

UNIVERSITY OF MISSOURI

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COLLEGE OF AGRICULTURE

Agricultural Experiment Station

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BULLETIN NO. 126



*Cowpeas on the Monroe City Experiment Field.*

**Soil Experiments on the Level  
Prairies of Northeast Missouri**

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COLUMBIA, MISSOURI

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## COLLEGE OF AGRICULTURE

# Agricultural Experiment Station

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## SOIL EXPERIMENTS ON THE LEVEL PRAIRIES OF NORTHEAST MISSOURI

(Soil Type—Putnam Silt Loam)

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

The experiments here reported form a part of a general system of soil investigations which is being conducted by the Missouri Agricultural Experiment Station. These investigations consist of two parts—the mapping of the soils county by county, and the study of the needs and adaptations of the various soil types by means of field and laboratory experiments. As the various soil types of the state are definitely determined and outlined on maps,<sup>1</sup> experiment fields are established on the larger and more important of these for the purpose of determining the proper systems of soil management adapted to each. The plan of these fields includes a systematic crop rotation together with the use of green manure, barnyard manure, lime, and fertilizers, so combined as to determine the effect of each upon the crop yield and money return.

The soil type on which these particular experiments were conducted is what is known as the Putnam silt loam, which includes practically all of the level prairie lands of Northeast Missouri. The surface soil consists of a gray to dark gray silt loam, from 8 to 10 inches deep underlain by an ashy, gray silt, faintly mottled with yellow. This gray silt layer is one of the distinguishing characteristics of the type. Beneath this is found a clay subsoil, beginning abruptly at an average depth of about 18 inches, which is made up of two layers. The upper layer is a stiff, almost impervious, chocolate brown to grayish brown clay, faintly mottled with red, and from 6 to 10 inches in thickness. The lower layer is a silty clay, gray in color, mottled with yellow and brown.

For one to fully understand experiments of this nature, it is necessary to know that plants require at least ten different chemical elements for growth. Three of these, carbon, hydrogen, and oxygen are taken from the air and water. Even in a dry season there is enough water for this purpose tho there may not be enough to supply the large amount needed to carry the other plant foods up from the roots to the leaves where they are made into plant tissue. The four

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<sup>1</sup> The soil mapping is being done in cooperation with the U. S. Department of Agriculture.

elements, iron, sulphur, magnesium, and calcium, are necessary, but are used in small amounts and are found in all normal soils in such quantities that they are seldom exhausted. The other three, nitrogen, phosphorus, and potassium are used by plants in considerable quantities and soils frequently become sufficiently exhausted of available supplies of these elements to limit plant growth. They are used to such an extent that they have a commercial value on the fertilizer market and are a common item of trade. It is well known that abundance of nitrogen gives the plant a dark green color and increases the growth of stem and leaf. Phosphorus may also increase the vegetative growth but it is used chiefly in the seed and a large supply in available form hastens ripening and improves the quality of the grain. If not accompanied by a correspondingly large supply of nitrogen, phosphates may cause a lighter color in the leaves but not an unhealthy appearance. While a large per cent of the potassium is used in the stem and leaf growth, yet on a soil in which it is deficient, potassium also increases the yield and improves the quality of grain.

Plants can not substitute one of these elements of plant food for another, but must have them in definite proportions. Hence, applying one of them which does not already limit production may not increase the yield in the least. It is important, therefore, to know which is the limiting factor in the particular soil in question.

The chemical analysis of a soil is not sufficient to show either the amount or kind of fertilizer to apply because an analysis shows how much plant food is present in a soil, but does not show how much is available. Hence the necessity for combining field experiments with soil analysis, in order to determine most accurately a soil's needs. Nevertheless, the soil analysis is of much value in showing striking soil deficiencies and indicating general systems of management as to the building up of certain elements in the soil.

In order that plant foods be available in a soil, these substances must be in compounds which will dissolve in the soil water so that they may be absorbed through the outer walls of the roots and pass up in the sap to the leaves, there to be manufactured into plant tissue. Hence to make plant foods available it is necessary to supply conditions which will bring them into solution. To make nitrogen available it is necessary first to get it into combination with other substances, as the immense supply of free nitrogen in the air is not directly of any use to the plant. Some kinds of bacteria have the power of using it, however, and after combining it with other materials in their bodies leave it for the benefit of higher plants. Certain of these bacteria are found in all soils especially where the aeration is good and the soil is

not sour. The most common way of increasing nitrogen in the soil is in growing legume crops such as clover and alfalfa upon the roots of which these bacteria grow in abundance. The processes of decay help to make phosphorus and potash available, besides giving off substances, particularly carbon dioxide, which enter into solution in the soil water and enable it to dissolve materials which are not soluble in pure water alone. A better supply of the desired products are given off when decay takes place in a well aired soil, which is one of the benefits of good tilth and proper cultivation, as well as of satisfactory drainage.

On the prairies of Northeast Missouri, the making available of plant food is of great importance. The chemical analyses of the soil from this area show it to have a comparatively large supply of potassium and a fair supply of phosphorus. It is somewhat low in nitrogen and in the vegetable or organic material which supplies nitrogen and the products of decay. These analyses also show that the soil is acid. The amount of acid varies to a considerable extent over the territory, but very little of the type is free from it. It is caused by the leaching out of the lime carbonate and other basic material, a condition common to older soil formations. The desired bacteria do not thrive in a sour soil and hence do not bring sufficient plant food into available form. Another characteristic of the soil in question is the presence of a heavy clay layer in the subsoil which does not let the water through readily and hence interferes with drainage and air supply. This also tends to reduce the number of desirable bacteria and the supply of available plant food.

With these conditions in mind, an experiment field was started near Monroe City in Ralls County in 1905. In 1907, two additional fields were established, one at Bowling Green in Pike County, and another at High Hill in Montgomery County. The results of the various soil treatments at these places have been quite similar and the reports of these fields are combined for discussion in this bulletin.

In preparing the tables giving the results with various crops on each field, it was thought best to figure the value of the crops at the average of farm prices given by the Missouri State Board of Agriculture for the last five years. Fertilizers are figured at the average of retail prices collected by the fertilizer inspectors from many parts of the state, and green manure crops at the cost of seed and seeding. 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  |
| Barley .....     | .69 per bu.    |

**Soil Treatments**

|                              |                                 |
|------------------------------|---------------------------------|
| Cowpea green manure crop.... | \$ 2.00 per acre per treatment. |
| Ground limestone .....       | 3.00 per ton                    |
| Steamed bone meal .....      | 28.00 per ton                   |
| Muriate of potash .....      | 47.50 per ton                   |
| Sulphate of potash .....     | 56.00 per ton                   |
| Rock phosphate .....         | 10.00 per ton                   |
| Barnyard manure .....        | .85 per ton                     |

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

**Soil Treatments.**—The method of giving the different soil treatments varied somewhat from field to field, but in general the plan was the same. The use of a cowpea green manure crop consisted chiefly in drilling peas in the corn at the last cultivation and plowing this growth under before the next crop, the purpose being to supply nitrogen and organic matter. Occasionally a crop of cowpeas was grown for green manure instead of the regular crop but this increases the cost so as to make it almost prohibitive where it is impossible to secure some return from pasturing. Lime in most cases has been applied at the rate of a ton of ground limestone per acre once in a period of six years. The limestone was applied after the ground was plowed and worked into the soil while preparing the seed bed, the purpose being to mix it with the soil as thoroly as possible. (The latest indications are that 2 to 3 tons of lime would have been better.) Steamed bone meal was used as the phosphorus carrier, this usually being applied at the rate of 150 pounds per acre before corn, and 150 pounds before wheat in a corn, oats, wheat, clover rotation. Potassium was applied chiefly in the form of the muriate of potash at the rate of 50 pounds before corn and 50 pounds before wheat. The bone meal and potash were both applied with a fertilizer drill ahead of the corn planter in case of corn, or while drilling in the case of wheat.

Where applied together they were thoroly mixed by hand. The manure used was an ordinary grade of barnyard manure and was all applied before corn in the four year rotation. The amount varied from six to eight tons for the four year period. Where rock phosphate was used it was always applied with manure in order that the products of decay might help to make the insoluble phosphorus in the rock available. The rate of application of the rock phosphate varied from 500 to 1000 pounds per acre, all being applied with manure and plowed under for corn. It should be noted that under this plan there is a direct addition of phosphorus in the manure which probably reduces somewhat the effect of that in the rock phosphate. Where rock phosphate is plowed under with a green manure crop, or with the straw and stalks grown on the land, there is no other direct addition of phosphorus and that in the rock phosphate should produce a greater effect.

#### Monroe City Experiment Field

The experiment field at Monroe City was established in 1905 and continued until 1908. It was located on the farm of Byron McFarland, two and one-half miles northeast of Monroe City (Section 4, Township 56 north, Range 7, West) in the edge of Ralls County. The soil is the typical Putnam silt loam of the level prairie of that region. It is a gray silt loam to a depth of 8 or 9 inches, underlain by a yellowish gray silt which is plastic and sticky when wet, and which tends to crack and crumble when exposed to air. This subsoil increases in clay content downward to a depth of 20 to 24 inches, below which it becomes somewhat coarser as a rule, frequently being mottled with red in the lower layers. The term "hardpan" is often applied to this subsoil locally, altho technically it is nothing more than a compact and rather impervious silty clay. By analysis the soil is found to have only about half the nitrogen and organic matter contained in the most fertile soils. It is deficient also in phosphorus and lime, but fairly well supplied with potassium.

The field as laid out consisted of twenty plots, each one-fifth of an acre in size, arranged in four series of five plots each. Each series was an exact duplicate of the others as to soil treatment and the four year rotation of corn, oats, wheat, and clover furnished a crop for each series each year. The arrangement of plots is shown in the following diagram.

