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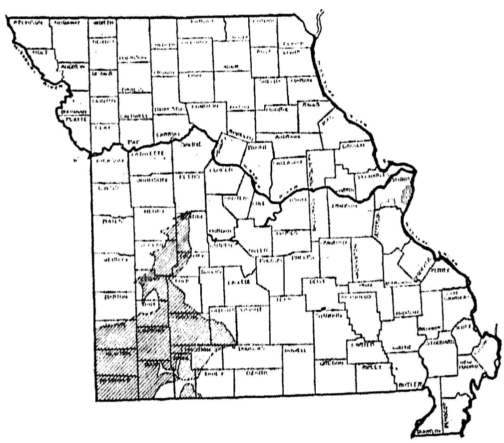

Shaded Area Shows Territory in which this Soil Occurs.

Soil Experiments on the Rolling Limestone Upland of Southwest Missouri

COLUMBIA, MISSOURI.
March, 1910.

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[1] In the service of the U. S. Department of Agriculture.

SOIL EXPERIMENTS ON THE ROLLING LIMESTONE UPLAND OF SOUTHWEST MISSOURI.

M. F. MILLER AND C. B. HUTCHISON.

In 1905 the Missouri Agricultural Experiment Station began a series of experiments at Billings, Christian County, for the purpose of determining the most profitable treatment for the soil in this region. The field on which these experiments have been conducted is located 3 1-2 miles south of Billings on the farm of E. G. Napper and represents the typical rolling upland of that section of southwest Missouri known as the Springfield Group of Soils. The soil is of limestone origin and contains varying amounts of flint or chert, considerable quantities of which may be found on the surface in large sections of this region. The soil is a reddish brown to gray silt loam, averaging about eight inches in depth and merging into a yellowish red subsoil, the color and clay content of which gradually increase to a depth of twenty inches where it is usually a bright red containing much soft chert in small pieces. The soil is friable and loose and where the surface flint does not interfere or where it has been picked off and in the areas where the surface rock does not occur it is a very tractable soil. It washes considerably when exposed, due to its texture and the rolling topography.

COMPOSITION OF THE SOIL.

Of the ten chemical elements that plants require for their proper growth and development seven come from the soil. They are nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and iron. Fortunately for the farmer the last four with the occasional exception of calcium (lime) are found abundantly in most soils. With nitrogen, phosphorus, and potassium this is not the case. These elements are commonly lacking in most soils (more so in some than others), and it is upon their presence in a form available to the plant that the yield of our crops depends. In virgin soils these elements are usually found abundantly, but after long continued cultivation, and the growing and removing of crops, the available supply becomes low and hence the yields of crops are materially decreased. The total amount of these elements 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 relative amounts of these elements may be reversed.

Plants always use these elements in definite proportions and cannot substitute one for another. If a soil in question be especially deficient in one of these, that becomes the limiting element and the yield of crops produced on that soil is limited by the amount of that 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 only be 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 planned.

As previously noted, the elements in which soils as a whole are most apt to be deficient are nitrogen, phosphorus (sometimes referred to as phosphates or phosphoric acid), potassium (sometimes referred to as potash), and rarely lime. The following analysis of the soil shows its composition compared with a very fertile soil as a standard:

	Nitrogen.	Phosphorus.	Postassium.	Lime.
A very fertile soil contains in the top 7″ of an acre.	6,000 ℔	2,000 ℔	5,300 ℔	7,000 ℔
The Billings soil contains in the top 7″ of an acre.	2,020 ℔	427 ℔	4,814 ℔	4,680 ℔

As the analysis of this soil indicates, it is strikingly deficient in both nitrogen and phosphorus and only slightly deficient in potash and lime. It would be expected, therefore, from this composition that the treatments to be recommended would be, first the building up of the nitrogen supply, and second the addition of phosphorus.

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 vegetable matter rapidly oxidizes and disappears (burns out as it is commonly said). With the burning out of this vegetable matter 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 which it contains. It should be said, too, that a large humus content is necessary in 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 products arising from this decaying vegetable matter.

The phosphorus supply is naturally deficient in this soil. It is possible with a large humus supply for plants to secure sufficient available phosphorus for their use, and maximum crops would be produced even with the small supply in this soil, but with the amount of humus which is normally present the application of phosphorus in a commercial form will prove profitable. The kinds and amounts of phosphorus to apply will be discussed later.

