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Soil Experiments on the Gravelly Ozark Upland

Farmers' Meeting on Willow Springs Field, 1921. These meetings have been held annually and have been attended by large numbers of farmers from Howell and adjoining counties.

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WHAT THESE EXPERIMENTS SHOW

1. Dairy and poultry farming along with small fruits offer much opportunity on this land since the profits from grain or general farming can not be expected to be very great.

2. The most successful general farming on this type of land is dependent on the use of large acreages of timber pastures.

3. This land is greatly in need of phosphates and they should be used on the cropped and improved pasture land, in every system of dairy or general farming.

4. The use of farm manure and acid phosphate is one of the most effective ways of increasing the yields of crops on this soil.

5. Clover stands can be obtained practically every year when phosphates and manure are used.

6. Phosphate fertilizers should always be used with small grain when it is to be followed by clover or grass.

7. Phosphate fertilizers increase the growth of legumes and in that way build up the nitrogen content of the soil, especially when these crops are fed and the manure returned to the land.

8. The crops grown on treated soil in these experiments have been sufficient to produce two and one-half times as much manure as the crops grown on the untreated land.

9. Limestone has not given large returns as the acidity of this field is not high.

10. Potash is little needed on this soil.

Soil Experiments on the Gravelly Ozark Upland

(SOIL TYPE—CLARKSVILLE GRAVELLY LOAM)

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There are thousands of acres of more or less gravelly upland soil in the Ozark Region of southern Missouri on which the farmers are having difficulty in securing profitable crop yields. This land was formerly covered with a scattering to heavy growth of timber, mostly black oak, and rather small white oak with some blackjack oak, post oak and hickory. Most of the merchantable timber was removed a good many years ago and considerable areas were cleared and put into cultivation. This cultivated land has been farmed so long that much of it is badly worn. The original fertility of the soil was not high and continued cultivation has resulted in the reduction of yields to a point that special efforts are needed to make the land bring profitable returns. It is on this type of soil that the experiments reported in this bulletin were conducted.

The experiment field was located on the farm of S. W. Atkinson, about three miles west of Willow Springs, Howell County. The land had been in cultivation for about 50 years before the experiments were begun in 1915. During the course of the experiments the field work has been done by Mr. Atkinson and it has been largely through his interest and painstaking care that it is possible to report satisfactory results.

This experiment field is one of a series that is being conducted to study the needs of the important soil types of the state. The soil represented is similar to a large amount of the Ozark upland and the results should have wide application in that region.

DESCRIPTION OF THE SOIL

The soil of this experiment field is classed in the soil survey reports as Clarksville gravelly loam. The surface soil to a depth of 5 to 8 inches consists of a gray to pale yellow gravelly loam or gravelly silt loam. The upper subsoil is a yellowish or brownish gray silt loam, but at about 24 inches this becomes a stiff, silty clay. In many places much gravel and sometimes reddish clay is found above 30 inches. The surface of the land varies from fairly level to hilly.

COMPOSITION OF THE SOIL

Every soil supplies seven necessary chemical elements for the use of plants. These are nitrogen, phosphorus, potassium, calcium, magnesium, iron and sulphur. The first three—nitrogen, phosphorus and potassium—are the principal ones with which the farmer should concern himself, since they are the ones most likely to be deficient in the soil, so far as the needs of the plant are concerned. Calcium which is the important chemical element in lime is also deficient in many soils. This may cause soils to be acid and

it becomes necessary to add this material in some form of lime or limestone. The other three elements—magnesium, iron and sulphur—are abundant in most soils.

The following table shows the amount of nitrogen, phosphorous and potassium found in a very fertile soil, as compared with the Clarksville gravelly loam.

TABLE 1.—POUNDS OF NITROGEN, PHOSPHORUS AND POTASSIUM IN SURFACE SEVEN INCHES OF AN ACRE.

Soil	Nitrogen	Phosphorus	Potassium
Very fertile soil	6,000	2,000	30,000
Clarksville gravelly loam	1,080	430	24,420

An examination of these figures will show that this soil is very low in nitrogen and phosphorus, while the amount of potassium is not far below that found in a very fertile soil. It might be assumed from these figures that applications of nitrogen and phosphorus would give increases in crop growth. The truth of this assumption will be brought out later in this bulletin. From the analyses it could not be determined how much profit could be obtained from the application of these elements. This is the great difficulty in determining fertilizer needs from soil analyses. It is not possible to tell how much of the fertility the plants will be able to get during any one season, since this depends upon the weather and methods of cultivation. The money return from soil treatments must therefore be determined by actual field tests carried on for a number of years.

PLAN OF EXPERIMENTS

This experiment field was planned with the idea of determining treatments which would be most profitable on this soil. The field was divided into four series of ten plots each, and each plot was one-sixth acre in size. The eight plots on each series were given different soil treatments, two plots being left untreated for the purpose of comparing with the treated ones. (See figure 1 for diagram of field.) A four-year rotation of corn, soybeans, wheat and clover was followed in which each series grew a different one of these crops each year. The series which was in corn was seeded to rye in the fall, on all plots except the untreated ones. The rye was plowed under the next spring for green manure before soybeans.

SOIL TREATMENTS

The materials used in the soil treatments and the amount and methods of application may be given briefly as follows:

The bonemeal used was a high grade steamed bone containing 0.82 per cent nitrogen and 29 per cent available phosphoric acid. It was applied with a drill ahead of the corn or with the wheat, 150 pounds per acre.

