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Soil Experiments on the Brown Silt Loam of the Ozark Border Region

Portable lime pulverizer used on the Klenke farm where this experiment field is located. This is also used for pulverizing limestone for other farms in the community.

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TEN POINTS IN THE SUCCESSFUL MANAGEMENT OF THE UNION SILT LOAM

1. Much of this type of soil should be used for dairying or for general farming in which dairying forms an important part.

2. Careful attention should be given to selecting systems of cropping adapted to the individual farm.

3. A crop rotation should be adopted in which red clover or other good legume occupies the land from one-fourth to one-half the time.

4. The maintenance of fertility on this soil demands that less wheat be sold from the farm and more land be kept in grass and clover.

5. Use should be made of Mangum terraces and other means for controlling soil erosion.

6. Acid phosphate or bonemeal should be used with all small grain crops, especially when followed by clover and grass.

7. Phosphate helps produce larger yields of grain, clover and grass crops. This makes it possible to produce more and better manure.

8. On much of this land lime is essential to successful clover production.

9. A combination of phosphates and lime will make clover stands more regular and the yields larger.

10. Pasture improvement by the use of phosphates and manure is highly important in increasing yields on this soil.

Soil Experiments on the Brown Silt Loam of the Border Ozark Region

(Soil Type—Union Silt Loam)

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The farmer who expects to secure the greatest returns from the Union silt loam of the Border Ozark Region of Missouri must consider the outstanding needs of the soil. This land which has been subjected to long continued grain farming, with too little attention to clover and grass, has been much reduced in fertility. The supply of phosphates in the soil is naturally low, large areas are in need of lime, while erosion and the removal of many corn and wheat crops has resulted in a great reduction in the supply of organic matter and nitrogen.

The experiments reported in this bulletin were carried out on the Klenke farm, 2½ miles southeast of Union, Franklin County. The field work has been conducted by George H. Klenke in cooperation with the Department of Soils, Missouri Agricultural Experiment Station. The experiments were started in the fall of 1912 and are still in operation. The purpose of these investigations is to determine the underlying principles that control the maintenance and upbuilding of the soils of this type of Border Ozark land. This work forms a part of a general scheme to study the needs of the important soils of the state. The Experiment Station has established experiment fields and carried out work of this sort on fifteen of the principal soil areas in Missouri.

There is a rather general impression that a chemical analysis of a soil will show its fertilizer needs. Unfortunately this is true only in a very general way and the analysis must always be accompanied by the results of actual field experiments to be of the greatest value. It is for this reason that these experiment fields have been established on all the more important soil types of the state.

THE LOCATION AND CHARACTER OF THE SOIL

The Union silt loam of Missouri, occupies large areas of the rolling to rough country on both sides of the Missouri River, extending from the Mississippi River west almost to the center of the

state. It also extends in irregular areas along the eastern border of the state south of St. Louis County occupying considerable areas in Jefferson, Ste. Genevieve, Perry and Bollinger counties. It is one of the important soil types in Missouri.

The soil is of limestone origin and is usually free of loose chert or flint. The surface is a brown silt loam, 7 to 10 inches deep. The subsoil is a yellowish brown clay loam, not particularly compact in nature. In some places both soil and subsoil are lighter in color and the fertility is much lower than the average for the soil. The topography is rolling to hilly. When well cared for and properly managed the soil is quite productive. Poor care results in much erosion and a great reduction in productivity.

THE COMPOSITION OF THE SOIL

The elements of fertility to which the farmer should give greatest attention are *nitrogen, phosphorus,* and *potassium.* Some soils also need lime.

The following table shows the approximate amounts of nitrogen, phosphorus and potassium contained in the Union silt loam, as compared with the amounts in a very fertile soil.

Pounds of Important Plant Food Elements, in 2,000 000 Pounds of Surface Soil (Approximately the Surface 7 Inches of an Acre.)

Soil	Nitrogen	Phosphorus	Potassium
In the Union Silt Loam*	1600	650	35,265
In a very fertile soil	5000	2000	30,000

*Average of 10 analyses.

It will be seen from the table that the soil contains only about one-third of the nitrogen and phosphorus found in a very fertile soil but that the amount of potassium is rather high. While not shown in this table, a great deal of this type of soil also needs lime. The lime need varies more or less from farm to farm, however, some farms needing much lime, some a moderate amount and some need none at all. The lime need must therefore be determined for each farm or field.

