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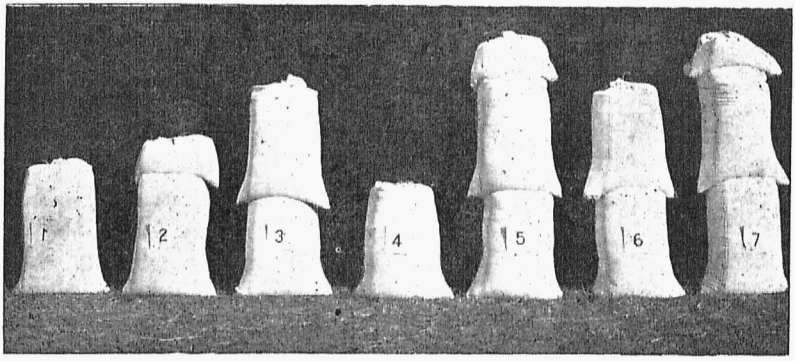
SOIL EXPERIMENTS ON OZARK UPLAND



Comparative Wheat Yields St. James Experiment Field, Six-Year Average.

1. Legume; 2. Legume, Lime; 3. Legume, Lime, Bone; 4. No Treatment; 5. Legume, Lime, Bone, Potash; 6. Manure; 7. Manure, Rock Phosphate.

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UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Soil Experiments on the Ozark Upland

(SOIL TYPE—GERALD SILT LOAM)

M. F. MILLER AND F. L. DULEY

Considerable areas of non-timbered upland exist in the Ozark region of Missouri. Because of a rather level topography and a freedom from timber and stone much of this land has been in cultivation for many years. These areas were originally covered with a rather heavy growth of "blue stem" grass and are known today as rather good grass lands where not too flat. They were originally quite productive but they are not well supplied with plant food naturally and they deteriorate rapidly under cultivation. These soils are classed in the soil survey records principally as Gerald and Cherokee silt loams. They occur not only in the Ozark region but also in the prairie region of Southwest Missouri.

The experiments reported in this bulletin were conducted on this non-timbered land. The experiment field is located on the farm of Woodworth and Linnenburger, one mile west of St. James, Phelps county. They were begun in the spring of 1910 and form a part of a general scheme of soil investigations now being conducted by the Agricultural Experiment Station of the University of Missouri. The purpose of these investigations is to determine the best systems of soil management for the various soil types of the state. This particular type of soil forms an important part of the tillable land of the Ozark region, and the results secured should have a wide application on the level to undulating uplands of that section.

There is a general impression among farmers that a soil analysis will give all the information needed regarding the fertilization of the soil, but unfortunately this is not the case. The soil analysis is valuable, but the handling of a piece of land so as to make a net return depends upon a number of different factors. The most reliable information is secured only when a soil analysis is accompanied by careful field experiments. It is for this reason that these experiment fields have been established on the more important soil types in Missouri.

DESCRIPTION OF THE SOIL

The soil type on which this St. James experiment field is located is known as Gerald silt loam. It consists of a gray to brown silt loam, seven to nine inches in depth underlain by yellowish gray or gray, heavy silt loam. A brown to grayish brown stiff clay loam is encountered at twenty-eight to thirty inches, changing to more friable yellowish gray silty material. Small chert (popularly known as flint) fragments, highly weathered, are scattered thruout the soil section and are rather conclusive evidence that the soil was derived from limestone. No pronounced gravelly substratum occurs within three feet of the surface.

COMPOSITION OF THE SOIL

The seven elements supplied to plants from the mineral and organic matter of the soil are nitrogen, phosphorus, potassium, calcium, magnesium, iron and sulphur. Of these the first three, nitrogen, phosphorus and potassium, are the principal ones with which the farmer need concern himself, since they are the ones most likely to be deficient in the soil, so far as the needs of plants are concerned. The element calcium, usually referred to in the compound known as lime, may not be sufficient in quantity to keep a soil sweet, in which case it also becomes important. Its importance, however, is not because it is deficient as a plant food but simply because there is not enough lime to keep the soil from becoming sour. A soil containing too little lime is therefore said to be acid and to have a certain lime need or lime requirement. That is, it requires a definite amount of lime carbonate or ground limestone to sweeten the surface soil. The following table shows the quantity of nitrogen, phosphorus and potassium in the Gerald silt loam, as well as the lime requirement of this soil, in comparison with what might be termed a very rich soil.

	Pounds in surface 7 inches of an acre			
	Nitrogen	Phosphorus	Potassium	Lime Need
Very Rich Soil	6000	2000	30,000	0
Gerald Silt Loam at St. James	2340	1320	21,480	4800

An examination of these figures shows that this soil is deficient in its stock of all three of the important elements of fertility as compared with what might be termed a very rich soil and that it is also sour enough to require 4800 pounds of finely ground limestone to sweeten the surface seven inches of an acre. Such an analysis indicates that the soil would respond to increasing the nitrogen supply

Plan of Experiment Field.

Series B

14 Manure
Rock Phosphate

13 Manure

12 Legume, Lime
Bone meal, Potash

11 No Treatment

10 Legume, Lime
Bone meal

9 Legume, Lime

8 Legume

Series D

28 Manure
Rock Phosphate

27 Manure

26 Legume, Lime
Bone meal, Potash

25 No Treatment

24 Legume, Lime
Bone meal

23 Legume, Lime

22 Legume

7 Manure
Rock Phosphate

6 Manure

5 Legume, Lime
Bone meal, Potash

4 No Treatment

3 Legume, Lime
Bone meal

2 Legume, Lime

1 Legume

Series A

21 Manure
Rock Phosphate

20 Manure

19 Legume, Lime
Bone meal, Potash

18 No Treatment

17 Legume, Lime
Bone meal

16 Legume, Lime

15 Legume

Series C

thru proper farm practices such as rotation, manuring and the growing of legumes, that the addition of phosphorus and potassium in the form of fertilizers would give some return and that lime should be used to sweeten the soil. The analysis shows nothing, however, as to the economic return to be expected from such treatments. It is left to the field experiments to determine just how remunerative such treatments would be. An examination of the results of the experiments will show that a response was secured from these various treatments with certain definite financial returns.