The acid phosphate used was the 16 per cent grade applied in the same manner as the bonemeal, but at the rate of 175 pounds per acre. The potassium used was applied as the muriate of potash at the rate of 25 pounds

FIG. 1.—PLAN OF EXPERIMENT FIELD.

Series B

11	Rye for green manure
12	Rye, Bonemeal
13	No Treatment
14	Rye, Acid Phosphate
15	Rye, Acid Phosphate Potash
16	Rye, Acid Phosphate Potash. Lime on surface
17	Rye, Acid Phosphate Potash. Lime plowed under
18	No Treatment
19	Rye, Manure
20	Rye, Manure Acid Phosphate

Series A

1	Rye for green manure
2	Rye, Bonemeal
3	No Treatment
4	Rye, Acid Phosphate
5	Rye, Acid Phosphate Potash
6	Rye, Acid Phosphate Potash. Lime on surface
7	Rye, Acid Phosphate Potash. Lime plowed under
8	No Treatment
9	Rye, Manure
10	Rye, Manure Acid Phosphate

Series D

31	Rye for green manure
32	Rye, Bonemeal
33	No Treatment
34	Rye, Acid Phosphate
35	Rye, Acid Phosphate Potash
36	Rye, Acid Phosphate Potash. Lime on surface
37	Rye, Acid Phosphate Potash. Lime plowed under
38	No Treatment
39	Rye, Manure
40	Rye, Manure Acid Phosphate

Series C

21	Rye for green manure
22	Rye, Bonemeal
23	No Treatment
24	Rye, Acid Phosphate
25	Rye, Acid Phosphate Potash
26	Rye, Acid Phosphate Potash. Lime on surface
27	Rye, Acid Phosphate Potash. Lime plowed under
28	No Treatment
29	Rye, Manure
30	Rye, Manure Acid Phosphate

per acre along with the acid phosphate. The lime stone was finely pulverized and applied at the rate of two tons per acre at the beginning of the experiment.

Prices Used in Calculations.—The acre costs of materials represent approximate prices of materials and the crop values are moderate farm prices for a long series of years. These are given in the following table:

CROPS

Corn	$ 0.50 a bushel
Soybeans	2.00 a bushel
Wheat	1.00 a bushel
Clover hay	10.00 a ton

FERTILIZERS

Acid phosphate (16% P_2O_5)	$20.00 a ton
Steam bonemeal (.82% N—29% P_2O_5)	35.00 a ton
Potash (muriate of potash)	60.00 a ton
Manure	1.00 a ton
Limestone	3.50 a ton
Rye for green manure	2.25 an acre

In figuring net returns for the 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 straw and stover produced so that one tends to offset the other in the final accounting.

The fertilizer treatments were applied to corn and wheat only, but since the other crops benefited from the residual effects, the cost has been divided equally between all crops.

The average yield of each crop in the rotation is shown in Table 2. The yield of the untreated plots gives an idea of the general fertility of this soil and the yields of treated plots show the benefit derived from soil treatment.

TABLE 2.—AVERAGE YIELDS OF ALL CROPS GROWN ON WILLOW SPRINGS EXPERIMENT FIELD.

Treatment	Corn 7 crops Bu.	Corn stover Lbs.	Soybeans 6 crops Bu.	Soybean straw Lbs.	Wheat 7 crops Bu.	Wheat straw Lbs.	Clover hay Lbs.
Rye (for green manure)	9.13	739	2.58	358	2.00	243	377
Rye, bonemeal	26.14	1351	6.57	820	10.65	1019	2648
No treatment	12.15	895	3.75	433	3.33	400	536
Rye, acid phosphate	29.86	1404	6.50	806	12.95	1260	2235
Rye, acid phosphate, potash	28.44	1358	6.37	752	12.00	1095	2068
Rye, acid phosphate, potash. Limestone applied on surface	32.55	1535	7.48	892	13.40	1252	2046
Rye, acid phosphate, potash. Limestone plowed under	33.94	1604	7.95	956	14.33	1358	2620
No treatment	12.00	846	3.72	410	4.32	532	856
Manure	32.98	1616	6.20	800	10.77	1105	1611
Manure, acid phosphate	38.45	1906	8.25	1003	16.72	1588	3037

EXPERIMENTS WITH CORN

(Seven crops 1916-1922)

The production of corn on such land as is represented by this field is not usually profitable unless some soil treatment is given. The use of some phosphate, together with as much manure as can possibly be produced, is essential to the production of a profitable crop of corn. The increases from the use of proper soil treatment are sufficient to pay well for the cost of fertilizing materials, as shown by Table 3.

Fig. 2.—Effect of Soil Treatment on Corn, 1918. Plot on left received acid phosphate, limestone and potash. Plot on right had no soil treatment.

TABLE 3.—RESULTS OF EXPERIMENTS WITH CORN—SEVEN CROPS.

Treatment	Average yield bu. per acre	Increase yield over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net returns per acre
Rye for green manure	9.13	—3.02	$—1.51	$0.56	$—2.07
Rye, bonemeal	26.14	13.99	7.00	1.87	5.13
No treatment	12.15	.....	.....	.....	.....
Rye, acid phosphate	29.86	17.71	8.86	1.44	7.42
Rye, acid phosphate, potash	28.44	16.29	8.15	1.81	6.34
Rye, acid phosphate, potash. Limestone applied on surface	32.55	20.55	10.28	2.81	7.47
Rye, acid phosphate, potash. Limestone plowed under	33.94	21.94	10.97	2.81	8.16
No treatment	12.00	.....	.....	.....	.....
Manure, rye	32.98	20.98	10.49	2.56	7.93
Manure, acid phosphate, rye	38.45	26.45	13.23	3.44	9.79

It may be seen from this table that the yields of the untreated plots of about 12 bushels an acre are too small to pay the cost of production. The first plot in the list, which had had rye sown for green manure, is essentially like the no treatment plots. In fact the land on which this plot was located was probably slightly poorer than the no-treatment plots and this doubtless accounts for the average yield falling below the untreated plots. The rye treatment could not have had a noticeable effect because the soil was so thin that practically no growth of rye was produced for green manure on this plot. On the fertilized plots the growth of rye was good.

