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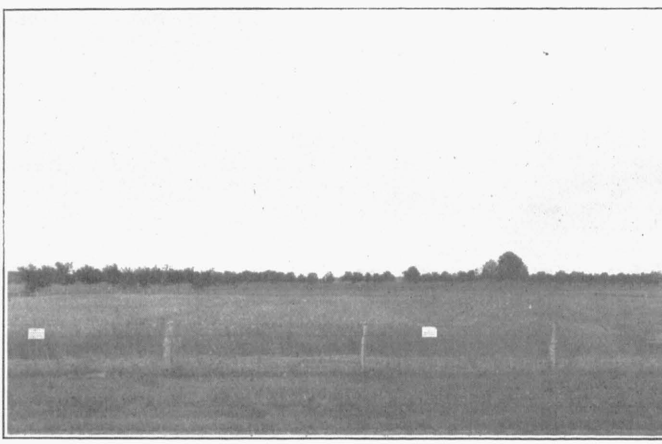
BULLETIN NO. 130



Wheat on Lamar Experiment Field

Soil Experiments on the Gray Prairie of Southwest Missouri

SECOND REPORT

COLUMBIA, MISSOURI
April, 1915

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SOIL EXPERIMENTS ON THE GRAY PRAIRIE OF SOUTHWEST MISSOURI

(SOIL TYPE—CHEROKEE SILT LOAM)

M. F. MILLER, C. B. HUTCHISON, R. R. HUDELSON

In order that the soil studies of the Agricultural Experiment Station of the University of Missouri might reach the entire state a comprehensive plan of investigation of the main soil types was begun in 1905. This work naturally falls into two divisions, that of mapping the soil types county by county and that of field and laboratory experiments on these types. One of the first experiment fields established was that at Lamar in Barton County, a first report of which was published in 1910.[1] This field was located one-fourth mile southeast of Lamar on the farm of D. A. Beamer (T. 32, R. 30, S. 30) and was in operation during the seasons of 1906 to 1913 inclusive.

A map showing the soils of Barton County together with a report containing a discussion of their characteristics and other points of interest was published in 1914.[2] The work was done by the Missouri Agricultural Experiment Station in cooperation with the Bureau of Soils of the U. S. Department of Agriculture.

The soil type on which these experiments were conducted is the Cherokee Silt Loam. As found on the experiment field, it is from 8 to 10 inches in depth, of a gray color and somewhat ashy in appearance. From 10 to 18 inches in depth it is a lighter gray in color with a yellowish tinge. At about 20 inches it abruptly becomes heavy and sticky and is somewhat mottled with reddish brown. From 20 to 30 inches in depth this mottled plastic layer is very heavy. Below 40 inches the texture is somewhat coarser.

"The Cherokee silt loam is derived chiefly from a fine argillaceous shale. It is distinctly a prairie soil, and prairie grass constitutes the original vegetation. At present the Spanish nettle spreads over the ground in cultivated areas to the exclusion of almost everything else during the late summer and fall. The type occupies flat, level prairie land, which is slightly lower than the surrounding undulating types. Occasionally smaller areas, occurring along streams, resemble

[1] Miller, M. F. and Hutchison, C. B. "Soil Experiments on the Prairie Silt Loam of Southwest Missouri;" Mo. Agr. Exp. Sta. Bul. 84: 19-35, 1910.

[2] Krusekopf, H. H. and Bucher, Floyd S. "Soil Survey of Barton County, Missouri," U. S. Dept. Agr., Bur. of Soils, 1914.

high, flat terraces, but as a rule this type is separated from the stream by a belt of soil known as the Bates silt loam."[1]

The chemical analysis of this soil shows it to be deficient in all the main elements of fertility, particularly in nitrogen. The shortage of phosphorus and potassium is distinct but not quite so marked. Another feature of the analysis is the fact that the land is sour, the degree of acidity being such that about two tons of limestone are required to neutralize the surface 7 inches of an acre. The subsoil is shown to have less nitrogen and potassium but more phosphorus than the surface soil and to be only slightly more acid. The analysis does not show the amount of organic matter (humus) present but as the nitrogen in soils is practically all in organic form, the low content of nitrogen indicates that the soil is very low in organic matter also. The light color of the soil points to the same conclusion.

It is well known that the chemical analysis is not sufficient evidence by which to determine a soil's immediate needs with respect to fertilizer applications. This is due to the fact that plants can only take up the elements of fertility when they are in such compounds as will dissolve in soil water. A soil may be well supplied with the main elements of fertility and yet not be very productive. On the other hand, the analysis does show the total amount of plant food present and hence indicates the soil's wearing qualities. Furthermore, a soil containing very low amounts of the essential plant foods is nearly always low in productiveness. It is, therefore, important to follow the soil analysis with field experiments to determine the best methods of soil management.

