UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

BULLETIN NO. 128

Soil Experiments on the Rolling Glacial Land of North Missouri

COLUMBIA, MISSOURI
April, 1915

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SOIL EXPERIMENTS ON THE ROLLING GLACIAL LAND OF NORTH MISSOURI

(SOIL TYPE—SHELBY LOAM)

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In the spring of 1907, the University of Missouri, established a soil experiment field near Laclede in Linn County, the object of which was to determine the best systems of soil management for the North Missouri rolling glacial lands. This field is one of a number which have been established in different parts of Missouri for the purpose of determining by field trial the value of lime, fertilizers, barnyard manure, and green manures on the important soil types found in the state. Soil analyses alone are not sufficient to determine fertilizer requirements and profitable soil treatments, hence, the necessity of combining field experiments with soil mapping and soil analysis. These investigations are being extended as rapidly as funds permit and bulletins are being issued whenever the results of the experiments warrant.

The field in Linn County is located one mile north of Laclede on the farm of the Jones Brothers. The soil consists of weathered glacial till and it is classified as typical Shelby loam. The surface soil is a very dark brown loam to fine sandy loam, changing at about 10 inches to a light brown or grayish brown, heavy loam, faintly mottled with reddish brown. The subsoil below 18 inches is a light brown or yellowish brown, stiff, sandy clay, usually mottled brown and gray in the lower portion. The surface soil and the lower subsoil contain more sand than the middle portion of the soil section.

The Shelby loam is a soil type of common occurrence on the rolling lands of North Missouri and is formed by the washing away of the finer surface material thus exposing the glacial deposits. This glacial till, as it is called, is variable in composition, sometimes being a stiff, heavy boulder clay with little sand or gravel, and in other cases it is sandy or gravelly, especially on a steep slope where the finer particles have washed away. This lack of uniformity in size of particles is characteristic of soil materials carried by ice as distinguished from water or wind deposits. This glacial till covers almost the whole of North Missouri, but in the prairie sections it is covered with a finer water or wind deposit and the Shelby loam is found only in those areas where this covering has washed away.

Naturally such a soil is decidedly lacking in uniformity. It usually can be identified by the presence of sand and gravel particles more or less rounded in shape occurring mainly in the subsoil and coming from many kinds of rocks. The color and amount of organic matter depend to a considerable extent upon the topography and amount of erosion which has taken place.

The glacial till material gives rise to two rather distinct types of soil. The first is of a gently rolling topography, largely prairie land. It is the typical Shelby loam, represented by this experiment field. The second is rolling to rough in topography, almost entirely timbered and rather low in fertility. Both of these soil types are widely distributed in North Missouri, but the typical Shelby loam with which this report deals is found in largest areas in the counties of Linn, Chariton, Carroll, Livingston, Grundy, Mercer, Harrison, Worth, Gentry, Daviess, DeKalb, Clinton, Caldwell, Macon, Clark, Putnam, Knox, Scotland, Schuyler, and Lewis.

The chemical composition of the Shelby loam at Laclede is shown by the following comparison between it and a very fertile soil.

	Total nitrogen	Acid soluble phosphorus	Acid soluble potassium
A very fertile soil contains in the surface 7 inches over an acre	6000 lbs.	2000 lbs.	5300 lbs.
The Laclede Shelby loam contains in the surface 7 inches over an acre.....	3000 lbs.	1221 lbs.	5360 lbs.

A very productive soil should be neutral or slightly alkaline from the presence of at least a small amount of limestone. This soil is somewhat acid, requiring 1150 pounds of limestone per acre to neutralize or sweeten it. In many places this is not true of the Shelby loam for often it may be found containing chalky streaks or lime concretions, particularly in the subsoil, tho often this material is leached out of the surface as is the case at Laclede.

From the foregoing table it is clear that the soil is low in its supply of nitrogen and phosphorus, altho it is apparently well supplied with potassium. The small amount of nitrogen together with the light color indicates that the soil is lacking in organic matter and this would lead us to expect that the available plant food of all kinds might be rather low, owing to the fact that the presence of decaying organic matter helps to make plant food available. This is particularly true of nitrogen, since the plant gets its nitrogen from decaying organic matter directly, but it is also true of the mineral elements of plant food which are made available by the products resulting from this decay.