As will be seen from the analysis, this soil is fairly well supplied with potassium. The small increase in the yield of crops obtained by the application of potassium to this soil is probably due to the fact that with the low humus content an insufficient quantity of soluble potassium is made available. In a permanent system of soil management, however, in which crop rotation and manuring play an important part, the building up of the humus supply will for a great number of years make available sufficient potassium for large crops.

PLAN OF EXPERIMENT.

The plan of these experiments consists in blocking out the field into a number of series of plots, the various plots in each series being treated differently as to fertilizing, etc., in order to determine the treatments most profitable. These treatments include the use of cowpeas as a catch crop thrown in between the regular crops, the use of bone meal to supply phosphorus on certain plots, and the use of potash salts and lime on others. 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 by the diagram, the field is divided into three series of five plots, each plot being one-fifth of an acre in area. Each series is given the same 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 each 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.

The cowpea treatment is given for the purpose of adding nitrogen and humus through the well known action of legume plants; it consists in throwing in an extra crop of cowpeas whenever possible, usually in the corn at the last cultivation. The second crop of clover on these cowpea-treated plots is also plowed under to add additional nitrogen and humus. The lime is applied on the lime-treated plots in the form of ground limestone at the rate of 2,000 pounds per acre once in every two rounds 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 steamed bone meal at the rate of 150 pounds per acre before corn and before wheat with none before cowpeas or clover, thus making an application of 300 pounds during the four years. The potassium is applied as muriate of potash (potassium chloride) at the rate of 50 pounds 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 (BILLINGS FIELD).

1905

SOIL TREATMENT.	Yield bu. per acre.	Increase bu. per acre.	Value of increase	Cost of treatment.	Net Return
No treatment	34.5	—	$ —	$ —	$ —
Lime	37.2	2.7	1.35	.75	+ .60
Lime Phosphorus	42.5	8.0	4.00	2.62	+1.38
Lime Phosphorus Potassium	46.7	12.2	6.10	4.29	+1.81

1906.

SOIL TREATMENT.	Yield bu. per acre.	Increase bu. per acre.	Value of increase	Cost of treatment	Net Return.
No treatment	56.1	—	$ —	$ —	$ —
Cowpeas	41.5	0.0	0.0	2.00	—2.00
Cowpeas Lime	46.3	0.0	0.0	2.75	—2.75
Cowpeas Lime Phosphorus	69.4	13.3	6.65	4.62	+2.03
Cowpeas Lime Phosphorus Potassium	72.7	16 6	8.30	6.17	+2.13

1907

SOIL TREATMENT.	Yield bu. per acre.	Increase bu. per acre.	Value of increase	Cost of treatment	Net Return.
No treatment	34.6	—	$ —	$ —	$ —
Cowpeas	31.1	0.0	0.0	1.00	—1.00
Cowpeas Lime	40.5	5.9	2.95	1.75	+1.20
Cowpeas Lime Phosphorus	42.1	7.5	3.75	2.38	+1.37
Cowpeas Lime Phosphorus Potassium	44.3	9 7	4.85	3.08	+1.77

1908

SOIL TREATMENT.	Yield bu. per acre.	Increase bu. per acre.	Value of increase	Cost of treatment	Net Return
No treatment	27.9	—	$ —	$ —	$ —
Cowpeas	29.3	1.4	.70	.67	+ .73
Cowpeas Lime	31.8	3.9	1.95	1.42	— .53
Cowpeas Lime Phosphorus	35.7	7.8	3.90	2.47	—1.43
Cowpeas Lime Phosphorus Potassium	31.1	3 2	1.60	3.10	—1.50

BASIS OF CALCULATION.

Corn 50 cents per bushel.
Lime $4.00 per ton, labor and hauling included.
Bone meal $1.40 per 100 lbs.
Potash $2.50 per 100 lbs.
Cowpea treatment $2.00 per acre.
Total cost of treatment per plot divided between crops grown.

It will be seen by these tables that the largest returns have almost invariably been secured from the plot receiving the complete treatment of cowpeas, lime, phosphorus, and potassium, while the cowpeas, lime, and phosphorus treatment has come next.

It will be noticed, also, that both in 1906 and 1907 the plots which had cowpeas sown in the corn at the last plowing gave a less yield than the corn having no peas, probably due in part in the case of 1906 to the lack of uniformity of the soil, since Series B has shown a variable yield in every case. It is also partially due to the fact that cowpeas sown in the corn at the last cultivation frequently decrease the yield slightly, especially on dry seasons. The benefit of cowpeas to the soil

Plot on right received Legume-Phosphorus-Lime treatment and yielded 44.3 bushels of corn per acre. Plot on left received no soil treatment and yielded 34.6 bushels per acre.

usually much more than offsets this slight injury, however, by increasing the yield of the crops following.