PLAN OF THE EXPERIMENTS

The experiments were planned with the idea of determining the most remunerative systems of management for this soil, under a cropping system including the common crops. The field was divided into four series of seven one-fifth acre plots. A four year rotation of corn, soybeans, 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 thru this four year rotation. Each of the seven plots in these series was given a different treatment, altho the plan of each series was the same. The complete plan of treatment is shown in the diagram, page 5.

SOIL TREATMENTS

During the first year of the experiment the entire field was sown to cowpeas and these were plowed under on those plots marked legume treatment. They were removed from the no-treatment and manured plots. Since that time the legume treatment has consisted in seeding cowpeas at the last cultivation of the corn or in the hill with the corn at planting time and leaving them on the ground to add organic matter and nitrogen. The cost of such green manure treatment for both the first and subsequent years has been based on the cost of producing the crop, rather than on the value of the crop itself.

The bone meal used as a carrier of phosphorus was a high grade steamed bone meal containing 0.82 per cent nitrogen and 29 per cent phosphoric acid. It was applied at the rate of 150 pounds per 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 wheat drill, and in the case of wheat it was drilled in with the same drill at the time the wheat was sown.

The potassium was supplied in the form of a standard grade of muriate of potash. It was applied at the rate of 50 pounds per acre until the fall of 1915 when the application was reduced to 25 pounds per acre.

Effect of Soil Treatments in the Growth of Wheat 1914

Legume	Legume Lime	Legume Lime Bone	No Treatment	Legume Lime Bone Potash	Manure	Manure Rock Phosphate
Yield 20.9 bu.	Yield 20.4 bu.	Yield 33.6 bu.	Yield 14.5 bu.	Yield 35.8 bu.	Yield 29.0 bu.	Yield 33.6 bu.

The rock phosphate applied with manure to balance it in phosphorus was used at the rate of 1000 pounds per acre. It was scattered on the manure and plowed under for corn every fourth year.

The manure used was ordinary barnyard manure. It was applied once in the rotation (that is on the clover stubble) at the rate of 8 tons per acre and plowed under for corn.

The lime was added in the form of finely pulverized limestone applied at the rate of 2 tons per acre. One application only was made during the first six years, and that at the beginning of the experiment.

The acre cost of each of the soil treatments, as shown in the following table, represents the approximate cost to the farmer of these materials applied to the land. These costs have been computed at the prices of fertilizing materials somewhat above those prevailing before the outbreak of the war. It is assumed that the prices will drop again to these figures when the war is over.

In estimating farm value of various crops it has been deemed best to disregard the present abnormal prices due to war conditions. The prices, therefore, have been fixed at what might be termed fair average figures for the period just preceding the present price inflation. The value of wheat straw and corn stover has been estimated at the probable field value where no cost of handling is considered. The other prices are based on harvested valuations of these crops. A list of these crop prices together with the cost of the fertilizers and other soil treatments is shown in the following table.

Crop Prices		Fertilizer Prices	
Corn	$ 0.60 a bushel	Cowpea crop turned under	$ 8.50 an acre
Wheat	.90 " "	Legume, cowpeas in corn	.50 " "
Clover Hay	11.00 a ton	Steam bone meal	30.00 a ton
Cowpea hay	11.00 " "	Muriate of potash	60.00 " "
Soybean hay	11.00 " "	Rock Phosphate	10.00 " "
Wheat straw	2.00 " "	Ground limestone	3.00 " "
Corn stover	.75 " "	Barnyard manure	.85 " "

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 tends to offset the other in the final accounting. Losses are indicated by minus signs in the tables.

While the fertilizer treatments are given to corn and wheat only, it is known, of course, that the other crops tend also to benefit from these treatments. The total cost of all soil treatments used during the six years has been divided therefore, equally between the various crops receiving a benefit.

Results of various soil treatments have been secured on six crops of corn, six crops of wheat, six crops of soybeans, four crops of cowpeas and two crops of clover. The reason for the appearance of cow peas in the cropping system since 1912 is because of certain clover failures where cowpeas were substituted. The table which follows shows the average yields of these various crops during the period of the experiment.

TABLE 1.—AVERAGE YIELDS PER ACRE OF ALL CROPS GROWN ON ST. JAMES EXPERIMENT FIELD 1911-1916

Treatment	Corn Bu.	Corn Stover Lbs.	Wheat Bu.	Wheat Straw Lbs.	Soy-beans Lbs.	Cowpeas 4 crops Lbs.	Clover 2 crops Lbs.
Legume	20.75	1334	10.95	1133	2927	1488	775
Legume, lime	24.98	1607	12.08	1281	3196	1666	1687
Legume, lime, bone meal	26.56	1674	18.56	1963	3273	2017	4912
No treatment	20.84	1481	8.75	894	2592	1387	657
Legume, lime, bone meal, potash	36.25	2286	21.85	2344	3392	2065	5425
Manure	43.01	2593	17.71	2062	3646	2727	3087
Manure, rock.... phosphate	44.88	2735	21.38	2535	3934	2988	3837

An examination of this table will show a similarity in the response from the different treatments on all crops. Some crops, however, will be seen to respond very much more than others to the same treatments. This is particularly true in case of phosphates on clover and wheat, with which the response was materially larger than with the other crops.

EXPERIMENTS WITH CORN

The experiments with corn have shown that the average yield on the plot having no special soil treatment has been approximately that reported as the average yield in Phelps county during the same period. This shows that this land is probably not quite so good as the average land in corn in this county. It is at least no better. This means that those treatments which have brought marked return could be expected to bring similar return on this average upland anywhere in the county. The following table shows the financial return of the various treatments on the corn crop.