The plan of the Laclede experiment field includes the use of green manures (designated as legume treatment), barnyard manure, phosphorus, in the form of bonemeal, or rock phosphate, potassium, in the form of the chloride of potash, and lime in the form of ground limestone.

The legume treatment is given both for the organic matter added and for the nitrogen which the legumes may collect from the abundant supply in the air. It consists of the growing and turning under of an occasional crop of cowpeas usually sown in the corn at the last cultivation. Steamed bonemeal and rock phosphate, as carriers of phosphorus, are quite different in character and methods of use. The porous structure of the bonemeal as well as the intimate contact of the phosphorus with animal matter makes a considerable part of the phosphorus easily available, while that in rock phosphate is very difficult to dissolve and hence should only be applied in finely ground form and in intimate mixture with some kind of decaying material. Potassium is used in the form of chloride (or muriate) of potash because it is readily available and reasonable in price in this form. Lime is used as ground limestone and is applied for the purpose of correcting sourness.

To avoid insects, plant diseases and other bad effects of growing one crop continuously, a crop rotation is practiced. This rotation consists of corn, oats, wheat, and clover, with cowpeas substituted when clover fails. The most common and most profitable crops of the community are thus included, as well as a legume crop which is an essential part of a good rotation for general farming purposes.

The arrangement of the four series of plots, together with the plan for treatment of each plot, is shown in the following diagram of the field. The four series permit the growth of all of the four crops of the rotation each year, each series being occupied with a different crop.

The barnyard manure is applied at the rate of 8 tons per acre once in four years, plowed under before corn. On the plots getting rock phosphate, 500 pounds per acre of the finely ground untreated rock is mixed with the manure. (This application was changed to 1000 pounds in 1913.) Bonemeal is used at the rate of 150 pounds of steamed bonemeal before corn and 150 pounds before wheat drilled in with a fertilizer grain drill. Where potash is used 50 pounds of muriate of potash is applied by mixing with the bonemeal and drilling. Lime is applied on the limed plots at the rate of a ton of ground limestone per acre once in eight years. It is worked into the plowed soil before every second corn crop.

PLAN OF THE LACLEDE 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
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
	SERIES A		SERIES C

Basis of Calculations. In figuring the tables giving the results with various crops on each field it was thought best to consider the crops at the average of farm prices given by the State Board of Agriculture for the last five years (1909-13). The cost of fertilizers is placed at the average of retail prices collected by the fertilizer inspectors on their last trip of inspection over the state. Green manure crops are figured at the cost of seeds and seeding, while the

cost of bulky materials, such as limestone and rock phosphate, is placed sufficiently high to cover a reasonable haul in applying. These methods give the following list of prices.

Farm Crops

Corn	$ .55 per bu.
Oats	.37 per bu.
Wheat	.90 per bu.
Clover hay	11.25 per ton
Cowpea hay	11.21 per ton

Fertilizers

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

Net returns are determined by deducting the cost of treatment from the value of the increase secured. Losses are indicated by minus signs. No account is taken of the extra labor involved in harvesting the increase in crops but on the other hand no value is given to the extra straw and stover secured so that one of these will approximately balance the other.

When the field was staked out in the spring of 1907 it was in wheat, and the wheat was left to ripen except on series D which was plowed and put in corn, the lime and fertilizers being applied as planned. When the wheat was taken off the other three series, the ground was plowed and all the legume plots were sown to cowpeas to be plowed under for green manure. The first crop on each series was given the full fertilizer and lime treatment whether it was the regular crop to receive it or not. Series A was an exception as it received its first lime in 1909 on the second crop, the fertilizers being applied to the cowpea crop in 1908. The corn crop on this field has been injured seriously by drought three years out of the six. The dry weather was especially marked in 1911 and in 1913. In 1911 the drought ruined the best of prospects. The growth of cowpeas in the corn has not been satisfactory. Being seeded in the corn at the last cultivation under dry conditions, and in the shade where they had to compete with the corn for plant food and moisture the growth has been small. In spite of a generally poor growth of

peas, however, their presence has resulted in cutting the corn yield by an average of 5½ bushels per acre.

The results of the various soil treatments on each crop are shown in the following tables.

