6-1932

Soil Survey of Iowa, Report No. 68—Union County Soils

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SOIL SURVEY OF IOWA
UNION COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Farm Crops and Soils Section
Soils Subsection

Soil Survey Report No. 68
June, 1932
Ames, Iowa
# Iowa Agricultural Experiment Station

Soil Survey Reports*

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*For list of additional publications on soils see inside back cover.
June, 1932

Soil Survey Report No. 68

SOIL SURVEY OF IOWA
Report No. 68—UNION COUNTY SOILS

By P. E. Brown, J. A. Elwell, H. R. Meldrum and A. J. Englehorn

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa
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UNION COUNTY SOILS*

By P. E. Brown, J. A. Elwell, H. R. Meldrum and A. J. Englehorn

Union County is located in southwestern Iowa in the second tier of counties north of Missouri, and in the fourth tier east of the Missouri River. It is entirely in the southern Iowa loess area, and almost half of the soils of the county are of loessial origin, the remainder being of drift origin derived largely from the underlying glacial material which has become exposed through the action of erosion.

The total area of the county is 427 square miles or 273,280 acres. Of this area 262,534 acres or 96.1 percent are farm land. The total number of farms is 1,713, and the average size of the farms is 153 acres. Owners operate 51.2 percent of the total farm land and renters the remaining 48.8 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1930 show the utilization of the farm land in the county.

Acreage in general farm crops .................................................. 141,278
Acreage in farm buildings, public highways and feedlots ......... 12,495
Acreage in pasture ................. 107,176
Acreage in waste land not utilized for any purpose ............... 899
Acreage in farm woodlots used for timber only ................. 1,806
Acreage in crop land lying idle ............................................ 1,367
Acreage in crops not otherwise listed .................................. 75

THE AGRICULTURE OF UNION COUNTY

The type of agriculture practiced in Union County at the present time consists mainly of a system of general farming, including the growing of corn, small grains and hay and the raising and feeding of cattle and hogs. Corn is by far the leading crop grown. Other crops of considerable importance include oats, wheat, hay, alfalfa and sweet clover. The feeding of hogs and cattle is the most important of the livestock industries. There is some dairying, some raising of sheep for mutton and wool and considerable production of poultry and poultry products. Some of the farms are being operated almost on a strictly livestock basis. The farm income is derived chiefly from the sale of hogs, beef cattle, corn, wheat and oats.

There is a considerable area of waste land in the county, and much of this land might be reclaimed and made productive if proper methods of treatment were adopted. General recommendations for the reclamation of waste land cannot be given, as the causes of infertility are quite variable. Later in this report under the individual descriptions of the soil types, special treatments will be suggested which may be used under particular soil conditions to make the soils more satisfactorily productive. In special cases for more or less abnor-

mal conditions, advice regarding treatment may be secured upon request from the Soils Subsection of the Iowa Agricultural Experiment Station.

THE CROPS GROWN IN UNION COUNTY

The general farm crops grown in Union County in the order of their importance are corn, oats, hay, wheat, alfalfa, barley, potatoes and rye. The average yield and value of these crops are given in Table I.

Corn is the chief crop grown, and in 1930 it occupied 26.9 percent of the total farm land. Average yields amounted to 31 bushels per acre. Three-fourths or more of the grain produced is fed on the farms. Some of the corn grown is used for silage and some is cut for fodder, but on a considerable acreage the grain is harvested. The corn grown on the farms is used mainly as feed for the hogs, cattle, and work stock.

The second crop in acreage and value is oats. In 1930 this crop was grown on 11.75 percent of the total farm land, and the average yield amounted to 34.1 bushels per acre. Early oats are the most popular, the chief varieties being Iowa 103 and Iowa 105. Most of the crop grown is fed on the farms, but in some cases a considerable quantity is sold on the markets.

The third crop of importance is hay which consists mainly of clover and timothy mixed. In 1930 this crop was grown on 6.76 percent of the total farm land with an average yield of 1.55 tons per acre. Clover was grown alone in 1930 on 2.05 percent of the total farm land and timothy alone on 1.36 percent of the total farm land. The former yielded 1.23 tons on the average and the latter

### Table I. Acreage Yield and Value of Principal Crops Grown in Union County, Iowa*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage</th>
<th>Percent of total farm land of county</th>
<th>Bushels per acre</th>
<th>Total bushels or tons</th>
<th>Average price**</th>
<th>Total value of crops</th>
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<tr>
<td>Corn</td>
<td>70,631</td>
<td>26.90</td>
<td>31.0</td>
<td>2,189,561</td>
<td>$ 0.60</td>
<td>$1,313,737</td>
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<tr>
<td>Oats</td>
<td>30,557</td>
<td>11.75</td>
<td>34.1</td>
<td>1,052,462</td>
<td>$ 0.29</td>
<td>305,214</td>
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<tr>
<td>Winter wheat</td>
<td>2,024</td>
<td>0.77</td>
<td>17.1</td>
<td>34,517</td>
<td>$ 0.65</td>
<td>21,746</td>
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<tr>
<td>Spring wheat</td>
<td>42</td>
<td>0.02</td>
<td>12.8</td>
<td>936</td>
<td>$ 0.58</td>
<td>311</td>
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<tr>
<td>Barley</td>
<td>1,863</td>
<td>0.69</td>
<td>22.9</td>
<td>41,242</td>
<td>$ 0.45</td>
<td>18,506</td>
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<tr>
<td>Rye</td>
<td>184</td>
<td>0.07</td>
<td>16.5</td>
<td>3,049</td>
<td>$ 0.60</td>
<td>1,824</td>
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<tr>
<td>Clover hay***</td>
<td>5,895</td>
<td>2.05</td>
<td>1.23</td>
<td>6,936</td>
<td>10.12</td>
<td>67,156</td>
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<tr>
<td>Clover and timothy hay (mixed)***</td>
<td>3,591</td>
<td>1.36</td>
<td>1.19</td>
<td>4,237</td>
<td>10.12</td>
<td>43,243</td>
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<tr>
<td>Alfalfa</td>
<td>924</td>
<td>0.35</td>
<td>2.41</td>
<td>2,227</td>
<td>10.12</td>
<td>22,537</td>
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<tr>
<td>All other tame hay</td>
<td>390</td>
<td>0.15</td>
<td>1.61</td>
<td>628</td>
<td>10.12</td>
<td>6,355</td>
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<tr>
<td>Wild hay</td>
<td>466</td>
<td>0.18</td>
<td>1.20</td>
<td>656</td>
<td>8.98</td>
<td>5,442</td>
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<tr>
<td>Soybeans sown with other crops</td>
<td>1,287</td>
<td>0.49</td>
<td>1.55</td>
<td>27,519</td>
<td>10.12</td>
<td>278,492</td>
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<tr>
<td>Soybeans sown alone</td>
<td>465</td>
<td>0.18</td>
<td>2.41</td>
<td>2,227</td>
<td>10.12</td>
<td>22,537</td>
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<td>Soybeans harvested for beans</td>
<td>321</td>
<td>0.12</td>
<td>1.17</td>
<td>3,756</td>
<td>1.34</td>
<td>5,683</td>
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<td>Potatoes</td>
<td>121</td>
<td>0.05</td>
<td>76.0</td>
<td>9,196</td>
<td>1.40</td>
<td>12,874</td>
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<tr>
<td>Timothy seed</td>
<td>4,213</td>
<td>1.60</td>
<td>4.6</td>
<td>19,372</td>
<td>2.28</td>
<td>44,168</td>
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<tr>
<td>Clover seed****</td>
<td>2,990</td>
<td>0.87</td>
<td>1.60</td>
<td>1,963</td>
<td>10.85</td>
<td>14,789</td>
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<tr>
<td>Sweet Clover****</td>
<td>128</td>
<td>0.05</td>
<td>1.60</td>
<td>206</td>
<td>10.85</td>
<td>14,789</td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1930.
**Average county farm price.
***Sweet clover not included.
****All varieties for all purposes.
1.19. Some clover and some timothy are grown for seed. Other tame hay crops were grown on 0.15 percent of the total farm land, yielding 1.61 tons per acre. Wild hay is grown on a limited area, usually on the idle and waste acreages such as occur along the poorly drained swales. The yield of wild hay amounted to 1.30 tons per acre in 1930.