Examination of the returns secured from the various treatments when estimated singly, shows that phosphorus has brought the highest net returns, averaging $1.40 per acre for the period of 4 years, with lime second with an average return of $1.32 per acre for the period of 4 years. The potassium applied has been at an average loss of 67 cents per acre, while the effect from cowpeas has been a slight injury to the immediate crop. A benefit from the growing of cowpeas is, however, shown in the crops which follow.

Experiments have not been conducted on this particular field with the use of fertilizers applied to corn in the hill or row with a fertilizer planter, but experiments which have been carried on in other places have shown that on the whole it is somewhat more remunerative for the immediate crop to apply them in this way. At Lamar, for instance, the increase due to an application of fertilizers in the hill was 14 bushels per acre with a net return of $5.60, while the net return from the best treatment broadcasted was $3.91, showing a considerable margin in favor of the hill fertilization.

Fertilizer applied in the hill or drill is put on with an attachment to a corn planter which distributes the fertilizer either in the hill or in the drill, and the rate at which this is ordinarily used is much less than where fertilizer is used broadcast, thus cutting down considerably the cost of treatment. Ordinarily 60 pounds of a complete fertilizer, such as ammoniated bone and potash is sufficient. Bone meal is also frequently used for this purpose. It seems that the value of fertilizer applied in the hill or drill in this way arises largely from the fact that the corn is given a quick start, and therefore a complete fertilizer, such as ammoniated bone and potash, is to be recommended. There is always some danger from applying fertilizer in the hill or drill from the fact that on dry seasons the corn is very apt to "fire," due probably to the shallow root development induced by this fertilization. In seasons of average rain fall, however, the net return is usually large on lands low in fertility.

It must be understood that in the use of fertilizers in the hill such a treatment does not tend to build up the soil but simply to give an immediate crop and that its continued use, where corn is grown too often on the same land without crop rotation, manuring, and legume growing, will finally injure the land, due to the loss of humus by too much grain growing. Such a use of fertilizers must be looked upon, therefore, as a temporary expedient suited to the renter or to the man who must have a crop that immediate season. The only proper use of fertilizers in the hill or drill is in connection with the best system of crop rotation, manure saving, and legume growing that one can practice.

The use of bone meal, preferably the steamed bone, applied with a fertilizer grain drill at the rate of 150 pounds per acre, ahead of the corn planter is to be recommended on this land. This will not only be of benefit to the corn crop, but its effect will show on crops following. This is recommended particularly for the man who is to farm his land for a number of years rather than for the renter.

For the live stock farmer who will maintain the humus of his soil, the use of a raw rock phosphate will be cheaper than bone meal in the end. This is an insoluble form of phosphate which must be applied on soils high in humus for best results. It is best turned under with sod, cowpeas, or manure once in a 4 or 5-year rotation before corn, applying it at the rate of 600 to 800 pounds per acre. Used in this way the soil will be continually built up in phosphates, and no further application need be given to other crops in the rotation.

EXPERIMENTS WITH WHEAT (BILLINGS FIELD).

1906.

SOIL TREATMENT.	Yield bu. per acre.	Increase per acre.	Value of increase.	Cost of treatment.	Net Return.
No Treatment	6.0	—	$ —	$ --	$ —
Cowpeas	6.3	.3	.24	.67	.43
Cowpeas Lime	6.2	.2	.16	1.42	1.26
Cowpeas Lime Phosphorus	6.6	.6	.48	3.29	2.81
Cowpeas Lime Phosphorus Potassium	5.3	—	0.00	4 96	4.96

1907

SOIL TREATMENT.	Yield bu. per acre.	Increase per acre.	Value of increase.	Cost of treatment.	Net Return.
No Treatment	5.5	—	$ —	$ —	$ —
Cowpeas	5.1	—	0.00	.67	— .67
Cowpeas Lime	4 4	—	0.00	1.42	—1.42
Cowpeas Lime Phosphorus	9.	3.5	2.80	3.29	— .49
Cowpeas Lime Phosphorus Potassium	11.1	5.6	4.48	4.54	— 06

1909

SOIL TREATMENT.	Yield bu. per acre.	Increase per acre.	Value of increase.	Cost of treatment.	Net Return.
No Treatment	9.07	—	$ —	$ —	$ —
Cowpeas	12.19	3.12	2.50	.50	+2.00
Cowpeas Lime	13.04	3.97	3.18	1.25	+2.93
Cowpeas Lime Phosphorus	18.15	9.08	7.26	2.30	+4.96
Cowpeas Lime Phosphorus Potassium	18.15	9.08	7.26	2.93	+4.33

BASIS OF CALCULATION.