Figure 1.—Corn on Laclede Experiment Field 1909. Manure Plot (left) Yielded 39.5 Bushels and No Treatment Plot (right) Yielded 29.0 Bushels.

Table I. Results of Experiments with Corn (6 Crops) Laclede 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	32.6	−5.5	−$3.03	$0.69	−$3.72
Legume, bonemeal	39.1	0.95	0.52	1.81	−1.29
Legume, bonemeal, lime	43.3	5.16	2.84	2.28	0.56
Legume, bonemeal, lime, potash	46.1	10.0	5.50	2.85	2.65
No treatment	36.1				
Manure	47.2	11.2	6.19	1.77	4.42
Manure, rock phosphate	47.5	9.4	5.17	2.42	2.75
Manure, rock phosphate, legume	45.8	7.7	4.23	3.13	1.10

The bonemeal, lime, potash, and manure have all been profitable when applied to corn, but the legume and rock phosphate treatments have failed to make a profitable increase. Manure has been much the most profitable fertilizer on this crop, an 8-ton application having increased the yield by 11 bushels per acre as an average of six years. Of course the effect of the manure is not entirely spent on corn as all crops of the rotation have shown increases from it.

Table II. Results of Experiments with Oats (6 Crops) Laclede 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	28.3	−4.4	−$1.63	$ .60	−$2.23
Legume, bonemeal	35.3	2.6	0.96	1.86	−0.90
Legume, bonemeal, lime	37.3	4.6	1.70	2.17	−0.47
Legume, bonemeal, lime, potash	40.3	7.6	2.81	2.74	0.07
No treatment	32.7				
Manure	35.6	2.9	1.07	1.77	−0.70
Manure, rock phosphate	35.1	2.4	0.89	2.52	−1.63
Manure, rock phosphate, legume	35.6	2.9	1.07	3.15	−2.08

Table III. Results of Experiments with Wheat (6 Crops) Laclede 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	14.4	1.30	$1.17	$0.69	$0.48
Legume, bonemeal	16.9	3.76	3.39	1.81	1.58
Legume, bonemeal, lime	16.2	3.08	2.76	2.23	0.53
Legume, bonemeal, lime, potash	19.9	6.70	6.06	2.85	3.21
No treatment	13.1				
Manure	14.9	1.70	1.56	1.77	−0.21
Manure, rock phosphate	14.5	1.40	1.24	2.42	−1.18
Manure, rock phosphate, legume	14.3	1.18	1.06	3.14	−2.06

Table IV. Results of Experiments with Clover (2 Crops) Laclede 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	2970	−458	−$2.57	$0.75	−$3.32
Legume, bonemeal	4540	1076	6.03	1.97	4.06
Legume, bonemeal, lime	4650	1222	6.85	2.48	4.37
Legume, bonemeal, lime, potash	4940	1512	8.48	3.07	5.40
No treatment	3426				
Manure	3104	−324	−1.82	1.70	−3.52
Manure, rock phosphate	3560	132	0.74	2.32	−1.58
Manure, rock phosphate, legume	3670	242	1.36	3.07	−1.71

Table V. Results of Experiments with Cowpeas (4 Crops) Laclede 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	2727	331	$1.85	$0.66	$1.19
Legume, bonemeal	3377	981	5.49	1.73	3.76
Legume, bonemeal, lime	3604	1208	6.76	2.06	4.70
Legume, bonemeal, lime, potash	3582	1186	6.64	2.61	4.03
No treatment	2396				
Manure	2637	241	1.35	1.80	−0.45
Manure, rock phosphate	3116	720	4.03	2.63	1.40
Manure, rock phosphate, legume	3277	881	4.93	3.34	1.59

Figure 2. Wheat at Laclede 1914. Upper View on No Treatment Plot, Yield 16.3 Bushels per Acre. Lower View on Bonemeal Plot, Yield 35.4 Bushels per Acre.

No direct applications of fertilizers have been made on oats, it being thought best to depend upon residual effect of the corn fertilizers. When the oats crop is charged up with its share of the cost, however, the result is a net loss, except on the full treatment plot

where the increase is just large enough to balance the costs. Bonemeal, limestone, and potash have all produced sufficient increase in the oat crop to more than pay all costs, but it took all three of them to produce sufficient profit to balance the loss on legumes used with them. As a matter of fact the increase in bushels per acre has been as great for oats as for wheat but the smaller price per bushel makes the return less. Fertilizers can be used more profitably with higher priced crops.

