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Soil Experiments on the Upland Loam of Southeast Missouri.

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SOIL EXPERIMENTS ON THE UPLAND LOAM OF SOUTHEAST MISSOURI.

(Jefferson County.)

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In 1905 the Missouri Agricultural Experiment Station of the University of Missouri began a series of experiments near Victoria in Jefferson County for the purpose of determining the most profitable treatment for the soil in this region. The experiments were continued in 1906, 1907 and 1908, terminating in the fall of the latter year. The field on which the experiments were conducted is located two miles west of Victoria on a piece of land belonging to the Coulahan farm and represents the typical rolling upland of the Hillsboro group of soils. The soil is partly of limestone and partly of sandstone origin, free of gravel and of a very fine sandy or silty nature underlaid by yellowish clay loam. The soil on this particular field had been cropped for a number of years and was badly run down, having been turned out to weeds for a season or two previous to the beginning of the experiment. The field lies on the top of a ridge and while the land is not as uniform as could have been desired for an experiment of this sort it was fairly satisfactory.

Elements of Plant Food.

There are ten chemical elements that plants use as food all of which are essential to the growth and development of the plant. Of these, seven come from the soil and with one exception, are mineral elements. They are nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and iron. Fortunately, for the farmer however, the last four, with the occasional exception of calcium (lime), are found abundantly in most soils, and hence in a discussion of soil fertility nitrogen, phosphorus (sometimes referred to in the form of phosphate or phosphoric acid) and potassium (usually referred to in the form of potash) are the ones usually considered. These three elements are commonly lacking in most soils, in some more than in others, and it is upon their presence in a form available to the plants that the yield of crops depends. In virgin soils these elements are found abundantly but after long continued cultivation and the growing and removing of crops the available supply becomes low and hence the yields of the crops are materially decreased. The total amount of these elements also varies in different soils. The soil of one region may be comparatively well supplied with one and deficient in another while in the soil of another region the reverse may be true.

Plants always use these elements in definite proportions and cannot substitute one for another. If a soil in question be especially deficient in one, this becomes the limiting element and the yield of crops produced on that soil is limited by the amount of this element available. For instance if the supply of available phosphorus is sufficient for the production of only one-

half an average crop of corn, there can be only half a crop no matter how much potassium and nitrogen may be present. Many soils in Missouri have been depleted in available plant food to such an extent that the application of these elements to the soil in the form of manure, commercial fertilizers or green manure crops has been found to be a profitable operation. It is for the purpose of determining in which of these elements this soil is deficient and whether it will pay the farmer to supply them to the soil that these experiments are conducted.

The following chemical analysis of the Victoria soil shows its content of these elements as compared with a very fertile soil as a standard:

	Nitrogen	Phosphorus	Potassium	Lime
A very fertile soil contains in the top 7″ of an acre	6000	2000	5300	7000
The Victoria soil contains in the top 7″ of an acre	1460	453	4583	6240

As the analysis of this soil shows it is strikingly deficient in both nitrogen and phosphorus and also slightly deficient in potassium and lime.

Nitrogen is contained in all soils primarily in the "humus" or vegetable matter; and a low humus supply, usually means an insufficient supply of nitrogen. When soils are cultivated to grain crops, especially to corn for a series of years, this humus rapidly oxidizes and disappears (burns out as it is commonly said). With the burning out of this humus, the nitrogen is naturally decreased and it is to this fact that the low amount of nitrogen found in this soil is due. Evidently, therefore, one of the first things to be considered in making this soil more productive, would be to increase in some way the content of humus or vegetable matter therein. It should be said too, that a large humus content is necessary in practically all soils to make available the mineral plant foods such as phosphorus and potassium which are ordinarily held in insoluble compounds until acted upon by the acid products arising from this decaying vegetable matter.

