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Cowpeas grown in the corn on the Hurdland Experiment Field

Soil Experiments on the Dark Prairies of Central and Northeast Missouri

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SOIL EXPERIMENTS ON THE DARK PRAIRIES OF CENTRAL AND NORTHEAST MISSOURI

(Soil Type—Grundy Silt Loam)

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The Missouri Agricultural Experiment Station for a number of years has been engaged in a systematic study of the soils of the state, the object of which is to outline the various soil types as they exist and to determine the best systems of soil management for each. In working out this plan, detailed soil maps[1] are being made county by county, and both field and laboratory studies are in progress. The field studies include observations at the time the soil survey is made and the carrying out of systematic experiments on carefully selected experiments fields located in different parts of the state. The fields are divided into several series of plots, the plots being given different soil treatments. Careful records of yields, and other facts of importance are kept thru a period of years and the results are published for the benefit of all who are interested in the soil type on which the field is located.

The soil type with which this report deals is what is known as the Grundy silt loam.[2] This soil occupies the undulating to gently rolling prairie of northeast and north central Missouri, and consists of a very dark brown to nearly black silt loam, 9 to 12 inches deep, gradually becoming lighter in color with increasing depth. The subsoil consists of a dark drab, plastic clay loam changing at 30 inches to a yellow gray, silty clay, mottled with brown. The character of this soil varies considerably, particularly as to depth and the content of organic matter. In general the better phases of it are found in the northern and western parts of the region.

[1] This mapping is being done in cooperation with the Bureau of Soils of the U. S. Department of Agriculture.

[2] In former soil reports this has been classed as a dark phase of the Putnam silt loam, since it has only recently been differentiated from that type.

For a complete understanding of experimental work of this nature certain facts regarding the feeding of plants should be kept in mind. In order to make proper growth, plants must be supplied with at least ten different chemical elements. Three of these—carbon, hydrogen and oxygen—come from the air and water in such abundance as never to limit plant growth. Four of them—calcium, magnesium, iron and sulphur—are taken from the soil but are used in such small amounts and occur in such quantities as seldom to become limiting factors of plant growth. The other three—nitrogen, phosphorus, and potassium—often limit growth, and are of such usefulness in agriculture as to be common items of commerce and to have a well recognized value on the fertilizer market. It is to these three elements, therefore, that attention is given in field experiments. Lime also must be applied to soils at times to keep them sweet and in a healthy condition for plant growth.

The Grundy Silt Loam, is somewhat deficient in both nitrogen and organic matter. The supply of phosphorus and potassium is considerably above that of an average soil, but it would seem from the results of these experiments that these elements of plant food, particularly the phosphorus compounds, are largely in insoluble or unavailable forms. Another characteristic of the soil which has much to do with its productiveness, is its sour or acid condition. This is doubtless due to the leaching out of lime and other basic material which it may have contained. Much of this soil is so sour as to need an application of one to four tons of ground limestone to the acre.

Three experiment fields were placed on this soil type, one at Unionville in Putnam county, one at Hurdland in Knox county, and one at Callao in Macon county. The field at Callao was planned chiefly as a pasture experiment and complete records of yields were secured only when the field was in wheat. Complete records of the other fields are shown in the tables which follow.

In preparing the tables which give the results with various crops on each field, the crop valuation used was the average of farm prices given by the State Board of Agriculture for the past five years (1909-1913). Fertilizers were figured at the average retail prices collected by the fertilizer inspectors from many parts of the state during the same period, and green manure crops at the cost of seed and seeding. This method gives the following list of prices:

Farm Crops

Corn	$ .55 a bushel
Oats	.37 a bushel

Wheat	.90 a bushel
Clover hay	11.25 a ton
Cowpea hay	11.21 a ton

Fertilizers

Cowpea green manure crop	$ 2.00 an acre
Ground limestone	3.00 a ton
Steamed bonemeal	28.00 a ton
Muriate of potash	47.50 a ton
Sulfate of potash	56.00 a ton
Rock phosphate	10.00 a ton
Manure	.85 a ton

All net returns are figured after the cost of treatment has been deducted and losses are indicated by minus signs. No account has been taken of the extra labor involved in handling the increased crop secured, but on the other hand no value is given to the straw and stover so that one of these will roughly balance the other.

UNIONVILLE EXPERIMENT FIELD

An experiment field was started on the farm of Jesse B. Campbell one mile southeast of Unionville, in Putnam county, in the spring of 1905. The surface soil is a very dark gray to a very dark brown, mellow, silt loam, to a depth of 12 inches. This grades into a dull gray, friable silt loam changing at about 18 inches to a heavy waxy, plastic clay loam, dark drab in the upper portion and a yellowish gray below. The field is inclined to be wet, as the area is rather level, sloping only slightly to the east.

The land had been in meadow for twelve years before beginning the experiments and was yielding an annual return of a ton to a ton and a half of hay per acre. It was in corn and meadow preceding this but had never been manured or fertilized in any way. The meadow was running to red top and wild grasses, probably due to the sour condition of the soil, but there was still a fair amount of timothy. It was discovered after the field was laid out, that plot number one contained an old fence row, but it was taken as a check plot so as not to exaggerate the effects of fertilizer treatments. The plots extended across the wetter and drier areas in such a way as to eliminate as far as possible the error from differences in soil moisture content.

The amounts of the chief elements of fertility in this soil compared with those in a very fertile soil are shown in the following figures:

	Total nitrogen	Acid soluble phosphorus	Acid soluble potassium
A very fertile soil contains in the surface seven inches of an acre	6000 lbs.	2000 lbs.	5300 lbs.
The Unionville soil contains in the surface seven inches of an acre	2820 lbs.	1135 lbs.	4000 lbs.

This comparison shows the soil to be low in nitrogen and somewhat low in phosphorus and potassium. The small amount of nitrogen would also indicate that the store of decaying organic material is low, since nearly all of the nitrogen of the soil is in this organic matter. The chemical test also shows this soil to be sour.

Plan of Field. In order to avoid insects and diseases which are most prevalent in continuous cropping, as well as to try the effect of fertilizers on different crops a rotation was adopted consisting of corn, wheat, and clover. It was planned to substitute cowpeas for clover in case of failure to get a stand. The field was divided into three main divisions to accommodate the three crops of the rotation and each of these divisions was subdivided into five plots of one-fifth acre each. This arrangement together with the soil treatment of each plot is shown in the following diagram.

UNIONVILLE EXPERIMENT FIELD

SERIES A

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

SERIES B

6. No treatment
7. Legume
8. Legume, Lime
9. Legume, Bonemeal, Lime
10. Legume, Bonemeal, Lime, Potash

SERIES C

11. No treatment
12. Legume
13. Lime, legume
14. Legume, Bonemeal, Lime
15. Legume, Bonemeal, Lime, Potash

Soil Treatments. The legume treatment has consisted chiefly in the sowing of cowpeas in the corn at the last cultivation and turning these under for the nitrogen and organic matter which they supply.