The wheat yields have not been large on this field, but phosphate and potash fertilizers have given consistently profitable returns, potash being more profitable here than on most soil types. Fertilizers containing phosphorus and potash in available forms can be depended upon to return a profit with wheat where properly used.

Chiefly on account of dry seasons only two clover crops have been secured, cowpeas having been substituted during the years of clover failure. The results of soil treatments have been much the same on both clover and peas except in case of the legume treatment which netted a gain on cowpeas and a loss on clover. The lime, bonemeal and potash applications, tho made for the preceding wheat crop, have materially increased the clover and cowpea yields, resulting in a good profit when these crops are charged with their share of the cost.

Table VI. Average Annual Returns on All Crops, Entire Field

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	−$0.80	$0.67	−$1.47
Legume, bonemeal	2.63	1.78	0.85
Legume, bonemeal, lime	3.52	2.22	1.30
Legume, bonemeal, lime, potash	5.41	2.80	2.61
No treatment			
Manure	2.28	1.77	0.51
Manure, rock phosphate	2.55	2.47	0.08
Manure, rock phosphate, legume	2.52	3.17	−0.65

Summary. Table VI is a summary of the costs and returns from soil treatments on all crops. A glance at this table shows that the applications of bonemeal and potash have both brought good returns and lime fair returns on this field. The complete fertilizer and lime treatment has returned nearly double the cost. If the legume treatment had been omitted in this complete treatment the returns would have been still larger. If the applications of bonemeal, potash, and lime treatments be considered individually

it will be found that a ton of bonemeal valued at $28 has brought an average crop increase worth $85. Likewise a ton of muriate of potash worth $47.50 has brought $151 and a ton of ground limestone valued at $3 applied on the land has brought $5. The failure of manure to show larger returns was due primarily to the fact that the plots receiving manure were the three end plots of series B and D at the end of the field where the soil proved somewhat lower in fertility than the average of the land.

The practice of drilling cowpeas in the corn at the last cultivation has not been profitable on this experiment field. This has been due to the fact that they made a small amount of growth for turning under while at the same time they decreased the yield of corn appreciably. As a green manure crop alone it seems that cowpeas cannot profitably be sown in the corn at the last cultivation altho if the peas are pastured out so as to get a return from the forage they could probably be grown in the corn with profit. This is particularly true where the peas are sown in the hill or drill with the corn at the time of planting. This requires but one gallon of seed per acre as compared with two or three pecks in the case of drilling between the rows, and the labor of seeding is very little.

SUGGESTIONS REGARDING SOIL MANAGEMENT

The Use of Fertilizers and Lime.* The results of these six years of experiment, while not entirely conclusive on all points, warrant some rather specific recommendations regarding systems of soil management. The most striking returns have been secured with the use of phosphates and potash in readily available form. Both have paid well on the average. The amount of potash used was doubtless higher than necessary for the largest financial return so that somewhat less amounts combined with a high percentage of available phosphates are to be recommended. A safe application for wheat is one composed of 150 pounds of a good grade of acid phosphate and 20 pounds of muriate of potash per acre. Where a ready mixed fertilizer is used one 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 to 175 pounds per acre is to be recommended.

For corn, the same fertilizers recommended for wheat applied at rates equal to, or one-fourth heavier than those for wheat are to

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

be recommended. They should be distributed ahead of the planter with a fertilizer drill. The use of fertilizer on corn is not to be so commonly recommended, however, as is its use on wheat, particularly where barnyard manure is applied before corn. While fertilizer has not been applied directly to oats in these experiments, so that definite statements cannot be made regarding the possible effect on this crop, the low value of a bushel of oats as compared with wheat and corn and the rather poor results normally secured from fertilizing oats as a general proposition, indicate that the crop could not be fertilized with much profit. This is particularly true where oats follow corn, as is common in this section, and where barnyard manure is applied before the corn crop.