The phosphorus supply is naturally deficient in this soil and the lack of available phosphorus is one of the prime factors limiting crop production. It must be understood, however, that since the amount of available phosphorus in any soil is dependent not only upon the total quantity of phosphorus present but also upon the presence of decaying humus, the building up of the humus supply may temporarily make available sufficient phosphorus for large crops in spite of the fact that the total amount is limited. With the small amount of humus now present in this soil however, it will be remunerative in most instances to apply some form of soluble commercial phosphorus.

As will be seen from the analysis this soil is fairly well supplied with potassium. While the application of potassium has usually given an increase in the crops on this field yet these increases have never been highly remunerative. As in the case of phosphorus the amount of available potassium in the soil is dependent upon the presence of decaying humus and the increase in the crops obtained by the application of potassium was probably due to the fact that with the low humus content but a small quantity of soluble potassium is made available. In a permanent system of soil management in which crop

rotation and manuring plays an important part the building up of the humus supply will usually make available sufficient potassium for large crops on this soil.

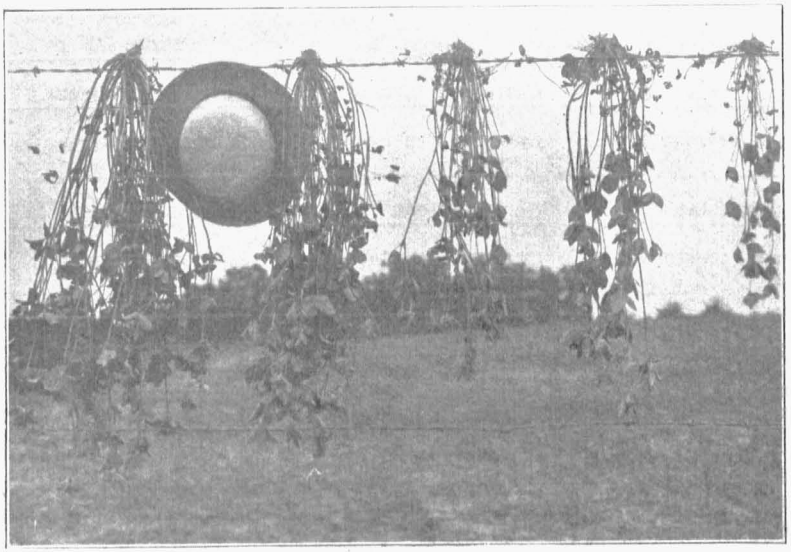
PLAN OF EXPERIMENT.

The plan of these experiments consisted in blocking out the field into plots, the various plots in each series being treated differently as to fertilizing, etc. The plan of the field is shown in the following diagram:

Series A.	Series B.	Series C.
1. Cowpea treatment.	Cowpea treatment.	Cowpea treatment.
2. Cowpea treatment. Lime.	Cowpea treatment. Lime.	Cowpea treatment. Lime.
3. No treatment.	No treatment.	No treatment.
4. Cowpea treatment. Lime. Phosphorus.	Cowpea treatment. Lime. Phosphorus.	Cowpea treatment. Lime. Phosphorus.
5. Cowpea treatment. Lime. Phosphorus. Potassium.	Cowpea treatment. Lime. Phosphorus. Potassium.	Cowpea treatment. Lime. Phosphorus. Potassium.

As will be seen, the field is divided into three series, each containing five plots, with each plot one-fifth of an acre in area. Each series is given a similar treatment, one plot having cowpeas turned under whenever possible, another having cowpeas and lime, a third cowpeas, lime and phosphorus, a fourth cowpeas, lime, phosphorus and potassium and a fifth receiving no soil treatment. Three series of plots are used in order that three different crops may be under experiment each year. These series are so rotated that instead of the same crop appearing each year on a given series the crops are changed through a rotation of corn, cowpeas. wheat and clover: that is, series A may have corn in 1909, series B cowpeas and series C wheat, while in 1910 series A would go to cowpeas, series B to wheat, series C to clover and so on. During the first two years of the experiments the rotation followed was corn, wheat, clover, but in 1908 the plan was changed to the four-year rotation mentioned above. Series A was in corn in 1905, wheat 1906, clover 1907 and corn in 1908. Series B was in cowpeas in 1905 with the exception of the untreated block and these were turned under for corn in 1906, which was followed by wheat in 1907 and clover 1908. Series C had the same cowpea treatment as B in 1905, cowpeas as a regular crop in 1906, corn in 1907 and cowpeas again in 1908.