Figure 1

Wheat on the Unionville Field, 1909. The legume-bone-lime plot (on left), yielded 25.2 bu. while the legume-lime plot yielded only 18.0 bu. per acre.

Lime was applied for the purpose of correcting the sour or acid condition of the soil. The acid interferes with the growth of certain bacteria that make plant food available thru the processes of decay as well as with that of other forms which fix the nitrogen of the air for the use of higher plants. The amounts applied at Unionville were 4500 pounds per acre on the limed plots of series A and series B, and only 2500 pounds per acre on those of series C. This was broadcasted on the plowed soil and thoroly worked in, all of it being applied in the season of 1905.

Steamed bonemeal was used for the phosphorus fertilizer. The phosphorus treated plots on series A received 450 pounds of bonemeal per acre before the corn crop of 1905, and 200 pounds before that of 1908. On series B they received 225 pounds of bonemeal before corn in 1906, 110 pounds before wheat in 1907 and 150 pounds before corn in 1909. On series C smaller amounts of bonemeal were applied, namely, 112½ pounds before cowpeas in 1906, the same amount before corn in 1907 and 150 pounds before wheat in 1909. The best method of application was found to be drilling with a fertilizer grain drill.

Potash was added in the form of muriate or chloride of potash which is very easily dissolved and readily available. It was applied by mixing and drilling with the bonemeal. From 1905 to 1908 muriate of potash was applied at just half the rate of the bonemeal. Since that time fifty pounds per acre have been used before corn and before wheat. Unlike phosphorus, potassium tends to accumulate in the stems and leaves of plants and hence is not lost rapidly if these be returned as manure. Most northeast Missouri prairie soils are well supplied with this element, and the chief problem is to make it available. The soil

Table I. Results of Experiments with Corn (7 crops) Unionville 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
No treatment	37.3				
Legume	36.6	– .7	–$ .38	$ .67	–$1.05
Legume, lime	41.7	4.4	2.42	1.71	.71
Legume, lime, bonemeal	47.1	8.3	4.56	3.00	1.56
Legume, lime, bonemeal, potash	51.9	13.1	7.20	4.00	3.20

Table II. Results of Experiments with Wheat (3 crops) Unionville 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
No treatment	9.0				
Legume	8.7	– .3	–$ .27	$ .67	–$ .94
Legume, lime	12.1	3.1	2.79	1.62	1.17
Legume, lime, bonemeal	17.5	8.5	7.65	3.18	4.47
Legume, lime, bonemeal, potash	18.1	9.1	8.19	4.53	3.66

Table III. Results of Experiments with Cowpea Hay (2 Crops) Unionville Field

Soil treatment	Average yield pounds hay 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
No treatment	3688				
Legume	4350	662	$3.70	$ .67	$3.03
Legume, lime	3925	238	1.33	1.54	-.21
Legume, lime, bonemeal	4450	762	4.27	2.53	1.74
Legume, lime, bonemeal, potash	5700	2012	11.27	3.21	8.06

Table IV. Results of Experiments with Clover Hay (1 crop) Unionville Field

Soil treatment	Average yield pounds hay 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
No treatment	1575				
Legume	1875	300	$1.68	$ .67	$1.01
Legume, lime	1800	225	1.26	1.29	- .03
Legume, lime, bonemeal	2100	525	2.94	2.34	.60
Legume, lime, bonemeal, potash	2000	425	2.38	2.94	- .56

at Unionville has somewhat less of it than that of the other fields, and potash has returned a good profit on the money invested in it.

The accompanying tables show in detail the results of the soil treatment on the various crops grown on the Unionville field.

The corn crops at Unionville were injured by wet weather in the springs of 1905, 1906, and 1908. The season of 1907 was the most favorable one during the period in which these experiments were conducted. When the weather conditions were favorable, the soil treatments had a better chance to increase the yields. The profitable applications for corn were potash, lime, and bonemeal in the order given. The peas drilled in the corn at the last cultivation reduced the yield of grain somewhat and the result was a loss.

Three very good clover crops were grown on this field, but two of them were not weighed plot by plot, so that the table is not complete for clover. In 1907 there were striking differences between the clover plots which graded up step by step from the one receiving no soil ing medium dark when wet, and a dark gray when dry. It is not so light in color, however, as the typical Putnam silt loam of the level prairies southeast of Knox county. The surface slopes slightly to the east and to the west from the middle driveway, giving it only fair drainage.

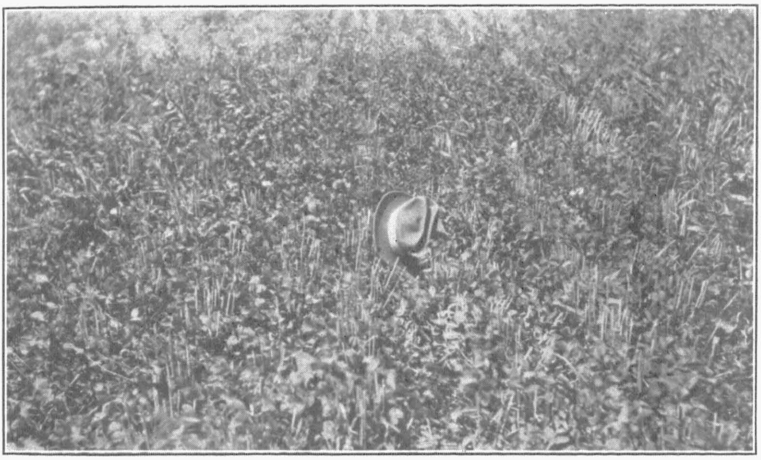

Figure 2
Stand of clover on the limed plot at Hurdland, 1914

The chemical analysis of this soil shows the following amounts of the important elements of fertility together with the corresponding analysis of a very fertile soil.

	Total nitrogen	Acid soluble phosphorus	Acid soluble potassium
A very fertile soil contains in the surface seven inches of an acre	6000 lbs.	2000 lbs.	5300 lbs.
The Hurdland soil contains in the surface seven inches of an acre	3760 lbs.	1978 lbs.	6009 lbs.

The analysis shows the soil to be well supplied with the mineral elements, phosphorus and potassium, but low in nitrogen. It is also sour. The lack of nitrogen indicates a low supply of organic matter and this fact together with the sour condition of the soil would indicate that bacterial growth is not so vigorous as it should be, and hence that the elements of plant food may be rather slow in becoming available. It is of interest to note that the sourness of the soil is such that it takes over three tons of ground limestone to neutralize the acid in the top seven inches of an acre.