Alfalfa is grown on a limited acreage. In 1930 it occupied 0.35 percent of the total farm land. The yields in that year amounted to 2.41 tons per acre. It is an extremely profitable crop and may be grown successfully provided the soil is limed and normal precautions are taken in the seeding of the crop. Sweet clover is grown to a very limited extent but is coming into more general use for hay and pasture. Some sweet clover is grown for seed.

Winter wheat was grown on 0.77 percent of the total farm land in 1930 with an average yield of 17.1 bushels per acre. There was a very limited area in spring wheat. From one-half to three-fourths of the wheat crop is marketed, the remainder being used for feed on farms.

Some barley is grown. In 1930 this crop occupied 0.69 percent of the total farm land, with an average yield of 22.9 bushels per acre. It is used mainly for feed on the farms, probably one-fourth of the crop being marketed. Mixtures of oats and barley are occasionally grown for feed.

Some rye is produced in the county, but it is grown on a very limited area and is relatively unimportant. Occasionally it is seeded as a cover crop to check erosion.

Soybeans are grown to some extent. In 1930 soybeans with other crops occupied 0.49 percent of the total farm land. When sown alone they occupied 0.18 percent of the farm land. They are coming to be a more important crop and are being grown more extensively each year.

Orcharding is of some significance. A few orchards are operated on a commercial scale. Many supply fruit to the home and sometimes a surplus for the local markets. Apples are the most common orchard fruit, the main varieties are the Oldenburg, Wealthy, Ben Davis, Sweet June, Wolf River, Yellow Transparent and Snow. Some grapes are grown, and some of the small fruits as strawberries, blackberries and raspberries are produced on small acreages.

THE LIVESTOCK INDUSTRIES IN UNION COUNTY

The livestock industries in the county rank in order of importance as follows: fattening hogs and cattle for market, dairying, raising sheep for mutton and wool and raising horses to supply work animals.

The fattening of hogs is the most important livestock enterprise, and it is estimated that 30 to 35 percent of the herds are purebreds. The most popular breeds are Duroc Jersey, Big Type Poland China and Chester Whites. A large part of the income on many farms is derived from the sale of hogs.

Beef production which is of considerable importance in the county is mainly from native farm raised cattle. It is estimated that about 3 percent of the
farmers of the county purchase feeder stock from the Omaha and St. Joseph markets for fattening during the fall and winter. Most of the beef cattle are grade Hereford, Aberdeen Angus and Shorthorn. Only a few farmers have purebred cattle. On many farms, a large part of the income is derived from the sale of fat cattle.

Dairying is usually a secondary enterprise on most of the farms. The dairy products are utilized mainly to supply the farm needs, and there is a small surplus for sale on the local markets. More dairy products are produced in the western tier of townships than in the remainder of the county except in two centers, near Lorimor and Afton. About 15 percent of the dairy cattle are purebred. The Holstein breed is most popular, particularly in the western part of the county. Jerseys rank second, Guernseys third and there are a few Ayrshires. There are four creameries in the county and they handle practically the entire output. The chief dairy product marketed is cream, skimmilk being fed on the farm.

Sheep raising is practiced to some extent, and there is a considerable production of wool in the county. Large numbers of feeder sheep are bought at the Omaha and St. Joseph markets and after a feeding period, are marketed.

A few colts are raised to supply the demand for farm animals. The work animals are a medium draft type of horses or mules. The sires are mostly purebred and the mares grade. Percheron and Belgian are the most popular breeds.

Some poultry is kept on practically all farms. There are a few flocks of turkeys, geese and ducks, but a large part of the poultry consists of chickens. Poultry products add considerably to the income on many farms, and the industry might be developed to a much greater extent with considerable profit.

THE FERTILITY SITUATION IN UNION COUNTY

While the crop yields secured on many of the soils in Union County are fairly satisfactory at the present time, much larger yields might be secured through the adoption of proper methods of soil treatment.

On some of the soil types, drainage is not entirely adequate, and if crop production is to be most satisfactory on these areas, the first treatment needed is the installation of tile to remove the excess moisture. There are areas in the Muscatine silt loam and the Grundy silt loam on the loessial uplands and in the Bremer silt loam, the Chariton silt loam and the Calhoun silt loam on the terraces, where the drainage is not entirely satisfactory. The installation of tile would be of special value on certain areas in these soils.

All the soils in the county are acid in reaction and in need of lime for the best growth of farm crops and especially of legumes. It is very essential that the soils in this county be tested for lime needs and applications of lime be made wherever necessary if most satisfactory crop yields are to be secured. Where alfalfa or sweet clover is to be grown, it is particularly necessary to apply lime to acid soils, as these crops make very little or no growth on acid soils.

Most of the soil types in the county are fairly well supplied with organic matter which is indicated by their dark color. Some of the types, however, are a little light in color and are apparently not properly supplied with organic matter to provide for satisfactory yields of general farm crops. Even on those
soils which are apparently better supplied with organic matter, additions of fertilizing materials supplying this necessary constituent are very desirable at regular intervals if the content of the soil is to be kept up. Applications of farm manure are of large value on all the soil types in the county. Even on the darker colored soils, farm manure will bring about large crop increases, and on the lighter-colored types the beneficial effects of farm manure are very pronounced. It is one of the most valuable fertilizing materials which can be employed in Union County.

Where farm manure is not available in sufficient amounts to permit an addition to all the soils on the farm, the use of leguminous crops as green manures will be of large value. Green manuring may be practiced as a supplement to or substitute for farm manuring. If legumes are employed as green manures, there is a double value from them because inoculated legumes take a large part of their nitrogen from the atmosphere and hence when the crop is turned under in the soil as a green manure, there will be an addition of nitrogen to the land as well as an addition of organic matter. On the lighter colored soils, the practice of green manuring will be of particularly large value, but it should be emphasized that on all the soils of the county, farm manure should be applied or leguminous crops should be used as green manures in order to keep up the supply of organic matter. The thorough utilization of all crop residues will also aid materially in building up and maintaining the supply of organic matter in the soil.

The phosphorus content of the soils in Union County is rather low especially in the case of the Shelby loam and Lindley loam on the drift uplands. In many of the other types the supply is certainly inadequate to meet the needs of crop growth on these soils for any considerable period of time. It is evident that on all the soil types, applications of phosphorus fertilizers will be needed in the very near future. Experiments which have been carried out on some of the more important types in this county and in adjacent counties indicate that phosphorus fertilizers may bring about profitable returns in many cases in this county at the present time. The experiences many farmers have had with these fertilizing materials also indicate the value which may be secured by their use. Either superphosphate or rock phosphate may be employed to build up and increase the supply of phosphorus in these soils. In some cases superphosphate apparently seems somewhat preferable for use. This is particularly true on the lighter-colored soils, but on many of the soils and especially on the darker-colored types, rock phosphate will undoubtedly prove quite as desirable. Farmers who are interested should test both rock phosphate and superphosphate on their own soils, under their particular crop conditions to determine which material may be used with the most profit.

Complete commercial fertilizers have been used on the soils of the county in many experiments, and increases in crop yields have occasionally been secured by the use of these materials. In general the increases have been no larger than those brought about by superphosphate or rock phosphate. It would seem, then, that for general farm crops, phosphate fertilizers may be used with greater profit inasmuch as the complete commercial fertilizers are much more expensive,
and much larger crop increases must be secured by their use if they are to prove as profitable as a phosphate. In any cases where truck crops or garden crops are grown, certain brands of complete commercial fertilizers may be used with profit. Such materials should always be tested on small areas, however, before extensive applications are made, and in such cases comparisons should be made with the value of superphosphate to determine which fertilizing material may be used with the greater profit.