Wheat 80 cents per bushel.
Lime $4.00 per ton including labor and hauling.
Bone meal $1.40 per 100 lbs.
Potash $2.50 per 100 lbs.
Cowpeas $2.00 per acre.
Total cost of treatment per plot divided between crops grown.

The experiments with wheat were very unsatisfactory in both 1906 and 1907, due to bad years for wheat following corn. In 1908 the rotation on the field was changed to one of corn, cowpeas, wheat, and clover, so that the wheat followed cowpeas that season, the peas being cut and the ground prepared by the use of a springtooth and drag harrow. It was found that on this soil the cowpeas left the ground most too loose for the best growth of wheat so that it started off poorly in the fall. It came out considerably in the spring, however, and, as will be seen by the table, the yields on the treated plots were fairly satisfactory. Numerous complaints have been reported by farmers growing wheat after peas on this soil stating that the wheat does not do well, but the use of a roller to compact the land in preparing it would doubtless go a long way toward remedying this difficulty.

Plot on right received Legume-Lime-Phosphorus-Potassium treatment and yielded 18.4 bushels of wheat per acre. Plot on left received no soil treatment and yielded 9 bushels per acre.

It will be seen from these results that the most striking returns have come from the treatments containing phosphates and cowpeas, while the results with lime and potassium have been inconsistent. The 1907 results are especially unsatisfactory and can not be considered of value because of the lack in uniformity in the plots in series B. This lack of uniformity has shown on all crops harvested from that series.

It will also be seen that the greatest net return was secured in 1909 from the cowpeas, lime, and phosphorus treatments, although all treated plots gave a remunerative return. The addition of potassium to the cowpeas, lime, phosphorus treatment lowered the net income received.

From these results the treatment to be recommended for wheat where an immediate crop is desired is the use of some form of soluble phosphate, such as bone meal or acid phosphate. This should be applied for best results with a fertilizer drill at the rate of 125 to 150 pounds per acre for the bone, or 150 to 175 pounds for the acid phosphate. In applying acid phosphate, while it is very soluble and gives quick returns, it has been found that its continued use tends to cause the soil to become acid; and since this soil is already somewhat in need of lime the use of lime should accompany the use of acid phosphate where it is applied for a number of years. The steamed bone meal is much the better form of soluble phosphate to apply as there is no tendency to acidity by its use, and it has a more lasting effect than the acid phosphate.

The fertilizers which are commonly used by wheat growers in this section are the so-called complete fertilizers and contain from one and one-half to two and one-half per cent of nitrogen, from eight to twelve per cent of available phosphoric acid, and from two to three per cent potash. On lands that are low in fertility the use of a fertilizer of this sort containing all three elements is usually more remunerative for the immediate crop than a phosphate alone; but for a man who is expecting to farm a piece of land for several years it is cheaper to supply the nitrogen through the growing of clover and cowpeas than it is to buy it in commercial fertilizers. Since potassium does not pay heavily for wheat on this land, the phosphorus is the only thing that need be applied under such a system; and here again the use of raw rock phosphate, applied with manure in a systematic crop rotation in which legumes will be grown and the humus supply kept up, will be cheaper in the end than the application of acid phosphates or bone meal. For average conditions, however, where the humus supply is somewhat deficient the use of steamed bone meal is preferable.

The use of phosphates where clover follows wheat is as important in securing a good yield of clover as in increasing the wheat yield. Frequently where the phosphates do not pay on the wheat the increased yield of the clover following will make their application very remunerative. This is strikingly shown on the clover following the poor 1907 wheat crop on these plots. These results are given in the tables which follow.

EXPERIMENT WITH CLOVER (BILLINGS FIELD).

1907.

SOIL TREATMENT	Yield per acre.	Increase per acre.	Value of increase	Cost of treatment.	Net. Return
No Treatment	1160	—	$ —	$ —	$ —
Cowpeas	1450	290	1.16	.67	+ .49
Cowpeas Lime	1435	275	1.10	1.42	— .32
Cowpeas Lime Phosphorus	2300	1140	4.56	3.29	+1.27
Cowpeas Lime Phosphorus Potassium	2500	1340	5.36	4.96	+ .40

1908

SOIL TREATMENT.	Yield per acre.	Increase per acre.	Value of increase	Cost of treatment.	Net Return.
No Treatment	1650	—	$ —	$ —	$ —
Cowpeas	1250	—	0.00	.67	— .67
Cowpeas Lime	2225	575	2.30	1.42	+ .88
Cowpeas Lime Phosphorus	3675	2025	8.10	3.29	+4.81
Cowpeas Lime Phosphorus Potassium	3610	1960	7.84	4.54	+3.30

BASIS FOR CALCULATION.