Bonemeal gave a good increase on corn, but not quite so much as that produced by acid phosphate. Potash used with acid phosphate decreased rather than increased the yield. Lime gave a fair increase, but there was no great difference whether the lime was applied on the surface after the land was plowed or put on the unbroken land and plowed under. Manure gave good returns and it is, of course, one of the best applications for this sort of land, in so far as a supply is available.

Fig. 3.—Effect of Soil Treatment on Corn, 1920.

Rye, bonemeal.	No soil treatment.	Rye, acid phosphate.
Yield, 30.26 bu.	Yield, 11.23 bu.	Yield, 31.11 bu.

However, the use of manure is not absolutely essential for greatly increasing the yield of crops. Chemical fertilizers can often be used for this purpose with good results where manure is scarce. No attempt should be made to make fertilizers take the place of manure. They should be used for growing larger crops, particularly clover and other legumes. The use of acid phosphate, along with manure, gave the largest yields and the greatest net returns of any of the treatments. The increase from acid phosphate, however, was not so great where used in connection with manure as where used alone.

When all costs of labor, seed, fertilizer and rent are considered, it was found that the cost of producing corn on the untreated land, where the yield was slightly over 12 bushels per acre, amounted to approximately $1.25 a

bushel. On the manure and acid phosphate treatment the cost of producing corn was reduced to about 58 cents a bushel. This shows that it was not only possible to greatly increase the yield by proper treatment, but thereby also to reduce the cost of production one-half.

EXPERIMENTS WITH SOYBEANS

(Six Crops)

The soybean crop has proved a very satisfactory one for this soil. No fertilizer treatments were added directly to this crop, but it was allowed to take out the residual material left in the soil from the treatment of the preceding corn crop. The increases from the treatments are therefore probably slightly less than if the fertilizer had been applied at the time of planting the soybeans. The cost of treatment, however, has been divided equally with the corn crop. The crop has been harvested for seed and threshed. The average yields and returns from treatments are shown in Table 4.

TABLE 4.—RESULTS OF EXPERIMENTS WITH SOYBEANS—SIX CROPS.

Treatment	Average yield bu. per acre	Increase yield over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net returns per acre
Rye for green manure	2.58	—1.17	$—2.34	$0.56	$—2.90
Rye, bonemeal	6.57	2.82	5.64	1.87	3.77
No treatment	3.75	.....	.....	.....	.....
Rye, acid phosphate	6.50	2.75	5.50	1.44	4.06
Rye, acid phosphate, potash	6.37	2.62	5.24	1.81	3.43
Rye, acid phosphate, potash. Limestone applied on surface	7.48	3.76	7.52	2.81	4.71
Rye, acid phosphate, potash. Limestone plowed under	7.95	4.23	8.46	2.81	5.65
No treatment	3.72	.....	.....	.....	.....
Manure	6.20	2.48	4.96	2.56	2.40
Manure, acid phosphate	8.25	4.53	9.06	3.44	5.62

It may be seen from this table that the value of the increase due to soil treatment is much greater than the cost of the fertilizer necessary to produce it. As was explained in the discussion for corn, the plot having rye alone for green manure is essentially like the untreated plots but due to a slight lack of uniformity of soil is probably less fertile than these. Phosphorus has given good returns wherever used. Potash has been of no value. Lime has given some increase above the extra cost of the treatment, although the increase has not been exceptional. Manure has given a lower yield and a lower net return on soybeans than any of the fertilizer treatments. Its residual effect has not been so marked as that of phosphate. Manure reinforced with acid phosphate gave a higher yield than any other treatment, but owing to its slightly higher cost the net return was about the same as for Plot 7 receiving only chemical fertilizers.

The soybean crop should have a much more prominent place on the thinner lands of the Ozark region than it now holds. It produces a good amount of very valuable feed and since it is a legume it gathers nitrogen from the air, and may therefore be used to build up the fertility of the

Fig. 4.—Soybean Crop, 1921.

Rye for green manure, acid phosphate, potash, lime. Yield, 9.6 bushels of seed.

No treatment Yield, 4.0 bushels of seed.

soil. To do this, however, it is necessary to feed the crop on the land or return the manure. Where soybeans have not been grown the seed or soil should be inoculated before planting to insure a supply of the proper soil bacteria.

EXPERIMENTS WITH WHEAT

(Seven Crops)

The increases from soil treatments on wheat have been very marked even though the total yields have not been as high as should be obtained for the most profitable production of wheat. The figures in Table 1 show that phosphorus is the element most lacking in this soil and good increases have been obtained in all cases where it has been applied. Acid phosphate has given somewhat greater returns than bonemeal while the bonemeal has been of more benefit to the following clover crop as shown by the results in Table 5. Potash has not increased the yield of wheat when used in connection with acid phosphate.

Manure greatly increased the yield of wheat when applied immediately before the crop was planted. This was shown in the crop of 1916 and 1917. The effect may be seen in figure 5. On the other years where manure was applied before corn and this followed by soybeans and then by wheat, the increase due to manure was much less. That is, the fertility of the manure was largely used by the corn and soybeans, before the wheat was seeded.