The cowpea treatment is given for the purpose of adding nitrogen and humus, through the well known action of legume plants, and it consists of throwing in an extra crop of cowpeas whenever possible, usually in the corn at the last plowing. The second crop of clover on these cowpea treated plots is also plowed under to add additional nitrogen and humus.



The Effect of Phosphates on Clover is Shown by These Average Plants From the Various Plots. The Two Plants on Left Are From Plots on Which Bone Meal Was Included in the Treatment.

The lime is applied on the lime treated plots in the form of ground lime stone at the rate of 2000 lbs. per acre once in every other round of the rotation, usually before corn. It is used for the purpose of keeping the soil sweet, rather than as a soil stimulant.

The phosphorus is applied in the form of bone meal at the rate of 150 lbs. per acre before corn and before wheat with none before cowpeas or clover, thus making an application of 300 lbs. during the four years.

The potassium is applied as muriate of potash (potassium chloride) at the rate of 50 lbs. per acre before corn and before wheat with none before cowpeas or clover. Both the bone and potash are either plowed under, drilled in or thoroughly disked into the soil before the crop is put in.

EXPERIMENTS WITH CORN (VICTORIA FIELD).

Soil Treatment.	Yield bu. per A.	Increase bu. per A.	Value of increase	Cost of treatment	Net return
1905					
No treatment	35.2				
Lime	35.8	.6	.30	.75	— .45
Phosphorus, Lime	50.6	15.4	7.70	2.62	+5.08
Phosphorus, Lime, Potassium	46.8	11.6	5.80	4.29	+1.51
1906					
No treatment	50.0				
Cowpeas	40.9	00.0	0.00	2.00	—2.00
Cowpeas, Lime	46.3	00.0	0.00	2.75	—2.75
Cowpeas, Lime, Phosphorus	57.6	7.6	3.80	4.62	—0.82
Cowpeas, Lime, Phosphorus, Potassium	57.6	7.6	3.80	6.29	—2.49
1907					
No treatment	21.9				
Cowpeas	24.5	2.6	1.30	1.00	+ .30
Cowpeas, Lime	19.1			1.75	—1.75
Cowpeas, Lime, Phosphorus	25.4	2.5	1.25	2.92	—1.67
Cowpeas, Lime, Phosphorus, Potassium	30.	8.1	4.05	3.96	+0.09
1908					
No treatment	19.0				
Cowpeas	20.6	1.6	0.80	0.67	+0.13
Cowpeas, Lime	26.1	7.1	2.55	1.42	+2.13
Cowpeas, Lime, Phosphorus	32.9	13.9	6.95	2.47	+4.48
Cowpeas, Lime, Phosphorus, Potassium	39.3	20.3	10.15	3.10	+7.05

Basis for calculations:
Corn 50c per bushel.
Lime $4 per ton, labor and hauling included.
Bone meal, $1.40 per 100 pounds.
Potash, $2.50 per 100 pounds.
Cowpeas $2 per acre.

The results of these experiments on corn show that the largest returns have almost invariably been secured from the complete treatment of cowpeas, lime, phosphorus, and potassium and usually the largest net return also, although in 1905 the phosphorus lime treatment was most paying and in 1906 no net return was secured from any treatment. A large part of this variation is due to lack of uniformity in the natural fertility of the blocks.

