The investigations reported in this circular deal with the ordinary gently rolling upland timber soils representing a very common type in northern Illinois. Similar lands are also found quite extensively in central Illinois, especially along the streams which were originally bordered with strips of native timber.

"Level timber land" is the term commonly applied to designate these soils, just as "level prairie" is the term most used to designate the common Illinois prairie lands, although neither type of soil has an absolutely level or flat topography. As a matter of fact, both the upland timber soils, referred to in this circular, and the most common prairie lands described in circular 96 ("Soil Improvement for the Illinois Corn Belt") are somewhat undulating, but not sloping enough to subject them to surface-washing, or erosion, under ordinary conditions. For information concerning the eroded worn hill lands of Illinois, see Bulletin No. 115.

It may well be kept in mind that the level or gently rolling timber land differs from the more rolling or steeply sloping eroded hill land, not only in topography, but also in composition, the eroded land being most deficient in humus and nitrogen while the more nearly level land is fairly well supplied with nitrogen, but very deficient in phosphorus to meet the needs of large crop yields,
as will be seen from a careful study of the actual results obtained from field experiments.

In considering the data secured from soil experiment fields, the reader should always keep in mind that the crops grown by the Experiment Station are subjected to the same general conditions as on the farms about, including occasional drouths, damaging storms, and attacks of such insect enemies and fungous diseases as we are not yet able to control. Furthermore, it is impossible to find even one acre of land that is absolutely uniform in every respect. Trustworthy conclusions are to be drawn only from considering a series of tests or experiments covering several years, such as are given in the following pages.

ANTIOCH SOIL EXPERIMENT FIELD

The Antioch soil experiment field is located about four miles southeast from Antioch, Lake County, on the farm of Mr. D. M. White. The soil is the ordinary timber land of that section of the state, which is known as the late Wisconsin glaciation. It is a gently rolling gray silt loam soil, with a rather stiff silty clay subsoil underlain by gravelly clay. The nitrogen and humus content of this soil is only moderate, the phosphorus content is very low, but the total amount of potassium is very great, as determined by absolute chemical analysis. This experiment field is typical of the gray silt loam timber soils of the northeastern part of the state.

The field was located in 1902 and originally consisted of one series of ten tenth-acre plots. In 1904 two other series were added to it. The original series has been used for a complete fertility experiment, where the different elements of plant food in easily available form have been applied directly in order to determine as quickly as possible the needs of the soil without having to wait on the slower methods.

The new series has been devoted to a rotation of crops where the nitrogen is supplied by the growing of legumes in the rotation and by the application of farm manures, and the phosphorus applied in the cheaper less readily available form of finely ground raw rock phosphate. The work on the rotation series has not progressed far enough to justify any definite conclusions, so the results from that part of the field will not be discussed in detail at this time.
PLAN OF EXPERIMENT

The plan of treatment for the older experiments has been as follows:

Plot 1, No treatment applied.
Plot 2, Lime applied.
Plot 3, Lime and nitrogen
Plot 4, Lime and phosphorus
Plot 5, Lime and potassium
Plot 6, Lime, nitrogen, and phosphorus
Plot 7, Lime, nitrogen, and potassium
Plot 8, Lime, phosphorus, and potassium
Plot 9, Lime, nitrogen, phosphorus, and potassium
Plot 10, Nitrogen, phosphorus, and potassium.

To supply the nitrogen about 800 pounds per acre of dried blood, containing about 12 1/4 percent (100 pounds) of nitrogen, have been applied every year. To supply the phosphorus and potassium, 200 pounds of steamed bone meal, containing about 12 1/4 percent (25 pounds) of phosphorus, and 100 pounds of potassium sulfate, containing about 40 pounds of potassium, have been applied per acre per year, or in correspondingly larger amounts, if applied less frequently.

A hundred-bushel crop of corn contains about 148 pounds of nitrogen (100 pounds in the grain and 48 in the stalks), 23 pounds of phosphorus (17 pounds in the grain and 6 in the stalks), and 71 pounds of potassium (19 pounds in the grain and 52 in the stalks). The usual cost of these elements in these commercial forms is 15 cents a pound for nitrogen, 10 cents for phosphorus, and 6 cents for potassium. If crops need more plant food than the soil can furnish naturally, we can get more nitrogen from the inexhaustible supply in the air and liberate more potassium from the practically inexhaustible supply in the soil; but if the supply of phosphorus in the soil is actually limited, we should adopt a system of farming under which the soil grows richer in phosphorus and more productive, and for this reason we apply slightly more phosphorus than we remove in very large crops.