The field on which these experiments were conducted was rather level and in places it was light brown with some buck shot in the subsoil. Such a condition results in a greater need for lime than is found in most of the Union silt loam. The results of the experiments show this very plainly. As has been said a chemical analysis in itself is not sufficient to show the exact response to be secured from different soil treatments. It merely shows the im-

portant deficiencies of the soil and the treatments likely to prove profitable. Field experiments are necessary to determine the profit from different treatments. In the case of this soil, however, the chemical analyses show striking deficiencies of nitrogen, phosphorus and lime, and the results of the experiments show that when these deficiencies are met the greatest profits are secured. Both the analysis and the experiments show that the amount of potassium is sufficient for crop needs.

PLAN OF THE EXPERIMENTS

These experiments were planned with the idea of determining the return to be expected from different treatments of this soil. The treatments were so combined that it should be possible to tell which particular element of fertility or which combination of elements would give most satisfactory returns in actual practice.

The field was divided into four parts, each of which was subdivided into seven one-fifth-acre plots, as shown in figure 2. A four-year rotation of corn, cowpeas, wheat and clover was adopted, in which each series of plots grew a different one of these four crops each year and each series was rotated through this four-year rotation.

SOIL TREATMENTS

The legume treatment on this field consisted of cowpeas seeded in the hill with corn at planting time. These were allowed to fall down and were plowed under the next spring before cowpeas. The benefit from this treatment is little, if any, as will be seen from the results obtained. The cost of the treatment was taken as the cost of seed, since the peas can be seeded with an attachment to the planter at seeding time. In addition to these peas, the second crop of clover was plowed under before corn. This gave some green manure, particularly on the fertilized and limed plots.

The phosphorus was applied in the form of a high grade steamed bonemeal carrying 0.82 per cent nitrogen and 29 per cent phosphoric acid. It was applied at the rate of 150 pounds an acre before corn and before wheat. In the case of corn it was drilled ahead of the corn planter with a fertilizer attachment on a grain drill, and in the case of wheat it was drilled in with the wheat with a fertilizer attachment at the time of seeding the grain.

The potassium was supplied in the form of a standard grade of muriate of potash, except for two years during the period of the war, when sulphate of potash was used, because it was not possible

FIG. 2.—PLAN OF EXPERIMENT FIELD

Series C

15	Legume
16	Legume, lime
17	Legume, lime, bonemeal
18	No treatment
19	Legume, lime, bonemeal, potash
20	Manure
21	Manure, rock phosphate

Series A

1	Legume
2	Legume, lime
3	Legume, lime, bonemeal
4	No treatment
5	Legume, lime, bonemeal, potash
6	Manure
7	Manure, rock phosphate

Series D

22	Legume
23	Legume, lime
24	Legume, lime, bonemeal
25	No treatment
26	Legume, lime, bonemeal, potash
27	Manure
28	Manure, rock phosphate

Series B

8	Legume
9	Legume, lime
10	Legume, lime, bonemeal
11	No treatment
12	Legume, lime, bonemeal potash
13	Manure
14	Manure, rock phosphate

to obtain a supply of the more common muriate of potash. It was applied at the rate of 50 pounds an acre until the fall of 1915 when the application was reduced to 25 pounds an acre. In the fall of 1921 the application was further reduced to 15 pounds an acre. The potash was mixed with the bonemeal and applied with the fertilizer drill, before wheat and before corn.

The rock phosphate was used to reinforce the manure in phosphorus content. It was applied at the time of spreading manure, at the rate of 1000 pounds an acre. It was scattered on the manure and plowed under before corn every fourth year. Ordinary barnyard manure was used at the rate of 8 tons an acre once in the rotation. It was spread on the clover sod and plowed under. The lime was applied in the form of finely pulverized limestone at the rate of 2 tons an acre. Only one application was made and this at the beginning of the experiment.

Cost of Treatments and Value of Crops.—The cost of fertilizer treatments and the value of farm crops are given in the table below. In this case rather conservative prices have been assumed for both fertilizers and crops. It must be remembered that prices are very unstable and if they deviate greatly from those listed, the value of any treatment can be recalculated by taking the average increase in yield and multiplying by the new price.

FERTILIZERS

Steamed bonemeal (.82% N - 29% P_2O_5)	$35.00 a ton
Muriate of potash	60.00 a ton
Rock phosphate	10.00 a ton
Manure	1.00 a ton
Limestone	3.50 a ton
Cowpeas for green manure	.50 an acre

CROPS

Corn, per bushel	$ 0.50
Wheat, per bushel	1.00
Clover hay, per ton	10.00
Soybean or cowpea hay, per ton	10.00

Cost of Individual Plot Treatments.—The cost per acre of individual soil treatments as used in these experiments is shown in the following table. The cost has been divided equally between the four crops in the rotation even though the fertilizer was applied to only the wheat and corn, and the manure and rock phosphate were put on but once in the rotation, just before the corn

crop. In calculating the returns for lime it has been assumed that it will cost approximately one dollar a year to keep land of this sort limed in proper condition for growing good clover.