It will be seen that in 1906 the plots having cowpeas sown in the corn at the last cultivation gave a less yield than the untreated plot probably due in this case largely to the fact that the untreated plot was somewhat higher in natural fertility than the other. Cowpeas sown in the corn at the last plowing do sometimes decrease the corn yield slightly, probably on account of

the cowpeas taking some of the moisture needed by the corn. The results of various experiments especially in dry seasons show a slight decrease in the yield of corn, due to this cause, but the benefit of cowpeas to crops following, together with the forage produced to be pastured off with the stalks is usually much more than enough to offset any slight injury to the corn crop. Where cowpeas are put in the hill or row with the corn this injury does not as a rule occur.

The use of lime has given very inconsistent returns on corn, although somewhat greater results were shown on the clover and wheat. Attention

Cowpeas Sown in the Corn at the Last Cultivation.

is called to the fact that the last year's corn crop showed a large and consistent increase from the various treatments due undoubtedly to the cumulative effect of these treatments, as the land was being continually built up in fertility.

No experiments have been conducted on this particular field with fertilizers applied in the hill or row with a fertilizer planter but experiments that have been made in other localities in the state have shown a striking increase from their use in this way. In Barton county, for instance, in 1906, the increase due to an application of fertilizer in the hill was 14 bushels per acre with a net return of $4.20 while the net return from the complete treatment broadcasted, was $1.88, thus showing a considerable margin in favor of the hill fertilization.

The kind of fertilizer to use in the hill or row for corn is, as a rule, one of the so-called complete fertilizers; that is, one containing all three of the elements commonly used in fertilizers. For this purpose one of the "grain

growers" or "ammoniated bone and potash" should be used. Such a fertilizer would contain from 1 1-2 to 3 per cent of nitrogen, 8 to 12 per cent available phosphoric acid, and 2 to 3 per cent of potash. It should be understood that fertilizers applied in the hill or row in this way are not used so much for the purpose of building up the soil but rather for supplying all three elements in soluble form in order to give the corn a quick thrifty growth. As a consequence all soils that are considerably run down will respond to about the same kind of fertilizer for this purpose. This fertilizer should be applied with a fertilizer attachment to a corn-planter at the rate of 50 to 90 pounds per acre, the smaller amounts being usually the more remunerative.

Bone meal may, also, be used as a hill or row fertilizer with good results, but usually one of the mixed fertilizers above mentioned will give better returns. There is considerable danger in dry seasons of a fertilizer in the hill or row causing the corn to fire, especially when applied in the larger amounts, and this seems more apt to occur where the complete fertilizer is used and where it is applied in the hill rather than in the row. On seasons of sufficient rainfall this hill or row fertilization is almost invariably the most remunerative method of fertilizing corn, but since it does not build up the land it is of value simply for the immediate crop, and its continued use year after year with corn on the same soil tends to soil depletion rather than to soil improvement. It is, therefore, a temporary practice suited to the renter or to the man who must have an immediate crop, and it should be used by the permanent farmer only in exceptional cases or in connection with a systematic crop rotation which will maintain the humus supply.

It will also pay on this land to apply a good grade of bone meal, preferably the steamed bone meal or the finely ground beef bone at the rate of 150 pounds per acre before corn, using a fertilizer grain drill for putting it in ahead of the planter. Such an application will be of benefit not only to the corn crop but, also, to the crops following. It is to be recommended, for the man who is to farm his land for a long series of years and who wishes to maintain the soil fertility. It is not so well adapted to the temporary farmer or renter.