All crops have been removed from the land, including stalks and straw. Thus far five crops have been grown; corn in 1902 and 1903, oats in 1904, wheat in 1905, and corn again in 1906. The yields by plots figured to bushels per acre are given in Table 1.
### Table 1. - Crop Yields from Antioch Soil Experiment Field

(Land not tile-drained)

<table>
<thead>
<tr>
<th>Soil plot Nos.</th>
<th>Gray silt loam level timber land, late Wisconsin glaciation.</th>
<th>Grain, bushels per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1902 Corn series 100.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total yield</td>
</tr>
<tr>
<td>1</td>
<td>None .................................................................</td>
<td>44.8</td>
</tr>
<tr>
<td>2</td>
<td>Lime ...............................................................</td>
<td>45.1</td>
</tr>
<tr>
<td>3</td>
<td>Lime, nitrogen ..................................................</td>
<td>40.3</td>
</tr>
<tr>
<td>4</td>
<td>Lime, phosphorus ...............................................</td>
<td>50.1</td>
</tr>
<tr>
<td>5</td>
<td>Lime, potassium ................................................</td>
<td>48.2</td>
</tr>
<tr>
<td>6</td>
<td>Lime, nitrogen, phosphorus ....................................</td>
<td>56.6</td>
</tr>
<tr>
<td>7</td>
<td>Lime, nitrogen, potassium .......................................</td>
<td>52.1</td>
</tr>
<tr>
<td>8</td>
<td>Lime, phosphorus, potassium ...................................</td>
<td>60.7</td>
</tr>
<tr>
<td>9</td>
<td>Lime, nitrogen, phosphorus, potassium ........................</td>
<td>61.2</td>
</tr>
<tr>
<td>10</td>
<td>Nitrogen, phosphorus, potassium ................................</td>
<td>59.7</td>
</tr>
</tbody>
</table>

Average gain for nitrogen... 3.0 4.7 1.6 -8.4 4.8 $1.10
Average gain for phosphorus 9.2 16.7 11.1 9.0 24.6 26.75
Average gain for potassium 6.0 13.0 6.9 .3 3.2 9.71

Plot No. 1 is naturally better land than the others and both 1 and 10 serve only as checks against the lime treatment. They are not used in studying the effects of plant food applied.

The oats crop in 1904 was practically a failure because of weather conditions and the results are not comparable with those obtained before or since; hence they should be discarded altogether in the discussion. The low yields of wheat from plots 3, 6, 7, and 9, in 1905, were due to the fact that the wheat on these nitrogen plots grew very rank and lodged badly before it ripened. The
straw on these plots also rusted badly, resulting in shriveled and light grain.

The wheat yields on plots 2, 4, 5, and 8 are more trustworthy, although too great weight must never be placed upon the results of a single season. These results show a very marked gain for phosphorus (Compare plots 2 and 4 and also plots 5 and 8). The gain produced by potassium applied without phosphorus is probably largely due to the stimulating action of the soluble potassium salt by which some phosphorus may be liberated from the soil. Where plenty of phosphorus is provided the addition of potassium appears to have been injurious (See plots 4 and 8).

The total gains for five years show very markedly the effects of soil treatment. After the first year the best treated plots produced about twice as much as plot 2 which serves properly as a check plot, to which no nitrogen, phosphorus, or potassium is applied.

If, however, we take only the yields of the three corn crops into consideration the results are more nearly normal and trustworthy. The yields for three corn crops are given in Table 2.