The legume treatment has given no benefit on the corn crop. During three years the yield of the plot receiving this treatment was slightly above the plot receiving no treatment but in the other three years it was slightly less. In 1911 and 1912 the yield was somewhat

TABLE 2.—RESULTS OF EXPERIMENTS WITH CORN (SIX CROPS)

Treatment	Average Yield Bu. per Acre	Increased Yield Over No Treatment Bu. per Acre	Value of Increase Per Acre	Cost of Treatment Per Acre	Net Return Per Acre
Legume	20.75	—0.09	$—0.05	$1.54	$—1.59
Legume, lime	24.98	4.14	2.48	2.54	—0.06
Legume, lime, bone meal	26.56	5.72	3.43	3.71	—0.28
No treatment	20.84	.....	.....	.....	.....
Legume, lime, bone meal potash	36.25	15.41	9.25	4.46	4.79
Manure	43.01	22.17	13.30	2.05	11.25
Manure, rock phosphate	44.88	24.04	14.42	3.42	11.00

increased due to the effects of the cowpea green manure crop that was plowed under in 1910. In the later years, however, this effect has not been appreciable and the growing of cowpeas between the rows of corn or in the hill with the corn has decreased the corn yield slightly, thus more than offsetting the effect of the cowpeas turned under the first year. This as well as other experiments in the state shows that cowpeas grown with the corn decrease the corn yield slightly. This decrease as a rule varies from one to five bushels, and since corn is a money crop any benefit derived on other crops following the corn has not usually been sufficient to offset the loss to the corn crop. If these peas could have been pastured down with hogs or cattle instead of being turned under, it is very likely that this would have brought an economic return.

Lime has been beneficial to the corn crop as may be seen by comparing the yields of the plot receiving legume treatment with that receiving both legume treatment and lime. Corn seems to respond to the use of lime somewhat better than wheat, altho it does not respond so well as the legume crops.

Bone meal has increased the yield of corn in all cases, excepting during the season of 1916 when a severe drouth followed a wet spring, thus greatly interfering with satisfactory returns.

It will be observed that the treatments so far discussed have not increased the yield of corn sufficiently to pay for the extra cost. This is largely due, however, to the fact that the cowpea green manure crop which was plowed under in the beginning of the experiments cost in labor, seed, and other things, $8.50. Furthermore, on account of late

seeding, the cowpea crop was rather light and no great amount of green material was turned under. Thus far the increase in yield due to this treatment has not been sufficient to meet the cost of this green manure crop when charged for at this rate.

The complete fertilizer treatment including legume, lime, bone meal and potash gave an average yield of corn of 15.41 bushels per acre above the untreated plot. This gave a very good net return in spite of the green manure charge. The beneficial effect of potash on this field is also shown on the growth of the wheat and clover.

Effect of Soil Treatment on Corn 1915

Plot on right received no soil treatment and yielded but 11.4 bushels of corn per acre. The plot on left received legume, lime, bone, potash treatment, yielding 36.3 bushels per acre. This same season the plot receiving manure and rock phosphate yielded 49.4 bushels per acre.

Manure has given a net return per acre considerably larger than the legume, lime, bone and potash treatment. When the manure was reinforced with rock phosphate the yield was increased but the net return was slightly decreased.

EXPERIMENTS WITH WHEAT

During the first four years of the experiments the seasons were fairly good ones for wheat and some very substantial increases were secured from the various soil treatments. The 1915 wheat crop was very seriously injured by the hessian fly. In spite of the fact that the yields were low the returns from the soil treatments were rather marked. The 1916 crop was badly winter killed and the yields were extremely low. This was particularly true on the untreated plot

which was more seriously injured by a heavy sleet than the other plots. This seems to have been due to the fact that the wheat was shorter and was therefore more completely covered by the ice on this plot. Table 3 shows the summarized results of the treatments and the financial return.

It will be observed that a net return on wheat is secured mainly with phosphates, potash and manure. Legume has brought a slight

Effect of Soil Treatment on Wheat 1913

The plot on the right received no special soil treatment. The plot had but three wheat shocks and the yield was only 14 bushels per acre. The plot on left received legume, lime, bone, and potash treatment. The plot had eight shocks of wheat and yielded 35.8 bushels of good wheat per acre.

TABLE 3.—RESULTS OF EXPERIMENT WITH WHEAT (SIX CROPS)

Treatment	Average Yield Bu. per Acre	Increased Yield Over No Treatment Bu. per Acre	Value of Increase Per Acre	Cost of Treatment Per Acre	Net Return Per Acre
Legume	10.95	2.20	$1.98	$1.54	$0.44
Legume, lime	12.08	3.33	3.00	2.54	0.46
Legume, lime, bone meal...	18.56	9.81	8.83	3.71	5.12
No treatment	8.75	.....	.....	.....	.....
Legume, lime, bone meal, potash	21.85	13.10	11.79	4.46	7.33
Manure	17.71	8.96	8.06	2.05	6.01
Manure, rock phosphate	21.38	12.63	11.37	3.42	7.95

return, altho lime has not increased the yield much more than enough to pay its cost. Where bone meal has been added a very substantial increase has been secured and this has been further augmented by the application of potash. A still larger net return has been secured by the use of barnyard manure reinforced with rock phosphate. It must be understood, however, that the manure and the rock phosphate have not been applied to the wheat crop directly but rather to the corn crop grown two years preceding, and only a fourth of the cost of these treatments is charged to the wheat. It must also be observed that manure has been used at the rate of 8 tons per acre once in four years which is probably somewhat more than the average farmer can apply. There is little doubt, however, that the application of manure and either acid phosphate or rock phosphate before corn will also bring excellent returns on the wheat crop which follows one or two years later.

EXPERIMENTS WITH SOYBEANS

The yields of soybeans thruout this experiment have been good. The average runs from about one and a fourth tons on the untreated land to almost two tons on the manure and rock phosphate plot. Very marked results have been secured from the various soil treatments on the crop. Soybeans are apparently well adapted to this region, even better than cowpeas as indicated by the comparative yields. The following table shows the yields and financial return secured.

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

Treatment	Average Yield Lbs. per Acre	Increased Yield Over No Treatment Lbs. per Acre	Value of Increase Per Acre	Cost of Treatment Per Acre	Net Return Per Acre
Legume	2927	335	$1.84	$1.54	$0.30
Legume, lime	3196	604	3.32	2.54	0.78
Legume, lime, bone meal	3273	681	3.75	3.71	0.04
No treatment	2592				
Legume, lime, bone meal, potash	3392	800	4.40	4.46	—0.06
Manure	3646	1054	5.77	2.05	3.72
Manure, rock phosphate	3934	1342	7.38	3.42	3.96

It will be observed in the case of soybeans that lime and legume treatment have had some influence, but that neither bone meal nor potash has paid the cost of application. Manure on the other hand has paid well and when reinforced with rock phosphate has paid still better.