EXPERIMENTS WITH WHEAT (VICTORIA FIELD)-

Soil Treatment.	Yield bu per A.	Increase bu. per A.	Value of increase	Cost of treatment	Net return
1906					
No treatment	5.8				
Cowpeas	2.9	0.0	0.00	0.67	—0.67
Cowpeas, Lime	4.7	0.0	0.00	1.42	—1.42
Cowpeas, Lime, Phosphorus	7.0	1.2	0.96	3.29	—2.33
Cowpeas, Lime, Phosphorus, Potassium	7.0	1.2	0.96	4.96	—4.00
1907					
No treatment	7.7				
Cowpeas	5.6	0.0	0.00	0.67	—0.67
Cowpeas, Lime	13.7	6.0	4.80	1.42	+3.38
Cowpeas, Lime, Phosphorus	11.1	3.4	2.72	3.29	—0.57
Cowpeas, Lime, Phosphorus, Potassium	6.6	0.0	0.00	4.96	—4.96

Basis for calculations:
Wheat 80c per bushel.
Lime $4 per ton including labor and hauling.
Bone meal, $1.40 per 100 pounds.
Potash, $2.50 per 100 pounds.
Cowpeas, $2 per acre.

The experiments with wheat have been very unsatisfactory for two or three reasons. The lack of plot uniformity, the fact that both 1906 and 1907 were bad wheat years in this section, and the lack of a fertilizer drill for distributing the bone meal and potash have all acted together in making the results untrustworthy. As a rule wheat is the crop which responds most strikingly to fertilizer treatments so that its failure to respond in this case, can only be accounted for by these unfavorable conditions. It will be seen, however, that there have been some striking increases from the cowpeas—lime, and from the cowpeas—lime—phosphorus treatments and under favorable conditions these would have brought good money returns. The effect on the clover following the wheat is very striking, as will be shown in the tables which follow.

The treatment to be recommended for wheat on the ridge soil of this region where it is badly worn is an application of 125 to 150 pounds per acre of a fertilizer containing from 1½ to 3 per cent nitrogen, from 8 to 12 per cent available phosphoric acid and from 1½ to 3 per cent potash. Such fertilizers are usually sold under the name of "grain growers" or "ammoniated bone and potash." This fertilizer is recommended because soils that are badly worn are usually in need of all three elements of fertility. Such a fertilizer is not one to be recommended for the farmer who is keeping up his humus supply by clover, cowpeas, manure, and rotation, but rather for the renter or the man who must have an immediate crop.

For the permanent farmer whose land is well kept up in humus or the man who makes a wide use of clover and manure it will be much better to apply 125 to 150 pounds of steamed or finely ground beef bone meal. This bone meal contains no potash but it contains 28 to 30 per cent of phosphoric acid about half of which is available and a small amount, 1 to 2 per cent, of nitrogen. In applying either the special fertilizer or bone meal a fertilizer drill should be used putting it in as the wheat is sown.

EXPERIMENTS WITH CLOVER (VICTORIA FIELD).

	Yield per A.	Increase per A.	Value of increase	Cost of treatment	Net return
1907					
No treatment	1000				
Cowpeas	750	000	0.00	0.67	+2.53
Cowpeas, Lime	875	000	0.00	1.42	—1.42
Cowpeas, Lime, Phosphorus	2410	1410	5.64	3.29	+2.35
Cowpeas, Lime, Phosphorus, Potassium	3915	2915	11.60	4.96	+6.64
1908					
No treatment	1500				
Cowpeas	2300	800	3.20	0.67	+2.53
Cowpeas, Lime	3500	2000	8.00	1.42	+6.58
Cowpeas, Lime, Phosphorus	4150	2650	10.60	3.29	+7.31
Cowpeas, Lime, Phosphorus, Potassium	4250	2750	11.00	4.96	+6.04

Basis for calculations:
Clover $8 per ton.
Lime $4 per ton including labor of application and hauling.
Bone meal $1.40 per 100 pounds.
Potash $2.50 per 100 pounds.
Cowpeas $2 per acre.

The results of the various treatments are clearly shown in the clover yields. The most striking returns have been secured both years by the complete treatment although the results from the cowpeas, lime, and phosphorus treatment are almost as great. It will be seen that cowpeas, lime, and phosphorus more than doubled the yield in 1907, that cowpeas, lime, phosphorus, and potassium almost quadrupled it in 1907 and almost trebled it in 1908, the net gain exceeding $6 per acre in four cases and more than $7 in one instance. The effect of both lime and cowpeas is inconclusive since in 1908 both brought remunerative returns while in 1907 they did not.