Acid phosphate used with manure gave good increases over the manure alone. Liming the land had little or no effect upon the yields of wheat.

If land of this sort must be farmed to wheat, the crop should never be seeded without a good application of phosphorus in the form of acid phos-

TABLE 5.—RESULTS OF EXPERIMENTS WITH WHEAT—SEVEN CROPS.

Soil treatment	Average yield bu. per acre	Increase yield over no treatment bu. per acre	Value of increase per acre	Cost of treatment per acre	Net returns per acre
Rye for green manure	2.00	—1.33	$ -1.33	$0.56	$—1.89
Rye, bonemeal 150 lbs.	10.65	7.32	7.32	1.87	5.45
No treatment	3.33	.....	.....	.....	.....
Rye, acid phosphate, 175 lbs.	12.95	9.62	9.62	1.44	8.18
Acid phosphate, 175 lbs., rye, potash 25 lbs.	12.00	8.67	8.67	1.81	6.86
Acid phosphate, potash, rye. Limestone applied on surface	13.40	9.08	9.08	2.81	6.27
Acid phosphate, potash, rye. Limestone plowed under	14.33	10.01	10.01	2.81	7.20
No treatment	4.32	.....	.....	.....	.....
Rye, manure	10.77	6.45	6.45	2.56	3.89
Rye, manure, acid phosphate	16.72	12.40	12.40	3.44	8.96

Fig. 5.—Effect of Soil Treatment on Spring Condition of Wheat, 1916.

Manure in fall.
Yield, 16.1 bu.

No treatment.
Yield, 1.4 bu.

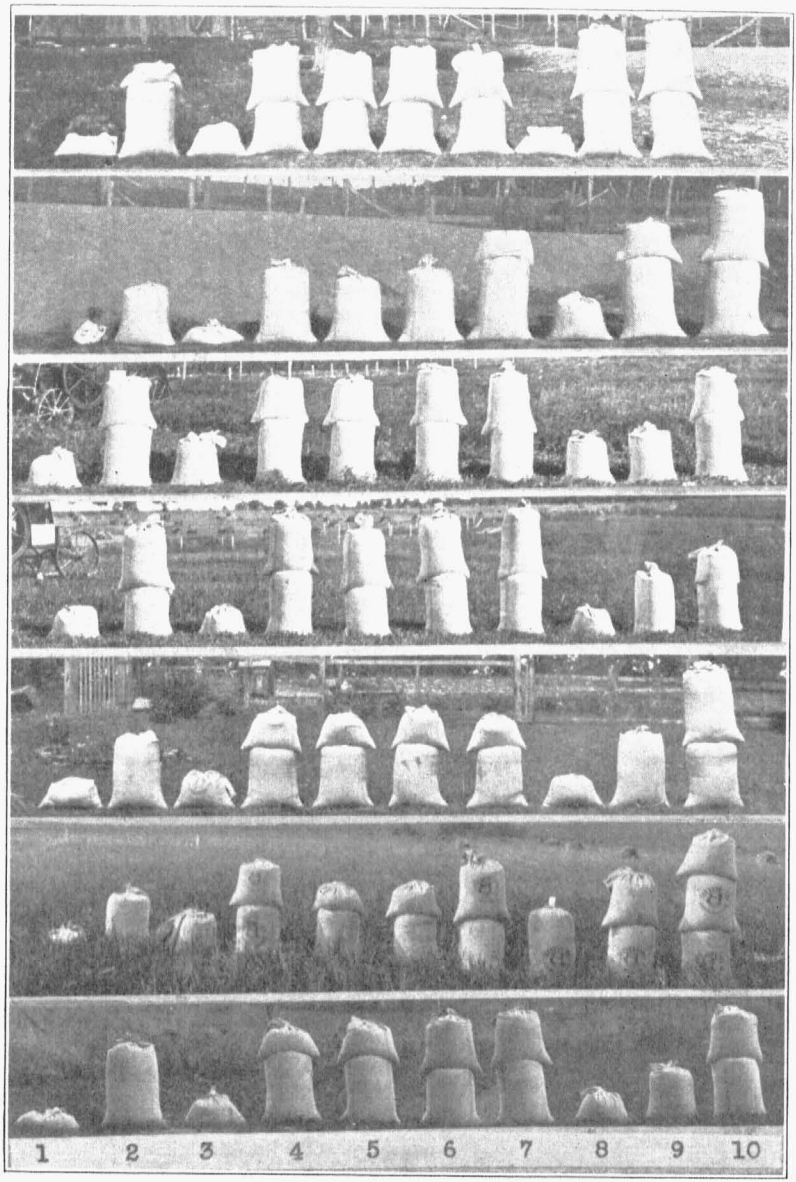

Fig. 6.—Yields of Wheat From All Plots Taken Immediately After Threshing Each Year.

1. Rye for green manure
2. Rye, bonemeal
3. No treatment
4. Rye, acid phosphate
5. Rye, acid phosphate, potash
6. Rye, acid phosphate, potash. Lime applied on surface.
7. Rye, acid phosphate, potash. Limestone plowed under.
8. No treatment
9. Manure
10. Manure, acid phosphate

phate or bonemeal. This is all the more important if the wheat is to be followed by clover or grass. Wheat should not be grown on this land oftener than once in a four- or five-year rotation, and then mainly as a nurse crop for clover.

Fig. 7.—Effect of Fertilizer on Wheat, 1919.
No treatment Yield, 3.45 bu. Bonemeal 150 lbs. Yield, 15.3 bu.