EXPERIMENTS WITH COWPEAS

During 1910 cowpeas were grown on this field as a regular crop to be turned under as green manure on the legume treated plots. They were grown as a regular crop in 1911 because there had been no opportunity to seed clover. Since then they have been grown only as a substitute for clover when clover failed. Light yields were secured in both 1912 and 1913, due possibly to dry weather at the time the cowpeas should have been making their greatest growth so that the results have not been entirely satisfactory. The yields in other years were good, however, and it seems reasonable to believe that while cowpeas are not as well adapted as soybeans they will make a very satisfactory crop for this land. The following table shows the results secured with this crop.

TABLE 5.—RESULTS OF EXPERIMENTS WITH COWPEAS (FOUR CROPS)

Treatment	Average Yield Lbs. per Acre	Increased Yield Over No Treatment Lbs. per Acre	Value of Increase Per Acre	Cost of Treatment Per Acre	Net Return Per Acre
Legume	1488	101	$0.56	$1.54	$—0.98
Legume, lime	1666	279	1.53	2.54	—1.01
Legume, lime, bone meal ..	2017	630	3.46	3.71	—0.25
No treatment	1387	.....	....	....	.....
Legume, lime, bone meal, potash	2065	678	3.73	4.46	—0.73
Manure	2727	1340	7.37	2.05	5.32
Manure, rock phosphate ...	2988	1601	8.81	3.42	5.39

It will be noticed that the untreated land has averaged for the four years a little less than a ton per acre, while the largest average yield—approximately one and one-half tons per acre—has been secured from the manure and raw rock phosphate treatment. None of the treatments, except manure alone and manure in combination with raw

phosphate, has paid. The manure alone, however, is by far the most important treatment given this crop. It would scarcely seem feasible, therefore, to fertilize cowpeas on this land, altho it must be remembered that the fertilizer has not been applied directly to the peas in this experiment but to the wheat crop preceding, so that the peas have secured the residual effect only. It is possible that the fertilizer would have paid if it had been applied directly to the pea crop.

EXPERIMENTS WITH RED CLOVER

It has been found very difficult to get a stand of red clover on this field, particularly without some soil treatment. As a matter of fact only two crops have been harvested from five seedings and no good yields have been secured except in the case of treated plots. The following table shows the results with red clover.

The value of lime on the clover crop is very apparent, altho the return from phosphates has been very much greater. Potash has increased the net return somewhat, while both manure and rock phosphate have paid well. It would seem that lime and phosphorus are evi-

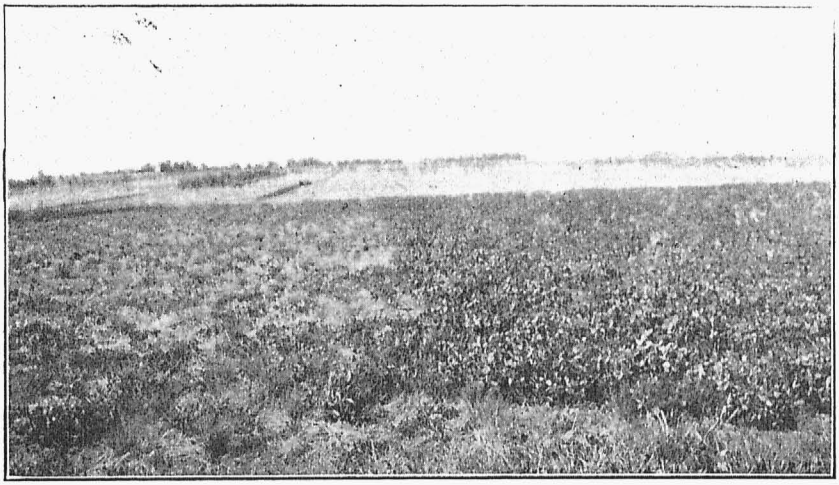
TABLE 6.—RESULTS OF EXPERIMENTS WITH RED CLOVER (TWO CROPS)

Treatment	Average Yield Lbs. per Acre	Increased Yield Over No Treatment Lbs. per Acre	Value of Increase Per Acre	Cost of Treatment Per Acre	Net Return
Legume	775	118	$ 0.65	$1.54	$—0.89
Legume lime	1687	1030	5.66	2.54	3.12
Legume, lime, bone meal ..	4912	4255	23.40	3.71	19.69
No treatment	657	.....	....	....	.....
Legume, lime, bone meal, potash	5425	4768	26.22	4.46	21.76
Manure	3087	2430	13.36	2.05	11.31
Manure, rock phosphate ...	3837	3180	17.49	3.42	14.07

dently essential to producing a good clover crop on this land. Such treatments will greatly increase the chances for a satisfactory stand as well as largely increase the yield. If lime, phosphates and manure are all applied in the proper amounts and in the proper manner there seems little doubt that clover can be made a rather profitable crop.

AVERAGE ANNUAL RETURN FROM EACH SOIL TREATMENT

The net return on individual crops is doubtless of first interest to the farmer, but in the final analysis the average net return per year is most important. The following table shows both in dollars and per cent on investment the yearly net return per acre from each plot treatment.



The Effect of Soil Treatment on Clover 1916

The plot on the left received no soil treatment and yielded 1015 pounds per acre of hay, mostly weeds. The plot on right received legume, lime, and bone meal and yielded 5950 pounds per acre of good clover hay.

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

Treatment	Av. Annual Net Return per Acre All Crops	Cost of Treatments	Per Cent Return on Investment
Legume	$—0.45	$1.54	—29.2
Legume, lime	0.39	2.54	15.3
Legume, lime, bone meal ..	2.82	3.71	76.0
Legume, lime, bone meal, potash	4.71	4.46	105.6
Manure	7.07	2.05	344.8
Manure, rock phosphate ...	7.79	3.42	227.7

It will be seen from this table that all treatments except the legume treatment, have given an excellent return on the money invest-

ed. The failure to secure a net return from the legume treatment has probably lessened somewhat the net return from the lime, bone meal, and potash, treatments since it has always been combined with them. The large percentage return on the cost of manure is one of the striking results when manure is figured at the value of 85 cents per ton which is an estimated charge for care and application when it is produced on the farm. Manure could rarely be bought and applied at this figure.