Using the measured yields of all crops and the prices previously given, Tables I to VI, inclusive, have been prepared showing the exact results with various soil treatments on all crops. It should be kept

Monroe City Experiment Field

SERIES A.

|   |                      |                         |                              |  |
|---|----------------------|-------------------------|------------------------------|--|
| 1<br>Cowpeas<br>(for green<br>manure<br>crop) | 2<br>Cowpeas<br>Lime | 3<br>No treat-<br>ment. | 4<br>Cowpeas<br>Lime<br>Bone | 5<br>Cowpeas<br>Lime<br>Bone<br>Potash |
|---|----------------------|-------------------------|------------------------------|--|

SERIES B

|              |                      |                        |                              |   |
|--------------|----------------------|------------------------|------------------------------|---|
| 6<br>Cowpeas | 7<br>Cowpeas<br>Lime | 8<br>No treat-<br>ment | 9<br>Cowpeas<br>Lime<br>Bone | 10<br>Cowpeas<br>Lime<br>Bone<br>Potash |
|--------------|----------------------|------------------------|------------------------------|---|

SERIES C

|               |                       |                         |                               |   |
|---------------|-----------------------|-------------------------|-------------------------------|---|
| 11<br>Cowpeas | 12<br>Cowpeas<br>Lime | 13<br>No treat-<br>ment | 14<br>Cowpeas<br>Lime<br>Bone | 15<br>Cowpeas<br>Lime<br>Bone<br>Potash |
|---------------|-----------------------|-------------------------|-------------------------------|---|

SERIES D

|               |                       |                         |                               |   |
|---------------|-----------------------|-------------------------|-------------------------------|---|
| 16<br>Cowpeas | 17<br>Cowpeas<br>Lime | 18<br>No treat-<br>ment | 19<br>Cowpeas<br>Lime<br>Bone | 20<br>Cowpeas<br>Lime<br>Bone<br>Potash |
|---------------|-----------------------|-------------------------|-------------------------------|---|

in mind that, in these, as in all the following tables, the oats and hay crops did not receive any additions of fertilizers directly. All treatments are given on the basis of one round of the rotation and the cost distributed to all crops, since they all get the benefit of any permanent soil improvement or any temporary residual effect of fertilizers. All losses due to any cause whatever are charged against the plot on which they occurred in order to avoid any chance of over-emphasizing the profit from a particular method of soil management.

Table I.—Results of Experiments with Corn (3 Crops) Monroe City Field

| Soil treatment                      | Average yield, bus. per acre | Average increase, bus. per acre | Average value of increase per acre | Average cost of treatment per acre | Average net returns per acre per year |
|-------------------------------------|------------------------------|---------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| Legume.....                         | 41.2                         | -3.9                            | -\$2.14                            | \$ .66                             | -\$2.80                               |
| Legume, lime.....                   | 49.2                         | 4.1                             | 2.25                               | 1.50                               | .75                                   |
| No treatment.....                   | 45.1                         |                                 |                                    |                                    |                                       |
| Legume, lime, bonemeal.....         | 52.8                         | 7.7                             | 4.23                               | 2.94                               | 1.29                                  |
| Legume, lime, bonemeal, potash..... | 54.6                         | 9.5                             | 5.22                               | 4.19                               | 1.03                                  |

Table II.—Results of Experiment with Oats (2 Crops) Monroe City Field

| Soil treatment                      | Average yield, bus. per acre | Average increase, bus. per acre | Average value of increase per acre | Average cost treatment per acre | Average net returns per acre per year |
|-------------------------------------|------------------------------|---------------------------------|------------------------------------|---------------------------------|---------------------------------------|
| Legume.....                         | 17.0                         | 2.1                             | \$ .78                             | \$ .75                          | \$ .03                                |
| Legume, lime.....                   | 19.6                         | 4.65                            | 1.72                               | 1.58                            | .13                                   |
| No treatment.....                   | 14.95                        |                                 |                                    |                                 |                                       |
| Legume, lime, bonemeal.....         | 19.3                         | 4.3                             | 1.59                               | 2.77                            | -1.18                                 |
| Legume, lime, bonemeal, potash..... | 19.7                         | 4.75                            | 1.75                               | 3.72                            | -1.97                                 |

Table III.—Results of Experiments with Wheat (3 crops) Monroe City Field

| Soil treatment                      | Average yield, bus. per acre | Average increase, bus. per acre | Average value of increase per acre | Average cost treatment per acre | Average net returns per acre per year |
|-------------------------------------|------------------------------|---------------------------------|------------------------------------|---------------------------------|---------------------------------------|
| Legume.....                         | 11.9                         | 2.6                             | \$2.34                             | \$ .50                          | \$1.84                                |
| Legume, lime.....                   | 15.5                         | 6.2                             | 5.58                               | 1.37                            | 4.21                                  |
| No treatment.....                   | 9.3                          |                                 |                                    |                                 |                                       |
| Legume, lime bonemeal.....          | 19.2                         | 9.9                             | 8.91                               | 3.18                            | 5.73                                  |
| Legume, lime, bonemeal, potash..... | 20.0                         | 10.7                            | 9.63                               | 4.79                            | 4.84                                  |

Table IV.—Results of Experiments with Clover Hay (1 crop) Monroe City Field

| Soil treatment                       | Yield<br>lbs. hay<br>per acre | Increase<br>lbs. per<br>acre | Value of<br>increase<br>per acre | Cost of<br>treatment<br>per acre | Net returns<br>per acre<br>per year |
|--------------------------------------|-------------------------------|------------------------------|----------------------------------|----------------------------------|-------------------------------------|
| Legume.....                          | 3,150                         | -900                         | -\$5.04                          | \$ .50                           | -\$5.54                             |
| Legume, lime.....                    | 2,700                         | -1,350                       | -7.56                            | 1.34                             | -8.90                               |
| No treatment.....                    | 4,050                         |                              |                                  |                                  |                                     |
| *Legume, lime, bonemeal.....         | 3,330                         | -720                         | -4.03                            | 3.27                             | -7.30                               |
| *Legume, lime, bonemeal, potash..... | 3,465                         | -585                         | -3.27                            | 5.14                             | -8.41                               |

\*Clover on these plots fell down badly and could not all be secured.

Table V.—Results of Experiment with Cowpea Hay (1 crop) Monroe City Field

| Soil treatment                      | Yield lbs.<br>hay per acre | Increase<br>lbs. per acre | Value of<br>increase<br>per acre | Cost of<br>treatment<br>per acre | Net returns<br>per acre<br>per year |
|-------------------------------------|----------------------------|---------------------------|----------------------------------|----------------------------------|-------------------------------------|
| Legume.....                         | 3,190                      | -40                       | -\$ .22                          | \$1.00                           | -\$1.22                             |
| Legume, lime.....                   | 3,398                      | 168                       | .94                              | 1.84                             | -.90                                |
| No treatment.....                   | 3,230                      |                           |                                  |                                  |                                     |
| Legume, lime, bonemeal.....         | 4,040                      | 810                       | 4.53                             | 2.63                             | 1.90                                |
| Legume, lime, bonemeal, potash..... | 4,093                      | 863                       | 4.83                             | 3.30                             | 1.53                                |

A study of these tables reveals the fact that of the four treatments used, lime and phosphorus, in the form of ground limestone and of bone meal, respectively, have been profitable on the main crops, wheat and corn. Unfavorable conditions and the short period during which the field was run made it impossible to get records on enough crops of oats and hay to justify general conclusions. It is evident that the use of cowpeas in the corn has materially cut the yield and in three years time has not increased the fertility enough to overcome this handicap. Results for a longer period would probably show a different outcome since small increases in the oat and wheat yields indicate slight improvement already. Any method of building up organic matter and nitrogen will take time. Late wet springs seriously handicapped the work on this flat, poorly drained soil. This was particularly true in case of the clover crop, which grew up taller and thicker on the fertilized plots, but fell down and decayed to a considerable extent so that the weights given do not accurately represent the effects of the treatments on the clover crop.





## WHEAT ON MONROE CITY FIELD 1907

Upper picture: Legume, Lime, Bone, Potash plot, yield 23.7 bu.

Lower picture: Legume, Lime plot, yield 16.7 bu.

Table VI.—Average for Entire Field, All Crops, Monroe City Field

| Soil treatment                     | Value of increase per acre | Cost of treatment per acre | Net return per acre per year |
|------------------------------------|----------------------------|----------------------------|------------------------------|
| Legume.....                        | \$-.31                     | \$ .65                     | \$-.96                       |
| Legume, lime.....                  | 2.03                       | 1.50                       | .53                          |
| Legume, lime, bonemeal.....        | 4.31                       | 2.98                       | 1.33                         |
| Legume, lime, bonemeal, potash.... | 4.96                       | 4.28                       | .68                          |

The above table is a summary of all work done on the Monroe City experiment field and indicates the relative profit of the different systems of soil treatment. The legume treatment, consisting of the growing of cowpeas as a catch crop in the corn, for green manure has not proved profitable in this short period. Where it is possible to grow the cowpeas at such a time as not to interfere with the regular crops or where some of the loss in corn can be made up from pasturing the peas, good profits would doubtless result. The use of lime has made up the loss from cowpeas, and in addition

turned it into a net profit of \$.53 on an outlay of \$.85. The value of the increase (\$2.03), as shown in the first column more nearly shows the worth of the lime. Bone meal, as is usual on prairie soils of this type gave a very satisfactory return considering the size of the investment and this was particularly true of its use for wheat. Potassium has given a small increase in the crops, but not enough to make it profitable.

### High Hill Experiment Field

The experiments at High Hill were begun in the spring of 1907. The field was located on the farm of H. G. Lewelling, one-fourth mile north of the railroad station at High Hill in Montgomery County. The soil is the typical Putnam silt loam, low in organic matter and gray in appearance. The experiment field lies on a slight ridge and slopes considerably to the west from the center of the field with the east one-fourth sloping slightly to the east. In neither case is the fall sufficient to cause the land to wash badly, altho there has been some soil loss from erosion on the west slope. The land had been farmed to corn and oats for twenty-five years, being in corn probably two-thirds of the time. The plots were laid out lengthwise across the slope.

The soil on this field is a gray silt loam from seven to nine inches deep, grading into a dull gray silt below. At a depth of eighteen to twenty inches, the subsoil becomes much heavier and continues to increase in heaviness to depth of about thirty inches where it changes to a somewhat coarser material. Water can not readily pass through this heavy layer, which seriously interferes with under drainage.

The chemical analysis shows that the soil is strikingly deficient in nitrogen, but fairly well supplied with phosphorus and potassium. Conditions indicate, however, that there is not enough of these materials in available form. Considerable acidity or sourness is shown by the analysis, indicating need of lime. As most of the nitrogen of soils is contained in the organic matter, the low supply of nitrogen in this soil means a shortage in the content of organic matter with correspondingly poor tilth and slow processes of making plant food available.

The four-year rotation of corn, oats, wheat, and clover was so handled that four crops were grown each year until the last year of the experiment when three of the series were planted to corn to determine the effect of the accumulation of fertility from previous treatments. The results for each crop are given in Tables VII to XIII inclusive.