Clover $8.00 per ton.
Lime $4.00 per ton including labor and hauling.
Potash $2.50 per 100 lbs.
Bone meal $1.40 per 100 lbs.
Cowpeas $2.00 per acre.
Total cost of treatment per plot divided between crops grown.

The results of the various treatments upon the yield of clover have been very striking. It will be noticed that the treatment which has paid the best net return has been that of cowpeas, lime, and phosphorus. The addition of potash to this combination has not increased the yield enough to pay. It will be seen that in 1908 the cowpeas, lime, and phosphorus treatment increased the yield slightly over a ton per acre, while in 1907 it was something over half a ton. The results from cowpeas and lime for clover are not conclusive and they are somewhat conflicting in the two years, the cowpeas giving an increase and the lime no increase in 1907, while in 1908 the reverse was true.

It is evident from these experiments that the use of phosphates is of special value in increasing both the yield of the clover and in enhancing the chances of a uniform stand. The photographs will show the very striking differences secured by the use of phosphates on the clover crop. It is, of course, rarely feasible to apply phosphates to clover alone, but where clover follows wheat the phosphate should be applied to the wheat, thus giving a benefit both to the wheat and to the clover. As is well known the addition of a small amount of manure will greatly increase the growth of clover, due partly to the fertility added and partly to the plant food made available by the decaying

Plot on right received Cowpea-Lime-Phosphorus treatment and yielded 3,675 pounds of clover per acre. Plot on left received no soil treatment and yielded 1,650 pounds per acre. Note the comparative height of the clover and the thickness of stand in each case.

humus. Clover failures rarely occur on any soil where the humus supply is high. It is on the soil of low humus content, which for this reason lacks available plant food, especially nitrates and phosphates, and on which clover is apt to freeze out, that the main difficulties in growing clover occur. If a man will adopt a systematic crop rotation in which most crops will be fed and the manure returned to the land, or where cowpeas will be used for turning under occasionally, there will be little difficulty in growing clover, especially where the phosphorus supply is likewise maintained.

EXPERIMENTS WITH COWPEAS.

1906.

SOIL TREATMENT.	Yield per acre.	Increase per acre.	Value of increase.	Cost of treatment.	Net Return.
No Treatment	2900	—	$ —	$ —	$ —
Cowpeas	3325	425	1.70	1.00	+ .70
Cowpeas Lime	3465	565	2.26	1 75	— .51
Cowpeas Lime Phosphorus	3650	750	3.00	3.15	— .15
Cowpeas Lime Phosphorus Potassium	3365	465	1.86	3.78	—1.92

1908

SOIL TREATMENT.	Yield per acre.	Increase per acre.	Value of increase.	Cost of treatment.	Net Return.
No treatment	3550	—	$ —	$ —	$ —
Cowpeas	4100	550	2.20	.50	+1.70
Cowpeas Lime	4675	1125	4.50	1.25	+3.25
Cowpeas Lime Phosphorus	5375	1825	7.30	1.95	+5.35
Cowpeas Lime Phosphorus Potassium	5650	2100	8.40	2.58	+5.82

BASIS OF CALCULATION.

Cowpea hay $8.00.
Lime $4.00 per ton labor and hauling included.
Bone meal $1.40 per 100 lbs.
Potash $2.50 per 100 lbs.
Cowpeas $2.00 per acre.
Total cost of treatment per plot divided between plots grown.

The results of the experiments with cowpeas are much the same as those with clover. The increased yields in 1907 were, however, not so large as those in 1908. It will be seen that the complete treatment in 1908 increased the yield in cowpeas something over a ton per acre with a net return of $5.82 per acre; while the cowpeas, lime, and phosphorus treatment gave an increase of a little less than a ton, and a net return of $5.35. Averaging the two years, however, it will be seen that the latter treatment is more remunerative than the one containing potassium. Cowpeas, therefore, are shown to behave very much as clover in their relation to the various soil treatments, and practically the same recommendations hold. It must be understood, however, that cowpeas are much more readily grown than clover under most conditions, and there is not so much necessity for having a soil high in humus and phosphorus in order to secure a crop. As a rule the farmers of southwest Missouri do not appreciate the value of cowpeas. The hay is just as nutritious as clover and practically as much benefit can be secured in adding nitrogen to the soil within a period of four months as can be secured from clover within a period of fifteen months.