These results on clover show very strikingly the value of phosphates on the clover crop and demonstrate thoroughly that even where their use might not be highly profitable on wheat the effect on the clover crop following is

Effect of Cowpeas and Lime on Clover in 1908. Cowpeas, Lime on Left, no Treatment on Right.

sufficient to warrant their use. The recommendation previously made regarding the application of fertilizers to wheat were, therefore, based partly on the effect which would be secured in the clover crop following and in many cases this result, according to these experiments, will be more important than on the wheat crop itself. The use of lime, of potassium, and the effect of the cowpeas have, also, been very noticeable in their benefit to the clover crop so that where these are used mainly for their effect upon the grain crops it may be confidently expected that their effect on clover will be equally as important.

GENERAL CONCLUSIONS AND RECOMMENDATIONS.

The chemical analysis of this soil as well as the results of these experiments indicate very strongly the lack of a sufficient quantity of humus, of

nitrogen and of phosphorus. A slight need of lime and of potash is also indicated. The potash has given considerable more return than the lime however, due undoubtedly to the fact that the low humus supply prevents its being made available in sufficiently large quantities.

The Humus Supply.

It is upon the humus supply more than upon any other one factor that the productiveness of a soil depends. The presence of a good amount of humus is essential to the making soluble or available of the mineral plant foods. Evidently, then, the first essential to increasing the productiveness of this soil is the building up of its humus content, through the growing of humus building crops, such as clover and cowpeas and either pasturing them off, feeding them and returning the manure or turning them under. A crop rotation which includes such crops is essential in most instances if they are to be handled most economically, while grass crops which are also humus builders should form a part of such a crop change. In other words, a system of farming should be adopted in which grain crops like corn, wheat, and oats, which are very wasteful of humus, should alternate with crops that tend to replace this humus. The live stock farmer can build this humus most rapidly since he can feed all his crops back on the land. The grain farmer will have to depend more upon the growing of special crops, such as cowpeas and clover for turning under if the humus is to be built up or even maintained.

Crop Rotation.

The crop rotation to be recommended for any soil, depends upon several factors, such as the nature of the soil, the kind of farming, the labor supply, and upon the size of the farm, but for a live stock system in this region a good rotation for the main fields of a farm of 160 to 200 acres is that of corn two years, wheat, clover and timothy. In such a system cowpeas may be seeded in the first year of corn at the last cultivation (as has been done constantly in these experiments), and pastured off with hogs or sheep. This will give much feed if conditions are favorable and will aid greatly in maintaining the supply of humus and nitrogen. It will be found better practice where the corn and peas are both to be hogged down, as is now commonly done in many sections of the state, to seed the corn and peas together, using rather an early variety of corn and planting about the last week in May. Where the peas are sown at the last cultivation, however, it is much better to drill them in with a one-horse drill two to three pecks per acre, than it is to broadcast them.

The second year's corn crop should be cut and shocked to allow the wheat to be seeded. The timothy should be sown in the fall with the wheat and clover in the spring following. In the fourth year of the rotation clover will be the main crop with some timothy while the fifth year there will be mostly timothy on the ground with some clover. Such a rotation gives a sufficient amount of corn and hay for feed and if all crops are carefully fed back on the farm the loss in fertility will be small.