## High Hill Experiment Field

## SERIES A

## SERIES B

## SERIES C

## SERIES D

|   |  |
|---|--|
| 9 | Manure<br>Rock phosphate<br>Legume<br>Lime |
| 8 | Manure<br>Rock phosphate<br>Legume         |
| 7 | Manure<br>Rock phosphate                   |
| 6 | Manure                                     |
| 5 | No treatment                               |
| 4 | Legume<br>Bone<br>Lime<br>Potash           |
| 3 | Legume<br>Bone<br>Lime                     |
| 2 | Legume<br>Bone                             |
| 1 | Legume                                     |

|    |  |
|----|--|
| 18 | Manure<br>Rock phosphate<br>Legume<br>Lime |
| 17 | Manure<br>Rock phosphate<br>Legume         |
| 16 | Manure<br>Rock phosphate                   |
| 15 | Manure                                     |
| 14 | No treatment                               |
| 13 | Legume<br>Bone<br>Lime<br>Potash           |
| 12 | Legume<br>Bone<br>Lime                     |
| 11 | Legume<br>Bone                             |
| 10 | Legume                                     |

|    |  |
|----|--|
| 27 | Manure<br>Rock phosphate<br>Legume<br>Lime |
| 26 | Manure<br>Rock phosphate<br>Legume         |
| 25 | Manure<br>Rock phosphate                   |
| 24 | Manure                                     |
| 23 | No treatment                               |
| 22 | Legume<br>Bone<br>Lime<br>Potash           |
| 21 | Legume<br>Bone<br>Lime                     |
| 20 | Legume<br>Bone                             |
| 19 | Legume                                     |

|    |  |
|----|--|
| 36 | Manure<br>Rock phosphate<br>Legume<br>Lime |
| 35 | Manure<br>Rock phosphate<br>Legume         |
| 34 | Manure<br>Rock phosphate                   |
| 33 | Manure                                     |
| 32 | No treatment                               |
| 31 | Legume<br>Bone<br>Lime<br>Potash           |
| 30 | Legume<br>Bone<br>Lime                     |
| 29 | Legume<br>Bone                             |
| 28 | Legume                                     |

Table VII.—Results of Experiments with Corn (8 crops) High Hill Field

| Soil treatment                            | Average yield bus. per acre | Average increase bus. per acre | Average value of increase | Average cost of treatment per acre | Average net returns per acre per year |
|---|-----------------------------|--------------------------------|---------------------------|------------------------------------|---------------------------------------|
| Legume.....                               | 27.1                        | 4.6                            | \$ 2.53                   | \$ .39                             | \$ 2.14                               |
| Legume, bonemeal.....                     | 32.7                        | 10.2                           | 5.61                      | 1.43                               | 4.18                                  |
| Legume, bonemeal, lime.....               | 34.3                        | 11.8                           | 6.49                      | 1.81                               | 4.68                                  |
| Legume, bonemeal, lime, potash.....       | 34.0                        | 11.5                           | 6.32                      | 2.41                               | 3.91                                  |
| No treatment.....                         | 22.5                        |                                |                           |                                    |                                       |
| Manure.....                               | 33.0                        | 10.5                           | 5.77                      | 1.23                               | 4.54                                  |
| Manure, rock phosphate.....               | 34.7                        | 12.2                           | 6.71                      | 1.81                               | 4.90                                  |
| Manure, rock phosphate, legume.....       | 36.4                        | 13.9                           | 7.64                      | 2.20                               | 5.44                                  |
| Manure, rock phosphate, legume, lime..... | 38.7                        | 16.2                           | 8.91                      | 3.00                               | 5.91                                  |

Table VIII.—Results of Experiments with Oats (5 crops) High Hill Field

| Soil treatment                            | Average yield bus. per acre | Average increase bus. per acre | Average value of increase | Average cost of treatment per acre | Average net returns per acre per year |
|---|-----------------------------|--------------------------------|---------------------------|------------------------------------|---------------------------------------|
| Legume.....                               | 31.0                        | 7.1                            | \$ 2.62                   | \$ .82                             | \$ 1.80                               |
| Legume, bonemeal.....                     | 40.6                        | 16.7                           | 6.18                      | 1.90                               | 4.28                                  |
| Legume, bonemeal, lime.....               | 34.8                        | 10.9                           | 4.03                      | 2.65                               | 1.38                                  |
| Legume, bonemeal, lime, potash.....       | 33.9                        | 10.0                           | 3.70                      | 3.25                               | .45                                   |
| No treatment.....                         | 23.9                        |                                |                           |                                    |                                       |
| Manure.....                               | 27.3                        | 3.4                            | 1.26                      | 1.47                               | -.21                                  |
| Manure, rock phosphate.....               | 30.0                        | 6.1                            | 2.25                      | 2.16                               | .09                                   |
| Manure, rock phosphate, legume.....       | 33.9                        | 10.0                           | 3.70                      | 2.99                               | .71                                   |
| Manure, rock phosphate, legume, lime..... | 37.6                        | 13.8                           | 5.10                      | 3.81                               | 1.29                                  |

Table IX.—Results of Experiments with Wheat (3 crops) High Hill Field

| Soil treatment                            | Average yield bus. per acre | Average increase bus. per acre | Average value of increase per acre | Average cost of treatment per acre | Average net returns per acre per year |
|---|-----------------------------|--------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| Legume.....                               | 8.5                         | .5                             | -.45                               | \$ .54                             | -.99                                  |
| Legume, bonemeal.....                     | 21.5                        | 12.5                           | 11.25                              | 1.55                               | 9.70                                  |
| Legume, bonemeal, lime.....               | 20.7                        | 11.7                           | 10.53                              | 2.06                               | 8.47                                  |
| Legume, bonemeal, lime, potash.....       | 22.2                        | 13.2                           | 11.88                              | 2.65                               | 9.23                                  |
| No treatment.....                         | 9.0                         |                                |                                    |                                    |                                       |
| Manure.....                               | 12.6                        | 3.6                            | 3.24                               | 1.49                               | 1.75                                  |
| Manure, rock phosphate.....               | 17.2                        | 8.2                            | 7.38                               | 2.06                               | 5.32                                  |
| Manure, rock phosphate, legume.....       | 20.5                        | 11.5                           | 10.35                              | 2.60                               | 7.75                                  |
| Manure, rock phosphate, legume, lime..... | 20.6                        | 11.6                           | 10.44                              | 3.59                               | 6.85                                  |

Table X.—Results of Experiments with Cowpeas (3 crops) High Hill Field

| Soil treatment                            | Average yield lbs. per acre | Average increase lbs. per acre | Average value of increase per acre | Average cost of treatment per acre | Average net returns per acre per year |
|---|-----------------------------|--------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| Legume.....                               | 2,117                       | 850                            | \$4.76                             | \$ .71                             | \$4.05                                |
| Legume, bonemeal.....                     | 2,057                       | 790                            | 4.42                               | 1.69                               | 2.73                                  |
| Legume, bonemeal, lime.....               | 1,943                       | 676                            | 3.78                               | 2.44                               | 1.34                                  |
| Legume, bonemeal, lime, potash.....       | 1,595                       | 328                            | 1.83                               | 3.03                               | -1.20                                 |
| No treatment.....                         | 1,267                       |                                |                                    |                                    |                                       |
| Manure.....                               | 1,842                       | 575                            | 3.22                               | 1.60                               | 1.62                                  |
| Manure, rock phosphate.....               | 2,071                       | 750                            | 4.20                               | 2.24                               | 1.96                                  |
| Manure, rock phosphate, legume.....       | 1,775                       | 508                            | 2.84                               | 2.95                               | -.11                                  |
| Manure, rock phosphate, legume, lime..... | 1,717                       | 450                            | 2.52                               | 3.82                               | -1.30                                 |

Table XI.—Results of Experiments with Barley (1 crop) High Hill Field

| Soil treatment                            | Yield bus. per acre | Increase bus. per acre | Value of increase per acre | Cost of treatment per acre | Net returns per acre per year |
|---|---------------------|------------------------|----------------------------|----------------------------|-------------------------------|
| Legume.....                               | 4.7                 | 1.0                    | \$ .69                     | \$1.00                     | \$-.31                        |
| Legume, bonemeal.....                     | 6.5                 | 2.8                    | 1.93                       | 1.96                       | -.03                          |
| Legume, bonemeal, lime.....               | 7.5                 | 3.8                    | 2.62                       | 2.71                       | -.09                          |
| Legume, bonemeal, lime, potash.....       | 7.5                 | 3.8                    | 2.62                       | 3.31                       | -.69                          |
| No treatment.....                         | 3.7                 |                        |                            |                            |                               |
| Manure.....                               | 3.7                 | 0.0                    | .00                        | 1.60                       | -1.60                         |
| Manure, rock phosphate.....               | 4.7                 | 1.0                    | .69                        | 2.44                       | -1.75                         |
| Manure, rock phosphate, legume.....       | 8.2                 | 4.5                    | 3.10                       | 3.44                       | -.34                          |
| Manure, rock phosphate, legume, lime..... | 9.4                 | 5.7                    | 3.93                       | 4.19                       | -.26                          |

Table XII.—Results of Experiments with Clover Hay (1 crop) High Hill Field

| Soil treatment                            | Yield lbs. per acre | Increase lbs. per acre | Value of increase per acre | Cost of treatment per acre | Net returns per acre per year |
|---|---------------------|------------------------|----------------------------|----------------------------|-------------------------------|
| Legume.....                               | 000                 | 000                    | \$0.00                     | \$1.00                     | \$-1.00                       |
| Legume, bonemeal.....                     | 000                 | 000                    | 0.00                       | 2.22                       | -2.22                         |
| Legume, bonemeal, lime.....               | 950                 | 950                    | 5.32                       | 2.98                       | 2.34                          |
| Legume, bonemeal, lime, potash.....       | 975                 | 975                    | 5.46                       | 3.57                       | 1.89                          |
| No treatment.....                         | 000                 |                        |                            |                            |                               |
| Manure.....                               | 000                 | 000                    | 0.00                       | 1.28                       | -1.28                         |
| Manure, rock phosphate.....               | 000                 | 000                    | 0.00                       | 2.05                       | -2.05                         |
| Manure, rock phosphate, legume.....       | 000                 | 000                    | 0.00                       | 3.05                       | -3.05                         |
| Manure, rock phosphate, legume, lime..... | 1,275               | 1,275                  | 7.14                       | 3.80                       | 3.34                          |

These tables show that corn and wheat have paid especially well for most of the soil treatments given. This is particularly true of bone meal and manure. Unlike most of the other experiments on this soil type, cowpeas in the corn have not reduced the yield appreciably. In fact, there was only one season, that of 1911, when the yield of corn was reduced by this treatment on the High Hill field and the result is a very satisfactory profit from their use. It should be noted that very serious difficulties have been encountered in securing a crop of clover. Lime seems to be essential to its growth on this soil and usually when all plots of a series in clover failed



WHEAT ON HIGH FIELD 1909

Legume, lime, bone, potash plot on left, yield 22.3 bu.