**TABLE 2.—CORN YIELDS FROM ANTIOCH EXPERIMENT FIELD**

<table>
<thead>
<tr>
<th>Soil plot Nos.</th>
<th>Gray silt loam level timber land, late Wisconsin glaciation.</th>
<th>Corn, bushels per acre.</th>
<th>Total value of increase for 3 years.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant food applied.</td>
<td>1902 Corn</td>
<td>1903 Corn</td>
</tr>
<tr>
<td>2</td>
<td>None.</td>
<td>45.1</td>
<td>38.9</td>
</tr>
<tr>
<td>3</td>
<td>Nitrogen</td>
<td>46.3</td>
<td>40.8</td>
</tr>
<tr>
<td>4</td>
<td>Phosphorus</td>
<td>50.1</td>
<td>53.6</td>
</tr>
<tr>
<td>5</td>
<td>Potassium</td>
<td>48.2</td>
<td>50.2</td>
</tr>
<tr>
<td>6</td>
<td>Nitrogen, phosphorus</td>
<td>56.6</td>
<td>62.7</td>
</tr>
<tr>
<td>7</td>
<td>Nitrogen, potassium</td>
<td>52.1</td>
<td>54.9</td>
</tr>
<tr>
<td>8</td>
<td>Phosphorus, potassium</td>
<td>60.7</td>
<td>66.0</td>
</tr>
<tr>
<td>9</td>
<td>Nitrogen, phosphorus, potassium</td>
<td>61.2</td>
<td>69.1</td>
</tr>
</tbody>
</table>

Average gain for nitrogen... 3.0 4.7 4.8 12.5 ........ $4.38
Average gain for phosphorus... 9.2 16.7 24.6 50.5 ........ 17.68
Average gain for potassium... 6.0 13.0 3.2 20.3 ........ 7.11
The total yield for the three corn crops varies from 115.5 bushels on plot 2, with no plant food applied, to 196.2 bushels on the land that had been given the full treatment, making a gain of 80.7 bushels, or 70 percent, for the treatment. A study of the table shows that every treatment has produced a gain. The gain for nitrogen is least, while that for phosphorus is by far the largest. The gain for potassium, while much smaller than that for phosphorus, is considerably greater than the gain for nitrogen. As explained elsewhere, the potassium is applied in the form of a soluble salt, and undoubtedly acts in part at least, and possibly solely, as a soil stimulant, rather than as plant food.

The total gain for nitrogen for the three years is only 9.4 bushels, while for phosphorus it is 45.6 bushels, almost five times as much. For potassium the total gain is 17.8 bushels. The total average gain for nitrogen under all conditions is 12.5 bushels, for phosphorus 50.5 bushels, and for potassium 20.3 bushels.

**Cumulative Effects**

It is interesting to note that the effects of phosphorus have been cumulative. The average gain for the first year was only 9.2 bushels, the second year it was 16.7 bushels, and for the third corn crop (in the fifth year) the average gain for phosphorus was 24.6 bushels per acre. The gain for nitrogen has remained practically stationary, while for potassium the increase was greater the second year, but smaller the last year.

The average gain for nitrogen for all tests as an average of three crops is 4.2 bushels; for phosphorus it is 16.8 bushels; and for potassium it is 6.8 bushels, per acre per annum.

It is also interesting to note that the yielding power, or productive capacity, of the untreated land has gradually grown less, while the productive power of the plots receiving phosphorus and nitrogen has increased. Even the plot receiving phosphorus alone has thus far steadily grown more productive, but it is certain that this cannot long continue unless some provision is made for supplying nitrogen also, because the natural supply of nitrogen in the soil is limited. In practice we must plan to secure nitrogen from the air by growing clover or other legumes and plowing these crops under, either directly or as farm manure. This plan is being followed on the newer part of the Antioch soil experiment field.

A study of Table 2 will show very plainly that the difference between the yielding capacities of the treated and untreated land is becoming greater and greater. The difference between the plot without plant food and the one with nitrogen and phosphorus was
10.3 bushels in 1902, and 23.8 bushels in 1903, and 27.8 bushels in 1906.

Phosphorus alone produced an increase of 45.6 bushels of corn in three years. When applied with nitrogen it produced an increase of 53.7 bushels; with potassium, 52.5 bushels; and with nitrogen and potassium, 50.2 bushels. It is clear from these figures that phosphorus is the limiting element in this soil.

**Financial Gains**

It is also interesting to note the financial gains from the treatment. The total average value of the increase for nitrogen for three years is only $4.38; for phosphorus it is $17.68, and for potassium $7.11. With an application of $15.00 worth of nitrogen per acre per year and an increase of crops valued at only $4.38 for three years it can readily be seen that it is out of the question to purchase commercial nitrogen.