COST OF TREATMENT

	4 yrs.	Per year
Legume	$ 0.50	$ 0.12
Legume, lime	4.50	1.12
Legume, lime, bonemeal	9.75	2.44
Legume, lime, bone, potash	11.25	2.81
Manure	8.00	2.00
Manure + rock phosphate	13.00	3.25

In figuring the net returns per acre for the various treatments, the cost of treatment has been deducted from the value of the crop increase in each case. While no cost has been allowed for handling the increased crop, no value has been given to the increased wheat straw and corn stover produced; one of these factors tends to offset the other in the final accounting. Losses are indicated by minus signs in the tables.

On this field results have been secured on eight crops of corn, nine crops of cowpeas, nine crops of wheat, four crops of red clover, and three crops of soybeans. The soybeans were not included in the regular rotation, but were substituted for clover when this crop failed. Some trouble was experienced during certain years due to chinch bugs and army worms, which made it necessary to eliminate the results of one crop of corn and one of wheat because the damage was not uniform on all the plots. The average yields of all crops obtained on this field during the period of the experiments are given in Table 1.

TABLE 1.—AVERAGE YIELDS PER ACRE OF ALL CROPS PRODUCED ON UNION EXPERIMENT FIELD, 1913-1922.

Soil treatment	Corn grain bus.	Corn stover lbs.	Wheat grain bus.	Wheat straw lbs.	Cow-peas lbs.	Clover lbs.	Soy-beans lbs.
Legume	12 56	1245	9.83	1312	1695	1016	727
Legume, lime	16.55	1300	13.81	1767	1941	3731	927
Legume, lime, bone-meal	19.38	1466	19.77	2351	2076	4511	1022
No treatment	13.97	1094	10.28	1476	1671	939	975
Legume, lime, bone-meal, potash	20.49	1496	20 22	2382	2161	4772	1447
Manure	21.92	1580	15.79	2060	2341	1662	1428
Manure, rock phos-phate	23.43	1587	19.49	2368	2485	1937	1543

It will be seen from this table that the response to fertilizer treatment is much the same for the various grain crops, but the yields of clover have been greatly increased on those plots treated with limestone and phosphate. A detailed discussion of the results for each crop will be given in the following paragraph.

EXPERIMENTS WITH CORN

The yields of corn as shown in Table 2 are somewhat lower than average yields in this region. This is due to some very unfavorable seasons for corn during the early years of the experiment. Bonemeal and lime increased the yield 5.41 bushels per acre. Manure alone increased the yield 7.95 bushels, and manure and rock phosphate used together increased the yield 9.46 bushels an acre. The potash application gave an increase of 1.11 bushels over the plot having similar treatment, but without potash.

TABLE 2.—RESULTS OF EXPERIMENTS WITH CORN (8 crops).

Soil treatment	Yield per acre, bu.	Increase due to treatment bu per acre	Value of increase	Cost of treatment	Net return per acre
Legume	12.56	—1.41	$—0.70	$0.12	$—0.82
Legume, lime	16.55	2.58	1.29	1.12	0.17
Legume, lime, bonemeal	19.38	5.41	2.70	2.44	.26
No treatment	13.97	----	----	----	----
Legume, lime, bonemeal, potash	20.49	6.52	3.26	2.81	.45
Manure	21.92	7.95	3.97	2.00	1.97
Manure, rock phosphate	23.43	9.46	4.73	3.25	1.48

When the net returns are considered it will be seen that the legume treatment failed to increase the yield, and resulted in a loss in the net returns. It has been observed on many of the experimental fields in Missouri that a crop like cowpeas or soybeans planted in the hill with corn reduces the yield of corn by 2 to 5 bushels an acre as an average.

The lime, bonemeal and potash gave only small increases in the net returns on corn, while the plot having rock phosphate gave a lower net return than the one receiving manure only. It has been observed on many of the soils experiment fields that the average return from the use of fertilizer on corn cannot be expected to be very great. During some years it may pay fairly well, but when the season is dry there is a tendency for the corn to fire

more on the fertilized land. This effect of fertilizers does not occur on most other crops as will be shown in the tables giving results with wheat and clover. Manure has given more satisfactory returns and is doubtless the most effective means of increasing the yields of corn. In a proper system of rotation where fertilizer is used to increase the yields of wheat and clover, the manure production will be increased and it will gradually become an easier matter to give the land a good dressing of manure before corn.