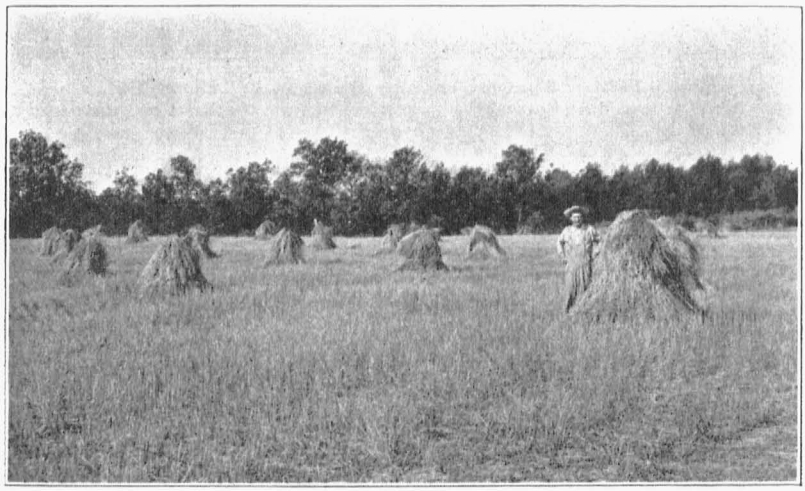

Fig. 8.—Rye Crop Cut for Grain, 1917. This land was treated in the fall with 160 pounds acid phosphate per acre. The yield of excellent quality grain was 25 bu. per acre.

EXPERIMENTS WITH RED CLOVER

(Six Crops)

The results with red clover have been as satisfactory as with any other crop on this experiment field. Where the land has received phosphates fair to good yields of clover have been obtained each year. The untreated soil has never produced a good crop. In the years 1919 and 1920 several of the plots made yields of over two tons of excellent clover hay per acre. Table 6 shows that each of the phosphate plots has averaged for the six years more than one ton an acre. These yields are significant because they show that where clover is properly treated with phosphate fertilizer it is a very sure crop on this soil. It withstands dry weather and is not killed out by

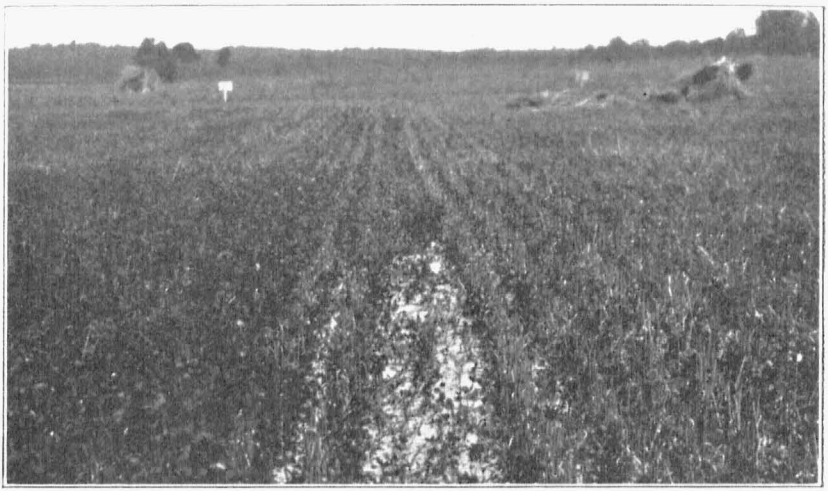

Fig. 9.—Effect of Limestone on Early Growth of Red Clover, 1921.
Fertilizer and limestone Fertilizer alone

the summer droughts as is the case on the untreated land. Furthermore, it makes a rapid growth and produces good yields of hay. On the untreated land the clover plants that come through are sickly and pale in color due to lack of fertility.

Lime has had little beneficial effect on clover on this soil, but has sometimes seemed to give a more uniform stand.

Manure has been of great value to the clover crop when applied to the wheat shortly before seeding the clover. Where the manure is applied before the corn in this rotation it is too far ahead of the clover to do it much good. Manure reinforced with acid phosphate has given an average yield of 3037 pounds of hay, which is considerably more than any of the other treatments.

Clover is a great soil building crop especially when some of the material is turned under, as has been done with the second crop on this field, or where the hay is fed to live stock and the manure returned to the soil.

Fig. 10.—Effect of Bonemeal on Clover Growth, 1922. Notice entire lack of clover on either side of fertilized plot. The yield of treated land was 2,515 lbs. an acre, of excellent quality clover hay.

TABLE 6.—RESULTS OF EXPERIMENTS WITH RED CLOVER—SIX CROPS.

Soil treatment	Average yield lbs. per acre	Increase yield over no treatment lbs. per acre	Value of increase per acre	Cost of treatment per acre	Net returns per acre
Rye for green manure	377	—159	$—0.80	$0.56	$—1.36
Rye, bonemeal, 150 lbs.	2648	2112	10.56	1.87	8.69
No treatment	536	.....	.....	.....	.....
Rye, acid phosphate, 175 lbs.	2235	1699	8.50	1.44	7.06
Acid phosphate, 175 lbs., rye, potash 25 lbs.	2068	1532	7.66	1.81	5.85
Acid phosphate, potash, rye. Limestone applied on surface	2046	1190	5.95	2.81	3.14
Acid phosphate, potash, rye. Limestone plowed under	2620	1764	8.82	2.81	6.01
No treatment	856	.....	.....	.....	.....
Rye, manure	1611	755	3.78	2.56	1.22
Rye, manure, acid phosphate	3037	2181	10.91	3.44	7.47

AVERAGE ANNUAL RETURN FROM EACH SOIL TREATMENT

The effect of a soil treatment is commonly measured or estimated by its effect upon some particular crop to which it is applied. To recognize the true value of a given system, however, we must consider the effects throughout a period of years and with the various crops in the rotation. Table 7 shows the average annual net return per acre from all crops used in the rotation. It should be remembered that in these tests the plots having rye as a green manure were on slightly poorer land than the untreated plots. Hence the increase due to bonemeal and the other soil treatments have been obtained by comparing with the untreated plots rather than with the rye plot since this might tend to exaggerate the effects of the treatments.