No treatment plot on right, yield 6.8 bu.

Table XIII.—Averages for Entire Field, All Crops, High Hill Field

| Soil treatment                         | Value of increase per acre | Cost of treatment per acre | Net returns per acre per year |
|--|----------------------------|----------------------------|-------------------------------|
| Legume.....                            | \$2.23                     | \$ .61                     | \$1.62                        |
| Legume, bonemeal.....                  | 5.93                       | 1.65                       | 4.28                          |
| Legume, bonemeal, lime.....            | 5.85                       | 2.23                       | 3.62                          |
| Legume, bonemeal, lime, potash.....    | 5.63                       | 2.83                       | 2.80                          |
| Manure.....                            | 3.42                       | 1.40                       | 2.02                          |
| Manure, rock phosphate.....            | 4.78                       | 2.03                       | 2.75                          |
| Manure, rock phosphate, legume.....    | 5.82                       | 2.65                       | 3.17                          |
| Manure, rock phosphate, legume, lime.. | 7.00                       | 3.49                       | 3.51                          |

except those which had been limed, the entire series was plowed up and seeded to some other crop. Oats, barley and cowpeas do not respond very readily to soil treatment, except in very favorable seasons. The yields of these crops seem to be limited more largely by climatic rather than soil factors.

Table XIII gives in condensed form, the results of all soil treatments on the High Hill field. This land, representing as it does, a rather poor phase of the Putnam silt loam, has responded to practically every application of fertilizer, and all treatments except those of potash and the light application of lime have returned a net profit. The best profits resulted from the use of bone meal and manure, altho the legume-green manure treatment has paid practically as well when the small cost is taken into consideration. It may be noted that two different plots on each series were given an application of lime. That on the manured end of the field was at the rate of two tons. The two ton application more than paid its cost while that at the rate of one ton did not sweeten the soil enough to affect the crop yield except in case of corn and clover. In fact, it is seldom that wheat or cowpeas are directly improved by use of lime, unless the soil is excessively sour. They may in time be indirectly benefited by the enrichment of the soil from better crops of clover or from the increase in the number of nitrogen-gathering bacteria.

In the spring of 1909, an experiment was begun at High Hill with different kinds and amounts of fertilizers in the hill for corn. This experiment was laid out on land very similar and quite close to the main experiment field at that place, and results were secured for the seasons of 1909, 1910, and 1912. Little difference was noticed in the color or growth of the different fertilizer plots, but the untreated plots were nearly always distinguished by the smaller and less vigorous corn on them. The complete results of this experiment are shown in Table XIV, from which it may be seen that the fifty-pound application was in every case the most profitable, and in most cases even produced a higher yield than the larger amounts. All these fertilizers were applied with an attachment on the corn planter and dropped in the hill with the corn.

The purpose of such an application of fertilizers is to stimulate early growth and give the plant a quick vigorous start. It is probable that too large an application is not quickly used up and hence tends to keep the feeding roots confined to too small an area thruout the season. With the small application, on the other hand, the fertilizer is quickly used up and the roots spread through the soil, making it less likely that the drought of the late summer will injure the plant.

These small applications of fertilizers proved profitable as is shown by the fact that on the average, fifty pounds of steamed bone meal has increased the yield of corn sufficiently to make the cost of this increase

Table XIV.—Different Kinds and Amounts of Fertilizers in the Hill with Corn at the High Hill Experiment Field

| Soil treatment      | Annual cost per treatment per acre | Yield of corn in bushels per acre. |      |      |                              |                         | Results per acre. Average of two years 1910 and 1912 |                   |            |                          |
|---------------------|------------------------------------|------------------------------------|------|------|------------------------------|-------------------------|--|-------------------|------------|--------------------------|
|                     |                                    | 1909                               | 1910 | 1912 | Average 3 yrs. '09, '10, '12 | Average 2 yrs. '10, '12 | Increase bus. per acre                               | Value of increase | Net return | Cost per bu. of increase |
| None                |                                    | 36.4                               | 45.0 | 26.3 | 35.9                         | 35.7                    |  |                   |            |                          |
| Bone meal, 50 lbs.  | \$.70                              | 36.9                               | 56.0 | 31.8 | 41.6                         | 43.9                    | 9.6  | \$5.28            | \$4.58     | \$.073                   |
| Bone meal, 75 lbs.  | 1.05                               | 39.7                               | 59.0 | 26.9 | 41.8                         | 43.0                    | 8.7  | \$4.78            | \$3.73     | .120                     |
| Bone meal, 100 lbs. | 1.40                               | 37.1                               | 57.0 | 25.1 | 39.7                         | 41.0                    | 6.7  | 3.68              | 2.28       | .209                     |
| None                |                                    | 32.5                               | 42.0 | 29.3 | 34.6                         | 35.7                    |  |                   |            |                          |
| 2-8-2, 50 lbs.      | .60                                | *34.7                              | 46.0 | 34.7 | 38.5                         | 40.3                    | 6.0  | 3.30              | 2.70       | .100                     |
| 2-8-2, 75 lbs.      | .90                                | *36.7                              | 49.5 | 27.7 | 38.0                         | 38.6                    | 4.3  | 2.36              | 1.46       | .209                     |
| 2-8-2, 100 lbs.     | 1.20                               | *38.3                              | 50.5 | 28.7 | 39.2                         | 39.6                    | 5.3  | 2.91              | 1.71       | .226                     |
| None                |                                    | *34.2                              | 40.5 | 24.8 | 33.2                         | 32.7                    |  |                   |            |                          |
| 3-8-6, 50 lbs.      | .80                                |                                    | 50.0 | 31.0 |                              | 40.5                    | 6.2  | 3.41              | 2.61       | .129                     |
| 3-8-6, 75 lbs.      | 1.20                               |                                    | 47.0 | 30.2 |                              | 38.6                    | 4.3  | 2.36              | 1.16       | .279                     |
| 3-8-6, 100 lbs.     | 1.60                               |                                    | 50.0 | 32.9 |                              | 41.4                    | 7.1  | 3.90              | 2.30       | .222                     |
| None                |                                    |                                    | 39.5 | 26.6 |                              | 33.0                    |  |                   |            |                          |

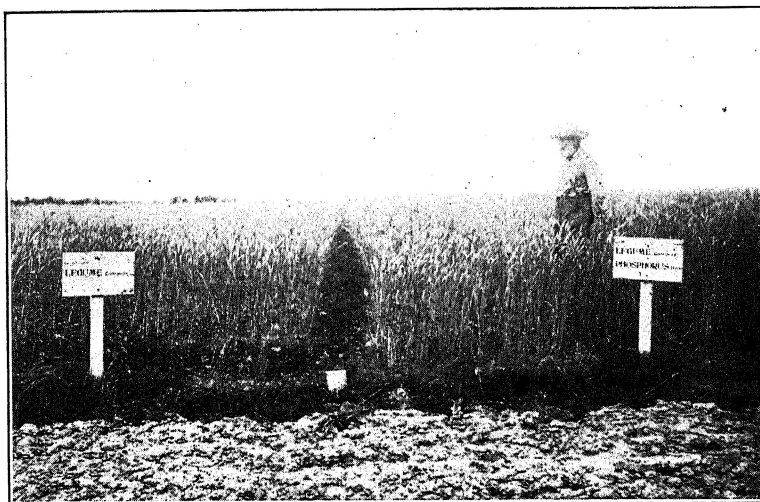
\*Average of two plots.

but seven and one-half cents per bushel. There were also small increases in yield from the mixed fertilizers. These increases in corn cost ten cents a bushel where fifty pounds of the 2-8-2 fertilizer was



used and thirteen cents in the case of the 3-8-6 mixture. (In the expressions 2-8-2 and 3-8-6, the first number indicates the per cent of ammonia, which is mostly nitrogen, the second number indicates the per cent of available phosphoric acid, and the last that of available potash.) The bone meal used analyzed about 2 per cent ammonia and 20 per cent phosphoric acid.

Judging from this test, it is profitable to use small amounts of fertilizer in the hill for corn. Steamed bone meal is one of the best kinds for this purpose on soils of the type found at High Hill. This



#### WHEAT ON HIGH HILL FIELD 1909

Legume—bone plot on right, yield 24.2 bu.

Legume plot on left, yield 16.0 bu.

use of fertilizers should always be combined with careful soil building practices however, and not depended upon to grow another crop on exhausted soils. It should be clearly understood that fifty-pound applications of fertilizer do not contain enough plant food to make a crop of corn.

The rather striking returns secured from small amounts of fertilizer in the hill seems to be largely due to the thrifty early growth induced by the fertilizer, thus better enabling the plants to withstand insect and plant diseases as well as to keep them ahead of the weeds.

### Bowling Green Experiment Field

The experiment field at Bowling Green in Pike County was started in the spring of 1907, and is located on the farm of W. B. McPike, one mile southwest of town. It is typical Putnam silt loam. The field was sown to timothy the fall before the experiments were started and it had a good stand over the whole piece. It had been in oats and corn alternately most of the time since 1884 though it had been in grass occasionally. It was so low in organic matter as to be in poor tilth and produced about twenty to twenty-five bushels of corn on average seasons.

The field slopes gently to the south so as to drain well, but not enough to wash. It also slopes very slightly to the west and is very



**COWPEAS ON BOWLING GREEN FIELD 1909**

Legume, bone, lime, potash plot in center.

uniform in appearance. The soil is nine to ten inches deep, of a gray silt loam grading into a light gray silt which becomes heavier with depth. At eighteen inches it changes into a mottled, reddish-yellow, clayey silt, stiff and sticky, becoming somewhat coarser again at a depth of thirty to thirty-five inches.