This field was laid out with four main divisions or series of eight plots each with the treatments shown in the following plan:

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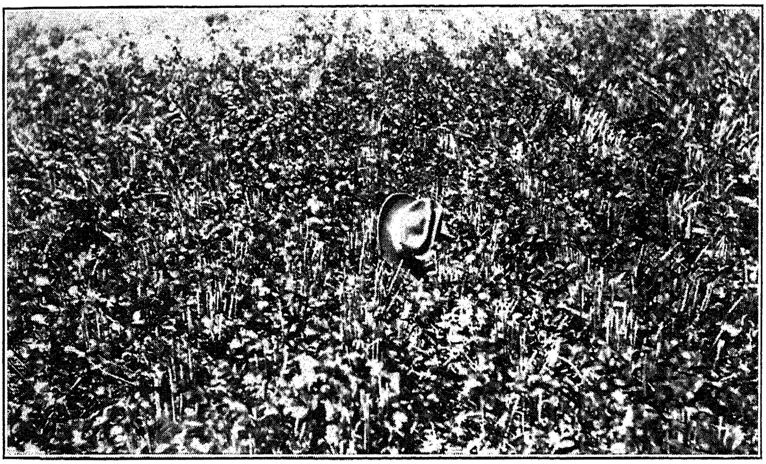

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This field was laid out with four main divisions or series of eight plots each with the treatments shown in the following plan:

Plan of the Hurdland Experiment Field

Series B		Series D	
16	Manure, Rock phosphate, Legume	32	Manure, Rock phosphate, Legume
15	Manure, Rock phosphate	31	Manure, Rock phosphate
14	Manure	30	Manure
13	No treatment	29	No treatment
12	Legume, Bonemeal, Lime, Potash	28	Legume, Bonemeal, Lime, Potash
11	Legume, Bonemeal, Lime	27	Legume, Bonemeal, Lime
10	Legume, Bonemeal	26	Legume, Bonemeal
9	Legume	25	Legume

Series A		Series C	
8	Manure, Rock phosphate, Legume	24	Manure, Rock phosphate, Legume
7	Manure, Rock phosphate	23	Manure, Rock phosphate
6	Manure	22	Manure
5	No treatment	21	No treatment
4	Legume, Bonemeal Lime, Potash	20	Legume, Bonemeal Lime, Potash
3	Legume, Bonemeal, Lime	19	Legume, Bonemeal, Lime
2	Legume, Bonemeal	18	Legume, Bonemeal
1	Legume	17	Legume

The rotation adopted on this field was one of corn, oats, wheat, and clover, substituting cowpeas for the clover in case of clover failure. The general plan was to apply the bonemeal at the rate of 150 pounds and the chloride of potash at the rate of 50 pounds per acre, drilled in before corn and with wheat. Limestone was applied at the rate of one ton per acre once in six years and manure before corn at the rate of eight tons per acre. The rock phosphate was applied with the manure at the rate of 1000 pounds with the exception of the first application on series A and C which was 500 pounds. The legume treatment consisted of drilling about a bushel of cowpeas between the rows of corn at the last cultivation, the pea crop being left on the ground to add organic matter and nitrogen.

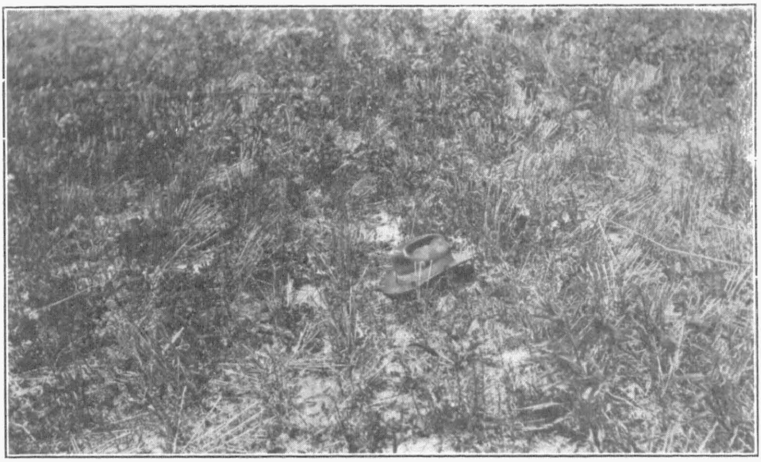

Figure 3
Stand of clover on the unlimed plot at Hurdland, 1914. Compare with Fig. 2.

Some exceptions to this plan were made. The corn crops of 1907 and 1908 each received 200 pounds of bonemeal, and the wheat crop of 1908 received 187½ pounds of bonemeal and 31 pounds of chloride of potash. Five tons of manure and 312 pounds of rock phosphate were applied before the 1908 wheat crop. The cowpea crop on series D in 1908 received one-fourth the usual application of manure and rock phosphate and 100 pounds of bonemeal on the bonemeal plots. Series B and C each had a crop of oats and cowpeas turned under on the legume plots in 1907 and series B had the regular crop of cowpeas turned under on the legume plots in 1909. It should be noted that these are exceptions only in the amount and time of application. All of these soil treatments were made only on the plots marked to receive such treatment in the general field plan.

Table VI. Results of Experiments with Corn (8 Crops) Hurdland 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	29.3	-3.80	-$2.35	$ .65	-$2.99
Legume, bonemeal	29.3	-3.76	- 2.07	1.80	- 3.87
Legume, bonemeal, lime	34.1	1.02	.55	2.45	1.89
Legume, bonemeal, lime, potash	37.8	4.65	2.55	3.02	- .45
No treatment	33.1				
Manure	41.6	8.40	4.62	1.72	2.89
Manure, rock phosphate	40.4	7.27	4.00	2.79	1.20
Manure, rock phosphate, legume	35.2	2.12	1.05	3.33	-2.27

Table VII. Results of Experiments with Oats (6 Crops) Hurdland 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	27.9	.98	$ .36	$ .75	-$ .38
Legume, bonemeal	31.2	4.33	1.60	1.93	- .33
Legume, bonemeal, lime	35.2	6.50	2.42	2.61	- .18
Legume, bonemeal, lime, potash	34.3	7.36	2.73	3.20	- .47
No treatment	26.9				
Manure	31.6	4.68	1.73	1.73	.02
Manure, rock phosphate	32.0	4.70	1.74	2.76	-1.02
Manure, rock phosphate, legume	35.7	8.80	3.26	3.34	- .08

Table VIII. Results of Experiments with Wheat (6 Crops) Hurdland 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	14.36	.63	$ .57	$ .70	-$ .12
Legume, bonemeal	18.11	4.38	3.94	1.88	2.06
Legume, bonemeal, lime	17.96	4.20	3.79	2.47	1.32
Legume, bonemeal, lime, potash	17.08	3.30	3.00	3.02	- .02
No treatment	13.73				
Manure	17.65	3.90	3.52	1.60	1.92
Manure, rock phosphate	17.20	3.46	3.12	2.75	.37
Manure, rock phosphate, legume	18.50	4.73	4.27	3.36	.91