Commercial nitrogenous fertilizers may be of value on some of the soils of the county in special cases, the fertilizers being applied as a top dressing for certain crops. In general, however, commercial nitrogen fertilizers cannot be recommended for use in the county. Nitrogen may be more cheaply supplied by the turning under of leguminous crops as green manures, the proper preservation and application of farm manure and the thorough utilization of the crop residues. Commercial potassium fertilizers may likewise sometimes prove of value on the soils in the county, but in general the soils are fairly well supplied with potassium, and additions of fertilizers carrying this constituent should not be necessary. Farmers who are interested should test their value by applying the fertilizers to small areas.

Erosion occurs to a considerable extent in Union County, especially in the Lindley loam, the Lindley silt loam and the Shelby loam on the drift uplands. Considerable areas of the Clinton silt loam also are badly eroded, and occasionally some erosion occurs in the other upland types. Wherever erosion takes place, some method for its prevention and control should be adopted.
THE GEOLOGY OF UNION COUNTY

The native bed rock materials underlying the soils of Union County have been buried so deeply by the deposits of glacial drift and the later loess deposits that they have no influence whatever on the present day soil conditions. The geological history of the county is, therefore, of little significance in connection with the study of the soils. These have been formed from the glacial drift deposits, or the loess covering, and in all parts of the county these drift and loess deposits are very thick.

During the glacial age, at least two ice sheets swept over the county and each upon its retreat left behind a vast deposit of glacial drift or till. There is very little evidence of the earlier glaciation which was known as the pre-Kansan except where occasional layers of sand are found between the beds of boulder clay in certain well borings. These deposits show that some time elapsed between the laying down of the pre-Kansan deposits and the deposition of the later Kansan till.

The second glacier known as the Kansan passed over the entire county and the drift deposits are made up of the debris which was left behind by this glacier. The depth of the Kansan till is variable, but it probably averages around 125 feet. Many of the earlier topographic features of the county were completely obliterated by this glacier. Old valleys were filled, and old knolls and hills were removed. In its unweathered condition the Kansan drift deposit consists of a bluish clay containing many small boulders and some large ones. Where weathered, the upper layer of this clay has become oxidized until the color has changed to a red or reddish-brown. Where the weathering has been less complete, it is yellow in color. Since the deposition of the loess on top of the Kansan drift, there has been much erosion and the loessial material has been washed away, often exposing the underlying Kansan till. Hence on considerable areas in the county, the soil is derived from the old Kansan deposits. Soils of the Shelby and Lindley series mapped in the county are derived practically entirely from the Kansan till. In the case of the Lindley soils, there may be some mixture with loess at the surface of the soil, but there is little evidence of loessial material in the areas where these two soil types are mapped.

Much later in geological ages at a time when the climatic conditions were certainly very different from those occurring at present, there was laid down over the entire surface of the county a layer of fine silt-like material which is known as loess. The previous topographic features were entirely covered by this deposit. While there was considerable variation in the depth of loessial material, it probably averaged between 15 and 25 feet in thickness, being somewhat thicker in the old valleys and thinner on the hills. Erosion has occurred to a considerable extent since this loessial material was laid down and now the depth of the deposits varies from 1 to 18 feet. Unweathered, the loessial deposit consists of a yellow to a light-gray silt loam. After weathering and accumulation of plant residues, the color has changed and in most of the areas the soil is now a dark brown to black soil. This is the characteristic color of the more level upland loess soils, the Muscatine, Grundy and Tama types. The Clinton soils on the
uplands are considerably lighter in color having been formed under forest conditions rather than under prairie conditions. All of the upland soils except the Shelby loam and the Lindley loam are derived from this loessial deposit.

There are considerable areas of terraces or second bottomlands and of first bottomlands in the county. These have been formed by the action of the various streams and are rather variable in character and depth. Generally they consist of mixtures of drift and loess material carried by the streams and deposited in layers, which vary widely in character and composition. The soils are largely loessial in character. They are classified in the Waukesha, Bremer, Chariton, Calhoun and Jackson series. The bottomland soils are all classified in the Wabash series.

**PHYSIOGRAPHY AND DRAINAGE**

The surface of Union County was originally a rather broad drift plain, but there have been so many modifications and changes through the action of stream erosion that now there are the irregular strips of rolling to strongly rolling or hilly land along the streams or drainageways, the narrow strips of level bottomland soils bordering the streams and the more or less level areas between the streams, which retain somewhat the original character of the drift plains. These interstream areas are usually narrow and in some places are distinctly flat. The slopes are gradual, especially at the heads of the drainageways. Further down the streams and along the larger streams, they are more abrupt. The north and west slopes are generally steeper than the south and east slopes.

![Fig. 2. Map showing the natural drainage system of Union County.](image-url)
In general it may be said that the upland areas are gently rolling to rolling. There is a distinct relationship between the actual topography and the soil types which are mapped. The Muscatine and Grundy silt loams occur on the level uplands, while the Tama silt loam occurs on the more rolling uplands in the interstream areas. The rougher uplands adjacent to the stream are largely covered by the Clinton silt loam, a loessial soil, and by the Shelby loam and Lindley loam which are of drift origin.

The natural drainage system of the county is very well developed as is indicated on the accompanying drainage map. Drainageways extend into practically every quarter section of land in the county. The general trend of the drainage is to the south and southeast and this is also the trend of the divides between the separate drainage basins. Practically the whole county is in the watershed of the Platte and Grand rivers. The East Fork Nodaway River drains part of Spaulding Township and Clanton Creek part of New Hope Township. All the tributary drainageways become dry at intervals. The Grand River does not maintain a steady flow during dry seasons. Summit Lake and Lake McKinley are artificial lakes made by damming streams. They are maintained for the water supply and as recreation resorts for the city of Creston.

There is considerable variation in the depth to which the streams have cut through the upland, in some places the river valleys being from 100 to 250 feet below the divides. The West Platte River is 100 feet and the Middle Platte River 50 feet below the level of the adjacent upland. The width of the valleys is directly proportional to the depth and size of the streams. The Grand River Valley ranges from 1/2 to 1 1/2 miles in width. The valley of the Grand River occurs in two levels, the first bottoms along the stream channel and the second bottomlands or terraces 5 to 75 feet above the first bottoms. Twelvemile Creek valley ranges from 1/6 to 1/2 mile in width. Terraces are less numerous up the valley and less elevated above the flood plain until in Lincoln Township there are no terraces. The valleys of the other tributaries of the Grand River have similar characteristics. The valleys of the West, Middle and East Platte rivers range from 1/8 to 1/2 mile in width and are at first bottom levels, with the exception of a few very small, low terraces.

It is apparent that the main streams and the intermittent drainageways provide adequate drainage for most of the county. On some of the more level interstream upland areas, drainage is not adequate, and occasionally on some of the level, flat terrace areas, tiling is necessary. The bottomlands are usually subject to overflow, but in many cases these may also be made productive when properly drained and protected from overflow. In all cases where the soils of the county are not thoroughly drained, the installation of tile would be very desirable.
The soils of Union County are grouped into four classes, according to their origin and location, drift soils, loess soils, terrace soils, and swamp and bottomland soils. Drift soils are deposits left by glaciers, and they consist of material varying widely in composition and containing sand and some boulders. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were very different from the present. Terrace soils are old soils raised above the bottoms by a decrease in the volume of the streams which deposited them or by a deepening of the river channels. Swamp and bottomland soils are those which occur in low-lying, poorly drained areas or along streams which overflow frequently. The occurrence of these groups of soils in Union County is shown in table II.

Table II. Areas of Different Groups of Soils in Union County

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>125,504</td>
<td>46.0</td>
</tr>
<tr>
<td>Loess soils</td>
<td>112,640</td>
<td>41.1</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>11,456</td>
<td>4.1</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>23,680</td>
<td>8.8</td>
</tr>
<tr>
<td>Total</td>
<td>273,280</td>
<td></td>
</tr>
</tbody>
</table>

Almost one-half of the total area of the county, 46.0 percent, is covered by the drift soils. The loess soils are slightly less extensive, covering 41.1 percent of the total area. Terrace soils are developed to a limited extent, covering 4.1 percent of the total area. There is a considerable area of bottomland soils, covering 8.8 percent of the total area.