AVERAGE RETURN FROM INDIVIDUAL SOIL TREATMENTS

While it is impossible to establish the exact effect of an individual soil treatment such as liming, for instance, when combined with other treatments, nevertheless a comparison of the different combinations shows approximately what may be expected. For instance the effect of lime in a legume and lime treatment may be determined by comparing the yield of the plot receiving legume treatment alone with that receiving legume and lime. The following table shows the return from each treatment on each crop, calculated in this manner where calculation has been necessary.

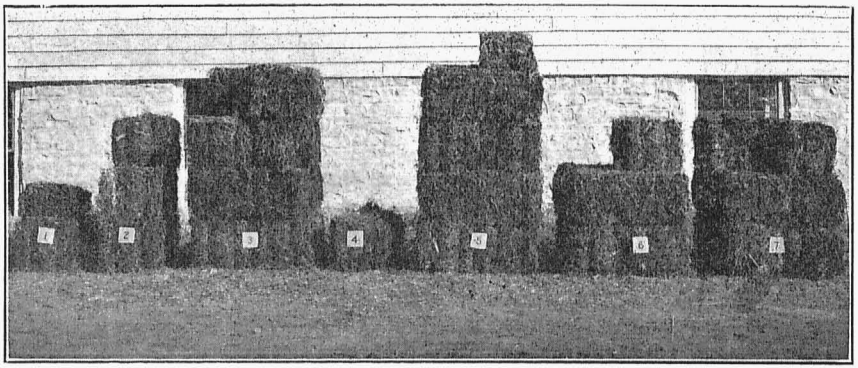
TABLE 8.—AVERAGE ANNUAL RETURN FROM INDIVIDUAL TREATMENTS

Treatment	6 yrs. Av. Return on corn	6 yrs. Av. Return on wheat	6 yrs. Av. Return on soybeans	4 yrs. Av. Return on cowpeas	2 yrs. Av. Return on red clover
Legume ...	$—1.59	$0.44	$0.30	$—0.98	$—0.89
Lime	1.53	0.02	0.48	—0.03	4.01
Bone meal	—0.22	4.66	—0.74	0.76	16.57
Potash	5.07	2.21	—0.10	—0.48	2.07
Manure ...	11.25	6.01	3.72	5.32	11.31
Rock phosphate	—0.25	1.94	0.24	0.07	2.76

It will be seen that the legume treatment has paid on wheat and soybeans only, and this has not been sufficient to make up for the losses on the other crops. The lime has paid on all crops except cowpeas where the loss is very small. The bone meal has paid best on wheat, as has been the case on most other experiment fields in the state. The loss on corn was caused mainly by the low yield of 1916 probably resulting from the severe drouth of that season. Potash has brought exceptionally good returns on this field, especially on corn, wheat and clover, but it has failed to give a net return on cowpeas and soybeans. Manure has given a very substantial return on all crops, while raw rock phosphate combined with it has paid well on wheat and clover.

TABLE 9.—AVERAGE ANNUAL ACRE RETURN AND PER CENT INCREASE FOR INDIVIDUAL TREATMENTS ON ALL CROPS

Treatment	Cost of Treatment per Acre	Net Return from Treatments per Acre	Per Cent Increase on Investment
Legume	$1.54	$—0.45	—29.2
Lime	1.00	0.84	84.0
Bone meal	1.17	2.43	207.7
Potash	0.75	1.88	250.6
Manure	2.05	7.08	345.3
Rock phosphate	1.37	0.72	52.6



Comparative clover Yields St. James Experiment Field, Two-Year Average

1. Legume—Yield, 775 lbs.; 2. Legume, Lime—Yield, 1687 lbs.; 3. Legume, Lime, Bone—Yield, 4912 lbs.; 4. No Treatment—Yield, 657 lbs.; 5. Legume, Lime, Bone, Potash—Yield, 5425 lbs.; 6. Manure—Yield, 3087 lbs.; 7. Manure, Rock Phosphate—Yield, 3837 lbs.

The foregoing table showing the per cent return on the investment for each individual treatment greatly favors the manure. The returns on bone meal and potash have also been very significant. At approximately normal prices potash will give good return on the money invested in it. The low price charged to the manure, as compared with the return secured, in part accounts for the higher percentage return on a dollar invested. The important column in this table is that showing the net return per acre. It will be noticed that barnyard manure stands far ahead of the other treatments and that bone meal stands next. This certainly emphasizes the great importance of saving every bit of available manure to use on this land and of buying it if it can be secured at a reasonable price. Each ton of manure has returned $3.54 above the cost of handling and it might be said further that not all the value of the manure has yet been obtained, since the manure plots are in a much better state of fertility than formerly. The table also indicates the importance of using phosphate and lime while at the normal price of potash this can also be used with much profit.

COST OF PRODUCTION

The foregoing tables and discussions have had to do with the return from soil treatment as shown by the value of the increase secured, together with the cost of treatment. This however does not show the net return to the farmer per acre cultivated, since no account has been taken of the cost of producing the various crops as based on labor, taxes and interest on the investment. While it is manifestly impossible to give exact figures on the cost of producing crops, attempts to establish a fairly accurate estimate have been made by various farmers and experiment station workers. The figures used here are those obtained by the Department of Farm Management of the University of Missouri thru the investigation of costs of production on a large number of Missouri farms valued at $75 per acre. These are pre-war figures. They include interest on land, taxes, upkeep, cost of labor and seeds. The following statement shows the cost of production. The figures are taken at the nearest dollar to the actual figures secured.

	Acre Cost of Production
Corn	$12.00
Soybeans	12.00
Wheat	11.00
Cowpeas	11.00
Clover	7.00

For the treated land there must be added to the foregoing figures the cost of treatment (Tables 2 to 6) as well as the cost of harvesting and marketing the crop increase secured. The following statement shows the harvesting and marketing figures used.