Lime has given some beneficial effect on the corn crop on this land. While limestone is used chiefly to insure a stand of clover, it has some beneficial effect on most all the common crops.

EXPERIMENTS WITH WHEAT

The wheat yields have been much more satisfactory on this field than those of corn. The soil is much better adapted to the wheat crop, largely because the wheat comes off the land before serious effects of dry weather are evident. It will be seen from Table 3 that the use of the combined treatment of legume, lime, bonemeal and potash has given an increase of approximately 10 bushels of wheat an acre with a net return above the cost of fertilizer of $7.13 an acre a year. The same treatment without potash has given a net return of $7.05 an acre, showing that the use of potash on wheat can scarcely be termed profitable. It will also be seen that manure is much less effective on wheat than on corn, while fertilizer is more effective.

TABLE 3.—RESULTS OF EXPERIMENTS WITH WHEAT (9 crops).

Soil treatment	Yield per acre, bu.	Increase due to treatment bu. per acre	Value of increase	Cost of treatment	Net return per acre
Legume	9.83	—0.45	$—0.45	$0.12	$—0.57
Legume, lime	13.81	3.53	3.53	1.12	2.41
Legume, lime, bonemeal	19.77	9.49	9.49	2.44	7.05
No treatment	10.28	----	----	----	----
Legume, lime, bonemeal, potash	20.22	9.94	9.94	2.81	7.13
Manure	15.79	5.51	5.51	2.00	3.51
Manure, rock phosphate	19.49	9.21	9.21	3.25	5.96

The net return from manure on wheat has been less than half that of the best fertilized plots. This is largely due to the fact the manure was applied before corn, two years before the

wheat was seeded. Of the fertilizers used, the soluble phosphate in the form of bonemeal has been the most profitable. The rock phosphate has given a fair return, but it has been less than for bonemeal. On several other experiment fields acid phosphate has given approximately the same results as has steamed bonemeal, and with present prices is probably more advisable on most soils than the bonemeal.

Limestone has given a fair average return on wheat, but this has not been so marked as its effect on red clover. A combination of lime and phosphates will give most satisfactory results, not only on wheat, but on the following clover crop.

EXPERIMENTS WITH COWPEAS

It was considered advisable on this land to include two legumes in the four-year crop rotation. Consequently cowpeas were used between corn and wheat and red clover or soybeans after wheat in the rotation. The yields of cowpeas have not been heavy and when one-fourth the total cost of soil treatments is charged against the crop the increased yields have been hardly sufficient to justify the expense. While all the treatments have given increased yields of cowpeas as shown by Table 4, the increase has not been sufficient

TABLE 4.—RESULTS OF EXPERIMENTS WITH COWPEAS (9 crops).

Soil treatment	Yield per acre, lbs.	Increase due to treatment lbs. per acre	Value of increase	Cost of treatment	Net return per acre
Legume	1695	24	$0.12	$0.12	$0.00
Legume, lime	1941	270	1.35	1.12	0.23
Legume, lime, bonemeal	2076	405	2.02	2.44	—0.42
No treatment	1671	----	----	----	----
Legume, lime, bonemeal, potash	2161	490	2.45	2.81	—0.36
Manure	2341	670	3.35	2.00	1.35
Manure, rock phosphate	2485	814	4.07	3.25	0.82

to pay the cost of fertilizer, except in the case of manure and lime. Most tests on other experiment fields bear out these results in showing that cowpeas and soybeans can be produced on relatively thin soil, and that they do not usually respond to soil treatment as readily as do most of the other crops. It is therefore considered best in most cases not to fertilize these crops directly, but to allow them to use the residual material of the fertilizer not taken up by the preceding corn or wheat crop.

Fig. 3.—Effects of Soil Treatment on Growth of Wheat 1917.

Soil Treatment						
Legume	Legume Limestone	Legume Limestone Bonemeal	No soil treatment	Legume Limestone Bonemeal Potash	Manure	Manure Rock phosphate
Yield Per Acre						
13.65 bu.	21.40 bu.	27.55 bu.	14.55 bu.	26.00 bu.	18.80 bu.	20.75 bu.

The value of cowpeas in the rotation lies largely in the fact that they gather nitrogen from the air as do other legumes and that they have a high value as feed. When the crop is fed and the manure returned to the land the nitrogen content of the soil is gradually built up. It is by this method of handling legumes that the thinner soils can be built up in fertility.

EXPERIMENTS WITH RED CLOVER

During the early years of these tests it was difficult to get a stand of red clover, but in more recent years the stands have been more regular. It has been thoroughly demonstrated on these plots and on adjoining land in Mr. Klenke's fields, as well as at other places in this community, that clover growing can be made a very important and profitable part of the cropping system, provided the proper soil treatment is given. Where lime is used, the stands are more uniform and there are few failures. When this is used along with treatments of available phosphate the yields per acre are greatly increased.