There are 19 individual soil types, 3 drift soils, 6 loess types, 5 terrace soils and 5 bottomland types. These various soils are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The type names which are given to the individual soils denote certain group characteristics which will be described later. The areas of the different soil types are shown in table III.

The Shelby loam is the most extensively developed soil type in the county and the largest drift soil. It covers 44.6 percent of the total area. The Lindley loam, the second drift soil, is minor in extent, covering 1.3 percent of the county. The Lindley silt loam, the third drift type, of very limited occurrence, covers only 0.1 percent of the total area. The Muscatine silt loam is the largest loess soil and the second most extensively developed soil. It covers 24.3 percent of the total area. The Grundy silt loam, together with the shallow phase, which is much less extensive, is the second largest loess type and the third most extensively developed soil, covering 11.3 percent of the total area. The Tama silt loam, together with the shallow phase which is less extensively developed, covers 4.3 percent of the county. The Clinton silt loam is less extensively developed, covering 1.2 percent of the total area. The Bremer silt loam is the
largest of the terrace types, covering 1.3 percent of the county. The Jackson silt loam covers 1.1 percent of the county. The remaining terrace types cover less than 1 percent of the total area.

The Wabash silt loam, together with the gray, subsoil phase is the most extensively developed of the bottomland soils and the fourth largest soil in the county, covering 5.4 percent of the total area. The Wabash loam is the second largest bottomland soil. It covers 3.1 percent of the county. The Wabash silty clay loam and fine sandy loam are both of very limited occurrence, covering 0.2 and 0.1 percent of the county, respectively.

The occurrence of the various soil types on the uplands indicates something of the topographic features of the county. The Lindley and Shelby soils on the drift uplands are developed on the more rolling to hilly, or broken sections. On the loessial upland, the Muscatine and Grundy types are found on the very gently rolling to level areas, while the Tama is developed on the more rolling areas and the Clinton on the strongly rolling to rough areas. There is very little difference in the topography of the terrace and bottomland soils, although some of the terrace types are developed on older terraces and show some topographic features. This is true of the Jackson and Waukesha types particularly. The Bremer, Calhoun and Chariton silt loams show practically no topographic features, having a rather level surface.

### TABLE III. AREAS OF DIFFERENT SOIL TYPES IN UNION COUNTY

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>121,856</td>
<td>44.6</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>3,584</td>
<td>1.3</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>64</td>
<td>0.1</td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>66,560</td>
<td>24.3</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>24,064</td>
<td>11.3</td>
</tr>
<tr>
<td>248</td>
<td>Grundy silt loam (shallow phase)</td>
<td>6,848</td>
<td>4.3</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>3,968</td>
<td>1.2</td>
</tr>
<tr>
<td>143</td>
<td>Tama silt loam (shallow phase)</td>
<td>3,968</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>3,200</td>
<td>1.2</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>3,468</td>
<td>1.3</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>3,136</td>
<td>1.1</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>2,368</td>
<td>0.9</td>
</tr>
<tr>
<td>105</td>
<td>Chariton silt loam</td>
<td>1,472</td>
<td>0.5</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>832</td>
<td>0.3</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>13,632</td>
<td>5.4</td>
</tr>
<tr>
<td>26b</td>
<td>Wabash silt loam (gray subsoil phase)</td>
<td>1,088</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>8,448</td>
<td>3.1</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>448</td>
<td>0.2</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>64</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>273,280</td>
<td></td>
</tr>
</tbody>
</table>
The Fertility in Union County Soils

Samples were taken from the various soil types mapped in the county except the Lindley silt loam on the drift uplands, the shallow phase of the Grundy silt loam, the shallow phase of the Tama silt loam, and the Wabash fine sandy loam. All of these types occur to such a limited extent that it did not seem necessary to analyze them. The more extensively developed soils were sampled in triplicate, while only one sample was taken of the minor types. Samplings were all made with the greatest of care so that the samples should be representative of the types and that any variations due to local conditions or special treatments should be eliminated. The samplings were made at three depths, 0 to 6-2/3 inches, 6-2/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

The total phosphorus, total nitrogen, total carbon, total inorganic carbon and limestone requirements were determined in all the samples. The official methods were followed in the case of the nitrogen, phosphorus and carbon determinations, and the Truog qualitative test was used in the determination of the limestone requirements. The results given in the tables are the averages of duplicate determinations on all samples of each type.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2 million pounds of surface soil per acre.

The phosphorus content of the soils in this county varies widely, ranging from 444 pounds per acre in the Lindley loam on the drift uplands up to 2,545 pounds per acre in the Wabash silt loam on the drift uplands.

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>759</td>
<td>3,813</td>
<td>37,714</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>444</td>
<td>1,760</td>
<td>24,188</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>1,279</td>
<td>4,533</td>
<td>53,040</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,239</td>
<td>4,800</td>
<td>60,485</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>129</td>
<td>Tama silt loam</td>
<td>1,185</td>
<td>4,200</td>
<td>42,404</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>86</td>
<td>Clinton silt loam</td>
<td>1,057</td>
<td>4,150</td>
<td>48,704</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>1,495</td>
<td>4,880</td>
<td>51,922</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>1,037</td>
<td>2,600</td>
<td>29,042</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,198</td>
<td>3,500</td>
<td>42,922</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>105</td>
<td>Chariton silt loam</td>
<td>1,320</td>
<td>4,000</td>
<td>45,513</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,545</td>
<td>6,320</td>
<td>56,857</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,589</td>
<td>5,920</td>
<td>51,922</td>
<td></td>
<td>7,000</td>
</tr>
<tr>
<td>26b</td>
<td>Wabash silt loam (gray sub-soil phase)</td>
<td>1,589</td>
<td>4,640</td>
<td>43,877</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,158</td>
<td>3,160</td>
<td>38,369</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,670</td>
<td>3,640</td>
<td>34,332</td>
<td></td>
<td>6,000</td>
</tr>
</tbody>
</table>
per acre in the Waukesha silt loam on the terraces. Very little evidence is shown of any relationship between the phosphorus content of the soils and the soil groups. The terrace and bottomland soils are a little better supplied on the average than the upland types which might be expected because of the greater crop growth, and hence the greater removal of plant food constituents from the upland soils. The loess soils are somewhat better supplied than the drift types. This difference is undoubtedly due largely to the characteristics of the various soil types mapped in these two groups. The two soils occurring on the drift uplands are naturally poorer in plant food constituents and lower in fertility than those found on the richer, loessial uplands.

Within the various groups, there are some interesting relationships among the various soil types. Thus, on the drift uplands the Shelby is richer than the Lindley loam. On the loessial uplands, the Muscatine silt loam is the richest in phosphorus, followed in order by the Grundy silt loam, the Tama silt loam and the Clinton silt loam, the latter being the lowest in phosphorus of any of the loessial soils. On the terraces, the Waukesha silt loam is the highest in phosphorus. The Bremer silt loam is second, the Chariton silt loam third, the Calhoun silt loam fourth, and the Jackson silt loam is the lowest in phosphorus. No comparisons are possible on the bottomlands because they are all of the same series. It is certainly evident from these comparisons that the characteristics which serve to distinguish the various soil series have an effect on the phosphorus content. Thus the color of the surface soil, the topographic position, the character of the subsoil and the origin of the soils, are of significance. Those types which are darker in color are richer in phosphorus; those which are more nearly level are richer in phosphorus; and those types which have heavier subsoils are better supplied with the element. Thus, the dark colored Muscatine and Grundy soils are richer than the lighter colored Tama and very much richer than the light colored Clinton soil. The Waukesha and Bremer soils which are darker in color are richer than the Jackson and Calhoun types. The more level Muscatine and Grundy are richer than the more rolling to strongly rolling Tama and Clinton soils, and types having the heavier subsoils like the Bremer, Waukesha and Chariton on the terraces are richer than the Jackson silt loam which has a lighter textured subsoil.