Corn—husking and marketing the crop increase secured.....$ .07 a bu.
Soybeans—harvesting and hauling to barn the crop increase secured ..... 1.20 a ton
Wheat—harvesting and marketing the crop increase secured..... .13 a bu
Cowpeas—harvesting and hauling to barn the crop increase secured ..... 1.20 a ton
Clover—harvesting and hauling to barn the crop increase secured ..... 1.20 a ton

In the previous discussion on net return from the various soil treatments no account was taken of the corn stover and wheat straw increases. In determining the net return when cost of production is

taken into account it is necessary to place a value on these increases and add it to the value of the grain produced. Consequently corn stover has been valued at $0.75 per ton in the field and the wheat straw at $2.00 per ton in the stack.

Taking all crop values and cost of production figures into account and including the number of years each crop was grown, the average annual acre values of all crops above the cost of production and soil treatment are as shown in the following table.

The table shows that on the untreated land the crop return has been insufficient to pay the cost of production. This means that at the price of farm crops used in these calculations the farmers on this type of soil must in some way increase yields, without a correspond-

TABLE 10.—ANNUAL VALUE OF CROPS PER ACRE ABOVE COST OF PRODUCTION AND COST OF TREATMENT

Soil Treatment	Value above Cost of Production and Treatment	Rank
Legume	$—1.11	7
Legume, lime	.45	5
Legume, lime, bone meal	1.73	4
No treatment	—0.57	6
Legume, lime, bone meal, potash	3.41	3
Manure	5.81	2
Manure, rock phosphate	6.40	1

ing increase in cost of production if they are to realize a satisfactory labor income from their farms.

It will be seen also that the legume treatment as used in these experiments failed to produce a return so that it alone cannot be looked to as a solution of the problem. Lime has increased the return over the legume treatment alone by $1.56. This is a very substantial increase when the low cost of liming is considered and when it is further considered that lime helps materially in securing a stand of clover, thus aiding the manure and fertilizer in producing paying yields. The phosphate and potash treatments have materially increased the return above the cost of production altho manure alone and manure with rock phosphate have brought the greatest returns. The annual value of crops per acre above the cost of production and treatment, $5.81 for manure alone and $6.40 for manure and rock phosphate, are remarkable figures. It must be remembered that these various returns represent the real labor income of the farmer, that is, the return in addition to interest on investment, taxes and cost of labor, seed and soil treatment.

It is to be regretted that in an experiment of this kind it is impracticable to try all of the combinations of treatments. The results show that lime, phosphates, potash and manure paid good returns. There is little doubt that still higher net returns would be secured if lime and potash had been combined with manure and phosphates. Of course, potash could probably not be applied with any great profit at war prices but lime certainly should be combined with manure and phosphate treatments.

RETURNS DURING ONE ROTATION

The farmer who is handling this land to best advantage should establish a rather definite system of cropping or crop rotation. These experiments have been conducted with a rotation of corn, soybeans, wheat and clover, or cowpeas when clover failed. It is therefore of interest to show the total return secured from each treatment during one round of the rotation.

TABLE 11.—NET RETURN PER ACRE ABOVE COST OF PRODUCTION (INCLUDING 5 PER CENT INTEREST ON INVESTMENT) AND TREATMENT DURING ONE ROUND OF ROTATION

Soil Treatment	Net Return Per Acre During 4 Years	Net Return from 80 A of Rotated land During 4 Years
No treatment	$—2.30	$—184.00
Legume	—4.45	—356.00
Legume, lime	1.80	144.00
Legume, lime, bone meal	6.93	554.40
Legume, lime, bone meal, potash	13.63	1090.40
Manure	23.26	1860.80
Manure, rock phosphate	25.60	2048.00

Certainly some of these treatments have shown very good returns, when it is considered that these figures represent the actual income after taking out the interest on investment and all expenses. It must also be remembered that these results are secured from averages of six years of cropping. If these results were applied to 80 acres of rotated land, which might be the amount of cultivated land on a 160 acre farm in this region, the returns during the four years would be as shown in the last column of the table.

SUGGESTIONS FOR SOIL MANAGEMENT

This experiment field, representing as it does much of the more or less level uplands found in many parts of the Ozark region, should give valuable information on soil management for farmers in that section. The composition of the tillable soils of the Ozark upland is

similar thruout with the exception of the lime need, which is somewhat variable and should be determined for each farm. Consequently the needs of these soils should be expected to be much the same, and the recommendations here made, excepting those having to do with lime, should apply quite generally to the central Ozark upland, particularly that which is fairly free of stone.

TYPES OF FARMING

Livestock farming is preeminently adapted to this type of soil. The great need of this soil for organic matter, the fact that it is not sufficiently fertile to make pure grain farming successful and the further fact that much of it is surrounded by rough lands best suited to cheap pastures are the principal reasons why livestock farming should be adopted. The type of livestock kept should be determined by the character of the particular farm, by the location with reference to the railroad and by the tastes of the farmer.

Dairy farming is well suited to much of this land. The growing of stocker cattle and hogs has a wide adaptation, particularly where much rough land is also available. Mixed farming including the keeping of some stocker cattle, hogs and dairy cattle has an important place, while poultry raising should form a part of practically every system.

Types of specialized farming such as growing certain canning crops—tomatoes, beans, cucumbers and other vegetables—may be practiced near the canneries by those who will give these crops sufficient attention to learn how to handle them. As a general statement it can be said that this rather level land is not particularly adapted to fruit, altho well cared for home orchards do well. Apples may be grown commercially on the better drained areas of this land but there are other Ozark lands better suited to this business.

This is not a type of soil suited to tenant farming. It should be a region of livestock farms, or of small farms devoted to specialized farming, and in either case the careful attention of the land owner is usually essential. Successful tenancy will therefore be the exception rather than the rule on this land. It will not yield consistent profits under the usual tenant system.

CROP ROTATIONS

It has been definitely proved both by carefully conducted experiments and by the experience of good farmers that a properly planned crop rotation is one of the first essentials to continued success in soil management. The experiments conducted on this experiment field have been planned with the idea that rotation pays, and a regular rotation has been followed thruout. This land will not stand

continuous grain farming. A change of crops is necessary and the more systematic the crop change and the more regular the rotation the better for the land and for the farmer.