The chemical analysis shows this soil to be well supplied with phosphorus and potassium, but low in nitrogen and decidedly sour. The small amount of nitrogen indicates a low supply of organic matter

Bowling Green Experiment Field

SERIES C

|                              |    |
|------------------------------|----|
| Legume                       | 17 |
| Legume Bone                  | 18 |
| Legume Bone Lime             | 19 |
| Legume, Lime Bone, Potash    | 20 |
| No treatment                 | 21 |
| Manure                       | 22 |
| Manure Rock phosphate        | 23 |
| Manure Rock phosphate Legume | 24 |

SERIES D

|                              |    |
|------------------------------|----|
| Legume                       | 25 |
| Legume Bone                  | 26 |
| Legume Bone Lime             | 27 |
| Legume Bone Lime Potash      | 28 |
| No treatment                 | 29 |
| Manure                       | 30 |
| Manure Rock phosphate        | 31 |
| Manure Rock phosphate Legume | 32 |

SERIES A

|                              |   |
|------------------------------|---|
| Legume                       | 1 |
| Legume Bone                  | 2 |
| Legume Bone Lime             | 3 |
| Legume, Lime Bone, Potash    | 4 |
| No treatment                 | 5 |
| Manure                       | 6 |
| Manure Rock phosphate        | 7 |
| Manure Rock phosphate Legume | 8 |

SERIES B

|                              |    |
|------------------------------|----|
| Legume                       | 9  |
| Legume Bone                  | 10 |
| Legume Bone Lime             | 11 |
| Legume Bone Lime Potash      | 12 |
| No treatment                 | 13 |
| Manure                       | 14 |
| Manure Rock phosphate        | 15 |
| Manure Rock phosphate Legume | 16 |

as does the light color of the soil. This lack of organic material accounts, in part, for the fact that the phosphorus and potassium are largely in a form that is not available for plant use.

The plan of the field is similar to that at High Hill, except that there is one less plot in each series. The following diagram shows the arrangement. The four main divisions or series are devoted to the usual four-year rotation of corn, oats, wheat, and clover with cowpeas or soybeans substituted when clover fails.

All crops have been weighed and records kept. Tables XV to XXI, inclusive, show these yields together with the cost of treatment and net return after the cost has been deducted. A careful study of the tables should make clear the value of any soil treatment included in the experiment, on each individual crop.

Table XV.—Results of Experiments with Corn (7 Crops) Bowling Green Field

| Soil treatment                     | Average yield,<br>bus. per acre | Average increase,<br>bus. per acre | Average value of<br>increase per acre | Average cost of<br>treatment per<br>acre | Average net re-<br>turns per acre<br>per year |
|------------------------------------|---------------------------------|------------------------------------|---------------------------------------|--|---|
| Legume.....                        | 24.6                            | 1.5                                | \$.83                                 | \$.51                                    | \$.32   |
| Legume, bonemeal.....              | 27.6                            | 4.5                                | 2.47                                  | 1.58                                     | .89   |
| Legume, bonemeal, lime.....        | 28.2                            | 5.1                                | 2.80                                  | 2.18                                     | .62   |
| Legume, bonemeal, lime, potash.... | 29.9                            | 6.8                                | 3.74                                  | 2.77                                     | .97   |
| No treatment.....                  | 23.1                            |                                    |                                       |  |   |
| Manure.....                        | 28.1                            | 5.0                                | 2.75                                  | 1.28                                     | 1.47  |
| Manure, rock phosphate.....        | 29.5                            | 7.9                                | 4.35                                  | 2.42                                     | 1.93  |
| Manure, rock phosphate, legume.... | 26.4                            | 3.3                                | 1.81                                  | 2.93                                     | -1.12   |

Table XVI.—Results of Experiments with Oats (4 crops) Bowling Green Field

| Soil treatment                     | Average yield,<br>bus. per acre | Average increase,<br>bus. per acre | Average value of<br>increase per acre | Average cost of<br>treatment per<br>acre | Average net re-<br>turns per acre<br>per year |
|------------------------------------|---------------------------------|------------------------------------|---------------------------------------|--|---|
| Legume.....                        | 30.0                            | 0.21                               | \$.08                                 | \$.52                                    | \$.44   |
| Legume, bonemeal.....              | 31.1                            | 1.30                               | .47                                   | 1.69                                     | -1.22   |
| Legume, bonemeal, lime.....        | 31.8                            | 2.0                                | .74                                   | 2.27                                     | -1.53   |
| Legume, bonemeal, lime, potash.... | 34.47                           | 4.65                               | 1.73                                  | 2.86                                     | -1.13   |
| No treatment.....                  | 29.81                           |                                    |                                       |  |   |
| Manure.....                        | 31.8                            | 1.95                               | .72                                   | 1.28                                     | -.56  |
| Manure, rock phosphate.....        | 32.7                            | 2.9                                | 1.06                                  | 2.26                                     | -1.20   |
| Manure, rock phosphate, legume.... | 35.0                            | 5.2                                | 1.92                                  | 2.86                                     | -.93  |

Table XVII.—Results of Experiments with Wheat (6 crops) Bowling Green Field

| Soil treatment                      | Average yield bus. per acre | Average increase, bus. per acre | Average value of increase per acre | Average cost of treatment per acre | Average net returns per acre per year |
|-------------------------------------|-----------------------------|---------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| Legume.....                         | 14.2                        | .00                             | \$ .00                             | \$ .77                             | \$-.77                                |
| Legume, bonemeal.....               | 21.5                        | 7.26                            | 6.54                               | 1.89                               | 4.65                                  |
| Legume, bonemeal, lime.....         | 21.9                        | 7.7                             | 6.93                               | 2.22                               | 4.71                                  |
| Legume, bonemeal, lime, potash..... | 24.26                       | 10.03                           | 9.03                               | 2.82                               | 6.21                                  |
| No treatment.....                   | 14.2                        |                                 |                                    |                                    |                                       |
| Manure.....                         | 17.6                        | 3.4                             | 3.06                               | 1.42                               | 1.64                                  |
| Manure, rock phosphate.....         | 18.8                        | 4.6                             | 4.16                               | 2.41                               | 1.75                                  |
| Manure, rock phosphate, legume..... | 23.8                        | 9.55                            | 8.59                               | 3.18                               | 5.41                                  |

Table XVIII.—Results of Experiments with Clover Hay (2 crops) Bowling Green Field

| Soil treatment                      | Average yield lbs. per acre | Average increase, lbs. per acre | Average value of increase per acre | Average cost treatment per acre | Average net returns per acre per year |
|-------------------------------------|-----------------------------|---------------------------------|------------------------------------|---------------------------------|---------------------------------------|
| Legume.....                         | 1,100                       | 50                              | \$ .28                             | \$ .88                          | \$-.60                                |
| Legume, bonemeal.....               | 2,325                       | 1,275                           | 7.14                               | 2.01                            | 5.13                                  |
| Legume, bonemeal, lime.....         | 3,600                       | 2,550                           | 14.28                              | 2.51                            | 11.77                                 |
| Legume, bonemeal, lime, potash..... | 3,650                       | 2,600                           | 14.56                              | 3.11                            | 11.45                                 |
| No treatment.....                   | 1,050                       |                                 |                                    |                                 |                                       |
| Manure.....                         | 1,900                       | 850                             | 4.76                               | 1.12                            | 3.64                                  |
| Manure, rock phosphate.....         | 2,575                       | 1,525                           | 8.54                               | 1.89                            | 6.65                                  |
| Manure, rock phosphate, legume..... | 2,425                       | 1,375                           | 7.70                               | 2.76                            | 4.94                                  |

Table XIX.—Results of Experiments with Cowpea Hay (3 crops) Bowling Green Field

| Soil treatment                      | Average yield lbs. per acre | Average increase lbs. per acre | Average value of increase per acre | Average cost of treatment per acre | Average net returns per acre per year |
|-------------------------------------|-----------------------------|--------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| Legume.....                         | 2,533                       | 233                            | \$1.30                             | \$ .79                             | \$ .51                                |
| Legume, bonemeal.....               | 2,717                       | 417                            | 2.33                               | 1.92                               | .41                                   |
| Legume, bonemeal, lime.....         | 2,583                       | 283                            | 1.58                               | 2.42                               | -.84                                  |
| Legume, bonemeal, lime, potash..... | 2,267                       | -33                            | -.18                               | 3.02                               | -3.20                                 |
| No treatment.....                   | 2,300                       |                                |                                    |                                    |                                       |
| Manure.....                         | 2,617                       | 317                            | 1.77                               | 1.66                               | .11                                   |
| Manure, rock phosphate.....         | 2,933                       | 633                            | 3.54                               | 2.72                               | .82                                   |
| Manure, rock phosphate, legume..... | 3,200                       | 900                            | 5.04                               | 3.52                               | 1.52                                  |

Table XX.—Results of Experiments with Soybeans (1 crop)  
Bowling Green Field

| Soil treatment                      | Yield, lbs. per acre | Increase, lbs. per acre | Value of increase per acre | Cost of treatment per acre | Net returns per acre per year |
|-------------------------------------|----------------------|-------------------------|----------------------------|----------------------------|-------------------------------|
| Legume.....                         | 2,400                | -500                    | -\$2.80                    | \$ .50                     | -\$3.30                       |
| Legume, bonemeal.....               | 2,500                | -400                    | -2.24                      | 1.55                       | -3.79                         |
| Legume, bonemeal, lime.....         | 2,700                | -200                    | -1.12                      | 2.05                       | -3.17                         |
| Legume, bonemeal, lime, potash..... | 2,700                | -200                    | -1.12                      | 2.65                       | -3.77                         |
| No treatment.....                   | 2,900                |                         |                            |                            |                               |
| Manure.....                         | 2,800                | -100                    | -.56                       | 1.28                       | -1.84                         |
| Manure, rock phosphate.....         | 3,200                | 300                     | 1.68                       | 2.52                       | -.84                          |
| Manure, rock phosphate, legume..... | 3,600                | 700                     | 3.92                       | 3.02                       | .90                           |

Table XXI.—Averages for Entire Field, All Crops, Bowling Green Field

| Soil treatment                      | Value of increase per acre | Cost of treatment per acre | Net return per acre per year |
|-------------------------------------|----------------------------|----------------------------|------------------------------|
| Legume.....                         | \$ .34                     | \$ .65                     | -\$ .31                      |
| Legume, bonemeal.....               | 3.33                       | 1.76                       | 1.57                         |
| Legume, bonemeal, lime.....         | 4.15                       | 2.26                       | 1.89                         |
| Legume, bonemeal, lime, potash..... | 4.99                       | 2.85                       | 2.14                         |
| No treatment.....                   |                            |                            |                              |
| Manure.....                         | 2.38                       | 1.35                       | 1.03                         |
| Manure, rock phosphate.....         | 3.87                       | 2.38                       | 1.49                         |
| Manure, rock phosphate, legume..... | 4.62                       | 3.05                       | 1.57                         |

Consulting these records on the various crops, it may be seen that corn has responded most to applications of manure, tho it has paid a fair profit for the bone meal and rock phosphate applied. Unfavorable seasons have given low yields but have not prevented a margin in favor of increased fertility. Cowpeas have generally made a satisfactory growth when drilled in the corn on this field and when plowed under have tended to increase the yield of some of the crops, but, on the whole, the increase has not been sufficient to cover cost of seed and sowing. Every treatment given made some increase in the corn crop and in most cases at a profit.