The phosphorus content of the soils is influenced also by the texture of the soil. Very few comparisons are possible of the textural effect on soils in the same series. Only in the case of the bottomland types can comparisons be made. Here it will be noted that the Wabash silt loam is the highest in phosphorus, and it is the heaviest type of the Wabash series which is mapped. This is followed by the Wabash silt loam. The Wabash loam is the lowest in phosphorus. It would seem, therefore, that fine-textured types are better supplied with phosphorus than coarse textured soils. Silty clay loams are richer than silt loams, and these in turn are better supplied than loams. These results are quite in accordanee with other results which have been secured where more comparisons are possible.

In general, it is apparent that the content of phosphorus in the soils in Union County is rather low, and phosphorus fertilizers will certainly be needed in the
very near future, even if they are not of value at the present time. Experiments which have been carried out on many of these soil types and which will be discussed later in this report indicate very definitely that applications of phosphorus fertilizers will be of value on these soils at the present time.

The nitrogen content varies considerably in the soils of Union County, the amount present ranging from 1,760 pounds per acre in the Lindley loam on the drift uplands up to 6,520 pounds per acre in the Waukesha silt loam on the terraces. It is interesting to note that these are the same soil types which showed the lowest and highest content of phosphorus, respectively.

Again, as in the case of phosphorus, however, there is little evidence of any relationship between the nitrogen in the soils and the various soil groups. The loessial upland types are better supplied than the drift upland soils, which is probably due largely to the differences in characteristics of the types which are mapped in these two groups. The terrace and bottomland soils are a little richer on the average than the upland soils, but there is no significant difference.

These analyses indicate that there is a relationship between the nitrogen content of the soil and the series in which the type is mapped. Those characteristics which serve to distinguish the soil series seem to have some effect on the nitrogen content of the soil. The color of the soils is of importance, those types which are darker in color being richer in nitrogen. Thus, the Shelby loam is richer than the Lindley loam, and the Muscatine, Grundy and Tama types are richer than the Clinton silt loam. On the terraces the Waukesha and Bremer soils are richer than the other types which are lighter in color. The topographic position is also of importance. Those types like the Muscatine and Grundy which are more level in topography are richer in nitrogen. The Bremer and Waukesha soils are richer in nitrogen than are the terrace types which are not so level nor depressed in topography. Those types which have heavier sub-soils like the Muscatine and Grundy are richer in nitrogen.

There is little opportunity to determine the effect of texture on the nitrogen content inasmuch as only in the case of the Wabash types on the bottomlands are there different textured soils in the same series mapped. Here there is some variation as noted in the case of the phosphorus. The Wabash silt loam showed the highest content of nitrogen, followed by the silty clay loam and loam. Ordinarily, the silty clay loam would show the largest content of nitrogen, followed by the silt loam. Apparently there is some variation here in the samples of soil which were analyzed.

The supply of nitrogen in many of the soils is not particularly high, and in some cases it would seem that the application of a nitrogenous fertilizing material would be very desirable. It would be particularly worth while to make such an application to the lighter colored soils. The use of leguminous crops as green manures is the best and cheapest method of increasing the nitrogen content of the soil, and green manuring is a valuable practice which should be followed on many of the soils. It is particularly desirable on grain farms where farm manure is not available, but it is also worth while under practically all farming conditions as an aid in maintaining and building up the content of nitrogen and organic matter in the soil. The proper preservation and appli-
cation of all manure produced on the farm and the proper utilization of all crop residues will aid materially in keeping up the supply of nitrogen.

The total amount of organic carbon or organic matter in the soils of Union County varies in much the same way as did the nitrogen, ranging from 24,188 pounds in the Lindley loam up to 56,857 pounds in the Waukesha silt loam. These are the same types which showed the lowest and highest content of nitrogen, respectively.

Little evidence of the relationship between the organic matter and the soil group is seen except that the drift soils are lower than the loessial types as was noted previously and the bottomland soils are slightly better supplied than the upland types.

The differences among the soil series and types are more definitely indicated, very much the same relationships being noted as in the case of nitrogen. The same factors certainly are of significance. Thus, the color of the soil indicates the content of organic matter. The dark colored Muscatine and Grundy types are the richest of the loessial soils in organic matter, and the Bremer and Waukesha types are richer in organic matter than the other terrace soils which are lighter in color. The relationship to topography is similarly indicated, the Muscatine and Grundy soils being on the more level to slightly rolling areas, while the Tama and Clinton are on the more rolling to rough areas. The subsoil conditions are of significance, those types with heavier subsoils being richer in organic matter.

The relationship of the texture to organic matter content is indicated only in the case of the Wabash types on the bottomlands. Here the Wabash silt loam shows the highest content of organic matter as it did of nitrogen, being followed in order by the Wabash silty clay loam and the Wabash loam. Ordinarily, the silty clay loam would be expected to be somewhat richer than the silt loam, but apparently there was some variation in the samples of these two soils taken in the field.

The soils in the county are in general fairly well supplied with organic matter, but in some cases the amount is inadequate to provide for the best crop yields. On the lighter colored soils which are rougher in topography, the supply is inadequate for the best crop growth. On these types, the application of fertilizing materials supplying organic matter is particularly necessary, and on all the soils in the county the addition of such fertilizers is necessary at regular intervals if the supply of organic matter in the soils is to be kept up. The application of farm manure is of especially large value on the light colored soils, and it also brings about large crop increases when it is applied to the darker colored types, which are apparently richer in organic matter. The liberal use of farm manure on the soils is strongly recommended. Green manuring will also undoubtedly prove profitable on many of the soils. Green manuring may be followed as a substitute for or supplement to the use of farm manure and will often bring about large crop increases. The utilization of crop residues will also aid materially in maintaining the supply of organic matter in the soils.

No inorganic carbon is present in any of the soils. The types are all acid in reaction and the limestone requirements are rather high. The figures given in
the table showing the limestone requirements are to be considered, however, merely indicative of the lime needs of the soils. There is a wide variation in the reaction or lime requirements of soils, and even samples of the same types from different fields may show considerable variation in lime requirements. It is very important, therefore, that samples be secured from any field and tested before lime is applied. From the figures given it is evident that the soils in the county are all strongly acid and that applications of lime are necessary for the best growth of general farm crops, and particularly of legumes.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and the subsoils are given in tables V and VI. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre. It is hardly worth while to consider the analyses of these lower soil layers in detail inasmuch as the needs of the soils are indicated rather definitely by the analyses of the surface soils. There is no large content of any plant food constituent, nor is there any striking deficiency in any of the elements shown in the case of the subsurface soils and the subsoils. There will be little influence, therefore, upon the fertilizer needs of the surface soils by the content of fertilizer constituents present in the lower soil layers.

Considering the results of these analyses as a whole, they seem to confirm the conclusions drawn from the analyses of the surface soils. They show that the phosphorus content of the soils is low, and it is evident that phosphorus fertilizers will be of value on these soils in the very near future and might probably be used with profit on many farms at the present time.