The largest average net returns from the use of bonemeal and potash on this field were secured on clover, altho this is an average of but two years results. In both cases the bonemeal and potash were applied on the wheat preceding the clover. There is little doubt that the use of the fertilizers recommended for wheat will have a very marked beneficial effect on the following clover and grass crops. Phosphates in particular can be relied upon to greatly assist in securing profitable crops of clover and grass.

In these experiments the fertilizer applied to wheat had quite marked effects upon the yield of cowpeas the year following the harvesting of the wheat crop. Potash failed to pay on the peas, however, the main return being secured from bonemeal. These results, being the average of four crops, indicate that cowpeas might be fertilized profitably with available phosphates on this land, particularly on the poorer phases of it.

In no case should this application of fertilizer alone be depended upon to maintain the fertility of this soil but it should be supplemented by manure preferably applied before corn. On most farms, even with the most careful handling, probably not more than 8 tons per acre once in four years can be applied. To secure this much it will be necessary to feed where the manure can be saved to avoid leaving it in loose piles to ferment, and as far as possible to prevent exposure to washing rains until the manure is on the field where the leachings will run into the soil.

This soil type is on the whole not seriously in need of lime, but where it is found to be acid, an application of a ton to a ton and a half of ground limestone per acre is recommended. It can be hauled when the men and teams have most leisure, but it is best applied after the ground is plowed and thoroly mixed with the soil. The thoro seed bed preparation and cultivation usually given to corn probably furnishes the best means of mixing the lime and soil, altho it may be

more convenient to apply it in the fall before wheat. The most satisfactory method of applying is with one of the lime distributers now on the market. In selecting a lime distributer care should be taken to choose a very strongly built machine that will withstand the strain of handling such heavy material. Where clover grows well on this soil type, lime will not be needed.

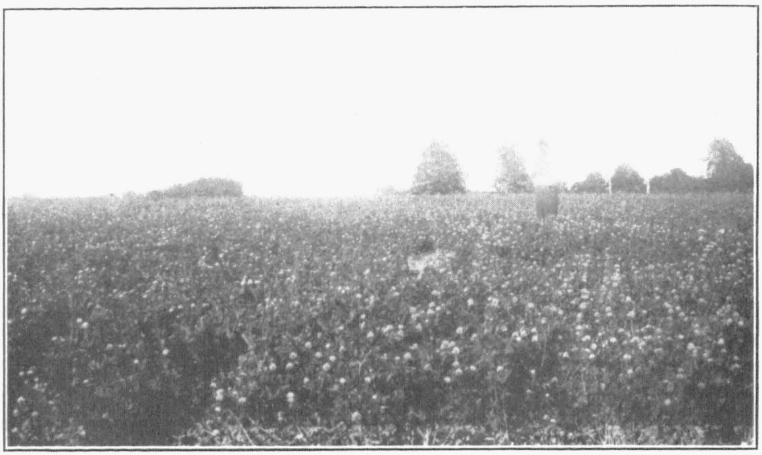

Figure 3.—Clover on the Legume-Bo nemeal Plot 1910, Yield 5400 lbs. Hay per Acre.

Maintaining Organic Matter and Nitrogen. The fact that the organic matter and the nitrogen are deficient in the larger part of the Shelby loam makes it important that these be built up and maintained, if the soil is to give large returns. This is the most important principle in connection with the handling of this soil. A crop rotation is, therefore, one of the first essentials and this rotation should contain legume crops as often as feasible. Clover grows well over a great deal of this soil type, and where this is true there is little difficulty in maintaining the organic matter and nitrogen, providing the clover is grown often and used to the best advantage. Where clover has begun to fail the difficulty is usually due principally to one or both of two things—the sour condition of the soil, or exhaustive systems of farming which have greatly decreased the supply of organic matter. A low supply of organic matter usually causes a compact condition of the soil and during late winter when the ground is freezing and thawing such a soil offers the most favorable conditions for the clover to heave out. There are probably few cases where sourness alone is the cause of clover failure

on this soil, so that liming alone can rarely be depended upon to give a stand of clover. Even where lime is needed its use usually must be accompanied by the addition of organic matter if clover is to be entirely successful.