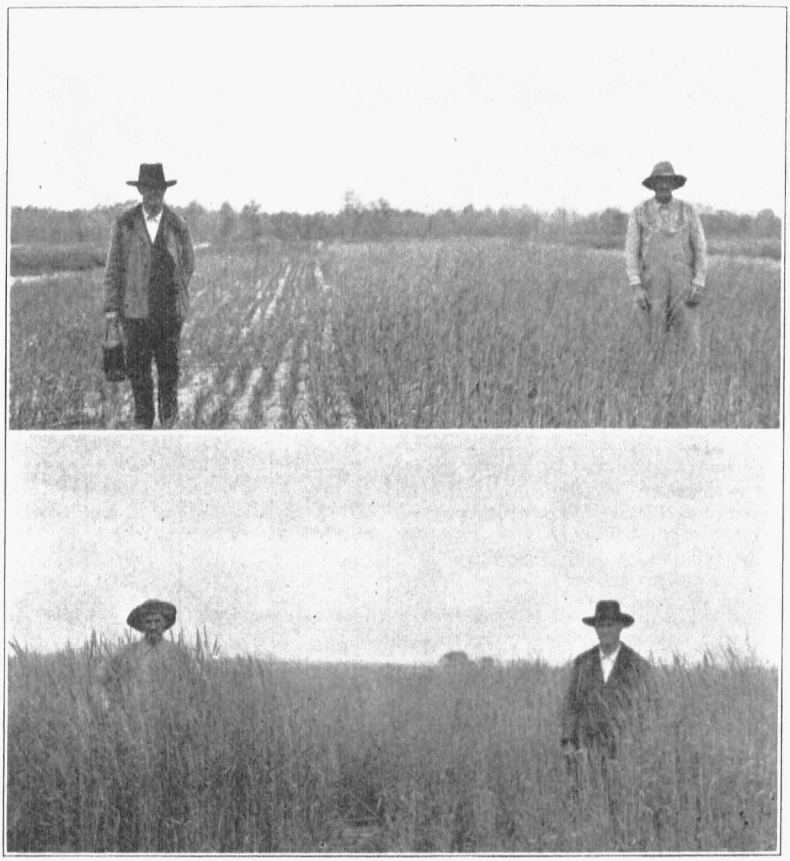

Fig. 11.—(Above) Rye Used for Green Manure in 1918. Plot at left had no treatment; plot at right, bonemeal.

(Below) Plot at left, manure and acid phosphate; plot at right, manure alone.

The green manure produced without fertilizer is worth very little. Where soil is properly treated a large amount of organic matter can be turned under.

TABLE 7.—ANNUAL NET RETURN FROM THE VARIOUS SOIL TREATMENTS AND ANNUAL PER CENT INCREASE ON INVESTMENT.

Soil treatment	Av. annual net return per acre all crops	Cost of treatments	Per cent return on investment
Rye for green manure	$—2.05	$0.56	—366
Rye, bonemeal	5.76	1.87	308
Rye, acid phosphate	6.68	1.44	464
Rye, acid phosphate, potash	5.62	1.81	310
Rye, acid phosphate, patash. Limestone applied on surface	5.40	2.81	192
Rye, acid phosphate, patash. Limestone plowed under	6.75	2.81	240
Rye, manure	3.86	2.56	150
Rye, manure, acid phosphate	7.96	3.44	231

When the per cent increase on investment is considered it will be seen that the returns from most of the treatments are high. There are few other farm operations that could be expected to pay 300 to 464 per cent on the investment as was the case where bonemeal and acid phosphate were used. There is no question, but that the use of these phosphatic fertilizers will be highly profitable on that great area of Ozark Upland represented by this experiment field.

SOIL MANAGEMENT BASED ON RESULTS OF THESE EXPERIMENTS

The results of these experiments should be of value to great numbers of livestock or general farmers in the Ozark Region of Missouri and Arkansas. They suggest very definite systems of management for this more or less gravelly upland soil. They agree in general with the results of other experiments in that region, particularly those of the St. James Experiment Field. (See Missouri Experiment Station Bulletin 148.) They differ from these experiments in showing little need for potash, but the other requirements for high yield are much the same. In both cases lime has brought only moderate returns, since the soil of neither field is very acid. The need for lime varies from farm to farm however, and the results to be expected from liming vary with the needs of any particular soil. Recommendations regarding the best systems of soil management are given in the following paragraphs.

Types of Farming.—Systems of farming adapted to this soil are limited to dairying and general livestock farming along with some fruit growing and special cropping. In the main, dairy farming is the most important; but both general livestock farming and dairy farming give best results when the farm includes some valley or bottom land to supplement the upland soil, and when a considerable amount of timber pasture or improved pasture is available. On many farms a small part of the area may well be devoted to special crops, such as tomatoes, grapes, strawberries or other small fruits. To these few acres the farmer can devote considerable of his time and expect

a large acre return. The remainder of the cultivated land can be used for growing feed for dairy cattle. In many cases, instead of the fruit and special crops, poultry raising may be followed with profit. There are few regions better suited to poultry farming.