Wheat has made exceedingly satisfactory profit on the bone meal applied to it, as has also the clover following. Potash fertilizer has been less satisfactory, but its use has resulted in a gain. The stronger, more vigorous wheat plants on the properly fertilized plots have shown a marked tendency to come through the winters in good condition.

Clover when grown on the Bowling Green field has shown large increases for applications of lime, bone meal, and manure, the lime

and manure being put on before corn and the bone meal before wheat in the rotation. The effect of lime is especially noticeable on clover as it is the only crop of this rotation not able to stand a sour soil fairly well.

Oats and cowpeas as was observed on the High Hill field apparently have been limited more by seasonal or climatic factors than by the fertility of the soil, and hence have generally made but small and unprofitable increases for soil treatment. It must be remembered, however, that in no case have the fertilizers been applied to these crops directly, although they have been charged with their share of the fertilizer cost. It is quite possible that had the fertilizer been applied directly to these crops, fair returns would have been secured.



#### CLOVER ON BOWLING GREEN FIELD 1910

Legume, bone, lime, potash plot on left, yield 5150 lbs. clover hay.

No treatment plot on right 1500 lbs. hay, mostly witch grass.

The field as a whole, has given good returns on limestone, manure, and bone meal and a smaller profit on rock phosphate. The amount of this profit, together with the cost, is shown in Table XX. This is what might be expected on a sour soil, low in organic material and fairly well supplied with phosphorus. Altho the phosphate in bone meal, is not immediately soluble in water, yet the bone meal itself decays readily and, in the process of decay, makes the phosphate available. When bone meal can not be secured, some other fertilizer high in available phosphate may be substituted.

To summarize, the soil of the type found at Bowling Green and known as typical Putnam silt loam, should give profitable returns for an initial application of about two tons of limestone per acre, followed by an addition of one ton every six or eight years. All the manure that can be applied at a cost not to exceed \$1.50 per ton, should be used, preferably before corn. It will also be found profitable to apply a fertilizer high in available phosphorus at the rate of 150 to 200 pounds before wheat. It should be noted, however, that these figures were secured under a system in which a good rotation was followed.

### General Conclusions

There has been a striking similarity in the results of these experiments tho carried out at rather widely separated places. The potash fertilizer has been applied at a loss except at Bowling Green, where a small net profit resulted from its use. The growth of cowpeas as a leguminous green manure crop has proved satisfactory only at High Hill which is on a comparatively thin phase of the Putnam silt loam. It is probable, however, that had some value been secured from the forage produced before turning the cowpeas under, a more satisfactory return might have resulted. During the last two years the method of sowing cowpeas in the corn has been changed from drilling between the rows at the last cultivation to dropping in the hill with an attachment on the corn planter. In this way less seed is needed and hence the expense is reduced while the peas make most of their growth before the corn produces a dense shade and before moisture becomes scarce. Whether this will pay except in corn that is to be pastured or hogged down, has as yet to be demonstrated.

Raw rock phosphate, the cheapest form in which phosphorus can be bought, has given a small net profit where used in these experiments. It must be borne in mind, however, that it should always be applied in close contact with decaying organic matter.

The results of these tests seem to indicate that when quick profit must be secured money would better be invested in readily available forms of phosphorus which are lacking in this soil. Where the soil has been sweetened with lime and its supply of vegetable or organic matter increased thru the use of manure and a good rotation, it is more than likely that some of the phosphorus bought may well be in the cheap form of raw rock phosphate.

The use of phosphorus in the more readily available form of steamed bone meal has been profitable on each of these experiment fields. Most of this profit has been secured from the wheat crop and the clover following it which leads to the conclusion that this material



can be most profitably applied to wheat where the rotation includes this crop and where the money expenditure must be kept low. Unfortunately, the supply of bone meal is limited and cannot be expanded to meet the increasing demand. Because of this fact large and profitable use is being made of the acid treated rock phosphate, commonly known as acid phosphate. The small amount of acid contained has little influence on the sourness of the soil and the supply of acid phosphate is large. Most of the ready mixed fertilizers on the market at present contain the phosphorus in this form. Acid phosphate is especially well adapted for spring sown and all quick growing crops that need a phosphatic fertilizer, tho for long season crops, like winter wheat, the more slowly available bone meals seem to be somewhat better.

Lime at a price of \$3 per ton has returned a profit on each field covered in this bulletin, the only exception being the light application of one ton on the High Hill field. In the same field the two-ton application proved profitable. In no case was the profit strikingly high, but should the improved bacterial conditions due to liming continue to bring this soil into a better state of tilth and fertility, as seems likely from numerous older experiments in this country, this gain may be somewhat increased.

Two of the experiment fields included in this discussion had plots receiving ordinary barnyard manure at the rate of six tons once in the four-year rotation, or one and a half tons annually. The yearly return has been at the rate of \$2.40 to \$3.40 per acre for the one and one-half tons applied, or \$1.60 to \$2.25 per ton for the manure. Judging from general experience, the corn crop is able to make the best use of fresh manure while the succeeding crops profit from the more thoroughly decayed material left in the soil. According to these results manure should not be looked upon as having to be hauled, simply to get it out of the way, as is too common in a new country, but rather as a very important farm asset entirely worth the time required to take care of it. It should be borne in mind that a loose, unpacked pile of manure decays very rapidly and that manure exposed to rain may have much of its plant food washed away before it reaches the field where it is needed. The best principle to follow seems to be to get it on the field as soon as possible, considering the labor supply and type of farming common in this country.

Briefly, therefore, the important considerations in handling soils of this type are the adoption of a good crop rotation; the application of two or three tons of ground limestone, thoroly worked into the soil and followed by additional applications of a ton every six years;

the use of all the manure possible to secure at a cost not exceeding \$1.50 per ton, including hauling and spreading it on the field—this to be applied chiefly before the corn crop; and, finally, the application of 150 to 200 pounds of steamed bone meal or acid phosphate to be drilled in with the wheat where this crop is used in the rotation. Tho this soil is fairly well supplied with the very slowly available forms of phosphate, it should be found profitable to keep up this supply by making an occasional application of 1000 pounds or more of finely ground phosphate rock. It should always be applied in close contact with manure, a green manure crop or other decaying material and in no case should large immediate returns be expected. The application of rock phosphate in this way is a soil building process.

#### RECOMMENDATIONS REGARDING SOIL MANAGEMENT ON THE NORTHEAST MISSOURI LEVEL PRAIRIE

**Drainage.** The very compact nature of the subsoil, together with a rather level topography, results in a lack of drainage which is characteristic of the greater part of the Northeast Missouri level prairie land. This need of drainage is one of the most fundamental needs of the soil. Unfortunately the compact subsoil hinders the efficient action of the drains to a certain degree so that tiling has thus far been practiced to only a limited extent. Experiments made by the Missouri Agricultural Experiment Station in draining this land<sup>1</sup> have shown that this can be done economically, particularly on the very level land, altho the tile must be laid not more than five rods apart for efficient service. This necessitates an expenditure of not less than \$20 per acre which will prevent most farmers from tiling their land.

Another factor which is retarding the use of tile on this prairie is the fact that the average farmer is handling the land extensively rather than intensively, and largely in systems of livestock farming. Thoro drainage which is always a costly process, is usually associated with high land values and intensive farming. The rapid increase in the value of this prairie land during recent years is bringing about conditions under which tile drainage may be encouraged.

It is not recommended that even the smaller and more intensive farmers should proceed at once to tile their entire farms thoroly. It will be better for them to begin by laying tile in those places needing it most and so planning that a complete system of tiling may be installed as funds become available. It can be taken as a safe statement, that, except in extraordinary cases, this very level prairie land after it has reached a valuation above \$80 per acre, must be subjected

<sup>1</sup> Bul. 118, Drainage Investigation on the N. E. Missouri Level Prairie.

to something more than mere surface drainage, if the land is to pay a fair rate of interest on the investment. For the more rolling areas, this statement will not necessarily hold true. It is a proven fact, however, that intensive farming and high average yields are only possible on a soil which is either naturally or artificially well drained.

For the man who is farming this level prairie on small capital, or in an extensive way, under-drainage cannot be recommended. For such men a thoro "bedding" of the land, which is already practiced on the better farms, is to be recommended with tile only on exceptionally wet areas and in the low wet sags or sloughs which occur here and there.

**Cropping Systems.** The general crop adaptations of the Northeast Missouri level prairie have been well worked out by the farmers themselves. These include such general crops as corn, oats, wheat, rye timothy, blue grass, redtop, sorghum, and millet, among the more common grains and grasses, while, among the legumes, white clover, soybeans, and cowpeas do well. Neither red clover nor alfalfa are well adapted to Putnam silt loam, altho on the more rolling phases of it, especially where it is in a high state of fertility, red clover is a satisfactory crop. Alsike clover is much better adapted to this land than is red clover. Altho it is not as large a plant as red or mammoth clover it makes a fairly good clover to mix with timothy on this land. On the typical level prairie, alfalfa can be grown only after thoro drainage has been accomplished and after intensive manuring and liming. Soybeans and cowpeas have not as yet received their just share of attention on this level prairie. They are well adapted and are very valuable legume forage crops.

**Systems of Farming.** Livestock farming is particularly adapted to the level prairie land of Northeast Missouri. Blue grass grows well and stock water is readily provided either by wells or ponds. Grain crops cannot be grown continuously without an early reduction in yields. While the virgin soil was, in early years, most economically handled under systems of grain and timothy hay farming, there is little possibility of continuing this much longer. There is but one method of maintaining soil fertility under grain farming, and that is thru the growing of legumes to turn under. Since the clovers are not particularly adapted to this soil, the possibilities of establishing a satisfactory green manuring system with grain farming will doubtless be limited to particular farmers and livestock farming is to be generally recommended. Whether this will be dairy farming or some form of cattle, sheep, or hog farming, depends on the location and the tastes of the individual farmer.