Plan of Experiment. The main experiment field at Lamar was divided into three groups or series of one-fifth-acre plots, seven plots in each series. A rotation of corn, cowpeas, wheat and clover was planned, but several factors caused considerable variation from this scheme. During two years oats were substituted for wheat, and so much difficulty was encountered in growing clover on this land that during every season except that of 1908 it was necessary to substitute cowpeas. Even during the season of 1908 there was a stand of clover only on three of the seven plots in the series. With only three series to use, one of the four crops of the rotation had to be omitted each year. This also interfered with the best management of the rotation. All plots of a series were devoted to the same crop during a season. The plan of the field together with the treatment given each plot is shown in the following diagram.

[1] Krusekopf, H. H. and Bucher, Floyd S. "Soil Survey of Barton County, Missouri," 1914, U. S. Dept. Agr.

PLAN OF THE EXPERIMENT FIELD AT LAMAR

SERIES A

1	2	3	4	5	6	7
Legume Bonemeal	No treatment	Legume Potash	Bonemeal Potash	Legume Bonemeal Potash	No treatment	Legume Bonemeal Potash, Lime

SERIES B

Legume Bonemeal	1
No treatment	2
Legume Potash	3
Bonemeal Potash	4
Legume Bonemeal Potash	5
No treatment	6
Legume Bonemeal Potash Lime	7

SERIES C

7	6	5	4	3	2	1
Legume Bonemeal Potash Lime	No treatment	Legume Bonemeal Potash	Bonemeal Potash	Legume Potash	No treatment	Legume Bonemeal

The plots planned to receive the legume treatment usually had cowpeas sown in the corn at the last cultivation, the peas being turned under before the next crop. This treatment was made for the purpose of supplying nitrogen and organic matter to the soil which was badly in need of both. The growth secured from peas in the corn was so small that these plots were benefited but little by it, however. The legume plots on series B and C were given an application of fifty pounds of dried blood per acre to furnish nitrogen the first year.

The bonemeal was applied for the phosphorus it contained. The form used carried 2 to 3 per cent nitrogen and 20 to 24 per cent phosphoric acid. The first application on each series was at the rate of 200 pounds per acre, but all other applications have been at the rate of 150 pounds. This amount was applied before each crop of corn and before each crop of wheat or oats. The method of application in all cases was to drill the bonemeal with a fertilizer drill just before planting corn or while sowing the wheat and oats. Potash was applied at the same time and in the same way as the bonemeal. The first application on each series was 100 pounds to the acre. Since that time 50 pounds per acre have been used. This is considerably heavier than potash is commonly used but the results seem to justify its use even in these quantities.

On plot 7 of each series, lime was applied at the rate of a ton per acre. It was put on series B and C in 1906 and on series A in 1907. No other lime was added during the period covered by this report. It was broadcasted after plowing and worked into the soil while preparing the seed bed.

Basis of Calculation. The results of the soil treatments on the various crops grown are recorded in the following tables. It should be noted that altho bonemeal and potash were applied only once in two years, the cowpea crops, growing between, were charged with their share of the cost. The cost of the lime was distributed between all crops grown within the eight-year period of the experiment. It was thought best to figure the crops at the average of farm prices given by the State Board of Agriculture for the past five years (1909-1913). Fertilizers are figured at the average of retail prices collected by fertilizer inspectors from many parts of the state during 1914, and green manure crops at the cost of seed and sowing. This method gives the following list of prices:

FARM CROPS

Corn	$ .55 per bu.
Wheat	.90 per bu.
Oats	.37 per bu.
Cowpea hay	11.21 per bu.

SOIL TREATMENTS

Cowpea green manure crop	$ 2.00 per acre
Ground limestone	3.00 per ton, applied
Steamed bonemeal	28.00 per ton
Muriate of potash	47.50 per ton
Dried blood	65.00 per ton

All net returns are figured after the cost of treatment has been deducted. Losses are indicated by minus signs.

Figure 1.—Corn on Lamar Experiment Field 1907. Corn on left received no fertilizer treatment and yielded 18 bushels per acre, while that on the right was on the legume, bonemeal, lime and potash plot, and gave a yield of 45 bushels per acre.