A rotation to be recommended for the stock farmer where the land is

considerably worn is that of corn, cowpeas, wheat and clover, each one year. This will give two regular legume crops for building up nitrogen and humus in each round of the rotation. Then if cowpeas are seeded in the corn, that will allow a legume crop on the land each year since the clover is of course growing on the wheat land the third year. Wheat is seeded on the cowpea stubble by simply disking and harrowing. If the land is loose after the cowpeas, a roller may be necessary. The second crop of clover the third year may either be pastured, or plowed under for the benefit of the land. Where more corn is desired than is possible with one year in four, this last named rotation may be extended to include another year of corn, making it, corn, corn, cowpeas, wheat, clover. Cowpeas may then be seeded in the corn both years or rye may be seeded the second year for winter and spring pasture, allowing it to stand until April before plowing for the regular crop of cowpeas.

The sowing of rye or some winter cover crop after a corn crop on this land, is a practice to be recommended wherever it is possible. The washing of this soil is a serious matter where it lies bare over winter and in both of the rotations suggested above, where cowpeas follow corn, rye may well be seeded in the corn during the late summer or after the corn is cut. This will help materially in holding the land during winter and it will also give a good amount of spring pasture which will be of much value on the stock farm. The rye should be sown early in the fall however, if it is to be of the greatest value in preventing washing. Wheat is practically as good as rye for this purpose and it also makes as good hog pasture in the spring, while winter barley, and in some cases, winter oats may be used.

The Saving of Manure.

The low humus supply existing in this soil together with the low content of nitrogen and phosphorus warrants the feeding of all roughage on the farm and the scrupulous saving of barn yard manure where live stock farming is practiced. Manure is best applied with a manure spreader on clover sod or other sod that is to be broken for corn. Where a careful system of lot feeding is practiced and the manure carefully saved it is possible to apply from 4 to 8 tons of manure per acre before corn once in each round of a four or five year rotation.

These figures may seem high to the farmer who is in the habit of feeding directly back on the fields although where all roughage is fed in lots or fields the amount returned would of course be the same in either case. Where the manure is accumulated in stables and lots and properly saved, it goes on the land more evenly as a rule which is an important consideration where a man is endeavoring to keep up the land's fertility and get as much out of it as possible at the same time.

Manure scattered in this way will bring considerably more return per ton than where it is scattered irregularly and in larger amounts on the thinner places as is commonly done where scattered by hand. A manure spreader will usually pay on a live stock farm of 100 acres or more in this region.

The Use of Phosphates.

The most striking results of these experiments are those secured from the use of bone meal. Consequently the use of phosphates is to be confidently recommended for this soil. For wheat the use of 125 to 150 pounds per acre of finely ground beef bone or steamed bone meal is to be recommended. The use of 200 pounds per acre of acid phosphate will give as great, and in some cases greater returns, than will the bone meal, but the continued use of acid phosphate tends to make the soil acid so that occasional liming of the land should accompany its application.

The benefit of phosphate on clover is strikingly demonstrated by these experiments, the effect on the clover crop being even more striking than on the wheat crop to which the phosphate has been applied.

For corn the use of 150 pounds per acre of a good grade of steamed bone or finely ground beef bone meal applied with the fertilizer drill ahead of the planter are to be recommended. Such an application will also be felt on the crops following.

One of the cheapest forms of phosphates to apply to this soil, is the raw rock phosphate. This phosphate is quite insoluble under ordinary conditions however, and it should be plowed under with manure or sod to make it available. It is best applied before plowing for corn once in a four or five year rotation at the rate of 600 to 800 pounds per acre. Raw rock phosphate is best applied with special phosphate distributors, several of which are now on the market. (See footnote.) It may also be applied by scattering it on the manure either in the lot or shed, or even in the bed of the manure spreader, and putting it on with the manure. It should be understood that the use of raw rock phosphate is applicable particularly to the permanent farmer who wishes to build up his soil and maintain its fertility rather than to the renter or the man who must have an immediate profit. Its effects are not so prominent the first year as in years following, but for the man who will maintain the humus supply of his soil, especially through live stock farming, it may be one of the cheapest phosphates to use.

The Use of Commercial Fertilizers.