Table IX. Results of Experiments with Clover Hay (3 Crops) Hurdland 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	2500	– 241	–$1.36	$ .56	–$1.92
Legume, bonemeal	3213	475	2.66	1.73	.93
Legume, bonemeal, lime	3775	1031	5.79	2.27	3.51
Legume, bonemeal, lime, potash	4116	1375	7.70	2.80	4.90
No treatment	2741				
Manure	3341	600	3.36	1.70	1.66
Manure, rock phosphate	3241	500	2.80	2.53	.27
Manure, rock phosphate, legume	3300	558	3.13	2.93	.20

Table X. Results of Experiments with Cowpea Hay (1 Crop) Hurdland 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	3850	– 350	–$1.96	$1.00	–$2.96
Legume, bonemeal	7150	2950	16.52	2.14	14.38
Legume, bonemeal, lime	5850	1650	9.24	3.15	6.09
Legume, bonemeal, lime, potash	6100	1900	10.64	3.77	6.87
No treatment	4200				
Manure	3525	–675	–3.78	2.12	–5.90
Manure, rock phosphate	5450	1250	7.00	3.53	3.47
Manure, rock phosphate, legume	4150	– 50	–.28	4.03	–4.31

Table XI. Results of Experiments with Oat Hay (1 Crop) Hurdland 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	3850	1650	$ 7.42	$ .50	$6.92
Legume, bonemeal	4150	1950	8.78	1.55	7.23
Legume, bonemeal, lime	4650	2450	11.02	2.18	8.84
Legume, bonemeal, lime, potash	4050	1850	8.32	2.77	5.55
No treatment	2200				
Manure	3225	1025	4.61	1.70	2.90
Manure, rock phosphate	3700	1500	6.75	2.95	3.81
Manure, rock phosphate, legume	3500	1300	5.85	3.45	2.40

Figure 4

Corn on the Hurdland Field, 1908. The legume-bone-lime-potash plot (on right) yielded 44.3 bu. while the untreated plot (on left) yielded but 31.8 bu. per acre.

The final results of these experiments indicate, that for corn, barnyard manure is the best fertilizer, particularly on land that has a fair supply of mineral plant foods, but which is low in organic matter. As an average of eight crops, manure applied at the rate of eight tons to an acre every four years, or two tons a year, has increased the corn yield by eight and a half bushels annually, worth at the average farm price for corn, $4.67. Commercial fertilizers have not yet proved their worth when used for corn on the Hurdland field, but lime when added to the commerical fertilizer plots has greatly reduced the loss, indicating that it can be used before corn with profit. Of the different soil treatments with oats only manure and lime have returned their cost. As is usually the case, however, bonemeal has been profitably used on wheat, producing an average annual increase of about four bushels when the entire five crops are considered.

Insufficient drainage has had much to do with making poor wheat crops on this field. The excess of moisture causes heaving by freezing and thawing during the winter and prevents the air from getting down into the soil. As a result most of the wheat crops have been badly damaged. It was repeatedly noticed that plots receiving bone or manure produced stronger plants which stood the winter better. Limestone, bonemeal, and manure have all given profitable increases on the clover crop but their effects are somewhat different. On soils as sour as this one, limestone is the first thing needed in the way of soil treatment, if clover is to be grown. This was well illustrated during the season of 1914 when there was a fair stand of clover on the limed plots and none whatever on the unlimed ones. After being limed, the clover still needs the plant food contained in bonemeal and manure,

Figure 5
Wheat on the Hurdland Field, 1908. The legume-bone-lime-potash plot (on right) yielded 21.2 bu. while on the untreated plot (on left) only 13.1 bu. per acre was secured.

altho these are best supplied to the preceding wheat and corn crops respectively.

Table XII. Averages for Entire Field, All Crops, Hurdland Field

Soil treatment	Average value of increase per acre	Average cost of treatment per acre	Average net returns per acre per year
Legume	–$ .47	$ .68	–$1.15
Legume, bonemeal	2.00	1.85	.15
Legume, bonemeal, lime	3.17	2.49	.68
Legume, bonemeal, lime, potash	3.85	3.01	.84
Manure	3.17	1.70	1.47
Manure, rock phosphate	3.33	2.78	.55
Manure, rock phosphate, legume	2.74	3.32	– .58

As shown in the preceding table in which results on the whole field have been summarized, manure, bonemeal, and lime have been used with profit, while the returns from potash have paid for the cost. The other treatments have resulted in losses. Other experiments have shown that when bonemeal is not obtainable other forms of available phosphates may be substituted. Recommendations based on these experiments then would clearly include: first, the use of all the manure obtainable, to be used before corn; second, an application of at least two tons of ground limestone per acre worked into the freshly plowed soil at any convenient place in the rotation to be followed by somewhat lighter applications every 4 to 6 years; and third, the use of 150 to 200 pounds of a good grade of fertilizer, high in phosphorus, applied before wheat.

CALLAO EXPERIMENT FIELD

In the spring of 1909 a special soil experiment field was started on the farm of Ed Gates three miles southwest of Callao, in Macon county. The plan of this field is entirely different from those at Hurdland and Unionville, but the soil type is the same. It was planned chiefly as a test of the effect of catch and pasture crops on the fertility of the soil, but also included a test of bonemeal and rock phosphate in combination with pasturing.

The field is on the undulating prairie of that section of the state. The surface soil is a dark brownish gray silt loam about 12 inches in depth. This is underlaid by dark gray, heavy, silt loam. At about twenty inches it becomes very heavy and plastic and is mottled with brown and gray. There are many iron concretions and some fine gravel in this layer. Beyond thirty inches in depth it is not quite so heavy but is still mottled in color. The plots run east and west and slope rather sharply to the west so that the area is well drained.

Plan of Field. There was but one series of plots on this field and only one crop was grown each year. There were five plots, each three-fifths of an acre in area. The first or north plot received a straight rotation but with no catch or cover crops, all regular crops being removed. It thus served to measure the effect of catch or cover crops on the rest of the field. Plot 2, in addition to the rotation, had cowpeas sown in the corn and both corn and peas hogged off during the season of 1910. It also differed from plot 1 in having rye sown as a cover crop in the fall of 1910, the rye being pastured and plowed under during the next spring. Plot 3 was treated like plot 2 except that the cowpea crops of 1911 and 1912 were pastured off instead of being cut for hay as was done on plot 2. Plot 4 differed from 3 only in receiving two applications of bonemeal, 150 pounds per acre before corn in 1910 and 150 pounds before wheat in the fall of 1911. Plot 5 was treated with one 600 pound application of rock phosphate, this being the only difference between its treatment and that of plot 3. The regular crops grown were as follows:

1909—Oats for hay; cut and weighed on all plots.