RECOMMENDATIONS FOR HANDLING THIS SOIL.

The results of the chemical analysis of this soil as well as the results of these experiments indicate very strongly the lack of sufficient quantities of both nitrogen and phosphorus. The need for lime is also indicated (although not so strongly), while the application of potassium rarely pays on ordinary field crops. Since the nitrogen of a soil is contained in the humus or vegetable matter, the lack of nitrogen also means a lack of humus.

THE HUMUS SUPPLY.

The importance of a large humus supply to any soil can not be overestimated, since it is upon this more than upon any other one factor that the productiveness of a soil depends. The decay of humus in a soil is largely responsible for the making available of plant food, and a large humus supply is usually essential to maximum yields. Evidently then, the first essential to an increase of productiveness is the building up of this supply through the growing of clover or cowpeas and through a rotation of crops which includes a less number of humus destroying crops such as corn and wheat. The feeding of crops on the farm and the scrupulous saving of manure to be returned to the land will aid greatly in this building up process. Crops that are cultivated and those that allow the land to remain bare for considerable lengths of time, as corn and wheat, tend to a rapid "burning out" of the humus and an injury to the land through washing. Land should not lie bare over winter if it is rolling enough to wash. Fall plowing may be very beneficial to the corn crop which follows but it is very wasteful to a rolling soil when the practice is continued. The use of winter pasture crops as rye and barley are of much value in keeping a soil from washing and in building up humus, as well as in furnishing a profitable return in pasture.

CROP ROTATION.

The crop rotation to be recommended for any land depends largely on the kind of farming, the labor supply, and on the size of the farm. For a live stock system a very good rotation for the main fields of a farm of 160 acres on this soil is that of corn, cowpeas, wheat, and clover. In this system cowpeas may be seeded in the corn at the last cultivation, to be pastured off with hogs or sheep. Such a rotation allows of a wide use of legume crops for building up the humus and nitrogen supplies of this soil—a most important consideration.

A better system in many cases where more corn is needed will consist of two years of corn followed by cowpeas, wheat, anl clover as above indicated. In this case cowpeas may be sown in the corn the first year, and rye may be sown the second year, using a one horse drill and seeding within three or four weeks after the corn is laid by. Where rye is sown it may be pastured during the early spring and up until April when it may be plowed and the land prepared for cowpeas. If the peas are put in with a grain drill and cut for hay wheat may follow without break-

Plot on right received Legume-Lime-Phosphorus-Potassium treatment. Plot on left received no soil treatment. Photograph was taken in the fall of 1909. Note the comparative height of clover in the wheat stubble in each case.

ing the land, the only preparation necessary being a thorough working with a spring tooth and drag harrow and possibly with a roller. The latter may be necessary to compact the land sufficiently to prevent the wheat freezing out, since cowpeas leave the land very loose. Clover should, of course, be sown on the wheat in the spring.

A rotation of corn, wheat, clover and timothy two years is a good one where the corn is cut and the wheat properly put in. It has the advantage of a single breaking in four years, of giving a large amount of mixed hay for feed, and of allowing half the land to lie in grass for two years.

The idea to be kept constantly in mind in all crop rotations on this land is to seek to build up humus rather than "burn it out" and likewise to increase the nitrogen supply. This is the first essential to any permanently profitable rotation.

It should be understood that the rotations recommended above are for the main fields of a farm, but it usually happens that a man will carry a secondary rotation on a series of smaller fields. It frequently happens, too, that a man finds it impossible to follow any rotation absolutely owing to crop failures, etc., but a rotation should be established and adhered to just as closely as possible, and in most cases the more legume and pasture crops that can be used the better.

A very profitable plan of farming in this region will be found to be the growing of hogs or sheep by means of pasture crops. This is especially applicable to the secondary rotation on a series of smaller fields. A good rotation for such purposes is that of corn and cowpeas the first year, both hogged down followed by rye as a fall sown crop. This rye should be pastured up until May the second year, and then followed by soybeans or cowpeas with rye again seeded in the fall and this seeded to clover the following spring. The third year the rye will be allowed to ripen and then be hogged down. Clover is pastured the fourth year. To carry such a rotation four small fields should be provided, preferably five to ten acres in size on the ordinary 160 acre farm. By having one field in each year of the suggested rotation a continuous pasture will be provided for the whole of the season and with ten acre fields from 100 to 120 hogs may be carried. The main rotation furnishes corn for feeding and additional pasture for the summer and fall.