**Crop Rotations.** A systematic crop rotation is rarely found on this prairie land today. The old plan of growing corn two or more years, to be followed by oats and then by timothy for two or more years is still most common. This could scarcely be called a systematic crop change and it is not a soil building system. It is still most remunerative for the short time renter and it is the easiest plan for the land owner. It is not a plan, however, which can be depended upon for the permanent maintenance of soil fertility. Many farmers on this land have realized the importance of adopting a more careful system of cropping, particularly one in which legumes occur. Because of the difficulty in growing clover they have begun using cowpeas and soybeans in rotation with grain and hay crops.

Wheat has been gradually taking a place in the cropping systems on the level prairie since the introduction of fertilizers. Many farmers are finding it a more satisfactory crop than oats. It is commonly sown after oats in a rotation of corn (two or three years), oats, wheat and grass, the latter often being mixed with clover on the better drained areas, in spite of the fact that the clover is very uncertain. Some men, particularly where the silo is in use, have found it economical to omit oats and follow the silage corn with wheat and the wheat with grass. This is also sometimes done where the corn is cut and shocked.

A rotation to be recommended is one of corn, two years, followed by cowpeas or soybeans, these by wheat and the wheat by timothy and alsike clover for two years. It is also becoming rather common to seed cowpeas or soybeans in the corn rows at the time of planting with a cowpea attachment on the planter, using one gallon of peas or beans per acre. This practice will often result in a slight reduction of the corn yield, particularly in dry seasons, but the decrease in yield of corn should be more than offset by the benefit from the organic matter and nitrogen added to the soil by the peas or beans and from the feed secured from them. There is little interference with cultivation when peas or beans are sown in this way and it is a practice to be recommended, for the livestock farmer. Some livestock farmers will prefer to sow rye instead of cowpeas in the corn the first year for fall and spring pasture.

Wheat may be sown after cowpeas or soybeans without reploting the land, altho the soil should be well disked, and then preferably rolled and harrowed with a drag harrow before seeding. There has been some complaint of the cowpeas leaving the ground too loose for wheat unless a roller is used. On this account it is probably better to plant the cowpeas or soybeans in rows and cultivate them than to

sow them with a grain drill. For this purpose the soybeans are more easily handled as they stand up straighter than cowpeas when sown in rows. A grain drill may be used for seeding by stopping up a part of the holes so that the rows are placed about 30 to 32 inches apart. Some corn planters may also be adjusted for sowing the rows sufficiently close together for this purpose.

A rotation that will appeal to many men because it is not greatly different from the present system of cropping, is one of corn, two years, followed by oats, this by wheat, and the wheat by timothy and alsike clover two years. Besides being a more certain crop on the level prairies, alsike has the advantage of lasting somewhat longer where the land is to be left in grass more than two years. The use of lime and drainage will ultimately make red clover a satisfactory crop on this land, but this will come only with more intensive systems of farming. Meantime alsike clover is to be preferred. In this rotation, cowpeas or soybeans may be seeded with the corn, both years or rye the first year and cowpeas or soybeans the second. These decay sufficiently by spring so that there is no interference with the preparation of the stalk land for oats.

A rotation of corn, two years, followed by wheat and the wheat by timothy and alsike two years, is a satisfactory one, where oats is not considered a profitable crop, and where the wheat is fertilized. For best results this system should be used on a farm where half the corn is put into the silo, so that the wheat may be sown on this part of the corn land. Naturally corn is not as good a crop to precede wheat as is a crop like oats, but one plowing of the land is saved, which is a very important item. In this rotation cowpeas or soybeans may be sown with the corn as previously mentioned, part to be put into the silo with the corn and a part being pastured or left to lie on the ground.

Various modifications of the above suggested rotations might be used under particular circumstances. It should always be borne in mind, however, that corn should rarely occupy more than one-third of the rotated land, that is, one year of corn in a three-year rotation or two years in a six-year rotation. Two years in a five-year rotation should be considered the maximum amount of corn which should be grown. The partial substitution of legume crops for corn as a feed will usually give a more satisfactory ration and it will be much better for the land. Some men will be able to handle a system with but one year of corn in four, that is only one fourth of the land in corn, which is still better on the land, but somewhat more difficult to handle economically.

**Cultural Methods.** The level prairie land of Northeast Missouri presents some rather peculiar problems regarding cultural methods. The compact and level nature of the soil which results in poor natural drainage, is accompanied by a corresponding failure of the land to stand drought. This is due to the fact that the water will not readily penetrate deeply into the soil thus preventing a proper storage of moisture. A gradual deepening of the soil by plowing a half inch to an inch deeper each time until a depth of 9 to 10 inches is reached will assist in bettering these moisture relations, altho there is no conclusive evidence that excessively deep plowing will be economical.

Many inquiries are received at the Missouri Agricultural Experiment Station regarding the value of dynamite in loosening a heavy



**Cowpeas sown in the corn rows with planter attachment.  
Ready to be hogged down.**

subsoil, and while the station has secured some slight return from the use of dynamite in this way, it has not as yet been proved to be a profitable practice. It therefore can not be recommended at this time. Further results may show a profit from its use, but the matter is one which requires further investigation. The same may be said of the use of the subsoil plow. It would seem that the loosening of this heavy subsoil in any convenient way would be a benefit, and that subsoiling would be a good thing, but the experiments which have been made with the subsoiler do not substantiate this view. The

difficulties with subsoiling are: first, that it is expensive, and second that when land is in shape to plow well, the subsoil is still too wet to crumble under the subsoiler. Spring subsoiling is therefore rarely advisable, while in the fall when the subsoil is dry enough to pulverize, the soil is usually too dry and hard.

**Surface Tillage.** The fact that this level prairie does not absorb water readily because of its compact subsoil, warrants special attention being given to obviate drought in so far as possible. The disking of land before plowing, particularly stalk and stubble land, is strongly recommended. This puts the land into better condition to receive and retain moisture. At the same time it makes possible a better preparation of a seed bed together with a more thoro incorporation of the organic matter with the soil. A thoro stirring of the surface soil to prevent moisture evaporation in so far as practicable is always of value on this land, which is apt to become baked and hard if allowed to stand without a crop. In the cultivation of corn the use of a disk cultivator particularly for the first two cultivations, has been very popular on this level land. A disk cultivator enables one better to control the weeds which are apt to get a start early, because of the poorly drained condition of the land. Where the land is reasonably well drained, however, shallow working cultivators particularly for the later cultivations are to be recommended, except in those seasons when incessant rain keeps one out of the field until the weeds have become too large to handle with shallow cultivation.

**The Use of Barnyard Manure.** The large increase in the number of manure spreaders in this section of the state is an evidence of the better care which farmers are taking of barnyard manure. The experiments reported in this bulletin have shown a ton of manure to be worth from \$1.60 to \$2.25, during one round of a four-year rotation, in the value of increased yields secured. Doubtless this is a low estimate of the value of a ton of manure, since the experiments have not been in progress a sufficient length of time to return the full value of the manure in crops, but even at these figures, no man can afford to waste it. It is a common expression among farmers in this section that the effects of manure are very lasting. This is largely due to the close, retentive nature of the land, which largely prevents leaching. It should be an added incentive to the farmers to carefully save and apply all manure possible.

Too much emphasis scarcely can be placed upon the proper care of manure. Few farmers realize the great importance of saving every bit of organic matter to return to the land if a soil is to be maintained in fertility. The farmer usually thinks he is giving sufficient

care to the manure when he allows it to accumulate around a straw pile or in the open lot and then hauls it to the field with a spreader. The actual loss of organic matter as well as manurial constituents under such a system usually varies from 30 to 50 per cent. Most of this could be saved if the manure were allowed to accumulate under a covered shed of some kind, in which cattle are fed. Experiments have shown that the least loss occurs when manure is hauled directly to the fields as made, week by week, or day by day. Naturally this is often impracticable, except in the case of dairy farmers, and it is sometimes difficult even then to get it out during wet weather.

Manure may well be applied to the sod land which is to be broken for corn or to the grass crop directly. Where wheat is grown it may be used as a top dressing with good results. Where grass and clover are sown with wheat as a nurse crop the top dressing of the wheat in the fall is a very great aid in getting a stand of grass. Where the land is of fairly even fertility, the attempt should be made to spread the manure uniformly over the whole field which is in wheat or which is to go to corn, applying it with a spreader. The thinner manure is scattered the larger the return from each ton of manure applied.

Undoubtedly a feeding shed of some sort for cattle is most generally applicable where cattle are fed around the barns. Of course the most common system of feeding on this prairie is directly on the fields and this is one of the very best means provided the feeding is so distributed as to avoid accumulating the manure largely in one place. As a rule where cattle are fed on the fields, a well drained spot protected from the winds is chosen which, while best for the animals, gives a very unequal distribution of the manure.

The pasturing down of crops is one of the best means of getting manure back on the land evenly and with little waste, altho this can rarely be done over any large part of the rotated land. On a hog farm a six-year rotation of corn, corn, with rye as a winter cover crop and for hog pasture, followed by soybeans, rye, timothy and alsike clover two years may be used. One field of corn, most of the soybeans and the rye may be hogged down, and a large part of the alsike clover and timothy pastured. Such a plan may be handled on this prairie land fairly well with such variations as are necessary to meet local conditions. Many men prefer to follow a main rotation of crops to be harvested, with a secondary rotation on smaller fields with crops of corn, rape, soybeans, rye, clover, etc., for hog pasture.\* The plan of hogging and pasturing down as many as possible of the

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\*See Missouri Station Bulletin 110.



main crops, where this is feasible, is a great saving of labor and is a very satisfactory means of returning the manure to the land evenly and with little loss.

**The Use of Lime.** The results secured with lime on these experiment fields show that it is needed in greater or less degree thruout the region. The chemical determinations have shown that from one to three tons of the ground limestone is necessary to sweeten the soil. This does not mean, however, that lime is a universal panacea for all the ills of the soil, but rather that if this soil is to produce its greatest acre return, lime will usually be needed. Lime is, however, not a soil treatment which gives large and immediate returns. Very often little return is secured the first year. It is, therefore, not to be used as fertilizer is used, for the immediate crop, except in the case of certain crops like clover or alfalfa. Lime alone, however, will not make either red clover or alfalfa succeed on this level prairie. Thoro drainage and good general soil management must accompany liming to make red clover entirely satisfactory and it is very doubtful if alfalfa can be economically produced on this land even by these treatments. The time may come, when this land is handled much more intensively than it is now, that alfalfa can be made profitable, but that time, except possibly on a few particular farms, is a good many years in the future.

