contained in all plant tissues and all humus it is particularly rich in the tissues of legume plants, such as clovers, alfalfa, and vetches. Moreover, these plants have the ability of securing nitrogen from the air under certain conditions and when plowed under, this nitrogen in the vegetable matter becomes available to other crops on decomposing.

The turning under of an occasional crop of clover or other legume is the surest way of maintaining the humus and nitrogen supply of such soils. It is true, of course, that manure, if it does not completely decompose in the soil, may produce some humus, and more humus is likely to be formed from manure in these than in lighter soils where its decomposition is more complete. Nevertheless, it must be remembered that the digestion of food by the animal causes a destruction of from two-thirds to three-fourths of the organic matter contained, so that manure would never return as much organic matter to the soil as was taken from it. All of the clovers do exceptionally well on this clay soil and even alfalfa will make excellent growth on well drained fields. These crops ought to be grown extensively on such land and a system of farming in which they are sown with all grain crops grown, the clover to be turned under for succeeding crops, will greatly increase the fertility of these soils. In growing clover seed, the clover may be cut off once or twice. Letting it lie on the ground while the seed crop of clover grows will add much humus and nitrogen to the soil.

Figure 5.—The addition of rock phosphate to manure on potatoes at Ashland gave a yield of 128 bushels per acre while that receiving manure alone yielded only 87 bushels per acre.

These soils do not naturally contain a large amount of phosphorus. The average of 12 determinations of phorphoric acid ($P_2 O_5$) shows 0.105 per cent. in the soil to the depth of 8 inches. This is not more than enough to supply 100 crops of wheat of 20 bushels to the acre. The amount of this element in the soil should never be allowed to go below what is now in the soil; it should rather be increased. All permanent systems of agriculture involve the maintenance of phosphorus.

At the Ashland Sub-station an experiment was made on heavy red clay to determine the influence of phosphate fertilizers used to supplement manure during the past year. While the field is too irregular for very satisfactory fertilizer tests, the yields of potatoes showed 87 bushels per acre for manure alone and 128 bushels for manure and rock phosphate. The yields of rutabagas were 108 bushels for the manure alone and 137 bushels for manure and rock phosphate. The effect of adding rock phosphate to manure on potatoes is shown in Figure 5.

The yield of corn at Ashland for the year 1910 on land receiving manure alone was 30.4 bushels per acre and on the plot receiving manure supplemented with rock phosphate the yield was 36.8 bushels per acre, a gain of 6.4 bushels or 21 per cent. The influence of the use of rock phosphate supplementing manure on the yield of clover, both on the first cutting for hay and on the seed of the second crop was well shown in the experiments at Ashland. Untreated ground rock phosphate at the rate of 600 pounds per acre was applied to certain plots in 1908 on which corn and other tilled crops were grown. This field was in grain in 1909 and in clover in 1910.

The yield of clover hay of the first cutting on land which received manure alone was 2,223 pounds per acre while that on the plot receiving manure supplemented with rock phosphate was 3,177 pounds per acre, showing an increase of 43 per cent. The yield of clover seed on the plot receiving manure alone was 217.5 pounds per acre and that on the plot receiving additional treatment of rock phosphate was 336.7 pounds, indicating an increase approximately 55 per cent, due to the phosphate applied three years before. This increase in yield of seed is particularly noticeable since the influence of phosphate, as is well known, is in the direction of heavier yields of seed. These results leave no doubt that the use of phosphate supplementing manure is beneficial.

While it is commonly supposed that live stock farming, and especially dairying, maintain the supply of phosphorus in the soil, this is very far from being the case. There are several ways in which this element is lost even from live stock farms. The bones of animals sold contain large amounts. Milk has appreciable quantities. Some is lost by erosion and leaching. It is only where there is considerable bran fed and these losses reduced to a minimum by the use of skim milk on the farm that it is possible to maintain the phosphorus supply of the farm without purchasing fertilizers containing this element. Moreover, it is quite possible that as large net returns may be made in grain raising as in live stock raising, and by the use of phosphate fertilizers it is possible to retain the fertility of the soil provided attention is given to keeping up the supply of organic matter by turning under clover as before mentioned. The various forms of phosphate fertilizers and their use are fully described in Bulletin 174, which may be had on request of the Director of the Experiment Station, Madison, Wis.

THE UNIVERSITY OF WISCONSIN

Agricultural Experiment Station

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