Table I. Results of Experiments with Corn (5 Crops) Lamar Field

Soil treatment	Average yield bushels per acre	Average increase bushels per acre	Average value of increase per acre	Average cost of treatment per acre	Average net return per acre per year
Legume, bonemeal................	24.3	-1.4	$-0.77	$1.67	$-2.44
No treatment.....................	25.6				
Legume, potash..................	33.3	7.6	4.17	1.21	2.96
Bonemeal, potash................	37.2	11.5	6.32	2.09	4.23
Legume, bonemeal, potash.........	37.3	11.6	6.37	2.49	3.88
No treatment.....................	25.8				
Legume, bonemeal, potash, lime.....	37.0	11.3	6.20	2.89	3.31

The poor drainage resulting from the level topography of this field has interfered seriously with the yields of all crops. Not only is the surface very level but the impervious subsoil will not permit a rapid absorption of the water by the deeper layers of soil. As a result either the soil is injured by plowing when wet, or spring planting is delayed until the season is too far advanced.

These conditions have materially interfered with the production of high yields of corn as may be seen in Table I. Proper soil management, however, has produced as large increases in the corn yields here as on fields operated under more favorable conditions. Where both bonemeal and potash have been used the corn yields have been increased by almost 50 per cent. Neither cowpeas nor lime have had much effect on the corn yields as an average of the entire period, altho the earlier years seem to show considerable benefit from lime. Potash without bonemeal has produced a fair increase in the corn crop, but bonemeal without potash has helped very little. The reverse was true with wheat. The most profitable fertilizer application, however, is a combination of phosphates and potash. It should be noted that the plot getting bonemeal without potash as well as the one receiving the complete fertilizer treatment with lime is on the end of the series in both Series A and C. These plots are somewhat more exposed to attacks of insects from the adjoining lands as well as to the hot winds of late summer. This doubtless has had some effect in making lower yields on these end plots.

Table II. Results of Experiments with Oats (2 Crops) Lamar Field

Soil treatment	Average yield bushels per acre	Average increase bushels per acre	Average value of increase per acre	Average cost of treatment per acre	Average net returns per acre per year
Legume, bonemeal	30.5	7.0	$2.59	$1.70	$0.89
No treatment	24.3				
Legume, potash	24.1	0.6	.22	1.25	-1.03
Bonemeal, potash	21.3	-2.2	- .85	2.09	-2.94
Legume, bonemeal, potash	28.9	5.4	1.99	2.52	-0.53
No treatment	22.8				
Legume, bonemeal, potash, lime	34.8	11.3	4.18	2.90	1.28

Only two crops of oats were grown on the experiment field, one in 1906 and one in 1912. In both cases the regular fertilizer treatment for wheat was given with the addition of dried blood on the legume plots in 1906. The dried blood and bonemeal combination was most effective in increasing the yield of oats. Potash had some effect in 1906. The season of 1912 was a very poor one for oats owing to the fact that hot, dry weather came on before the crop could mature. As a result fertilizers produced but small and inconsistent returns. The average results of these two crops are shown in Table II which shows fair increases on all plots receiving the combined legume and bonemeal treatment. However, the low value per bushel of oats makes these increases unprofitable except on the complete soil treatment plot. The difficulties in growing oats on this soil type are largely due to drainage and climate. Oats require a cool, moist growing season, which necessitates their being sown early in this latitude. On lands of this type which stay wet so late in the spring, early sowing is usually impossible. Consequently, hot dry weather comes on before the oats can mature and low yields result. Early maturing varieties help to obviate the difficulty in some degree. These facts were well illustrated by the oats grown in the drainage experiment at Lamar in 1913. The tiled area could be sown considerably earlier than the undrained part of the field, with the result that the tiled land made a fair yield and the untiled a failure. Some of the benefit from phosphate fertilizers on oats is probably due to the fact that they hasten maturity.

Table III. Results of Experiments with Wheat (5 Crops) Lamar Field

Soil treatment	Average yield bushels per acre	Average increase bushels per acre	Average value of increase per acre	Average cost of treatment per acre	Average net returns per acre per year
Legume, bonemeal	20.1	8.2	$7.38	$1.65	$5.73
No treatment	12.5				
Legume, potash	14.9	3.0	2.70	1.20	1.50
Bonemeal, potash	19.7	7.8	7.02	2.09	4.93
Legume, bonemeal, potash	20.9	9.0	8.10	2.47	5.63
No treatment	11.4				
Legume, bonemeal, potash, lime	21.0	9.1	8.19	2.90	5.29

As shown in Table III, fertilizers have been very profitable on wheat. The increase in bushels per acre was not quite so high as with corn but the higher value per bushel more than made up the difference. A high phosphate fertilizer has been found to be necessary in securing a profitable yield. The legume and potash treatments have had much less effect but they have more than paid their costs. Lime has not been profitable on wheat as an average of the entire period. During the first two seasons following the application of the lime, however, some increase in the wheat crops was secured. In view of the fact that wheat seldom responds profitably to liming according to the results secured on the various experiment fields in Missouri, this may have been accidental. On the other hand, the failure of wheat to show the effects of liming during the latter part of the experiment may have been due to the small amount used having been exhausted.