The analyses indicate also that the supply of organic matter and nitrogen in

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>1,077</td>
<td>3,627</td>
<td>38,414</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>754</td>
<td>1,840</td>
<td>24,106</td>
<td></td>
<td>8,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>1,912</td>
<td>6,960</td>
<td>80,101</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,579</td>
<td>6,867</td>
<td>56,212</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,074</td>
<td>4,000</td>
<td>62,884</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,400</td>
<td>3,040</td>
<td>35,341</td>
<td>6,000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,100</td>
<td>6,000</td>
<td>52,576</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>1,778</td>
<td>2,240</td>
<td>18,925</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,642</td>
<td>3,280</td>
<td>35,451</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>165</td>
<td>Chariton silt loam</td>
<td>1,480</td>
<td>3,840</td>
<td>44,995</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,774</td>
<td>6,800</td>
<td>70,465</td>
<td>6,000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,450</td>
<td>6,880</td>
<td>82,995</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>26b</td>
<td>Wabash silt loam (gray subsoil phase)</td>
<td>2,990</td>
<td>4,880</td>
<td>57,539</td>
<td>8,000</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2,236</td>
<td>3,280</td>
<td>43,213</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,990</td>
<td>6,240</td>
<td>74,283</td>
<td>5,000</td>
<td></td>
</tr>
</tbody>
</table>
TABLE VI. PLANT FOOD IN UNION COUNTY, IOWA, SOILS

Pounds per acre of 6 million pounds of subsoil (20'-40')

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Pounds per acre of 6 million pounds of subsoil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total phosphorus</td>
</tr>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>1,064</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>1,252</td>
</tr>
</tbody>
</table>

LOESS SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>3,245</td>
<td>4,000</td>
<td>34,278</td>
<td>34,523</td>
<td>4,000</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>2,869</td>
<td>3,000</td>
<td>34,278</td>
<td>34,523</td>
<td>2,000</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,745</td>
<td>3,960</td>
<td>34,278</td>
<td>34,523</td>
<td>4,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>2,907</td>
<td>3,240</td>
<td>34,278</td>
<td>34,523</td>
<td>8,000</td>
</tr>
</tbody>
</table>

TERRACE SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,868</td>
<td>2,880</td>
<td>40,250</td>
<td>40,013</td>
<td>4,000</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>3,030</td>
<td>2,760</td>
<td>40,250</td>
<td>40,013</td>
<td>4,000</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>3,513</td>
<td>3,240</td>
<td>30,351</td>
<td>30,351</td>
<td>7,000</td>
</tr>
<tr>
<td>105</td>
<td>Chariton silt loam</td>
<td>2,424</td>
<td>3,720</td>
<td>38,041</td>
<td>38,041</td>
<td>3,000</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>3,912</td>
<td>7,560</td>
<td>46,331</td>
<td>46,331</td>
<td>5,000</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,949</td>
<td>3,920</td>
<td>90,318</td>
<td>90,318</td>
<td>6,000</td>
</tr>
<tr>
<td>26b</td>
<td>Wabash silt loam (gray subsoil phase)</td>
<td>3,636</td>
<td>3,480</td>
<td>50,640</td>
<td>50,640</td>
<td>8,000</td>
</tr>
<tr>
<td>49</td>
<td>Wabash silt loam</td>
<td>2,706</td>
<td>2,640</td>
<td>28,851</td>
<td>28,851</td>
<td>3,000</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silt loam</td>
<td>4,281</td>
<td>6,000</td>
<td>50,248</td>
<td>50,248</td>
<td>5,000</td>
</tr>
</tbody>
</table>

The soils is not high, and the supply must be maintained if the land is to remain productive. On some of the soil types, the supply of organic matter and nitrogen must be increased if the most satisfactory crop yields are to be secured. By the proper utilization of farm manure, the turning under of leguminous crops as green manures and the utilization of crop residues, the soils may be built up and maintained in their supply of organic matter and nitrogen.

There is no lime present in any of the lower soil layers, and all show a high lime requirement. This indicates that they are all acid in reaction and the needs of the surface soil for applications of lime are emphasized by the acidity occurring in the lower soil layers. It is evident that all of the soils should be tested for lime needs and that lime should be applied regularly in the rotation if the best crop yields are to be secured, and especially the best yields of legumes.

Greenhouse Experiments

Two greenhouse experiments were carried out on the Grundy silt loam and the Shelby loam, two of the most extensively developed soil types in the county, in order to determine the needs of the soils and to secure indications of the value of certain fertilizing materials when applied to these types. In addition the results secured on the Grundy silt loam and Shelby loam from Clarke County are included, inasmuch as these soil types are the same as those occurring in Union County.

The treatments used in these experiments included manure, lime, superphosphate and muriate of potash. These materials were applied in the same amounts in which they are used in the field, hence the results for the greenhouse tests may be considered definitely indicative of what may be expected in the field.
The farm manure was applied at the rate of 8 tons per acre; lime was added in sufficient amounts to neutralize the acidity of the soil. Superphosphate was used at the rate of 200 pounds per acre and muriate of potash at the rate of 25 pounds per acre. Wheat and clover were grown in the tests, the clover being seeded about one month after the wheat was up.

RESULTS ON THE GRUNDY SILT LOAM FROM UNION COUNTY

The results secured in the greenhouse experiments on the Grundy silt loam from Union County are given in table VII. The application of manure increased the yield of wheat and enormously increased the yield of clover. Lime applied

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>6.9</td>
<td>9.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>8.5</td>
<td>24.3</td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>10.8</td>
<td>31.0</td>
</tr>
<tr>
<td>4</td>
<td>Superphosphate</td>
<td>6.8</td>
<td>17.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure+superphosphate</td>
<td>7.5</td>
<td>35.8</td>
</tr>
<tr>
<td>6</td>
<td>Limestone+superphosphate</td>
<td>8.1</td>
<td>31.3</td>
</tr>
<tr>
<td>7</td>
<td>Manure+limestone+superphosphate</td>
<td>8.9</td>
<td>47.3</td>
</tr>
<tr>
<td>8</td>
<td>Manure+limestone+superphosphate+</td>
<td>8.5</td>
<td>46.3</td>
</tr>
</tbody>
</table>

with manure showed a considerable gain in the wheat crop and brought about a further increase in the yield of clover. Superphosphate applied alone had little effect on the wheat but brought about a considerable increase in the yield of clover. Manure with superphosphate showed a beneficial effect on wheat and brought about a large increase in the clover. Lime with superphosphate benefited the wheat and clover crops, the latter to an especially large extent. Superphosphate applied with manure and limestone increased the yield of clover to a very large extent but had no effect on the wheat. Potassium applied with

![Fig. 3. Wheat on Grundy silt loam from Union County; greenhouse experiment.](image)
manure, lime and superphosphate had no effect on the yield of wheat and showed little influence on the clover.

These results indicate that manure is of large value on this soil, lime is necessary to correct the acidity and superphosphate would undoubtedly prove of value.

RESULTS ON THE SHELBY LOAM FROM UNION COUNTY

The results secured in the greenhouse experiment on the Shelby loam from Union County are given in table VIII. Manure increased the yield of wheat on this type and brought about a large increase in the yield of clover. Limestone applied with manure increased the yields of both crops to a considerable extent. Superphosphate had an appreciable effect on the wheat and showed a very slight influence on the clover. Manure and superphosphate together showed no particular increase in the wheat over the manure alone, but did bring about a large increase in the yield of clover. Limestone with superphosphate showed little effect on the wheat and practically none on the clover. Superphosphate applied with manure and limestone showed a little greater effect than manure alone, but not as large an influence as manure and limestone without the phosphate in the case of the wheat. Superphosphate applied with manure and limestone more than doubled the yield of clover over that secured with manure and limestone without superphosphate. Muriate of potash applied with manure, lime and superphosphate had no effect on the wheat but showed a slightly increased clover yield.

These results indicate the value of manure when applied to the Shelby loam. They show that lime is necessary in order to secure the best growth of crops
on this type, having an effect even on the grain crops. Superphosphate applied in addition to manure and lime may have a very large effect on the legume crops grown on this soil.

RESULTS ON THE GRUNDY SILT LOAM FROM CLARKE COUNTY

The results secured in the experiment on the Grundy silt loam from Clarke County are given in table IX. Superphosphate increased the yields of wheat and clover to a considerable extent. Limestone applied with the phosphate showed no effect on the wheat but gave a further gain in the clover. Manure increased the wheat yield to a considerable extent and also the clover yield, giving about the same effect on the latter crop as that occasioned by limestone and superphosphate. On the wheat manure brought about somewhat larger effects than superphosphate and limestone. The addition of superphosphate with manure gave a further increase in the yield of the wheat, but showed more

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>15.2</td>
<td>18.5</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>17.8</td>
<td>32.4</td>
</tr>
<tr>
<td>3</td>
<td>Limestone + superphosphate</td>
<td>17.3</td>
<td>35.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>18.7</td>
<td>35.8</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>19.0</td>
<td>33.6</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>24.2</td>
<td>39.7</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>19.8</td>
<td>42.3</td>
</tr>
</tbody>
</table>

These results indicate the beneficial effect of manure, limestone and a phosphate fertilizer on this soil type.