Lime should be looked upon as one of the cheaper means of improving the general productiveness of the soil by putting it in better condition for bacterial growth. It is a soil sweetener—a soil ameliorant—rather than a fertilizer and should be so regarded. It is applied only once in 4 to 6 years as a rule, particularly where ground limestone is used, and the return is distributed over a series of years. In these experiments the return has not been large for any one year but it has been rather consistent, with the exception of the one-ton application at High Hill which was evidently too light for that field.

There are three forms in which lime may be applied to soils for the purpose of correcting acidity. They are known as the oxide of lime, which is ordinary lump lime such as is used for plaster, the hydrate of lime which is lump lime with just enough water added to bring it to a powder, and the carbonate of lime which may be old air slaked lime or ground limestone, the compound being the same in each. When either of the first two forms of lime are applied to the soil they eventually take up carbon dioxide from the air and become air slaked. Hence no matter which form is used the results are practically the same. It takes less of either lump lime or hydrate of lime, however, because they become considerably heavier by taking up carbon dioxide while reaching the air slaked condition. This is

particularly true of lump lime which almost doubles in weight in becoming air slaked. In nearly all cases the cheapest and hence the best form of lime to use on soils is ground limestone. It should be applied evenly and thoroly worked into the soil, preferably after plowing. The most satisfactory method of applying it where a quantity is to be used is with a machine made for the purpose. There are several such machines on the market at present. Smaller amounts can be applied by hand, a good method being to put piles at equal intervals over the field in order to get a regular distribution and then scatter with a shovel. The size and distance apart of the piles will depend upon the rate of application. Piles of 200 pounds placed 50 feet apart each way will give approximately  $1\frac{1}{2}$  tons per acre. The manure spreader may also be used for this work by spreading a layer of litter over the apron and putting a layer of limestone on it. As the manure spreader is comparatively high, it is necessary to choose still days or have a hood to prevent blowing the lime away before it reaches the ground. Where any large amount of lime is to be used, it is most satisfactory to secure a lime spreader. Three or four farmers in a neighborhood could buy one cooperatively as a means of saving expense.

It must not be understood from what has been said that lime is recommended for every farmer on this level prairie. As a matter of fact much depends upon one's system of farming as to whether liming will prove profitable. Its use is adapted to the man who is seeking to farm more intensively and increase his acre yields at not too great an expense. The price at which lime can be delivered and spread on the land will naturally determine largely the profit secured. From the results of these experiments it may be said that \$3.00 per ton for ground limestone spread on the field is about the maximum price one should pay for this material. Consequently those farms lying more than five miles from the railroad or the crusher can rarely be limed economically. On this level prairie, however, the roads are usually very good in the fall and with very few grades, so that limestone can be hauled at less cost than in many other parts of the state. Where other forms of lime are cheaper per pound of calcium applied, they may be used in preference to the ground limestone. This may be true near lime kilns. In determining this matter, 2000 pounds of ground limestone can be figured as equivalent to 1120 pounds of freshly burned lump lime or to 1480 pounds of fresh water-slaked lime. Old air-slaked lime is practically the same as ground limestone. The lump lime must be slaked after it has been hauled. This usually is done by placing it in small piles over the field and covering with moist dirt, after which it may be scattered with a shovel. Such a plan is very common in the Eastern states.

The use of grinding machines for grinding limestone locally, wherever outcrops of good limestone occur is entirely feasible. Small grinders are now on the market designed for this purpose. Where a number of farmers can cooperate in buying and using such a machine, it will usually be found satisfactory. Where counties own rock crushers, it would be a good plan for them to buy a lime pulveriser to be used in connection with this other machinery and supply the lime to farmers at low price.\*

**The Use of Fertilizers.** The results secured on these experiment fields, show that a fertilizer containing a high per cent of rather available phosphorus, such as acid phosphate or bone meal can be applied to this soil with good profit while a small amount of potassium will usually pay. Bone meal, particularly the steamed bone meal, containing 1 to 2 per cent nitrogen and 26 to 28 per cent phosphoric acid applied at the rate of 100 to 200 pounds per acre before wheat, is to be recommended. It can be applied before corn at the rate of 150 to 225 pounds to an acre on the more worn land with good results. As it is doubtless only a question of time until bone meal will be too scarce to supply the demand for it, acid phosphate must undoubtedly come into wider use. While these experiments have not included acid phosphate, the effect as shown by other experiments is quite similar to that of steamed bone meal, so that it can be recommended at the rate of 125 to 200 pounds before wheat and 175 to 250 pounds before corn. It is much cheaper than the bone meal and should be used at a higher rate.

These phosphates are very effective on grass and clover and where these are seeded alone or with a nurse crop of wheat, good results can be expected. It is not very remunerative to apply phosphates to either oats or rye unless clover or timothy is seeded with them, and in this case a return on the grass and clover should be secured.

Highly phosphatic mixed fertilizers applied at approximately the same rates as the bone meal will also prove remunerative on this land, although the percentages of both nitrogen and potash should be low, not over 2 per cent each as a rule. Such a fertilizer would be one containing 1 to 2 per cent nitrogen, 10 to 12 per cent available phosphoric acid and 2 per cent potash. Such fertilizers contain approximately the same amounts of nitrogen and phosphorus available the first season as does the bone meal. Since the bone meal contains about an equal amount of phosphorus that is not available the first year, but becomes available mainly during the two years following,

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\*A list of companies putting out limestone pulverizers and lime spreaders as well as those selling agricultural lime, may be obtained by addressing the Department of Soils, University of Missouri, Columbia.

the effect is somewhat more lasting than that of the mixed fertilizers or the acid phosphate. Bone meal, therefore, is usually preferred as a fertilizer to be used with a small grain where it is to be followed by grass or clover. The use of either a mixed fertilizer or bone meal in the hill or drill for corn as shown by the High Hill results may be quite remunerative when applied in rather small quantities, 75 to 90 pounds. Over 100 pounds is apt to cause the corn to "fire" in dry seasons. Of course this is merely a temporary system of fertilization used largely to give the corn a quick start. It should be used only in connection with systems of farming which maintain the organic matter or by the tenant or land owner who must have immediate returns at small cost. Where large amounts of fertilizer are applied to corn either phosphates or a mixed fertilizer should be applied before the planter with a fertilizer grain drill.

The rates of application of either phosphates or mixed fertilizer depends both on the state of the soil's fertility and on the intensity of the system of farming one is practicing. As a general rule the more intensive the system of farming, the larger the amount of fertilizer one can afford to apply. It is only with careful systems of rotation and with thoro preparation of seed beds that the large amounts can be economically used. Further, as the land is farmed more intensively, tile drainage must be employed and the largest amounts of fertilizer are only economically applied after tiling the land. Where a small amount of capital is available the use of medium to small amounts phosphates is recommended, particularly when combined with the growing of legumes such as cowpeas and soybeans which grow well on this land.

The use of raw rock phosphate has not proven as profitable in these experiments as has the bone meal. The length of time the experiments have been in progress is doubtless not sufficient to allow the rather slow acting raw rock to have its complete effect. The owner of the High Hill field on which it was necessary to close the experimental work in 1912, reports that the effect of the raw rock was plainly visible to the eye on the crops grown in this field during the seasons of 1913 and 1914. For the man who must have immediate returns, such as the tenant or the land owner with a heavy indebtedness, the raw rock phosphate cannot be recommended. It is better suited to the landowner who can wait for returns and who is following a system of soil improvement in which he is building up his soil in organic matter. For such men the use of 800 to 1000 pounds of finely ground raw rock phosphate once in 4 to 6 years, plowed in with manure, sod or other organic matter, is to be recommended.

A word of caution should be given regarding the use of commercial fertilizers on the land. Fertilizer applied in the smaller quantities recommended in this bulletin cannot be considered as soil builders. They are used rather to supply an additional amount of available plant food to that already in the soil, and with the exception of the raw rock phosphate mentioned, they cannot be considered as a means of building up the soil unless the supply of organic matter is maintained. Used alone without crop rotation, manuring, or other means of keeping up the supply of organic matter, they simply enable one to farm his land longer to grain crops with the result that the land may be rendered even less productive, if their use is discontinued, than if they had not been used. Properly used, therefore, fertilizers will prove very profitable on this land, but improperly used the land may be actually impaired after a number of years of use. The trouble, however, is not with the fertilizer in this case but with the farmer. The only proper use of commercial fertilizer, except possibly for the tenant or for the land owner who must have immediate returns, is in connection with the best system of crop rotation, manuring and legume growing that a man can practice.

#### SUMMARY

1. The seeding of cowpeas between the rows of corn at the last cultivation as a green manure crop has proven satisfactory only at High Hill which is on a rather thin phase of this Putnam Silt Loam.
2. Bone meal has brought good returns on each of these experiment fields, the best results being secured on wheat and the clover crop following it.
3. The use of raw rock phosphate has given only a small net profit in these experiments. It is better adapted for the land owner who is practicing a system of soil building and who is not in need of immediate returns.
4. Lime figured at a cost of \$3.00 per ton applied, has returned a fair profit wherever used in these experiments, except in the case of a light application of one ton at High Hill. On the same field the two ton application proved profitable.
5. Barnyard manure has brought a return of \$1.60 and \$2.25 per ton respectively on the two fields on which it was used.
6. Fertilizer in the hill for corn on the High Hill field has shown a fair net return.
7. The use of systematic crop rotations in which wide use shall be made of cowpeas and soybeans, and where possible of red or alsike clover, is strongly recommended.

8. For the man who wishes to farm this land very intensively and who has capital to invest, the thoro underdraining of the very level areas is recommended.

9. The use of 100 to 200 pounds of steamed bone meal or 125 to 225 pounds of acid phosphate per acre is recommended to be applied with wheat or before rye or oats where clover or timothy follows.

10. The use of 150 to 225 pounds of bone meal, or 175 to 250 pounds of acid phosphate is recommended to be applied before corn with a fertilizer grain drill on the thinner phases of this prairie where a man wishes to farm with a fair degree of intensity.

11. On the average of this land the application of 75 to 90 pounds of a fertilizer containing 1 to 2 per cent of nitrogen, 8 to 10 per cent available phosphoric acid and 2 per cent of potash in the hill or drill for corn will usually give good net returns. This system is a temporary one adapted particularly to the tenant farmer.

12. The use of  $1\frac{1}{2}$  to 3 tons of ground limestone, the amount depending on the degree of acidity of the soil, is recommended for those farmers who are sufficiently near the railroad or a lime supply that this material can be delivered and spread on the land for \$3.00 or less per ton.

13. Systems of stock farming or general farming are recommended for this prairie, in which the manure is carefully returned to the land, preferably applied before corn or as a top-dressing for wheat.