Figure 2.—Wheat at Lamar, 1911. The legume, bonemeal, lime, and potash treatment (right) increased the yield over the no treatment plot (left) by 7½ bushels per acre.

The plots receiving bonemeal nearly always have made the best growth of wheat thruout the season. The wheat on these plots also ripened earlier and more evenly. Potash showed no tendency to hasten ripening, and at least in one case seemed to delay it somewhat. In the season of 1913 a very interesting observation was made on the effect of chinch bugs on fertilized and unfertilized wheat. The wheat on the bonemeal plots withstood the attacks of chinch bugs much better than that on the remainder of the series. Close observation also showed that there were fewer bugs on these plots than on the adjoining unfertilized ones. It is quite probable that most of the value of fertilizers in preventing damage from chinch bugs, is due to the greater vigor and resistance of the fertilized wheat which enables it to support the bugs and still make growth.

Table IV. Results of Experiments with Cowpeas (6 Crops) Lamar Field

Soil treatment	Average yield pounds per acre	Average increase pounds per acre	Average value of increase per acre	Average cost of treatment per acre	Average net returns per acre per year
Legume, bonemeal	2400	196	$1.10	$1.64	-$.54
No treatment	2154				
Legume, potash	2413	209	1.17	1.18	- .01
Bonemeal, potash	2697	493	2.76	2.02	.74
Legume, bonemeal, potash	2754	550	3.08	2.42	.66
No treatment	2254				
Legume, bonemeal, potash, lime	2666	462	2.59	2.83	- .24

Experiments with cowpeas at Lamar have demonstrated that while this is a good crop to grow on lands of this type, it does not respond very well to fertilizer treatments. Had the fertilizers been applied directly to the cowpeas instead of to the preceding crops, there is little doubt that greater increases would have been secured. The combined bonemeal and potash treatment has more than paid its cost, however, even on cowpeas.

Clover and alfalfa, two other possible legume hay crops, were tried repeatedly on the experiment field, with little success. Poor drainage and a tight subsoil cause heaving in winter and drying out in summer. When the soil is built up in organic matter and limed, fair success may be obtained. Alfalfa was found to stand thru one cutting season fairly well but out of several sowings no permanent stand was secured. A thoro manuring was found necessary to grow it at all. Results with red clover were very similar. Some clover was sown every year but a good permanent stand was secured only once and then only on the plots receiving a combination of the legume and bonemeal treatments. More organic matter and available phosphates together with lime seem to be essential to the growth of clover on this soil.

Table V.—Average of Results on Entire Field, All Crops, Lamar

Soil treatment	Average value of increase per acre per year	Average cost of treatment per acre per year	Average net returns per acre per year
Legume, bonemeal	$2.49	$1.65	$0.83
Legume, potash	2.32	1.20	1.12
Bonemeal, potash	4.53	2.06	2.46
Legume, bonemeal, potash	5.26	2.46	2.80
Legume, bonemeal, potash, lime	5.32	2.87	2.45

Table V shows the effect of the various soil treatments on all crops of the rotation. Judging by these results, which cover a period of eight years, the most profitable system of soil management tried is one of using green manure catch crops to supply organic matter and nitrogen, bonemeal to supply phosphorus, and chloride (muriate) of potash to supply available potassium. Lime has not proved profitable as an average of the entire period tho it was profitable during the first two or three years. The later failure may easily have been due to the fact that the application was too small. The soil analysis indicates that it was only about half as large as it should have been. A heavier liming was begun in 1913 but as it was found necessary to discontinue the work at that time no results were secured.

Experiments with Tile Drainage. Poor drainage is so characteristic of this soil type that it was thought best to investigate the possibilities of tiling it. In the fall of 1906 an experiment was started with two plots of 3.4 acres each, one of them tiled with the laterals laid six rods apart and the other left untiled. The average depth at which the tile was laid was between 2 1-2 and 3 feet. Four-inch tile was used for the laterals and six-inch tile for the main drain. The grades were accurately established with an engineer's level and the tile carefully installed.

The cost of laying tile in this way naturally varies considerably, depending on distance from a tile factory, cost of labor and the character of the soil. The digging and laying where the ditch is from 2 1-2 to 3 feet deep will cost, if contracted, from 30 to 40 cents per rod. Where a farmer can do the work with his own hired help in early spring before field work begins, it can usually be done considerably cheaper than this. The cost of six-inch tile at the factory is about $25 to $28 and four-inch tile $15 to $16 per thousand. With a tile factory in the neighborhood, as is the case at Lamar, six-inch tile could be delivered on the ground at a cost not to exceed $33 per thousand or 55 cents per rod, while four-inch tile under the same conditions should not cost over $20 per thousand or 33 cents per rod.