RESULTS ON THE SHELBY LOAM FROM CLARKE COUNTY

The results secured in the greenhouse experiment on the Shelby loam from Clarke County are given in table X, only the yields of wheat being recorded. The application of superphosphate increased the wheat yield considerably. Lime with superphosphate had no further effect on the wheat. Manure alone brought

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>6.4</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>7.8</td>
</tr>
<tr>
<td>3</td>
<td>Limestone + superphosphate</td>
<td>7.7</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>10.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>10.4</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>10.6</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>10.9</td>
</tr>
</tbody>
</table>
about a much larger increase than that occasioned by lime and superphosphate. The addition of superphosphate with manure showed practically no effect on the yield of wheat, and the further addition of limestone with manure and phosphate had no effect. The addition of muriate of potash with manure, limestone and superphosphate showed little effect on the crop yields.

The results of this experiment indicate rather definitely the beneficial effects of manure on this soil. They indicate further that the addition of limestone would be of value, especially for the growth of legumes. The use of a phosphate fertilizer would also undoubtedly prove of value on this type. There are no indications that a potassium fertilizer would prove profitable on this soil.

**Field Experiments**

No field experiments are located in Union County, but experiments have been under way for a number of years in counties in the same soil area. These experiments are located on the same soil types as those which occur extensively in this county. The results will be given here as they indicate fairly definitely the fertilizer effects to be expected on the same soil types in Union County. Tests on the Shelby loam on the Millerton Field in Wayne County; on the Muscatine silt loam on the Bluegrass Field in Scott County, on the Delmar Field in Clinton County, and on the Letts Field in Muscatine County; on the Grundy silt loam on the Agency Field in Wapello County, on the Mount Pleasant Field, series 100, in Henry County, and on the West Point Field No. 1 in Lee County; and on the Tama silt loam on the Greenfield Field in Adair County, are given here.

These field experiments are carried out to determine the value of various soil treatments. They are laid out on land which is thoroughly representative of the particular soil type. The fields include 9 or 13 plots 155 feet 7 inches by 28 feet and are one-tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions to secure accurate results are taken in the application on fertilizers and in the harvesting of the crops.

The experiments are carried out under both the livestock and grain systems of farming. In the former, manure is applied as a basic treatment, while in the latter crop residues are employed. The other fertilizer materials tested include limestone, superphosphate, rock phosphate, a complete commercial fertilizer and muriate of potash. Manure is applied at the rate of 8 tons per acre once in a 4-year rotation. The crop residue treatment consists of the plowing under of the cornstalks which have been cut with a disc or stalk cutter in the spring after having been winter pastured. Sometimes the second crop of clover is plowed under, but usually it is used for seed, hay or pasture and only the residues are plowed down. Lime is applied in amounts sufficient to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a 4-year rotation. Until 1923 this material was applied at the rate of 2,000 pounds per acre once in a 4-year rotation. Superphosphate is added at the rate of 120 pounds per acre of the 20 percent material three times in the 4-year rotation. Until 1923, 16 percent superphosphate was added at the rate of 200 pounds per acre annually. In 1929 the 20 percent material was first employed. Until 1923 the old standard 2-8-2 commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. From 1923 to 1929
TABLE XI. FIELD EXPERIMENT, SHELBY LOAM, WAYNE COUNTY.

**MILLERTON FIELD, SERIES I**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 corn bu. per A. (1)</th>
<th>1923 w. wheat bu. per A.</th>
<th>1924 clover tons per A.</th>
<th>1925 corn bu. per A.</th>
<th>1926 corn bu. per A.</th>
<th>1927 oats bu. per A.</th>
<th>1928 alfalfa tons per A. (2)</th>
<th>1929 alfalfa tons per A. (3)</th>
<th>1930 corn bu. per A.</th>
<th>1931 oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>60.8</td>
<td>10.3</td>
<td>0.76</td>
<td>58.3</td>
<td>34.0</td>
<td>30.7</td>
<td>0.48</td>
<td>12.2</td>
<td>18.8</td>
<td>42.8</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>63.0</td>
<td>14.5</td>
<td>0.69</td>
<td>65.3</td>
<td>36.0</td>
<td>30.7</td>
<td>0.46</td>
<td>18.8</td>
<td>36.5</td>
<td>42.8</td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
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<td>10.3</td>
<td>0.86</td>
<td>64.3</td>
<td>44.4</td>
<td>24.9</td>
<td>1.35</td>
<td>18.0</td>
<td>43.2</td>
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<td>15.1</td>
<td>1.09</td>
<td>72.3</td>
<td>49.2</td>
<td>31.9</td>
<td>1.16</td>
<td>17.2</td>
<td>18.0</td>
<td>71.7</td>
</tr>
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<td>Check</td>
<td>58.1</td>
<td>9.6</td>
<td>0.92</td>
<td>60.6</td>
<td>35.2</td>
<td>29.9</td>
<td>0.35</td>
<td>16.5</td>
<td>38.7</td>
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</tr>
<tr>
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<td>Manure+limestone+superphosphate</td>
<td>60.5</td>
<td>16.4</td>
<td>1.32</td>
<td>64.2</td>
<td>41.6</td>
<td>36.7</td>
<td>1.33</td>
<td>2.40</td>
<td>16.5</td>
<td>55.5</td>
</tr>
<tr>
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<td>34.7</td>
<td>17.0</td>
<td>1.54</td>
<td>60.6</td>
<td>43.6</td>
<td>38.3</td>
<td>1.40</td>
<td>2.34</td>
<td>9.1</td>
<td>59.0</td>
</tr>
<tr>
<td>8</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>65.6</td>
<td>17.6</td>
<td>1.29</td>
<td>59.9</td>
<td>46.0</td>
<td>41.6</td>
<td>1.28</td>
<td>2.47</td>
<td>8.6</td>
<td>59.0</td>
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<tr>
<td>9</td>
<td>Check</td>
<td>59.8</td>
<td>10.9</td>
<td>1.08</td>
<td>54.7</td>
<td>36.8</td>
<td>31.2</td>
<td>0.41</td>
<td>43.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) No limestone applied for the 1922 corn.
(2) Few scattered piams on plots 1, 2, 5 and 9. First cutting clipped back. Results on 1 cutting in August.
(3) Total of 3 cuttings. Plots 1, 2, 5 and 9 mostly timothy. Plot 3 partly timothy.
(4) Very dry season. Corn fired badly. Plot 9—no corn.

*The Millerton Field was established in the fall of 1921 on the farm of J. C. Davis, east of Millerton in Wayne County. It is located in the NW ¼ of the NE ¼ of Section 26, R. 21 W., T. 70 N. in Union Township.

a standard 2-12-2 brand was employed, the applications being made at the rate of 200 pounds per acre annually, thus applying the same amount of phosphorus as that in the superphosphate. Since 1929 a 2-12-6 fertilizer has been used on the Grundy and Tama soils, a 2-16-2 on the Muscatine types and a 4-16-4 on the Shelby soil. The muriate of potash is applied at the rate of 25 pounds per acre three years out of four in the 4-year rotation.

**THE MILLERTON FIELD**

The results secured in the field experiment on the Shelby loam on the Millerton Field, Series I, in Union County, are given in table XI. The application of manure increased the crop yields on this soil in most seasons, the largest effects being evident on the corn in 1925. There was no effect on the clover in 1924, and no effect on the alfalfa in 1929. Limestone applied with manure brought about increases in some cases on the grain crops, particularly on the corn in 1926. It had little effect, however, on the clover in 1924 and on the alfalfa in 1929.