There are some soils where lime alone may give good yields, and some soils where phosphate alone may be sufficient for red clover, but usually a combination of lime and phosphate will be most certain to give satisfactory returns, as it does on this soil.

TABLE 5.—RESULTS OF EXPERIMENTS WITH RED CLOVER (4 crops).

Soil treatment	Yield per acre, lbs.	Increase due to treatment lbs. per acre	Value of increase	Cost of treatment	Net return per acre
Legume	1016	77	$0.38	$0.12	$0.26
Legume, lime	3731	2792	13.96	1.12	12.84
Legume, lime, bonemeal	4511	3572	17.86	2.44	15.42
No treatment	939	----	----	----	----
Legume, lime, bonemeal, potash	4772	3833	19.16	2.81	16.35
Manure	1662	723	3.61	2.00	1.61
Manure, rock phosphate	1937	998	4.99	3.25	1.64

These results show that the average increase has been exceptionally good for the four crops on the limed and phosphated plots. The average yield on the best plot was 2.38 tons an acre, or 1.91 tons more than was produced by the untreated land. In addition to the increased yield the quality of hay on the treated plots was much superior to that on the untreated land.

When the net returns are considered it will be seen that lime

has given $12.84; lime and phosphate $15.42; and lime, phosphate and potash $16.35 an acre, above the cost of treatment. The manured land during the same period has given an annual net return of only $1.61. This failure of manure to produce good clover on

Fig. 4.—Effect of Soil Treatment on Red Clover.—Photographed May 8, 1916.

(Above) Plot at left, no soil treatment; yield, no clover, all weeds. Plot at right, legume, limestone, bonemeal, potash; yield, 3550 lbs.

(Below) Plot at left, legume, limestone, bonemeal, potash; yield, 3550 lbs. Plot at right, manure; yield, no clover, all weeds.

Note that manure did not hold the clover stand so well as did soil treated with limestone and phosphates.

this field has been due to the fact that lime seems to be the first thing required for getting a satisfactory stand. Figure 4 shows that in the season of 1916 the manured land had no more clover than the check plot. In this case it is evident that it was not so much a matter of fertility as it was of having a sufficient supply

of lime in the soil to give a good stand and bring this stand through the unfavorable conditions of a summer drought. When the soil

Fig. 5.—Union Experiment Field.—Red Clover 1919. This plot was treated with limestone, bonemeal, and potash. Yield, 5390 lbs. per acre. Excellent clover.

Fig. 6.—Union Experiment Field.—Red Clover 1919. This plot had no soil treatment. Yield, all weeds, no clover.

has been supplied with lime the use of manure as a top dressing on the wheat may be one of the most effective means of getting a stand of clover.

AVERAGE ANNUAL RETURNS FROM EACH SOIL TREATMENT

While the effect of soil treatment on each individual crop is of very great importance it is also of value to know how the average results of soil treatments compare when the whole rotation is considered. Before a given treatment can be adopted as a part of a system of soil management it must be shown to be profitable throughout a period of years, or during the entire course of the crop rotation. Table 6 shows the average results of soil treatments when the average returns on the four crops, corn, cowpeas, wheat and clover are considered.

TABLE 6.—AVERAGE ANNUAL NET RETURNS FROM SOIL TREATMENTS, 1913-1922.

Soil treatment	Av. annual net return per acre from all crops	Cost of treatment	Per cent return on investment
Legume	$—0.28	$0.12	—233
Legume, lime	3.91	1.12	349
Legume, lime, bonemeal	5.58	2.44	228
No treatment	----	----	----
Legume, lime, bonemeal, potash	5.89	2.81	209
Manure	2.11	2.00	105
Manure, rock phosphate	2.47	3.25	75

It will be seen from this table that all the treatments except the legume planted in the corn have given excellent returns for the money invested. There are few other investments that can be made on the farm which will return such a high interest on investment as may be obtained from the application of proper soil treatments.

AVERAGE RETURNS FROM INDIVIDUAL SOIL TREATMENTS

In a region where the system of farming has not usually included the use of commercial fertilizers it is desirable to know the effect of each individual material that may go to make up a complete soil treatment. These experiments have been planned with this idea in mind and from the results it is possible to tell fairly definitely the particular fertilizing element that is most needed and those which can be expected to give most economical returns. While it is not possible to tell from building up different combinations of treatments exactly what would be the result of applying each one separately, it is possible to get a fair idea as to whether a given material is seriously needed. Table 7 shows the increase

on each crop that can be attributed to the different constituents in the fertilizers used.