Where clover fails, the difficulties of building up the supply of organic matter and nitrogen is naturally increased. In such cases other legumes such as cowpeas and soybeans must be used, together with grass crops which may in some cases be accompanied by alsike clover. In addition, the careful saving of all manure must form an important part of the system where crops are fed.

On those parts of the Shelby loam where clover grows well the following crop rotations are suggested:

Corn, oats or wheat, clover;

Corn, oats or wheat, clover and timothy two years;

Corn, corn, oats or wheat, clover and timothy two years;

Corn, corn, oats, wheat, clover and timothy two years.

On those parts of the soil where red clover is uncertain such a rotation as corn, corn, soybeans or cowpeas, oats or wheat, timothy and alsike clover two years, may be used while the supplies of organic matter and nitrogen are being increased.

In using the various rotations suggested it must be remembered that crop rotation alone is not sufficient for maintaining organic matter and nitrogen. A rotation is but the first essential. In addition the crops must either be fed and the manure carefully returned, or if the crops are sold legumes must be grown for turning under.

This soil is not well adapted to pure grain farming. Live stock farming is to be generally recommended. Of course, many farmers will sell part of the grain and feed the remainder under what might be termed a system of general farming, but if any large amount of grain is to be sold, the amount of manure which one can return to the land will be so reduced that some green manure crops must be used if the organic matter is to be maintained.

Where the soil is to be built up in organic matter and nitrogen, the greatest care must be taken to feed crops and save manure, or wide use must be made of catch or cover crops to be turned under or pastured. Such systems are not always easy to put into practice. The following is an example of such a system. Adopt a rotation of corn, corn, oats, clover and timothy two years. Sow rye in the first crop of corn in early September, pasture it lightly and turn under before it begins to joint the next spring. Sow cowpeas or soybeans in the hill or drill with the second corn crop at the time the corn is planted. Pasture these down in the fall. Feed all regular crops

and carefully save the manure, scattering it evenly over the sod land to be broken for corn each year. The manure must be handled very carefully to actually build up organic matter and nitrogen under this system. The average farmer does not appreciate what this means. The crops must either be fed on the land, changing the location of the feeding place regularly so as to scatter the manure evenly, or if the crops are fed around a barn, the manure must be kept under cover, preferably in an open feeding shed where it will be tramped down by the animals. It should then be scattered evenly with a manure spreader.

Farmers who can adopt such systems of building up or maintaining organic matter and nitrogen will usually find it profitable to use some raw rock phosphate on this land to supply phosphorous. The analysis shows the soil to be somewhat deficient in this element but the experiments showed no remunerative return from the raw rock phosphate. More available phosphates gave good returns. There is little doubt, however, that future results will show better returns from the raw phosphate, since those plots on which this material is being used are being built up in organic matter, and a large supply of decaying organic matter is favorable to the successful use of rock phosphate. Consequently, the use of raw rock phosphate can only be recommended for those men who are handling this soil under systems in which the organic matter is being built up or maintained at a rather high level. Such men usually own the land they are farming and have sufficient capital to wait for returns. The proper rate of application is from 800 to 1000 pounds once in 4 to 6 years, turning it under with sod, green manure or barnyard manure. For the tenant or the farmer who must have immediate returns, the more soluble phosphates are recommended.

Soil Conservation. This rolling soil must be handled carefully to prevent washing. It is a type of land on which erosion causes much loss unless good soil management is practiced. Consequently it should be kept covered with a crop during the fall, winter and spring months, wherever possible. The land produces good grass so that systems of farming in which much of the land is left in pasture are those which will conserve the soil. Where possible wheat or rye should be sown to keep corn land covered during fall and winter. Systems of rotation planned with the idea of preventing washing are the only ones which will be permanently successful. Where fall plowing is done, it should be at least 8 inches deep and the land should be left as rough and open as possible over winter in order to catch the snow and absorb the moisture. Shallow fall plowed land, or fall plowed land which is not left open and rough, will wash badly.