The type of rotation to adopt must be determined by the type of farming, but the following rotations are suggested: (1) Corn, wheat or rye, clover and timothy two years; (2) Corn, soybeans, wheat or rye, clover and timothy. Both these rotations are well suited to the region provided that manure, phosphates and lime are used to make clover growing successful. Sorghum can often be used advantageously in the rotation, while catch crops of rye or cowpeas to be pastured down or turned under should be used where possible. While soybeans grown in the corn will usually decrease the yield from 2 to 5 bushels, they will produce a good amount of highly nitrogenous seed and when the whole is hogged down, very good money returns can be secured. While it is doubtful if an entire season's crop of soybeans or cowpeas can be plowed under economically for green manure, they may be pastured and the soil improved at small cost.

USE OF MANURE

The great need of this land for organic matter and nitrogen gives manure a high value when applied to it. It can always be depended upon to give returns. In these experiments it has given an annual net return, above cost of handling, of $3.54 per ton. This is the most important reason for adopting a system of livestock farming. The production and care of barnyard manure and the proper distribution of it upon the land is one of the things for the farmer to consider. A crop rotation including legumes helps to maintain the supply of organic matter and nitrogen, so essential in this soil, but unless these crops are largely fed and the manure carefully applied to the land, the proper return cannot be expected.

Since the proper utilization of farm manures is one of the great problems in connection with the most profitable handling of this land, farmers should inform themselves regarding this matter. A full discussion is impossible in this report. The following important facts might however, be mentioned. Manure loses least when it is put on the land as it is produced. Hence, crops should be pastured if possible. This also saves labor. Dairy farmers should provide a manure spreader and if possible haul manure to the field directly from the stable. Where cattle are lot or stable fed, a covered shed should be used in which the manure may be tramped by the animals. Loose manure, such as that piled in the open, loses much fertility. A manure spreader saves labor and makes every ton of manure go much farther. Since about half the plant food value of manure is in the liquid portion,

this should not be lost. Straw should be saved and used for bedding in stables and sheds.

In addition to saving manure all residues of crops which cannot be fed or used as bedding should be plowed under. Nothing in the way of organic substance should be burned or otherwise wasted. The addition of organic matter to this soil is one of the best ways of maintaining its productivity.

USE OF PHOSPHORUS

These experiments have shown conclusively the value of applying phosphates to this land. The analyses show it to be rather low in phosphorus, and even where all crops are fed and the manure carefully returned there is still a need for this element. Much of the phosphorus in the feed is removed in the bones of the animals so that barnyard manure is quite deficient in phosphorus in view of soil needs. Consequently phosphorus should be applied either with the manure, or as a special application to the grain crops. One of the best ways is to apply it directly with the manure at the rate of 60 or 70 pounds of raw rock phosphate or about 40 pounds of acid phosphate per ton of manure. Either may be scattered on the manure in the spreader or on the field after the manure is applied. If all manure were thus reinforced, its efficiency would be greatly increased.

While in these experiments rock phosphate only has been used to reinforce manure, other experiments have shown acid phosphate to be equally or even more efficient. The normal price of raw rock phosphate in South Missouri is about $9.50 per ton while the acid phosphate containing 16 per cent available phosphoric acid retails at about $18. Consequently almost twice as much raw rock phosphate as acid phosphate can be applied for a dollar. The larger amount of the rock phosphate is recommended because the phosphorus in it is less soluble than that in the acid phosphate. The prices of both these phosphates have increased somewhat because of the war, but the prices of farm crops have advanced to a much greater degree.

The experiments on this field have also shown good returns from applying phosphorus in the form of steamed bone meal as a direct application to corn or wheat. Where no phosphate is applied with manure, excellent return can be expected from the use of 150 pounds of steamed bone meal on corn and wheat, but amounts up to 200 pounds often pay better. While acid phosphate has not been used in comparison with the steamed bone meal in these experiments there is little doubt, from the results of other experiments, that practically the same immediate return may be expected from equal applications of it as from the steamed bone. The steamed bone carries consider-

ably more phosphate but it is not so soluble as that in the acid phosphate. It seems to give a somewhat greater effect the second season than the acid phosphate, so that on wheat where clover and timothy follow, it is often preferred. Clover, particularly, responds remarkably to phosphates. After barnyard manure, phosphate is the most important application for this land.

USE OF POTASSIUM

The application of potassium to this land in the form of muriate of potash has been very effective in increasing yields. At normal prices of potash these applications have brought good financial returns. At present, however, potash is selling at more than 400 per cent above normal prices because of the war, thus making its use show very little profit. When prices again approach normal the use of 3 to 5 per cent of potash in the fertilizer for wheat and corn will bring excellent money return. A mixture of seven parts acid phosphate or bone meal and one part of muriate of potash, would give a good combination. The rate of application of either of these should be about 200 pounds per acre for corn and 150 pounds per acre for wheat.

USE OF MIXED FERTILIZERS

The low grade mixed fertilizers, while rather commonly used because of the lower selling price, are not recommended for this soil. It is true that they will give some return, particularly on wheat, but if a man is to buy ready mixed fertilizers he should buy the better grades. Fertilizers containing less than 10 per cent available phosphoric acid are to be avoided.

A mixed fertilizer containing 10 to 12 per cent available phosphoric acid and 3 to 5 per cent potash will give good returns on this land, especially on wheat. It will give fair returns on corn also, altho the return is not so certain. Weather conditions influence the results on corn to a greater extent than on wheat. Where land has received little manure and where little clover has been grown, a fertilizer containing these same amounts of available phosphoric acid and potash and in addition 2 to 3 per cent nitrogen will give good returns at normal nitrogen prices. Such fertilizers should be applied to wheat at the rate of 150 pounds per acre and to corn at the rate of about 200 pounds. Somewhat larger applications may often be used advantageously, particularly on corn. A fertilizer containing 2 per cent ammonia (1.65 per cent nitrogen) 10 to 12 per cent available phosphoric acid and 2 per cent potash, is a common kind of a medium grade fertilizer found on the market when nitrogen and potash prices are normal. Such a fertilizer is a fairly satisfactory wheat fertilizer

for this land. At present potash prices however even these fertilizers containing as small an amount as 2 per cent of this element can scarcely be recommended. Consequently phosphates alone or phosphates with some nitrogen must be used.