A word should be said regarding the general use of commercial fertilizers on this soil. The recommendations made in the preceding part of this circular regarding their use apply largely to the man who is farming for the greatest profit commensurable with the maintenance of the soil fertility. It must be remembered, however, that fertilizers as ordinarily put on the market are used almost entirely for their immediate effect on the crop and usually on lands that are not giving a satisfactory return without them. While this is perfectly justifiable for the renter or the man who must have an immediate crop such a use of fertilizers has little effect in permanently increasing productiveness. In fact, it usually occurs that such a use of fertilizers tends rather to depletion of soil fertility than to the building up of the land, since a man is apt to

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Footnote.—Phosphate and Lime distributors are manufactured by the Peoria Drill Co., Peoria, Ill., the American Seeder Co., Springfield, Ohio, King Weeder Co., Richmond, Va.

grow too much corn and other grains depending almost entirely upon the fertilizer to bring a yield. Such a practice ignores the important principle of maintaining the humus supply and with the larger amount of grain grown the humus is rapidly depleted, thus resulting in an injury to the land. The proper use of commercial fertilizers for the man who is to maintain the fertility of his land, is only in connection with the best system of crop rotation, of manuring and of legume growing that he can practice. Under such a plan their use will not only be remunerative, but they will never injure the soil.

The Use of Lime.

The value of applying lime to this soil according to these experiments is sufficient to warrant its use especially for its effect on clover. The best form to apply under ordinary conditions is the ground lime stone which may be secured of two or three firms in the state, at about $1 per ton in car lots at the crusher. It should be applied at the rate of from 1 to 2 tons per acre once in every 6 or 8 years and it is best put on immediately after plowing the land for a crop, preferably corn, scattering it with an endgate seeder or with a special lime distributor. It will usually be best to harrow the land once after plowing before scattering the lime so that a wagon will run over the land readily. The further preparation of the seed bed will work the lime into the soil. Lime should not be plowed under; it is always better to mix it with the plowed soil.

In an experimental way practically any sort of lime that is available may be used. Air slacked lime may frequently be had in sufficient quantity for trial purposes and it is also perfectly feasible to slack lime to a powder and use this. There is some danger in applying freshly slacked lime with seeds but where it is broadcasted and worked into the soil as above mentioned this is of no consequence. The idea of applying lime to this soil is not to give a stimulation to the land, but simply to keep it sweet.

SUMMARY.

1. This soil is lacking first in nitrogen and humus, second in phosphorus, and it is slightly lacking in potassium and lime.
2. The experiments show a striking response to the application of phosphates, especially in the case of clover.
3. The application of lime has given some return, as has also, the use of potash and the growing of cowpeas.
4. The recommendations for handling this soil are briefly as follows:
   a. Build up the humus by adopting a systematic crop rotation which shall include clover, cowpeas, and grass crops to be fed back or in some cases to be turned under.
   b. Adopt a four or five year rotation, such as corn, cowpeas, wheat, clover or corn, corn cowpeas, wheat clover, and apply 150 pounds of steamed bone meal before corn and 125 to 150 pounds before wheat.
   c. On badly worn lands where an immediate profit is desired, apply with the wheat 125 to 150 pounds per acre of a fertilizer containing 1½ to 3 per cent nitrogen, 8 to 12 per cent available phosphoric acid, and 2 to 3 per cent potash.

d. Avoid using fertilizer repeatedly on the same land unless the humus supply is maintained.
e. Save barn yard manure scrupulously and return to the land.
f. Where the land is to be farmed carefully for a number of years, adopt a systematic crop rotation which will maintain the humus and then apply 600 to 800 pounds of raw rock phosphate before corn once in four or five years, turning it under with manure or sod.

Note.—The names of all firms selling fertilizers in Missouri are given in Bulletin 82 which may be had by applying to the Director of the Missouri Experiment Station, Columbia, Missouri. The Station will also furnish names of companies handling ground limestone and raw rock phosphate on application.