This type of land is not suited to tenant farming. The crops which lend themselves to production by tenants are not well suited here. Or if such crops are produced, they require more careful systems of management than the tenant will give. Systems of dairy farming and special cropping require the careful attention of the land owner. Moreover, the soil is not one which can be exploited. The fertility is low, even in the virgin soil, and this fact should be borne in mind when planning a system of farm management.

Proper Cropping Systems.—This soil is poorly suited to corn growing. Kafir corn is usually better. Moreover, the dairy farmer on this land can not produce all his grain feed. Some of this must be bought. His principal crops should be legumes and other forages. Few soils need legumes more than this and few systems of farming need them more than a dairy or livestock system. Consequently, clover, soybeans and cowpeas, along with grass should make up the larger part of the rotation. An example of such a rotation would be corn or kafir, (grown mainly for silage), soybeans or cowpeas, wheat or rye, clover and grass two years. In this rotation, if the corn is removed for silage, rye may be seeded after it, to be pastured during the winter and early spring and the remainder turned under before planting the soybeans. Care should be taken to see that the soybeans are inoculated with the proper bacteria if they are being grown on the land for the first time. As a rule both clover and cowpeas bacteria are present in southern Missouri soils, although they may not be in soils where these crops have not been grown recently.

As a general thing only the better land on each farm should be kept in rotated crops where it is necessary to plow often. All the rough land should be seeded down to permanent pasture. This pasture land should receive enough attention to keep it producing a good crop of grass. This means that considerable attention will have to be given to killing sprouts, particularly on new land.

In getting this land down to pasture it is necessary to seed with the proper grasses. Orchard grass, redtop and Kentucky blue grass are among the most popular grasses for this region. These are best sown in mixtures and should usually include a small amount of red, alsike or white clover. Newly seeded grasses should not be pastured during the first year, and care should always be taken to avoid over-grazing, for this is one of the easiest ways to ruin a good pasture.

In addition to properly seeding mixtures or grasses it will doubtless be found profitable to use some phosphate fertilizer either at time of seeding or as a top dressing on the grass land. This together with the manure dropped on the land should gradually bring about more productive pasture.

Use of Manure.—Barnyard manure is usually considered the most valuable material for applying to soils to increase their productiveness. In fact

no one questions the value of this farm-produced fertilizer. It is worth noting, however, that in these experiments 8 tons of manure applied before corn in a four-year rotation has not given so great a crop return as has bonemeal or acid phosphate applied before corn and before wheat. On corn, the return from manure has been about the same as from acid phosphate. The residual effect on crops following the corn has not been as large as the returns from acid phosphate when applied before corn and before wheat. These figures, however, should not lessen our appreciation of the value of manure, but should serve rather to show the great need of this soil for phosphates.

There is always the complaint on soils of low fertility 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 can be increased. To produce large quantities of manure large crops must be grown, particularly legume crops. Low yields mean little manure and high yields much manure. If land produced only such yields as those of the untreated plots of this experiment field, these crops fed to stock would make but 2 tons of manure per acre during four years. On the other hand, if the land were fertilized, as in Plot 7, enough crops would be produced to give over 5 tons of high quality stable manure in four years, and in addition a heavy green manure crop of rye could be turned under once in each rotation. This shows very clearly how fertilizers may be used to increase the productiveness of a soil. If we can increase the amount of manure that can be applied in a 4-year rotation from 2 tons to over 5 tons and in addition turn under a heavy rye crop for green manure, we are on the right road to building up the fertility of this land. 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 increased production and use of farm manure is one of the most important things that can be done for the cultivated lands of southern Missouri. Manure must not be considered a waste product, but as one of the most valuable by-products of the farm.

(For further information regarding the production and handling of manure write for Bulletin 166, Missouri Experiment Station, Columbia.)

Use of Phosphorus.—These experiments have shown conclusively that phosphates are of tremendous value to this land. In fact they increase the yields and profits so much that no one should farm without them. Of the two phosphates used, acid phosphate and bonemeal, the results indicate that there is no great difference between them. The acid phosphate has given slightly better returns on corn and wheat, while the bonemeal has had a slight advantage on soybeans and clover. That is, the effect of the bonemeal has held over until the second year somewhat better than that of the acid phosphate. It is not an important question then, as to which one of these phosphates should be used, but rather, which can be used the most economically. 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 ¼ less than the 16 per cent acid phosphate, and it is slightly

better for the clover following wheat. However, bonemeal is usually somewhat high in price as compared with acid phosphate and the supply is often limited. Hence, in most cases, the acid phosphate will be the most economical. The acid phosphate should contain from 16 to 20 per cent available phosphoric acid. Some higher grade phosphates are coming on the market which can be used in smaller quantities and in time they may take the place of these common analyses.