In the treatments recommended, it is advised that these various fertilizers be applied with a fertilizer grain drill when the wheat is seeded, or with the same drill in advance of the planter when the corn is planted. Where no fertilizer drill is available they may be applied broadcast and worked into the soil.

Fertilizers may be applied in the hill or drill for corn where immediate returns are desired. While such experiments were not carried out on this field they have been conducted on some other fields with good results. In 40 trials extending over several seasons, $1.20 worth of fertilizer applied to corn in the hill or drill with a fertilizer attachment to the corn planter has brought an average increase of 7 bushels of corn. Such practice is not to be generally recommended because of the danger that it may be abused. One cannot depend on such a system for keeping up the yield of corn, since only a small amount of fertilizer is used. If this is practiced, and corn is grown on the same field several years in succession, the effect on the land is practically the same as if the corn had been grown without fertilizer. Properly used, however, as an adjunct to rotation, manuring and the use of phosphates or highly phosphatic mixed fertilizers, this small application in the hill or drill, when the corn is planted, may be made advantageously.

In hill or drill fertilization the same fertilizers recommended heretofore for corn may be used at the rate of 60 to 75 pounds per acre. Amounts up to 100 pounds or even more may often be applied advantageously, but with heavy applications, should the season turn dry in late summer, the corn is likely to fire. Small to moderate amounts give the corn a thrifty early start which is normally very beneficial, with less injury from firing during drouth. The best fertilizer practice, however, includes the use of larger amounts of fertilizing materials, applied over the whole surface of the land.

USE OF LIME

The analysis of the soil of this experiment field shows that it requires about 4800 pounds of ground limestone to sweeten the surface seven inches of an acre. The two tons of limestone applied to this soil at the beginning of the experiment did not completely sweeten the soil but was sufficient to give good returns. It was especially beneficial in securing a stand of clover. Lime may be added to soil

as burned lime, hydrated lime or as finely pulverized limestone. Where the shipping distance is not too great nor freight rates excessive the ground limestone is the most practical. It can be said that as a general rule a good grade of ground limestone should not cost more than about $3 a ton applied on the land. This price may sometimes be exceeded with paying returns, particularly where the stone is finely ground, but it is best to keep near or below this to obtain good results. In regions where limestone can be had it is sometimes economical for a number of farmers to buy a small crusher and grind the stone for their own use. Before applying lime, tests should always be made to determine the degree of soil acidity and the amount of lime needed to correct it, since the lime need of the same soil type varies considerably in different locations. Lime is needed mainly for growing leguminous crops like clover and alfalfa. Of the non-legumes corn seems to respond best to its use.

The limestone used should be ground to a corn meal fineness or finer for best results. The grade commonly recommended in this state is ground fine enough to pass a ten mesh sieve, that is a seive with ten holes to the linear inch—a little coarser than an ordinary fly screen. If coarser material is used the applications should be heavier.

The amount to apply depends upon the soil sourness, but on soil as sour as that on this experiment field, two tons should be applied in the beginning. This first application should then be followed with applications of one-half to one ton every four to six years. The limestone is best applied and thoroly worked into the soil after the ground has been broken for a crop. In the rotation of corn, soybeans, wheat, clover it may be applied before corn, altho work is often too pressing at that time of year. As the ground for wheat is not plowed after soybeans, but merely disked and harrowed, the limestone may be applied after the soybeans are off and worked into the soil as the wheat seedbed is prepared.

SUMMARY

1. The soil type on which these experiments have been conducted is typical of considerable of the more level, non-timbered land in the Ozark region, which shows in its composition a need of nitrogen, phosphorus, potassium and lime.

2. The experiments have included the use of legumes, lime, phosphates, potash and barnyard manure used in connection with a crop rotation of corn, soybeans, wheat and clover.

3. The greatest return per acre from any one fertilizing material has been secured from barnyard manure which netted $7.07 annually or $3.54 per ton for an application of 8 tons once in four years.

4. The greatest return from any combination of treatments has been secured from 8 tons of barnyard manure and 1000 pounds of raw rock phosphate applied on the clover stubble and plowed under for corn. The annual net return has been $7.79 per acre.

5. Bone meal, which netted $2.43 annually, has given somewhat greater net returns per acre than raw rock phosphate, which netted $0.72. Unfortunately the plan did not provide for a combination of manure and bone meal or manure and acid phosphate.

6. Potash has brought good financial returns on this soil when figured at normal prices. The annual net return has been $1.88 per acre.

7. Lime in the form of ground limestone, applied at the rate of 2 tons per acre at the beginning of the six year period, has paid well.

8. The legume treatment alone as used in these experiments has not brought paying returns. This evidently has been due to the poor crop of peas secured the first year, when they were grown purely as a green manure, to similar low yields when the peas were grown in the corn, and to a slight decrease in the yield of corn.

9. The summarized recommendations regarding soil management as based on the results obtained are as follows: (a) A livestock system of farming should be adopted in which little grain will be sold from the land and all manure will be carefully returned. (b) If possible a systematic crop rotation, such as corn, wheat, clover and timothy two years, or corn, soybeans, wheat, clover and timothy should be followed. (c) Ground limestone should be applied at the rate of two tons per acre. This should be spread preferably when the land is prepared for wheat. (d) Sixty pounds per ton of raw rock phosphate or 40 pounds per ton of acid phosphate should be applied with the manure in the spreader and plowed under for corn. (e) For wheat an application of 150 pounds of acid phosphate, bone meal or one of the highly phosphatic mixed fertilizers is recommended, and when potash prices are normal, sufficient potash should be included to give from 3 to 5 per cent in the mixture. (f) Where no phosphate is applied with the manure before corn, both corn and wheat should be fertilized. The corn should receive about 200 pounds of one of the same fertilizers suggested for wheat, preferably the acid phosphate, and at normal potash prices it should receive some potash.