1910—Corn; hogged down on plots 2, 3, 4, and 5; cut and removed from plot 1.

1911—Cowpeas; cut and removed from plots 1 and 2; pastured with hogs on 3, 4, and 5.

1912—Cowpeas; cut and removed from plots 1 and 2; pastured on 3, 4, and 5.

The purpose of sowing the entire field to oats the first season was to see if there were any marked differences in productiveness between the different plots. The yields secured showed that the differences were not important. Comparative yields were not secured again until wheat was grown in 1913, because all other crops were pastured except on plots 1 and 2 on which the cowpeas were cut and weighed up as hay both in 1911 and in 1912. Plot 1 yielded 1016 pounds of hay per acre in 1911 against a yield of 1608 pounds on plot 2, while in 1912 the yields were 2825 pounds and 4666 pounds respectively. This difference is apparently due chiefly to the hogging down of a crop of corn and cowpeas and the turning under of a rye cover crop and shows the response of this soil to increases in organic matter. Table 13, shows the yields of wheat from all plots in 1913 and serves as a measure of the relative fertility of the plots at the end of four years.

Table XIII. Wheat on Callao Experiment Field 1913

Plot No.	Soil treatment	Pounds straw per acre	Bushels wheat per acre
1	No catch crops, all crops removed	2826	14
2	Same as plot 1 except for one crop rye turned under and crop of corn and cowpeas pastured.	3436	16
3	All crops pastured except wheat	3779	18
4	All crops pastured except wheat, bonemeal used before corn and wheat	5004	25
5	All crops pastured except wheat, rock phosphate used before corn	5172	24

As might be expected wheat did not give such marked increases from pasturing as did cowpeas, but made its largest response to applications of phosphates. As is shown by the large increase in wheat straw the growth of the rest of the plant is favored somewhat more than that of the grain by increases in decaying organic material. Where wheat is one of the crops of the rotation it would seem best to combine the pasturing scheme with an application of phosphate when the wheat is sown. The form of phosphate to use will probably depend upon conditions. Rock phosphate is rather slow in action even when very finely ground, but only costs about one-third as much as bonemeal and contains fully as much phosphorus. Where turned under with a supply of manure or green manure crops as was done here it is very effective, the process of decay serving to bring it into an available form. Altho the bonemeal produced a slightly higher yield of wheat in this test than did the less easily dissolved rock phosphate, it was done at a little higher cost and more phosphorus has been added in the latter. If the entire amounts of bonemeal and raw rock phosphate be charged to this wheat crop the net return per acre from the bonemeal is $2.10 against $2.40 for the raw rock phosphate.

GENERAL RECOMMENDATIONS REGARDING SOIL MANAGEMENT

The results of these experiments warrant some definite conclusions and recommendations regarding methods of soil management on this dark prairie land. Some profit has been secured from all the treatments given excepting cowpeas drilled in the corn at the last cultivation for a green manure crop. The use of manure and lime have both brought consistent and valuable net returns, while good average net returns have also been secured from the use of phosphorus and fair returns from the use of potassium. The largest return will doubtless accrue from the building up of the organic matter and the nitrogen in the soil thru crop rotation, manuring and by occasional green manuring. This should be supplemented by the use of phosphates. Lime is essential, where this land is to be farmed most intensively, and it usually will be found profitable where the system of farming is only moderately intensive. The application of small amounts of potash fertilizers in connection with phosphates will usually be accompanied by good returns, particularly on those areas which are lowest in organic matter.

Systems of Cropping. The larger part of this rolling prairie land is ideally adapted to live stock farming. It is even better adapted for this purpose than is the level prairie. Consequently systems of cropping adapted to live stock farming are most widely used. Few farmers are practicing a systematic crop rotation, however, and this is a matter which deserves more attention by the farmers of the region. It is true, of course, that an irregular change of crops is better than no change at all, yet a regular and systematic rotation should be followed in so far as possible. This necessitates having as many fields as there are crops in the rotation, and they should be of approximately equal size. Where a crop fails, a similar crop should be susbstituted so as not to disarrange the rotation. Thus cowpeas or soybeans should be grown when clover fails.

Probably one of the best rotations for general live stock farming on this soil type is one of corn two years, followed by oats, and this by two or three years of grass. Such a rotation is a very satisfactory one, providing clover can be used with timothy to make the grass mixture. Since red clover is rather uncertain, alsike clover can often be used, altho where the land is properly limed and the supply of organic matter maintained, red clover can usually be grown. In this rotation, rye should be seeded in the corn the first season for fall and spring pasture. Where oats follow the second corn crop, there is some danger of the land washing during that fall and spring.

Figure 6
It was necessary, both to increase the fertility and to reduce the sourness by adding limestone, before this crop of clover could be grown.

A shorter rotation of corn, oats, and two years of alsike clover and timothy is a very satisfactory one for the man who is farming the more worn areas of this prairie. In order to get along with but one year of corn in four, on a live stock farm, very liberal use must be made of legumes for winter feed. Consequently the smaller growing alsike clover in the timothy will not be sufficient, and a secondary rotation consisting largely of cowpeas and soybeans must be used to supply extra nitrogenous feed. Where a man can grow red clover, this four year system can well be used, altho most farmers will find it difficult to get along with this amount of corn. In such a rotation cowpeas or soybeans may be seeded in the corn at planting time to increase the supply of nitrogenous feed. Some decrease in the yield of corn usually must be expected, however, when this is done. Another rotation suitable for a live stock farm on the more worn areas of this dark prairie is one of corn two years, soybeans or cowpeas one year, wheat or rye one year, and timothy with either alsike or red clover two or three years. This will give a large amount of nitrogenous feed and if rye is seeded in the corn both years, for fall and spring pasture, a large amount of pasture may be obtained. Such a system is particularly well adapted to a farm which is mainly devoted to the growing of hogs. Such a system where properly handled will build up the supply of organic matter and nitrogen of the soil.

For the better phases of this soil where the organic matter and nitrogen have been maintained, or on areas of average fertility where a man must have immediate returns, rotations including more grain crops can be used. Such cropping systems rarely build up the soil, however, and the greater part of this land cannot be farmed to grain crops for any length of time without material injury, unless liberal use is made of green manures for turning under. On this soil such systems are rather difficult to work out. Where clover is a fairly certain crop a rotation of corn, oats, and clover may be used as a grain-green manure system by the man who does not handle live stock. It is possible to maintain the organic matter and nitrogen of the soil under such a system provided the corn is picked and sold and the stalks left on the field, the oats grain sold and the straw returned to the land, the first crop of clover cut early and allowed to lie on the ground, and the second crop of clover allowed to grow up thru this and be cut for seed with a self rake reaper. Such a system would necessitate the ultimate return of considerable quantities of phosphates to make up for that removed in the grain crops, and good clover crops must be secured for turning under if the organic matter and nitrogen are to be maintained.