Another very profitable system of farming in Southwest Missouri, and one which is being developed faster than any other in this region, is dairying. Dairy farming is a profitable business in almost any locality, but the conditions here are especially favorable to its development. Under such a system of farming much rough feed that is unmarketable or of a low market value and which would be a complete loss in a system of grain farming is utilized and converted into a salable product.

The greatest value of dairy farming to this section, however, lies in its importance in maintaining soil fertility. Practically every crop with the exception of wheat can be fed on the farm, and, if the manure is carefully saved, three-fourths of all the plant food removed in the crops can be returned to the soil. The sale of cream or butter removes far less fertility from our farms than that of any other product. Where the skim milk is saved and fed to hogs in connection with corn and pasture crops, the farmer has one of the most economical rations for the production of pork, so that the growing of hogs in connection with the dairy is one of the most profitable systems of farm management, as well as the most efficient in maintaining the fertility of the soil.

The use of alfalfa for a hog pasture or for hay is to be recommended for the better lands of this region. Some experimental plots on the experiment field at Billings have shown that it can be successfully grown, especially where manure is used rather liberally, where the soil is inoculated, and where the alfalfa is cultivated after the second and third cuttings. Bone meal has also been shown to be very beneficial to this crop. The manuring is perfectly feasible because only a small acreage of alfalfa is usually desirable, not over ten acres as a rule, and if this be combined in the secondary pasturing rotation as a fifth field the increased fertility from a few years of pasturing will make alfalfa growing perfectly practical and exceedingly remunerative. Such a field could be started by manuring and run for a series of years, then plowed up and introduced into the rotation while a second field which had been enriched by continuous pasturing during this time could be seeded down.

THE USE OF PHOSPHATES.

The experiments on this soil type indicate very strikingly the value of using phosphates. For wheat, steamed bone meal and acid phosphate are usually the best forms, where a man wishes immediate returns. Acid phosphate, since its continued use tends to cause the soil to become slightly acid, should be used only where lime is also applied if a man expects to follow its use for a series of years. For the renter or the man who must have immediate return, and who does not intend to continue fertilizing the same piece of land long, the acid phosphate will usually bring greater net returns than will the bone meal.

Steamed bone meal contains a slightly greater amount of phosphate and a less amount of nitrogen than does the raw bone meal and retails at about $25.00 per ton, while the raw bone meal retails at about $28.00 per ton. The extra cost of the raw bone is due to the larger amount of nitrogen which it contains. For a man who expects to farm a piece of land for several years, it will be much cheaper to put nitrogen into the soil by means of legume crops and manure than by the use of commercial fertilizers containing it.

The cheapest form of phosphate to apply where a man is to farm a piece of land for many years and where he wishes to build up its fertility continually will be the raw rock phosphate. Where this is applied at the rate of 600 to 800 pounds per acre before corn once in every round of a 4, 5, or 6 year rotation, and plowed in with manure or some other form of decaying humus such as cowpeas, clover, or sod, this will prove cheapest in the end. This is a cheap form of phosphate, costing around $9.00 per ton in car lots delivered in Missouri but it is an insoluble form and does not, as a rule, give quick returns unless applied in connection with decaying humus. Where it is plowed under with manure a manure spreader is practically essential to its proper application, although it may be scattered on with a special phosphate distributer after the manure is applied. Several distributers are now on the market. When applied with the manure spreader it may either be mixed with the manure in the spreader or scattered over the manure from time to time as the manure is accumulating in the lot or shed.

The use of rock phosphate in this way is for the permanent farmer who wishes to farm his land to the very best advantage and who is willing to put the necessary study and expense into the operation. For the farmer who must have more immediate returns, the more available forms of phosphate are to be recommended.

THE EFFECT OF SOIL TREATMENT ON ALFALFA.

The various bunches show the comparative height and growth of alfalfa on the different plots. Bunch on left is from plot receiving bone and manure where the stand is very fine. The next bunch is from the plot receiving bonemeal—200 pounds per acre. This plot is also very good. The two bunches next in order are from the plot receiving manure alone. The small bunch is weeds, the large one alfalfa. The two bunches on the right are from the untreated plot. The smaller one is weeds, and the larger one alfalfa.

THE USE OF LIME.