The acre cost of draining land is always influenced by the distance to the outlet, considered in connection with the number of acres drained. The main tile is somewhat more expensive per rod than the laterals and if it is necessary to go a long distance to an outlet the acre expense is naturally increased since a proportionately larger main tile cost must be charged to each acre drained. In the case of this drainage experiment only 3.4 acres were drained but it was necessary to go a considerable distance to an outlet so that the acre cost of tiling was increased somewhat beyond what it should have been under normal conditions. Under average conditions it is safe to allow one to two rods of main tile for each acre drained. If we allow two rods of main to each acre, in this case, together with a cost of six-inch main tile installed at 90 cents per rod and a four-inch tile installed at 63 cents per rod, the total cost per acre is $18.31. In actual practice this cost can often be lessened, altho where one must ship in tile from a considerable distance the cost will be materially increased. Where the land is very level it will be necessary to employ an engineer for laying out the system, which will add considerably to the expense. Under ordinary conditions, however, the farmer should be able to lay out the system himself by the use of an ordinary carpenter's level and a fair amount of ingenuity.

Table VI. Experiment with Tile Drainage at Lamar

Year	Crop	Yield per acre		Value of crop per acre		Return from tile
		Drained	Undrained	Drained	Undrained	
1907	Corn	31.1 bu.	22.2 bu.	$17.10	$12.21	$4.89
1908	Corn	9.7 bu.	9.0 bu.	5.33	4.95	.38
1909	Wheat	13.5 bu.	13.2 bu.	12.15	11.88	.27
1910	Cowpeas	6631 lbs.	4900 lbs.	37.13	27.44	9.69
1911	Corn	27.5 bu.	26.2 bu.	15.12	14.41	.71
1912	Cowpeas	2059 lbs.	2070 lbs.	11.53	11.59	.00
1913	Oats	23.8 bu.	5.0 bu.	8.80	2.80	6.00
Total return per acre in 7 years						$21.94

Table VI shows the crops grown, with the effect of drainage on each for the entire period of the experiment. No fertilizer or other special treatment was given these plots, the sole purpose being to measure the effect of drainage. As a result the yields are somewhat low but there has generally been some increase in favor of tiling. The amount of this increase depends very largely on the season. On late wet springs the benefit is very marked. The seasons of 1907, 1910, and 1913 have shown striking increases in yields from tiling while the effect has been very slight on the remaining four seasons. During the seven years of the experiment the value of the crops on the drained plot has exceeded that on the undrained plot by a total of $21.94 per acre, which is sufficiently in excess of the cost of tiling this land under normal conditions to meet a reasonable interest charge. The tile is practically as good as when first laid, and any benefit from now on is clear gain. There is little doubt, therefore, that tiling will pay on the more level areas of this soil, altho no phenomenal gains should be expected, where the land is farmed in an extensive manner. With a more intensive system of farming, including better soil management, greater value should be secured from tiling than under the conditions here described. Where a man cannot afford the expense of laying the tile at regular intervals, he should if possible, run tile to the wettest areas. The best returns cannot be secured from this soil type until it is thoroly drained.

Experiments in Soil Blasting. Many requests for information regarding the value of blasting impervious subsoils led the Agricultural Experiment Station to start some investigations along this line in the spring of 1911. One of these tests was made at the Lamar experiment field and the results are shown in Table VII. Three plots were used, each of them containing five-sixteenths of an acre. The middle plot was blasted leaving one unblasted plot on either side for comparison. The blasting was done by boring holes with a soil auger to a depth of about 40 inches, putting in a half stick of low grade dynamite and tamping the soil above it. These charges were set about fifteen feet apart each way and the estimated cost including labor was $12 to $15 per acre. During the seasons of 1911 and 1912 the entire area was divided putting cowpeas on one-half and corn on the other. The cowpeas were materially benefited both seasons but the first crop of corn was not quite so good on the blasted plots as on the check plots. The second crop of corn gave the largest increase of any crop grown. During the third season the plots were sown to oats and there was practically no difference in yield between them. As an average of all crops grown the increase from blasting was worth approximately $1.60 per acre. At this rate it would take abount ten years to pay for the blasting, and it is doubtful whether the effect would be noticeable that long.