Another similar system consisting of corn, oats, wheat, and clover could be used with the grain crops handled in much the same manner, but in order to return sufficient organic matter and nitrogen with this extra grain crop thrown in, cowpeas or soybeans should be grown as a catch crop for green manure. Clover may also be sown in the oats to be turned under for wheat where the land is very good. Such systems of grain farming are rarely advisable. The greatest difficulties are to grow clover on this land with sufficient regularity, and the temptation to cut the first crop of clover for hay instead of allowing it to lie on the ground to be turned under.

Systems of so called general farming adapted to this land are those in which a part of the crops are sold and a part fed. Such systems are very common. The rotations already suggested under live stock farming and grain farming may be used as general farm rotations. Another which is adapted to those farms where clover is a fairly sure crop is corn, oats, wheat, and clover. Another is corn, corn, oats, wheat and clover, or corn, corn, oats or wheat, clover and timothy two years. In these rotations all the wheat and a part of the corn may be sold. If oats is grown it would be sold either all or in part.

Such systems of farming rarely maintain soil fertility. This can be done, however, if legume crops are occasionally turned under in addition to the manure returned, and if phosphates and potash are supplied in fertilizers. The fact that the supply of manure for turning under is much less than in live stock farming and that green manure crops are not readily thrown in between regular crops for turning under, makes it rather difficult to maintain fertility under such a system. It is under just such a system as this that most of those farms on which the fertility is waning, are being handled.

Use of Barnyard Manure and Green Manures. These experiments show that one of the needs of this soil is a greater amount of organic matter and that the best method of applying it is by means of a live stock system of farming. Attempts to grow cowpeas in the corn and plow them under have been unsatisfactory owing to the fact that the peas usually made little growth and generally reduced the corn yield. Where the corn and peas were pastured, the results were more satisfactory. In these experiments peas were sown between the rows of corn at the last cultivation. It has been found better to plant the peas in the hill or drill at the time the corn is planted by using a cowpea attachment on the planter. This requires but one gallon of peas to the acre and the peas usually mature, thus making somewhat better feed when pastured out. The yield of corn usually is reduced less than where they are sown between the rows and the growth of the peas usually is greater. Where the peas can be pastured out this plan seems more economical. It is certainly a good thing for the soil. The use of cowpeas or other crops for green manures, wherever they can be handled without interfering too greatly with the regular crops of the rotation, is to be recommended. Where such crops can be pastured instead of being turned under this will usually give greater immediate returns.

The keeping of live stock and the production of large supplies of manure is highly desirable on this soil. The utmost care should be taken to put all the manure on to the fields with the least possible loss. This is best done by applying it as soon after it is made as possible, especially on the lands which are only slightly rolling and where there is little danger of the manure being partly washed away. Where it cannot be hauled to the field immediately it keeps best in a compact pile where it may be thoroly packed down and kept moist so that the air does not penetrate it readily. One of the best ways of handling manure is to feed cattle in a covered shed so that the manure will accumulate under shelter and be packed by the tramping of the animals. Where considerable roughage or bedding is supplied animals keep reasonably clean.

Manure usually can be applied with the greatest advantage before corn. The corn crop is a gross feeder and makes excellent use of it. In a proper rotation, corn usually follows timothy and clover sod on which the manure can be easily scattered during the fall and winter. Wheat is also a good crop on which to apply manure. A top dressing of 5 or 6 loads to the acre is of much value to the wheat and where grass or clover follows, it will aid materially in securing a stand. The use of a manure spreader is essential to the proper handling of manure, when the animals are stable or lot fed.

Many farmers feed stock largely on the field and there is no better method of scattering manure providing the feeding is done so as to get the manure evenly distributed. Too often the feeding is done in one place where the manure largely accumulates. Often too, this is on a well drained ridge top from which the manure is washed into the streams. Where the feeding is properly done by changing the feeding area, or where crops like corn, cowpeas, or soybeans are hogged or pastured down, it will be found that these are very efficient means of getting manure back to the land without waste.

Use of Lime. Practically all of the soil of this type is somewhat sour owing to the leaching out of lime and other basic materials. This is true of most of the older soil formations regardless of the amount of lime they may have contained when first formed. The amount of ground limestone necessary to sweeten this soil varies from one to as high as four tons per acre, and on the more acid areas it is essential to the growth of clovers, tho most other crops are not exacting in this matter. One of the chief difficulties in handling a sour soil lies in its being a poor medium for the growth of certain desirable bacteria which help to make plant food available, particularly those which grow on the roots of legumes and enable them to use the nitrogen of the air.

There are three forms of lime which may be used to correct the sour conditions of soils, namely limestone, lump or quick lime, and hydrate of lime, which is quick lime with just enough water added to bring it to a powder. Either quick lime or hydrate of lime when exposed to the air becomes air slaked, but air slaked lime is the same compound as ordinary limestone or lime carbonate. From this it may be seen that whatever form of lime is used the final compound in the soil is the same. These forms are not equal in strength when applied, however, 2000 pounds of limestone or old air slaked lime being equal to 1120 pounds of quick lime or 1480 pounds of the hydrate of lime. When large amounts are to be applied, ground limestone should be used as it has no tendency to be caustic, a fault which is sometimes found with the other forms. Another and probably the more common reason for using limestone is that it is usually the least expensive.

The profits from the use of lime on these experiment fields while not remarkably large have been consistent. When ground limestone costs more than three dollars a ton applied it probably will be better to adopt a rotation of acid tolerant crops leaving out such crops as clover and alfalfa. On the other hand it seems that a soil well supplied with lime slowly but steadily improves in fertility, and it is likely that thru a long period of years the advantages of liming will be greater. Nevertheless, liming cannot be expected to bring any very large immediate returns, altho it influences the growing of certain legumes and these in turn benefit the soil. So the man who is expecting to farm this land under a moderately intensive system must expect to use more or less lime. Liming would probably not pay for the extensive farmer, or the man who is located more than four or five miles from the railroad or from a local source of lime.

To be most effective the lime should be thoroly mixed with the soil. Hence it is best applied after plowing and worked into the soil as the seed bed is prepared. It is so heavy and the cost of hauling and applying is so large a per cent of the total cost that the chief factors in deciding when to apply lime seem to be the leisure of men and teams and the condition of the roads. Where much liming is to be done, it will pay to purchase a lime distributer, but on a small scale it may be scattered with the manure spreader or with shovels on days when there is little wind.