TABLE 7.—NET RETURNS ON THE VARIOUS CROPS FOR EACH INDIVIDUAL TREATMENT.

Soil treatment	Corn	Cowpeas	Wheat	Clover	Total net return for each treatment in 4 yrs.
Legume	$—0.82	$0.00	$—0.57	$0.26	$—1.18
Lime	0.99	0.28	2.98	12.58	16.78
Bonemeal	0.09	—0.65	4.64	2.58	6.66
Potash	0.19	0.06	0.08	0.93	1.26
Manure	1.97	1.35	3.51	1.61	8.44
Rock phosphate	—0.49	—0.53	2.45	0.03	1.46

In calculating these results the effect of the legume in the corn has been obtained by comparing with the untreated plot. In this case the legume gave a decrease in yield. The effect of lime was then obtained by comparing with the legume plot. Since the legume gave a decrease, the real effect of lime was the sum of the decrease due to legume and the amount of increase where both were used together. The effect of manure was obtained by comparing with the no-treatment plot.

In Table 8 will be found the different treatments compared on the basis of percentage increase on the capital invested in fertilizer or manure.

TABLE 8.—AVERAGE ANNUAL NET RETURNS AND PER CENT INCREASE ON MONEY INVESTED IN SOIL TREATMENTS.

Soil treatment	Annual net return for each treatment	Annual cost of each treatment	Per cent increase on investment
Legume	$—0.28	$0.12	—233
Lime	4.19	1.00	419
Bonemeal	1.66	1.31	126
Potash	0.31	.37	83
Manure	2.11	2.00	105
Rock phosphate	0.36	1.25	28

SOIL MANAGEMENT

The results of these experiments show very clearly the important principles to be followed in handling this soil type. They show that for the most part this soil is very low in nitrogen and that every effort must be made to build up and maintain this element. They also show a very marked return from available phos-

phates and from lime, so that no system of farming will be very profitable without their use. The potash need of the soil is not sufficient to cause concern. It remains to apply these findings to the practical management of this soil type.

When the fundamental principles which have been shown by these experiments to be essential in maintaining or increasing the fertility of this soil become the common practice of farmers in this region, a more permanent and prosperous agriculture will result.

Types of Farming.—For the most part, this type of soil should be devoted to dairying or to general farming in which dairying or the production of livestock has an important place. The farmers, who have occupied much of this land, have grown mainly grain crops. This type of farming must either be modified or abandoned. Dairying is mentioned as a promising industry because of good markets and because the soil lends itself well to this type of agriculture. Much of the rougher parts of this land must be kept in grass, thus giving pasture for dairy cattle or sheep. Small fruit growing and poultry farming also offer good opportunities.

This type of soil is not well suited to tenant farming because the constant attention of the land owner is necessary in preventing erosion and maintaining fertility. Moreover, an intensive system of dairying or of livestock farming cannot well be handled through tenants. For farms of medium to small size, however, each handled by its individual owner under systems of dairying, general farming or specialized fruit and poultry farming, this soil type offers much opportunity.

Much more attention must be given to working out a system of farming that will be most nearly adapted to the conditions of a particular farm. That is, each individual farmer should carefully study his own problems in the light of as much definite knowledge as he can obtain. From this information combined with the results of his own observations and experience he must work out a system that will yield the greatest profits with a minimum of labor and expense and at the same time build up the productive capacity of the soil.

Proper Cropping Systems.—It is highly important on such soils as the Union silt loam to give a great deal of consideration to the system of cropping. The class of livestock handled should usually be such that the greater part of the feed can be produced on the farm. The soil is not particularly well adapted to corn and

for this reason hog raising can hardly be expected to become very important, except along the streams, where there is considerable bottom land for corn growing. Small grain does fairly well on much of the upland, but far too much of the land has been devoted to wheat farming. More attention must be given to the growing of legume crops, such as red and alsike clover, sweet clover, cowpeas and soybeans. These crops all gather nitrogen from the air and when fed and the manure returned, the soil is built up in this element. For the most part the land that can be plowed should be kept in clover of some sort, cowpeas or soybeans about half of the time. An example of a crop rotation might be one of corn, cowpeas or soybeans, wheat or rye, clover and timothy. If the corn is removed for silage the land may be seeded to rye and used for winter or spring pasturage, this being plowed for soybeans or cowpeas. The cowpeas and clover crops should be used for hay, and pasturage obtained for the most part from lands that are too rolling to be included in the regular rotation. Where soybeans are being grown on land for the first time care should be taken to see that the seed is inoculated with the proper nitrogen gathering bacteria. It is usually not necessary to inoculate for cowpeas or red clover.