Table VII. Results of Blasting Experiment at Lamar

Year	Crop	Yield per acre		Value of crop per acre		Returns from blasting
		Blasted	Not blasted	Blasted	Not blasted	
1911	Corn	18.2 bu.	22.5 bu.	$10.01	$12.37	–$2.36
1911	Cowpeas	1504 lbs.	1136 lbs.	8.44	6.36	2.08
1912	Corn	14.2 bu.	3.7 bu.	7.81	2.03	5.78
1912	Cowpeas	2368 lbs.	1936 lbs.	13.26	10.84	2.42
1913	Oats	19.3 bu.	19.1 bu.	7.14	7.06	.08

Average return from blasting, per acre, per crop................$1.60

GENERAL RECOMMENDATIONS REGARDING SOIL MANAGEMENT

The light color and low nitrogen content of this soil shows conclusively that it is very low in organic matter. Every effort should be made to build it up by the use of manure, green manure crops, and pasturing. A crop rotation is almost essential to a permanent improvement of any soil and this one is no exception. A good crop rotation for this land should provide for the largest possible use of legume crops to supply nitrogen. To use legume crops to the best advantage require livestock, and hence that would seem to be the most profitable type of farming for this section.

Figure 3.—Clover does not grow well on this soil. It required lime, available phosphates and a building up of the organic matter to produce this stand.

Cowpeas and Soybeans. Since clover and alfalfa do not thrive on this soil, cowpeas and soybeans will have to be depended upon for legume crops unless the land is put into condition for growing clover, thru tile drainage and the use of lime and phosphates. Cowpeas are commonly grown in this region, and soybeans, altho of rather recent introduction, are coming into use. They will produce more seed than cowpeas but their hay is coarser and on the whole not quite so good.

Soybeans usually do better after the first crop or two has been grown owing to the fact that many soils are not yet inoculated with the bacteria which grow on their roots. Some benefit often may be derived from inoculating the seed where the first soybean crop is to be sown. This may be done either by moistening the seed with a 10 per cen glue solution and sprinking soil from an old soybean field over them or by use of a commercial culture. Some dust will usually stick to the seed, however, and even if no attempt is made to inoculate them, some plants will be inoculated the first season, and a second or third crop grown on the same land, in most cases, will be thoroly inoculated. The roots of inoculated soybeans bear large nodules which makes it very easy to determine whether they are in need of inoculation. The seed of cowpeas and soybeans is usually so high in price as to make their use expensive, but in case of soybeans, at least, enough seed can easily be grown locally. Where the threshed hay is fed seed can thus be grown at a very reasonable cost. They are best threshed by means of pea or bean hullers, but most threshers can be adapted to thresh them. Where grown for seed, soybeans are best drilled in rows about 30 to 36 inches apart and cultivated. They stand up much better than cowpeas, and therefore can be handled in rows more satisfactorily than can cowpeas.

Practical Rotations. A good standard rotation for this region is one of corn, cowpeas or soybeans, wheat, and timothy one or two years. Where all crops except wheat are fed and the manure carefully returned to the soil, two corn crops may be grown instead of one. In such a case cowpeas or soybeans may be sown in part of the corn either with a planter attachment or between the rows at the last cultivation, and this part of the corn pastured down. This is a labor saving scheme and puts all the manure back on the land. Some care should be exercised in sowing cowpeas or soybeans in the corn, however, as they frequently cut the corn yield from three to five bushels per acre, and if the season is very dry, little growth of peas or beans is secured. Sometimes it is advantageous to pasture the cowpeas with lambs and thus leave the corn to be husked. Where the crop is to be pastured down with hogs, soybeans are better than cowpeas as hogs do not eat cowpeas readily. Another soil building process is to sow rye in the corn for fall and spring pasture, plowing it under before it gets too large and dries out the land too much in spring.

Where the corn is cut early, especially where it is used for silage, a good rotation is corn, wheat, and cowpeas or soybeans. If the wheat can be removed very early and the season is not too dry, the stubble may be plowed and cowpeas sown for a green manure crop that same season. If the late summer is dry, however, little growth can be expected. Rye also may be sown after the wheat and turned under the following spring before planting the cowpeas or soybeans. In case the land is drained, limed, and fertilized so that clover will grow with a fair degree of satisfaction, a rotation of corn, corn, wheat, timothy, red and alsike clover meadow two or three years, may be adopted. Since it will require considerable expense to put this soil in condition to grow clover, such a rotation will probably be adopted by few farmers on this soil type. Japan clover (*Lespedeza striata*) is coming into this region of the state and grows fairly well on this soil type. While the growth is small, its appearance in timothy fields is of importance, since the crop gives a small amount of nitrogenous forage as well as some benefit to the soil.