Use of Phosphatic Fertilizers. Altho this type is fairly well supplied with rather insoluble forms of phosphate, conditions do not seem to be favorable for bringing them into solution. The application of soluble phosphate in the form of bonemeal has been profitable with all crops at Unionville, and Callao, and with most crops, particularly with wheat, at Hurdland. Rock phosphate, which is not so readily available, has not been so satisfactory except at Callao where it was turned under with an abundance of decaying material in a pasture system of farming. It is the cheapest possible form of phosphate but is adapted particularly to permanent systems of soil building where it can be used to supplement barnyard manure and green manures and where immediate returns are not important. Where rock phosphate is used it is not advisable to apply it in much smaller amounts than 1000 pounds per acre, and this can be best done with a lime distributer altho a fertilizer drill may be used. Schemes for bringing it into closer contact with decaying materials are sometimes adopted such as scattering the phosphate in the stable or shed while the manure is accumulating or spreading it on top of the manure in the manure spreader. The decay of the manure will aid in dissolving the raw phosphate and thus make the phosphorus available. Its use, however, is to be recommended mainly for the landowner who is practicing a system of soil building and who has money to invest and time to wait for returns. The bonemeal used in these experiments was the steamed bonemeal which can be ground finer than raw bonemeal, and having less oil in it the phosphorus is more easily dissolved. The most profitable increases have been made on the wheat crop, altho its use has considerably increased the growth of clover and cowpeas, and at Unionville, the corn. In general it may be concluded that available phosphates, particularly bonemeal, can be used profitably before wheat in applications of 150 pounds per acre, but that in systems of farming where large amounts of manure or green manure are available this may be supplemented by the use of larger applications of the cheaper form of phosphate in the form of finely ground rock phosphate. When bonemeal cannot be secured, probably the best substitute for it is acid phosphate, applied at the rate of 150 to 200 pounds to the acre. Mixed fertilizers containing 10 to 12 per cent available phosphoric acid and 2 per cent each of nitrogen and potash may also be used with good results. The rate of application of these should be approximately that of the bonemeal.

The Use of Potash. Potash fertilizers applied at the rate of 50 pounds of muriate of potash per acre before corn and before wheat have resulted in a net profit at Unionville and Hurdland, altho this profit was rather small at the latter place. They were not tried at Callao. These results need verification, but it seems probable that small amounts of potash can be used profitably with phosphates for the grain crops. The muriate or chloride is the cheapest form to use for general farm crops and is the form chiefly used in mixed fertilizers. It is somewhat injurious to quality in tobacco and is considered less satisfactory for this crop than the more expensive sulfate of potash. The same is true where large quantities are used with potatoes. In general, plants use most of their potassium in the stalks and leaves so that there is little removed from the farm when the straw, stalks and hay are returned either directly or in manure. Phosphorus, on the other hand, is used largely in the grain of plants and the bones of animals so that more of it is likely to be sold from the farm.

The Use of Mixed Fertilizers. It has been shown that both phosphates and potash have paid as fertilizer applications on this soil. Consequently mixed fertilizers can be used under certain conditions. The use of highly phosphatic fertilizers has already been suggested as being somewhat equivalent to the bonemeal and acid phosphate. In the light of these experiments the use of mixed fertilizers with wheat, and on the more worn areas of this soil with corn, will prove remunerative. For wheat 125 to 175 pounds per acre of a fertilizer containing 1 to 2 per cent nitrogen, 10 to 12 per cent available phosphoric acid, and 2 to 3 per cent potash is to be recommended in the same manner as is the use of bonemeal or acid phosphate. A fertilizer containing these amounts of available phosphoric acid and potash without nitrogen also may be used. Undoubtedly the increasing price of bonemeal will soon make the acid phosphate and the highly phosphatic mixed fertilizers more widely used. The benefit of such fertilizers to the grasses or clovers sown with the grain will be of importance. On the poorer phases of this land the same fertilizers may be used with corn. This should be applied at the rate of 150 to 200 pounds per acre with a fertilizer drill ahead of the corn planter.

Where fertilizers are applied in the hill or drill with corn, as is very common in some parts of Missouri, an application of from 75 to 90 pounds of one of the mixed fertilizers mentioned above is to be recommended. No experiments with fertilizers in the hill were made on these fields but experiments were conducted on the level prairie as reported in Bulletin 126 of the Missouri Experiment Station. Fertilizers applied with corn in this way do not supply any particular soil deficiency but give the plants a quick thrifty growth enabling them to overcome insect and fungus enemies. Consequently a complete fertilizer is recommended. Only small quantities, from 75 to 90 pounds, should be used since large amounts often injure the corn, particularly in dry seasons. One hundred pounds seems to be about the maximum that one can use with safety. It must be remembered that such a use of fertilizer is but a temporary expedient to increase the crop yield and it does not tend to build up the soil. Therefore it should be used only in connection with a good system of soil management including crop rotation, and manuring. Where the raw materials can be bought advantageously, as for instance where a carload may be purchased cooperatively by several farmers, or where a farmer can have his dealer order a certain amount of the raw materials with carload lots of mixed fertilizers, home mixing of fertilizers can be done to advantage. Where one must order the raw material in less than car lots, however, the extra freight cost makes home mixing of rather doubtful economy.

Controlling Erosion. One of the problems in handling this rolling prairie land is that of controlling erosion. While it is true that erosion on this soil type is not as serious as it is on some of the more rolling lands of the state, yet the annual loss from washing is very great. The muddy, sediment carrying streams, which are so common in this region, bear evidence to this fact. Farmers as a rule do not realize the losses due to this cause. The excessive growing of corn has been largely responsible for this loss because there are few cases in which erosion is greater than in the stalk fields during the fall, winter, and spring months. The time is ripe for a much wider use of fall sown grain, such as rye or wheat following corn. The use of the silo makes possible the early removal of the corn from a part of the corn land and will aid in the introduction of these crops.

Figure 7

The bare condition of the soil shown in the upper picture is entirely too common, but the lower view shows how this may be remedied by rye as winter cover crop to prevent washing. Much spring pasture is furnished too.

The incorporation of larger quantities of organic matter with the soil assists in preventing washing. Consequently, the building up of the supply of organic matter thru proper crop rotation and manuring is of importance from this standpoint as well as from many others. Where lands are kept largely in grass the washing problem is not serious.

The stopping of washes already formed is no simple matter. It requires persistent effort. The use of straw or other debris for stopping the small washes when they first appear is always to be recommended as they can be controlled readily at that time. After large washes have once been formed, strenuous and persistent efforts are necessary. Such efforts should include the use of brush or debris staked down, the use of quick growing plants in the bottom such as oats, millet, sorghum and the more hardy grasses. A mixture of redtop, timothy and blue-grass may be used where some dirt has already accumulated in the bottom of the wash. A little manure is always of great aid in getting these to hold. A tile drain laid rather shallow along a medium sized wash is of value in keeping down further washing and in enabling one to fill it. Where washes are very large a concrete or earth dam may be used. A large tile drain laid thru such dams and turned upward at a right angle, extending within a foot of the top, will be of much value in causing the dirt to accumulate above the dam and fill the wash. The most important thing, however, is to prevent washes from forming, and too much attention cannot be given to this matter on the more rolling areas of this prairie.