Other rotations such as the following may be worked out to suit conditions of a given farm:

1. Corn, wheat, clover.
2. Corn, wheat, clover and timothy 2 years.
3. Corn or kafir, soybeans, wheat, clover and timothy.
4. Wheat, clover and timothy 2 or more years. (For very rolling land.)
5. Kafir, rye, clover and timothy.

It must be remembered that these are only suggestions and that rotations will vary with the kind of livestock produced, the fertility of the soil, the steepness of the slopes, the special ability of the farmer to produce certain crops, and other factors.

Use of Manure.—Barnyard manure is usually considered the most valuable material for applying to soils for increasing their productiveness. In fact, no one questions the value of this farm-produced fertilizer. It must be considered as one of the most valuable by-products of the farm. It should be noted, however, that in these experiments the net returns from manure have been best on corn and cowpeas while bonemeal has given a larger increase with wheat and clover. Limestone has also been much more profitable

than manure on clover. However, these results should in no way lessen the appreciation of the value of barnyard manure, but should serve rather to show the great need of this particular type of soil for phosphates and lime.

On soils of rather low fertility there is usually the complaint that the manure supply is very limited and not enough can be produced to use on the cultivated land. These experiments show how the amount of manure may be increased. To produce large quantities of manure large crops must be grown. Low yields necessarily mean small amounts of manure. Consequently, on soils where manure is most needed the supply is usually the lowest. The increase in crop yields by the use of commercial fertilizer is the most direct way of increasing the amount of manure that can be applied. For instance in these experiments if all the crops grown on the untreated land had been fed to livestock and the straw used for bedding, it would have been possible to produce an average of only 3.28 tons of manure per acre during the course of a four-year rotation. On the other hand if the produce from the plot receiving lime, phosphates and potash had been converted into manure it would have been possible to produce 6.73 tons during the same rotation. This shows very clearly how the amount of manure can be more than doubled by proper soil treatment. Not only will the amount be greater, but the manure will be much richer in nitrogen due to the fact that more clover and other legumes are produced for feed. This increase in the growth of legumes which enrich the manure and the soil in nitrogen is one of the most important reasons for establishing the practice of using phosphates on this soil. If it is possible to increase the amount of manure for each acre from 3.2 tons to 6.7 tons during a four-year rotation, the prospect of building up the fertility of this soil is much better. Moreover, such a plan will give far more profit than was ever possible under the old system where no fertilizer was used and where little manure could be produced.

The Application of Phosphorus.—It is evident that the use of phosphates is a very profitable practice on this land. Not only is it profitable, but it can be used for increasing the production of manure and for increasing the fertility of the soil. Of the two phosphates used, the bonemeal has been more profitable than the raw phosphate rock. The phosphorus in the bonemeal is more available to the plants and gives somewhat larger increases in crops. This has been the case in most of the experiments carried out in

different parts of the state. Acid phosphate which is another soluble form gives about the same results as bonemeal and is rapidly replacing the latter on the market. This is due to the fact that the supply of bonemeal is limited and is not sufficient to meet the present demands. Furthermore, the price of bonemeal is usually considerably above that of acid phosphate. Where the two sell for only a few dollars difference in price per ton it may be more economical to use bonemeal, because it can be applied in quantities about one-fourth less than the 16 per cent acid phosphate, and it is slightly better for the clover following wheat. The acid phosphate should contain from 16 to 20 per cent available phosphoric acid. Some higher grade phosphates are coming on the market and in time they may take the place of the common analyses.

These phosphates should be applied about once every two years, chiefly on the grain crops. The residual effect the following year should be utilized by some legume crop like clover or soybeans. In these tests the phosphate has been applied to the corn and wheat and the following crops of cowpeas and clover have been allowed to take out the phosphate left by the grain crops.

The rates of application for most profitable returns should be from 150 to 225 pounds of 16 per cent acid phosphate or 125 to 175 pounds of steamed bonemeal per acre. The returns on wheat will usually be far greater than on corn, because in dry seasons there is a tendency for the dry weather to offset the effect of the fertilizer. It is therefore a good plan in many cases, where considerable manure is produced, to put most of the manure on before corn and use the greater part of the phosphate with the wheat. Phosphates should be used on this soil for small grain and clover even though considerable amounts of manure are applied. In fact the highest net returns may be expected from a combination of manure and phosphates. Growing animals retain considerable phosphorus in their bones and this is lost from the farm when the livestock is sold. Manure is therefore low in the necessary phosphoric acid. It is a good plan to apply 20 or 30 pounds of acid phosphate to each ton of manure put on before corn, in addition to the usual application to the small grains.