Another important consideration is the relation of tenant farming to the conservation of this soil. It does not stand poor management as well as the more level prairies and is a soil to which tenant farming is not well adapted. Nevertheless, it is being handled to a considerable extent under a tenant system so that the matter of properly caring for the land under such a plan of farming is becoming an important one. In the first place it should be the duty of the landowner to arrange for longer leases than those of one year wherever it can be done. There is no means of handling land so as to maintain fertility under a short lease system. In the second

Figure 4.—Cowpeas at Laclede 1914. Upper View on No Treatment Plot, Yield 3840 lbs. Hay. Lower View on Legume-Bonemeal-Lime-Potash Plot, Yield 4820 lbs. Hay.

place, the owner should establish such co-operative relations with the tenant as to enable him to keep some live stock, if possible, and to practice a systematic soil-building rotation. The landowner can do much along this line.

The tenant's duty naturally depends upon his financial condition and the attitude of the landowner. If the landowner requires a high rental and is not willing to co-operate for the improvement of the condition of either the tenant or the land, there is little left for

the tenant to do but to farm the land hard. In any case, except where the lease is a long one or the landlord liberal in his dealings, the tenant must depend upon those methods which bring quick returns. Where he uses fertilizers, those which give most immediate returns at the least cost will be found most satisfactory. For instance, the use of 75 to 90 pounds of a 2-8-2 or a 2-10-2[1] fertilizer, applied in the hill or drill for corn with an attachment to the corn planter, will be found profitable on the average to poor phases of this soil. Likewise rather small applications of 100 to 125 pounds of acid phosphate or a 2-10-2 fertilizer applied with the wheat will usually be a paying application. The same may be recommended for those landowners who are in unfortunate financial conditions and must have an immediate crop. Such systems are not soil building systems, however, and for the landowner with a reasonable amount of capital they either should be avoided or accompanied by those systems of soil management which maintain or build up the soil, particularly in the supplies of organic matter and nitrogen. The only satisfactory method of maintaining fertility under a system of tenancy is that which includes first, a long lease, and second, either a co-operative agreement between landowner and tenant regarding systems of crop rotation and manuring, or a legally prescribed arrangement between the two which makes it possible for the soil fertility to be preserved with a resulting benefit to both parties.

SUMMARY

I. The results on this experiment field show that the Shelby loam responds profitably, first, to available phosphates, second, to potash, and third, to lime. Insoluble phosphates in the form of raw rock phosphate during the rather short period covered by the experiments have not given good financial returns.

II. While this soil is low in organic matter and nitrogen, cowpeas drilled between the corn rows at the last plowing and used as a green manure, have not given profitable returns. This has been due to the fact that the growing of the peas in the corn has reduced the average corn yield 5½ bushels per acre. Where cowpeas or soybeans are grown in the corn, it is recommended that they be pastured out in order to get the value of this forage. In general it seems better to sow them in the hill or drill with the corn rather than at the last cultivation.

III. Systematic crop rotations under systems of live stock farming or general farming, together with the careful saving of

1. The terms 2-8-2 and 2-10-2 refer to fertilizers containing 2 per cent ammonia, 8 or 10 per cent available phosphoric acid, and 2 per cent potash.

manure, and the use of green manure crops, where feasible, are recommended for maintaining the supply of organic matter and nitrogen.

IV. The application of 150 to 175 pounds of a fertilizer containing 10 to 12 per cent available phosphoric acid and 3 to 4 per cent potash is recommended for wheat. The same fertilizer is recommended for corn, applied at the same or slightly heavier rates ahead of the corn planter with a fertilizer drill.

V. For the tenant farmer or the landowner who must have moderate but immediate returns at a small cost, the application of 75 to 90 pounds per acre of a 2-8-2 or 2-10-2 fertilizer in the hill or drill with corn is recommended. Under the same conditions, 100 to 125 pounds of acid phosphate or a 2-10-2 fertilizer applied with wheat is recommended.

VI. Only a part of this soil type needs lime, but where it is found to be sour the application of one to one and a half tons of ground limestone per acre is recommended, applied once in 4 to 6 years.

VII. For the man who is handling this soil so as to maintain the supply of organic matter at a high level, and who is not in need of immediate returns, the use of ground rock phosphate will probably be remunerative. It should be applied at the rate of 800 to 1000 pounds per acre once in 4 to 6 years and turned under with decaying organic matter such as sod, green manure, or barnyard manure.

VIII. In handling this land every reasonable precaution should be taken to prevent erosion, this being best done thru proper systems of rotation combined with the use of rye, or a winter cover crop.