The cost of the phosphorus treatment was $7.50 for the three years, while the value of the increase was $17.68, leaving a net profit of $10.18. The same amount of phosphorus in the form of raw rock phosphate could have been applied for $2.50, but this cheaper form of phosphorus can be used satisfactorily only in connection with decaying organic matter, as with farm manure or with clover as green manure. It is a fact, however, that either farm manure or legume green manure or both must be used on these soils to maintain the supply of nitrogen, so that to use rock phosphate with such decaying organic matter promises to be the most profitable practicable system for maintaining the productive power of these soils.

The cost of the potassium treatment for the three years was $7.50, and the value of the increase $7.11 thus lacking 39 cents of paying the cost.

Leaving the cost of the nitrogen out of consideration, the net gain from the nitrogen-phosphorus treatment is $14.59, and from the nitrogen-phosphorus-potassium treatment $13.25, for the three years.

**Permanent Systems**

The nitrogen supply of the soil can be kept up by growing legume crops in the rotation, and by applying farm manures, with practically no cash outlay. The purchase of phosphorus to be applied to these soils in connection with nitrogen that can be furnished by legumes and manure has certainly proved a profitable investment. The potassium has lacked a little of paying for itself, but when we take into consideration the very great amount already in the soil it is not strange.
The profitable system, therefore, is to grow legumes in the crop rotation and make as much manure as possible to maintain the supply of humus and nitrogen and to purchase somewhat more phosphorus, in the form of pure steamed bone meal or fine-ground raw rock phosphate, than is removed from the soil by cropping, so that the soil will grow richer rather than poorer.

In planning a system of profitable permanent agriculture for this soil it should be remembered that, while the supply of nitrogen in the soil is limited, there is enough in the air over each acre for large crops for 700,000 years; that the plowed soil contains sufficient potassium for two thousand years, but only sufficient phosphorus for the full time of one life, and that it is more profitable to increase than to decrease this meager supply.

RESULTS FROM ROCK PHOSPHATE

As already explained, raw rock phosphate is being used as the source of phosphorus on the two series of rotation experiments which were begun in 1904. It was not to be expected that any marked results would be secured in these experiments during the first course in the rotation, which will require four years. The rotation consists of corn for two years, with oats and clover seeded the third year, and clover the fourth year. While corn is being grown on one series for two years, oats and clover are grown on the other series, thus alternating every two years. On certain plots ground rock phosphate has been applied at the rate of one ton per acre, at a cost of about $9.00. Subsequent applications are to be made at intervals of four years. Ultimately the amount applied will be reduced so as to be only sufficient to fully maintain the phosphorus content of the soil.

During the years 1905 and 1906 one crop of clover, one of oats and two crops of corn were grown. As an average of four tests in each case, the rock phosphate increased the yields* per acre by 1.22 tons of clover, 1.2 bushels of oats, 5.8 bushels of corn in 1905, and 6.3 bushels of corn in 1906. These increases in crops would not require more than 10 pounds of phosphorus, whereas the ton of rock phosphate applied contained 250 pounds of phosphorus, so that the treated land still contains 240 pounds of phosphorus per acre more than the untreated land.

*When we remember that as an average of nine years' experiments the Ohio Experiment Station has secured increased yields of corn, wheat, and clover worth $8.07 for every dollar invested in rock phosphate at $8.00 a ton, there is reason to believe that its value on the Antioch field will be greater in the future than indicated by the increased yields thus far obtained, provided it is used in connection with plenty of decaying organic matter, as with farm manure, clover or other green manures.

Notes.—Finely ground raw rock phosphate (12½ percent phosphorus) can be obtained from Robin Jones, Nashville, Tenn., or from the N. Y. & St. L. Mining & Mfg. Co., St. Louis, Mo., delivered in carload lots for about $8.00 a ton in Southern Illinois, the cost being $8.00 to $9.00 higher for central and northern Illinois points.

A good grade of steamed bone meal (about 12½ percent phosphorus) can be obtained delivered in Illinois for about $25.00 a ton, from the local agents of Morris & Company, Swift & Company, or the Packers' Fertilizer Association, Chicago, Ill., or from Michigan Carbon Works, Detroit, Mich.