These phosphates should be applied about once every two years, chiefly on grain crops. The residual effect the following year should be utilized by some forage crop. In these tests where the rotation has been corn, soybeans, wheat, clover, the phosphate has been applied before corn and before wheat, and the soybeans and clover have taken out the fertilizer

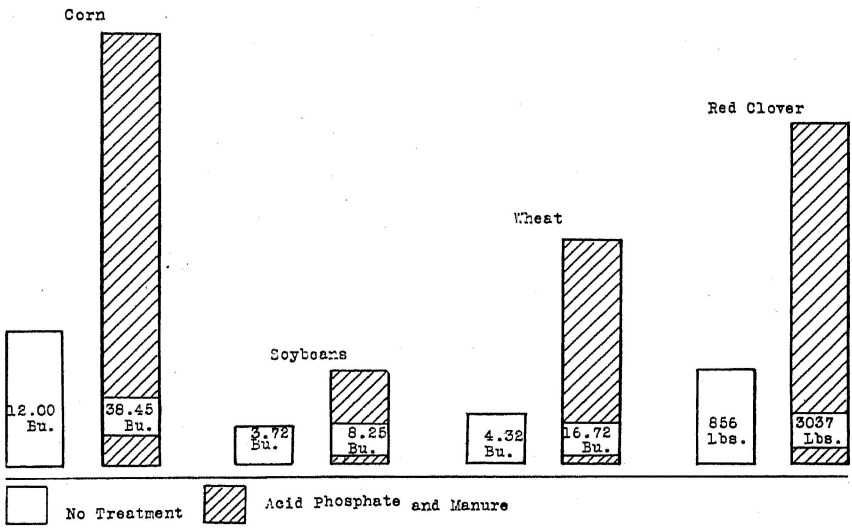

Fig. 12.—Relative yields of corn, soybeans, wheat, and clover on treated and untreated land.

left by the grain crops. Where the clover and grass are seeded alone the phosphate should be applied at the time these are put in. The rates of application should be from 175 to 225 pounds of 16 per cent acid phosphate or 125 to 175 pounds of bonemeal before the grain crops, such as kafir, corn, wheat or rye and slightly less when seeding clover and grass alone. As a rule steamed bone is more economical than raw bone. Phosphates should be used even though considerable manure is applied. In fact the highest returns may be expected from the combination of manure and phosphates. Animals retain considerable phosphorus in their bones and this is lost from the farm when the livestock is sold. Manure is therefore low in phosphorus. A good plan is to apply 20 or 30 pounds of acid phosphate to the manure before spreading, and in addition apply more phosphate at the time of seeding the unmanured grain crops.

Use of Potassium.—Potash has given no increase in crops on this field, so that its use could not be recommended for soils of this kind. It should be said, however, that on some soils in southern Missouri, particularly the prairie areas in the Ozarks and in southwestern Missouri, potash along with phosphate can often be used with considerable profit. On the rough uplands it is generally less likely to give returns.

Use of Mixed Fertilizers.—If factory mixed fertilizers are to be used on such land as this they should be of high grade, containing from 3 to 4 per cent of nitrogen (or ammonia) and 12 to 14 per cent available phosphoric acid. One of the standard brands of fertilizer in Missouri known as 4-12-0 may be used to advantage on the wheat crop. Or it may sometimes be used when seeding down meadows or pastures, in order to give the grass a good start. On the whole, however, it is better farm practice to produce most of the nitrogen on the farm by growing legumes such as clover and soybeans and by returning the manure to the land.

The Use of Lime.—Lime was used in two different ways on this field. In one case it was applied on the surface and disked in after the land was plowed. In the other it was put on before plowing, disked into the surface and then plowed under. The latter method has given slightly better results although the difference is doubtless within limits of error. The return from lime has not been very striking in either case and there seems to be less need for it on this soil than on many other soils. Soils such as this usually give their first and greatest response to phosphate rather than to lime. This has been the case on this field and on some other very thin lands in southern Missouri. In many cases, however, both materials are needed to insure the best returns during a rotation. Lime will often aid materially in getting a stand of clover, but phosphates are usually required to produce a luxuriant growth. It is always wise to have the soil tested for acidity in order to decide how necessary it is to use lime.

Limestone is usually applied at the time of seeding wheat. It can be put on either before or after plowing, but in either case it should be disked into the soil. Where lime is shipped from a distance the weather is usually more satisfactory in the fall and furthermore farm work is not so pressing as in spring. Where home grinding is done, it is often found more convenient to do this during the winter season. In this case the lime may be put on before corn or in some cases it may even be spread on winter wheat if the ground is not rolling enough to cause loss by erosion. As a rule the rate of application of ground limestone will be from one to two tons an acre on soils that have shown a marked need for lime.

SUMMARY

1. The experiments reported in this bulletin were begun in the fall of 1915, so that seven years' results are available.

2. The use of 150 pounds of steamed bonemeal or 175 pounds of 16 per cent acid phosphate has given excellent increases in the yield of all crops.

3. Money invested in these materials has returned a profit of 300 to 400 per cent on the investment.

4. Manure used along with acid phosphate has given a higher net return than any of the other treatments.

5. The amount of manure produced on farms of this sort should be increased. This can be done by improving the crop yields through the use of phosphatic fertilizers.

6. Much attention should be given to adapting a system of cropping to the farm. All cultivated land should have a good rotation of crops including legumes.

7 On most farms in this region some land should be devoted to intensive culture of special crops like strawberries, tomatoes, grapes and small fruits. The remainder of the farm could then be handled in a system of livestock or dairy farming preferably with the use of considerable land for pasture.

8. Poultry raising might well be made an important part of most farm operations on this type of land.

9. More attention should be given the matter of permanent pastures. These can be improved by the use of proper seeding mixtures and by the use of phosphate at the time of seeding.

10. Manure even in liberal applications is not sufficient for fertilizing this land; it should be supplemented by phosphates.

11. Potash has not given profitable returns when applied to this soil.

12. Legumes should be grown in all rotations because they gather nitrogen from the air, and if the crops are fed and the manure returned they afford the most practical method of increasing the nitrogen supply in this soil.

13. Red Clover should be grown at least once in four years. Where phosphates have been used, the clover crop has been practically certain. If the land is properly treated clover failures will occur very seldom. Dry weather seldom kills clover if the land is well supplied with phosphates and lime.

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