Handling Manure. On soils of this type manure has a high value. The experiments here reported did not include a comprehensive test

Figure 4.—Wheat at Lamar, 1907. The legume, bonemeal, potash, lime plot (left) gave a yield of 25.9 bushels per acre, while the no treatment plot produced but 12 bushels.

of the value of manure but on similar soil types it has returned values varying from $2 to $4 per ton, which makes it worth the most careful saving. So long as manure is tramped down in the feeding shed, there is little waste, but thrown out into loose piles where the air can circulate in it, decay is rapid and the loss of nitrogen and organic matter is great. If piled under the barn eaves, rain washes out the soluble plant food, and if left to wash down the side hill of a well drained feed yard, much of it eventually gets into the drainage ways and is lost. Under the present conditions of labor supply the most economical method of handling manure seems to be to leave it tramped down in feeding sheds, using an abundance of bedding to keep the stock clean, until it can be hauled directly to the field. The more bedding used the better, for it makes more manure and soaks up the valuable nitrogen carrying liquid manure. In this section where much wheat straw is available, it should certainly be used liberally for bedding. If all of it cannot be used to make manure the rest should be spread back on the land.

Experiments as well as practice have shown that corn and the grasses are good crops on which to use fresh manure, altho a light top dressing on wheat is often very advantageous not only in increasing the wheat yield but in securing a following stand of grass.

The Use of Commercial Fertilizers. These experiments have shown very clearly that the proper use of commercial fertilizing materials on this soil is a profitable practice. Little nitrogen should be purchased on account of its very high cost in commercial forms. The practice of growing legumes and carefully returning all manures and crop residues as outlined above will make it unnecessary to buy this expensive plant food. The use of nitrogenous fertilizers is justified only on very thin lands which may be cropped to grain, and when there is no time to use legumes or make manure. Nitrogen is generally expressed in fertilizer analyses as ammonia, a compound in which nitrogen is the chief component. Only those fertilizers containing a minimum of ammonia should be purchased.

The first plant food to be bought for this soil is phosphorus, commonly expressed as phosphoric acid and usually bought in the form of bonemeal or acid phosphate. Most mixed fertilizers contain it in the form of acid phosphate. Steamed bonemeal was the form used in these experiments and it is especially good for winter wheat, the crop which returns the largest profit on phosphates. The supply of bonemeal is limited, however, and the price is gradually increasing. Comparative tests have shown acid phosphate to be a fair substitute for bonemeal even for wheat, and for spring crops it is probably as good if not better than bonemeal. The medium grades of acid phosphate contain 14 to 16 per cent of phosphoric acid practically all of which is available. Bonemeal contains from 20 to 29 per cent of this compound altho it is not all available the first year. The insoluble phosphorus, however, is made available gradually during succeeding years. Another form in which phosphorus may be purchased is finely ground rock phosphate. It contains as much phosphoric acid as a good grade of bonemeal and costs only about one-third as much. It is very slowly available, however, and can be used profitably only when thoroly mixed with some decaying material which helps to dissolve it. Even then it is slowly available and is to be recommended only for the landowner who wants to build up his soil and who can wait for returns.

Potash has proved to be needed on this soil more than on most soils of the state and for the greatest profit should be mixed with the phosphate fertilizers. For general field crops the chloride (muriate) of potash is used since it is cheaper than the sulfate and just as good. Mixed fertilizers usually contain potash in this form, unless the sulfate is specified.

An application of 150 to 200 pounds per acre of a fertilizer containing 10 to 14 per cent of available phosphoric acid and 3 to 4 per cent of potash is recommended for corn, to be applied with a fertilizer grain drill in advance of the corn planter. One experiment conducted on the Lamar field and others on similar soil types indicate that where immediate returns on the smallest possible outlay are desired, 60 to 90 pounds per acre of a fertilizer containing 2 to 3 per cent nitrogen, 8 to 10 per cent available phosphoric acid and 2 to 3 per cent potash may be applied in the hill or drill with corn. This should be applied with a fertilizer attachment on the corn planter, being careful to drop the fertilizer a little behind the hill rather than immediately in contact with the seed. Larger applications of fertilizer in the hill are likely to cause the corn to "fire", particularly in dry seasons. This plan of putting light applications of fertilizer in the hill for corn is not a plan for soil building or even for soil maintenance. It should be used only in connection with the use of manure, green manure crops, and a good rotation. If used to grow grain crop after grain crop when the soil is too poor to make a crop without this help, injury to the land will result, not thru any fault of the fertilizers themselves but thru neglect of other factors which are essential to soil maintenance. The only permanently satisfactory method of using fertilizers is in connection with systems of rotation, manuring and legume growing which will maintain the supply of organic matter in the soil.