The return from lime according to these experiments is sufficient to warrant its use on the older pieces of soil in this region. The best form of lime to apply under ordinary conditions is the ground limestone which may be secured of two or three firms in the state. It should be applied at the rate of 2,000 to 4,000 pounds per acre once in six or eight years. It is best applied immediately after plowing for a crop, scattering it with an endgate seeder or with a special lime distributer after harrowing the land once so that a wagon will run over it readily, then allow the after preparation of the soil to work it in. It should not be plowed under, but must be mixed with the surface soil.

In a small way any sort of lime that is available may be used. Air slacked lime is frequently available in sufficient quantities for trial purposes, and it is also feasible to slack stone lime to a powder and use this. There is some danger in applying freshly slacked lime in connection with seeds, but where broadcasted and worked in as above mentioned this is of no consequence. The whole purpose of applying lime to this soil is for its sweetening effect and not for the purpose of stimulating it.

THE SAVING OF MANURE.

The low humus supply existing in this soil together with its low content of nitrogen and phosphorus warrants the recommendation of scrupulously saving all manure. It is best applied with a manure spreader on clover or other sod that is to be broken for corn and where a careful system of feeding is practiced and the manure carefully saved it is possible to apply from 4 to 6 loads of manure per acre before corn in every round of a four or five year rotation. The manure spreader must of course be used to make this distribution possible. Manure scattered evenly in this way will bring considerably greater return per ton than where it is scattered irregularly and heavily on the thinner places as is commonly done where it is scattered with a fork.

Where a man is following a pasture system with little or no lot feeding the manure spreader may not be needed but a spreader will usually pay on every livestock farm of 100 acres or more in this region. Attention should also be called to the too common practice of feeding in any sheltered place on the farm and allowing the manure to waste. Such a practice is no longer suited to the man who is to make the most out of his land. The humus supply of this soil must be built up and maintained, the nitrogen and phosphorus that are too commonly wasted through careless handling of manure must be saved, or their equivalent purchased in the form of commercial plant food or of concentrated feed, and thus returned to the soil, if it is to be kept permanently productive. The man who wastes his manure on this land today is doing so to his own disadvantage if he expects to farm the land for ten years or even five years to come.

THE USE OF COMMERCIAL FERTILIZERS.

A word should be said regarding the use of commercial fertilizers on this soil. It must be remembered that fertilizers as ordinarily placed on the market commonly contain all three elements of plant food and are used for the immediate crop. They have little effect in building up the soil. In fact their use as a rule tends to soil depletion rather than to soil building, since a man who has found them to bring results is inclined to grow too many grain crops, depending on the fertilizer to bring the yield. The result is that the humus is rapidly burned out and the soil made naturally less productive year by year. This is commonly expressed by saying that when the use of fertilizers is once begun it must be continued, and if one is to grow grain crops almost exclusively this is true. The difficulty lies in the fact that the humus supply is not maintained. The only proper use of commercial fertilizer including the bone meals and acid phosphate already mentioned is in connecting with a system of rotation and legume growing which will maintain the humus; and, if stock are fed and the manure returned in connection with the crop rotation, this maintaining of humus will be much easier on the average farm. The use of fertilizers without maintaining the humus supply is a practice suited only to the renter or the farmer who is more interested in immediate returns than in permanent productiveness.

SUMMARY OF RECOMMENDATIONS.

Adopt a crop rotation such as corn, wheat or oats, clover and timothy two years; or corn, cowpeas, wheat, clover in which all crops except wheat are fed and the manure returned. Apply 150 pounds of steamed bone meal before corn. Before wheat apply 125 to 150 pounds of steamed bone meal or 150 to 175 pounds of acid phosphate. Where acid phosphate is used continually as well as on all of the older pieces of land, and the high ridge land, apply 2,000 to 4,000 pounds of ground limestone before corn, once in every other round of a 4 or 5 year rotation.

The permanent livestock farmer will find it most economical to apply 600 to 800 pounds of raw rock phosphate plowed under with sod and manure before corn once in a four or five year rotation, and using no phosphate on wheat.

For the renter, or the man who must have immediate returns regardless of the effect on the soil, apply with wheat, 125 to 150 lbs. of a fertilizer containing 1½ to 2½ per cent nitrogen, 8 to 12 per cent available phosphoric acid, and 2 to 3 per cent potash. For corn apply the same fertilizer in the hill or drill at the rate of 50 to 75 lbs. per Acre.

NOTE.—The names of the principal fertilizer companies doing business in Missouri together with the analysis of the various brands handled are given in Bulletin 82 of the Agricultural Experiment Station, which may be had on application. The Experiment Station will also furnish on request, the names of the various companies handling rock phosphate, and ground limestone, as well as the names of the implement companies handling lime and phosphate distributers.