Tenant Farming. A great many farms in this section of Missouri are handled by tenants. Unfortunately most of these tenants are on short time leases and under such a plan the maintaining of soil fertility is almost impossible. Nevertheless, much can be done to improve methods of soil management under such systems and it is highly important that landowners give more attention to this matter. As a general proposition, the most helpful thing that could be done would be to lengthen the time of the lease. This matter is a very complicated one and since it is dependent largely upon economic conditions, the system is very difficult to change. Nevertheless a realization of the dangers and disadvantages of short time leases, not only in the effect upon the soil, but also upon the prosperity of the country community, will go a long way toward bringing about remedies. A more liberal attitude toward tenants and a willingness to allow them to remain on the place longer than one or two years, is essential. The present attitude on the part of some landowners is due to inferior tenants in many cases, but the observation of anyone who has given this matter particular attention, will show that those men who do best by their tenants usually have good men, and men who stay a number of years. Rapidly advancing land values have tended to preserve the spirit of speculation which has existed in this country for many years and this has had much to do in preventing the establishment of a long lease system. There is little doubt, however, that much of the difficulty lies in the attitude which the landowner has toward the tenant.

Among the specific things which the landowner may do to improve conditions in connection with a more liberal spirit toward the tenant is the supplying of clover seed for frequent seeding down of the land. There are, of course, many discouragements in connection with this practice, such as clover failures and the desire of the short time tenant to grow grain crops, but the principle is a good one to follow. Where a tenant is given assurance that he can remain on the place for four or five years, the landowner can usually dictate the cropping system and establish a more definite crop rotation. In such cases the tenant often can be induced to grow some stock. Sometimes the landowner may find it profitable to share in the cost and the returns on such live stock which is an added inducement for the tenant to go into the stock business. Where stock is kept, a manure spreader bought in cooperation is a great incentive for the tenant to take better care of manure and get it back on the land. It may often be a paying proposition for the landowner to furnish rock phosphate to apply to the land, or he may find it more desirable to share the cost of soluble phosphates with the tenant. In like manner on very sour areas of this soil, the landowner will often find it desirable to furnish ground limestone, if the tenant will meet the expense of putting it on the land.

Other plans for bringing about a better system of soil management under a system of tenancy will suggest themselves to the man who is interested in this matter and who studies the problem. Of course, all such plans mean that the immediate profit will be lessened but it is usually necessary to sacrifice somewhat on immediate returns if a soil is to be kept up, particularly under a system of tenancy. It is certainly to the interest of the average landowner who has no serious incumbrance on his farm and who is handling it through tenants, to plan a system whereby the fertility of his soil may be maintained.

SUMMARY

I. The dark prairie land of northeast and north central Missouri is adapted particularly to live stock farming, altho general farming, and on the better phases of this prairie, grain farming with green manuring, may be practiced. Some suggested cropping systems are as follows:

For Livestock Farming:

1. Corn, oats, clover and timothy, two years.
2. Corn, corn, oats, clover and timothy, two years.
3. Corn, corn, soybeans or cowpeas, wheat or rye, timothy and red (or alsike) clover two years.

For General Farming:

1. Corn, oats, wheat, clover.
2. Corn, corn, oats, wheat, clover.
3. Corn, corn, oats or wheat, clover and timothy, two years.

For Grain Farming:

1. Corn, oats, clover.
2. Corn, oats, wheat, clover.

Where red clover cannot be grown satisfactorily, alsike clover may be substituted or occasionally clover may be omitted and soybeans or cowpeas used.

II. One of the important needs of this prairie is building up and maintaining the supply of organic matter and nitrogen. This is best done thru a systematic crop rotation in which the crops are fed and the manure carefully returned to the land. It may also be done thru a system of grain farming and green manuring, or thru a combination of live stock and grain farming where both barnyard and green manures are used.

III. The use of barnyard manure under systems of live stock and general farming is one of the important factors in maintaining the organic matter and nitrogen. In these experiments, manure has brought an annual gross return of $3.17, or a total gross return $1.56 per ton. It is recommended that manure be applied with a manure spreader at the rate of 6 or 8 loads to the acre on meadow lands or before corn, and at the rate of 5 or 6 loads per acre as a top dressing for wheat. Where the supply of manure is limited, greater returns per ton of manure will be obtained by scattering it evenly and in the smallest convenient quantities per acre, than by applying unevenly and heavily.

IV. A system of farming where the animals can be fed on the fields partly thru the pasturing of crops, forms one of the cheapest means of returning organic matter to the land. Where animals are fed on the fields during the winter months, care must be taken that the feeding places are changed regularly, if possible, so as to distribute the manure and refuse feed over the land equally.

V. Lime is needed on much of this land, and on these experiment fields it has given a consistent, tho not a large return. It is needed in amounts varying from one to four tons of ground limestone to the acre. It is recommended that a ton be applied once in four to six years after the first application is made, spreading it on plowed land, preferably in the fall, and working it in with a disk and drag harrow. To make liming economical, ground limestone, or the equivalent in other kinds of lime, should be delivered and spread on the field at a cost of not more than $3 per ton.

VI. The use of phosphorus in the form of steamed bonemeal has proved generally profitable. On the other hand, raw rock phosphate plowed in with manure has failed to give a satisfactory return during the time in which these experiments have been conducted, altho when used in a system of pasturing and hogging down crops, it brought a slightly better net return than bonemeal. It usually will be found profitable to apply 125 to 175 pounds of bonemeal, or 150 to 200 pounds of acid phosphate to the acre with wheat, drilling it in with a fertilizer drill.

Potassium has brought a fair return on these fields. For the highest returns, particularly on the thinner areas of this soil, a mixed fertilizer containing 10 to 12 per cent available phosphoric acid, and 2 to 3 per cent potash will give good returns when applied at the rate of 125 to 175 pounds per acre before wheat, or at slightly higher rates before corn. Likewise a complete fertilizer containing 2 to 3 per cent nitrogen, 10 to 12 per cent available phosphoric acid and 2 to 3 per cent potash may be used.

VII. The man who is farming his own land under a system of soil building and who has sufficient capital so as not to be compelled to secure immediate returns, should adopt a careful system of rotation which provides for the maintenance of the organic matter and nitrogen. In addition, lime should be used for keeping the soil sweet, and phosphates, preferably the raw phosphate, should be applied while some soluble phosphates and potash should generally be used before wheat.

The man who must have immediate returns should adopt a system of rotation if possible. He will also find it advisable to use available phosphates, usually with some potash, before wheat and corn. Lime may or may not be used economically by such men, depending upon the length of the lease, if they are tenants, as well as upon the intensity of their farming operations.

VIII. Landowners handling their lands thru tenants should provide for as long leases as possible, and in addition should plan a system of cooperation with the tenants by which the fertility of the soil may be better maintained.