On the average soil of this type, an application of 150 pounds of a fertilizer containing 10 to 14 per cent available prosphoric acid and 3 to 4 per cent potash is to be recommended for wheat applied with a fertilizer grain drill at the time the wheat is sown. Where the supply of organic matter of the soil is well built up the potash may be omitted and 150 pounds of steamed bonemeal or 200 pounds of acid phosphate per acre may be used. Where the soil is very thin, a complete fertilizer containing 2 to 3 per cent nitrogen, 10 to 12 per cent available phosphoric acid, and 3 to 4 per cent potash applied at the rate of 150 pounds per acre may be used.

The Use of Lime.* Where any attempt to grow clover or alfalfa on this land is made, some lime must be applied. The amount necessary to sweeten the surface soil is about two tons per acre. This should be followed by additional applications of a ton once in six or eight years. The other general farm crops stand a sour condition of the soil fairly well, altho the years immediately following the application of lime in these experiments indicated that some increase in yield may be produced, particularly on corn. On the older and more worn areas, therefore, where an attempt is being made to build up the soil, the bacterial growth and eventually the fertility of the soil may be improved by the use of lime. The cheapest form to apply is usually the ground limestone. It is doubtful whether it can be used with profit, however, where the cost of the limestone applied to the soil is more than $3 per ton. It can usually be applied for less as the cost at the crusher is generally about $1 a ton. This is the best form to use under most conditions, altho air-slaked lime or quicklime slaked to a powder with water may be used where lime kilns are near. When exposed to the air for some time this soon changes to the same composition as ground limestone.

Lime is best applied with a limestone spreader. There are several makes of these on the market. Most fertilizer drills will not apply it in large enough amounts. On small areas it may be applied by hand or by putting a layer of litter in the bottom of a manure spreader and a layer of lime on top of the litter. In such cases it must be handled when there is litttle wind. It should be applied on plowed land and well worked into the soil. In general the use of lime is recommended for the man who wishes to make a permanent improvement in his soil. It is not adapted to the making of quick profits.

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*Note: The department of soils of the Agricultural Experiment Station will furnish on request, the names of companies handling ground limestone, lime spreaders and lime grinders. A list of dealers in rock phosphate can be furnished, also.

SUMMARY

I. The most marked returns have been secured on this soil type from the use of phosphates and potash. Lime brought good returns during the early period of the experiment but as only one ton per acre was applied little results were secured during the later period.

II. The increased yields resulting from tiling this land with tile laid at intervals of six rods, have paid the cost and a fair rate of interest on the investment, during seven years of experiment.

III. The use of dynamite for loosening the subsoil has brought an average increased yield worth $1.60 per acre per crop as an average of five crops grown during three years. The cost of the dynamiting was between $12 and $15 per acre.

IV. The low supply of organic matter in this soil warrants the general recommendation that every economical means be employed to build it up thru rotation, manuring, legume growing and green manuring.

Among suggested rotations are the following:

Corn, cowpeas or soybeans, wheat, timothy;

Corn, wheat, cowpeas or soybeans.

Livestock farming is especially recommended for this soil type and the careful handling of manure is essential to the maintenance of the organic matter and nitrogen.

V. An application of 150 to 200 pounds of a fertilizer containing 10 to 14 per cent available phosphoric acid and 3 to 4 per cent potash is recommended for corn. It should be applied ahead of the corn planter with a fertilizer grain drill. Where the land is very thin and immediate returns are desired, 2 to 3 per cent nitrogen may be added to this combination. For the man who must have immediate returns at the smallest possible cost an application in the hill or drill of 60 to 90 pounds of a fertilizer containing from 2 to 3 per cent nitrogen, 8 to 10 per cent available phosphoric acid and 2 to 3 per cent potash may be used. Such an application is not recommended as a continuous practice without maintaining the supply of organic matter in the soil.

VI. For wheat, an application of 150 pounds of a fertilizer containing 10 to 14 per cent available phosphoric acid and 3 to 4 per cent nitrogen is recommended to be applied with a fertilizer grain drill at the time the wheat is sown. Where the soil is well built up in organic matter, 150 pounds of steamed bonemeal or 200 pounds of acid phosphate per acre may be used. Where the soil is very thin, a complete fertilizer containing 2 to 3 per cent nitrogen, 10 to 12 per cent available phosphoric acid, and 3 to 4 per cent potash per acre may be used at the rate of 150 pounds per acre.

VII. For the man who is practicing a system of soil improvement and who is building up the soil in organic matter, the use of 800 to 1000 pounds per acre of ground rock phosphate once in four to six years may be economically used, turning it under with organic matter, such as barnyard manure, sod or green manure. In this case the available phosphates and the potash may be omitted before corn but the use of the phosphate and potash fertilizer, above recommended, will doubtless give good net returns with wheat.