Use of Potassium.—Potassium (potash) in the form of high grade muriate of potash at the average rate of about 50 pounds an acre during each rotation has paid a small return on the money invested. While it has given small increases on all of the crops, the returns have not been striking. When mixed fertilizers are

used it may sometimes be advisable to use one carrying small amounts of potash, but the profits from its use cannot be expected to be very great.

Use of Mixed Fertilizers.—If factory mixed fertilizers are to be used on this soil they should be of high grade. Some of the standard brands of fertilizer in Missouri such as 2-16-2, 2-14-2, or 2-12-2 will probably be found most satisfactory. Such fertilizers as these may be used on the corn and wheat crops, or they may sometimes be applied when seeding land down to meadows or pastures in order to give the grass a good start. On the average farm,

Fig. 7.—Red Clover 1916.—Plot on left had legume, limestone and bonemeal; yield 3345 pounds. Plot on right had no soil treatment and produced no clover, all weeds.

however, it will usually be found more profitable to use the phosphates, such as acid phosphate or bonemeal, since the selling price per ton is considerably less than for the mixed fertilizers. Where the phosphates are used alone they can be expected to increase the production of legume crops, so that the necessary nitrogen can be added through these crops rather than in the form of mixed commercial fertilizers.

Use of Lime.—Lime has been the most profitable material added to this soil. It has been practically impossible to get good stands of clover without it. This means that on such land as this it is likely that an application of approximately two tons of lime per acre should be an important principle in a system of soil improve-

ment. The reason for this lies in the fact that it is much easier to build up land where clover can be grown.

On some parts of this soil area where the soil is not very acid, it will be possible to get good yields of clover by the proper use of manure and phosphates alone. Most of the clover stands in this region are lost during hot dry spells in summer. The use of lime, manure and phosphate aids materially in bringing clover through these unfavorable conditions.

The value of ground limestone has not only been shown on this experiment field but has been remarkably well demonstrated on other fields of this farm and adjoining farms by Mr. Klenke and his neighbors. For several years they have been grinding limestone with a small pulverizer for local use. It has been found possible to do this crushing at a lower price than that at which the ground limestone could be shipped from a distance and hauled from the railroad station. Before attempting to crush limestone, however, an investigation should be made of all the costs involved and a sample of the stone should be analyzed for its carbonate content. (Information concerning the advisability of grinding limestone in any given community as well as tests on purity of stone may be had by writing the Department of Soils, Missouri College of Agriculture, Columbia, Missouri.)

Control of Soil Washing.—A large part of the Union silt loam is very rolling and in many places much of the surface soil has been lost through washing. Experiments conducted by the Experiment Station at Columbia, have shown that even on very gently rolling land the soil of a cultivated field is lost at a very rapid rate. For instance, in an experiment at Columbia, land with a slope of only 2½ feet per hundred has lost soil over seven times as fast when in continuous corn as when in rotation and sixty times as fast as when in bluegrass sod. All results show that the most effective ways to control soil washing are by keeping the land in grass or by rotating it in such a way that small grains, clovers and grass occupy an important place in the system of farming. Moreover, wider use should be made of the Mangum terrace. These terraces are being used in increasing numbers in Missouri and the farmers on this soil type should become familiar with them. The cost of installing them is low and they give good service. (Full information regarding them is given in Missouri Experiment Station Circular 98).

Finally every effort should be made to stop the small washes as they start. If this is done a tremendous amount of soil will be

saved. The farmers on this soil have generally given rather careful attention to the gullies but they have neglected the other means of erosion control.

SUMMARY

1. In this bulletin are reported the results of soil experiments carried out on the Union silt loam of the Border Ozark Region.

2. The results show that for the most profitable production of crops on this land the use of phosphate fertilizers is indispensable. Acid phosphate and steamed bonemeal are usually the best forms to use.

3. Ground limestone has been found very helpful in securing satisfactory stands of clover.

4. Barnyard manure has greatly increased the yield of crops. The value of manure measured in crop increases has been $2.05 a ton. For best results manure should be reinforced with acid phosphate.

5. A combination of manure, lime and phosphate in the form of acid phosphate or bonemeal will be highly profitable on this soil.

6. Potash has given slight returns, but these have not been sufficient to warrant the use of this material in very large amounts.

7. Rock phosphate has not been as profitable as a source of phosphorus as bonemeal on this experiment field.

8. Much care should be taken to choose the type of farming which can be adapted to a particular farm. A rotation should be adopted which includes legume crops for increasing the nitrogen supply and which keeps the ground covered much of the time to prevent serious soil erosion.