Rock phosphate with manure and lime increased the crop yields in all seasons, showing large effects on the clover in 1924, on the alfalfa in 1929, on the corn in 1925 and on the oats in 1927 and 1931. Superphosphate with manure and lime showed larger effects than rock phosphate on the wheat in 1923, on the clover in 1924, on the oats in 1927 and on the alfalfa in 1928 and 1929. On the corn crop, however, rock phosphate seemed to have a somewhat larger effect and especially on the oats in 1931 rock phosphate showed a larger effect than superphosphate.
Muriate of potash with manure, limestone and superphosphate increased the crop yields to a small extent in most seasons. It had no large effects except on the clover in 1924. In two cases there was no influence from the potash. The complete commercial fertilizer with manure and limestone showed slightly larger effects than superphosphate in several seasons. It showed less effect on the clover in 1924, on the corn in 1925 and on the alfalfa in 1928.

THE BLUEGRASS FIELD

The results secured on the Muscatine silt loam on the Bluegrass Field, Series I. in Scott County, are shown in table XII. Manure increased the crop yields in all but two seasons on this soil. In some cases very large effects were noted from the manure, as on the clover in 1920 and 1924, on the oats in 1929 and 1931 and on the corn in 1922. Limestone applied with manure increased the crop yields in all seasons, the largest effects being shown on the clover in 1920 and 1924, on the oats in 1923 and 1927 and on the corn in 1921, 1922, 1925 and 1928.

Rock phosphate applied with manure and limestone brought about increases in crop yields in some seasons. The clover in 1924 was benefited to a very large extent. The corn was increased in 1925. In the other seasons there was little or no effect from the application of rock phosphate. Superphosphate applied with manure and limestone showed slightly larger effects than rock phosphate.

| Plot No. | Treatment | 1918 corn | 1919 spring wheat | 1920 clover | 1921 corn | 1922 oats | 1923 corn | 1924 clover | 1924 oats | 1925 corn | 1926 corn | 1927 oats | 1928 corn | 1929 oats | 1930 corn | 1931 corn | 1931 oats |
|----------|-----------|-----------|-------------------|------------|-----------|---------|---------|------------|---------|-----------|-----------|---------|-----------|---------|---------|-----------|---------|---------|
| 1        | Check     | 74.1      | 11.5               | 57.4       | 62.9      | 27.2    | 1.62    | 85.2       | 63.2    | 65.2      | 66.9      | 49.9    | 61.2      | 48.5    |         |
| 2        | Manure    | 75.2      | 12.1               | 57.8       | 68.8      | 30.6    | 1.71    | 87.0       | 61.3    | 55.7      | 70.2      | 59.0    | 68.3      | 62.4    |         |
| 3        | Manure+limestone | 77.0 | 13.3               | 66.1       | 74.1      | 47.6    | 1.81    | 95.2       | 68.6    | 65.3      | 81.4      | 61.4    | 72.8      | 63.0    |         |
| 4        | Manure+limestone+rock phosphate | 73.3 | 13.1               | 67.5       | 72.5      | 48.4    | 2.30    | 100.0      | 65.3    | 64.0      | 80.8      | 64.6    | 70.2      | 68.6    |         |
| 5        | Manure+limestone+superphosphate | 71.4 | 18.9               | 63.5       | 74.1      | 45.3    | 2.90    | 98.2       | 65.5    | 53.3      | 77.0      | 62.4    | 73.3      | 70.0    |         |
| 6        | Manure+limestone+complete commercial fertilizer | 73.2 | 14.4               | 64.0       | 73.4      | 49.8    | 2.44    | 101.5      | 67.7    | 69.7      | 79.8      | 67.0    | 73.6      | 70.4    |         |
| 7        | Check     | 71.6      | 11.3               | 56.5       | 70.6      | 41.1    | 1.44    | 82.5       | 60.3    | 62.9      | 69.0      | 46.5    | 59.8      | 52.0    |         |
| 8        | Crop residues | 69.6 | 9.6               | 59.2       | 66.9      | 39.1    | 1.54    | 92.7       | 51.7    | 58.2      | 61.6      | 47.5    | 57.4      | 45.0    |         |
| 9        | Crop residues+limestone | 66.9 | 11.6               | 62.5       | 60.8      | 70.4    | 41.4    | 92.7       | 69.0    | 62.4      | 74.8      | 55.5    | 66.9      | 59.6    |         |
| 10       | Crop residues+limestone+rock phosphate | 73.8 | 13.9               | 66.7       | 73.8      | 45.3    | 2.17    | 97.5       | 64.8    | 68.4      | 79.7      | 60.1    | 73.4      | 61.5    |         |
| 11       | Crop residues+limestone+superphosphate | 65.6 | 15.0               | 63.2       | 66.9      | 47.6    | 2.26    | 97.0       | 62.6    | 70.9      | 75.2      | 53.4    | 70.7      | 54.5    |         |
| 12       | Crop residues+limestone+complete commercial fertilizer | 62.9 | 15.0               | 64.8       | 70.1      | 48.7    | 2.29    | 98.2       | 62.9    | 64.4      | 75.7      | 60.1    | 73.3      | 57.0    |         |
| 13       | Check     | 63.8      | 7.6               | 61.3       | 64.3      | 39.6    | 1.46    | 84.5       | 56.1    | 46.4      | 64.3      | 51.5    | 68.9      | 45.4    |         |

(1) Limestone applied 3 1/2 tons per acre in May. Growth of smartweed reduced crop on plots 11 and 12.
(2) Crop injured by blight.
(3) Limestone applied in fall.
*The Bluegrass Field was established in the fall of 1917 on the farm of H.C. Schroeder near Bluegrass in Scott County. It is located in the SW corner of the NE 1/4 of the NW 1/4 of Section 32, T. 78 N. and R. 2 E.
in one or two cases, especially on the wheat in 1919, but in most seasons there was very little difference in the yields secured with superphosphate over those obtained when rock phosphate was applied. The complete commercial fertilizer applied with manure and limestone showed slightly larger effects than superphosphate in some seasons, particularly on the clover in 1924, on the oats in 1923, 1927 and 1929 and on the corn in 1925, 1926 and 1930, but in the other years there was no larger increase from the complete commercial fertilizer than was secured when superphosphate was applied.

The crop residues showed little or no effect on the crops grown in most seasons. An increase was obtained in the clover in 1924 and slight increases in some of the other years. Limestone with the crop residues showed a beneficial effect on the crops grown in practically all seasons. Some of the gains were very pronounced as on the clover in 1920 and 1924, and on the oats in 1923, 1926, 1929 and 1931. Increases were also obtained on the corn in 1922, 1925, 1928 and 1930.

Rock phosphate with the crop residues and limestone showed a beneficial effect on the crops grown in practically all seasons. Considerable increases were obtained on the clover in 1920 and 1924, and increases were noted on the oats in 1927, 1929 and 1931, and on the corn in 1921, 1922, 1925, 1928 and 1930. Superphosphate with the crop residues and limestone showed slightly larger effects than rock phosphate in some seasons, but in most cases the differences were small and of little significance. Some of the increases brought about by superphosphate were somewhat less than those occasioned by rock phosphate. The complete commercial fertilizer with the crop residues and limestone showed slightly larger effects than superphosphate in some years, but in other seasons the results secured were very similar to those brought about by superphosphate, and in some cases smaller effects were evident.

THE DELMAR FIELD

The results secured on the Muscatine silt loam on the Delmar Field, Series I, in Clinton County, are shown in table XIII. The application of manure to this soil increased the crop yields in all but one season. In a number of cases very large increases were secured. The alfalfa in 1927, 1928, 1929 and 1930 was benefited to a very large extent. Increases were also secured on the corn in 1922 and 1925, and on the wheat in 1921. Limestone applied with manure increased the crop yields in most seasons, the alfalfa in 1927, 1928, 1929 and 1930 being benefited to a particularly large extent. The corn in 1919 and 1925 and the oats in 1923 were also benefited.

Rock phosphate with manure and limestone brought about considerable increases in the crop yields in most seasons. The alfalfa was benefited in 1927, 1928 and 1929, the barley in 1920, the corn in 1922 and 1925 and the timothy and clover in 1924 was benefited materially by rock phosphate. Superphosphate applied with manure and limestone showed very similar effects to rock phosphate in some seasons and in other cases had a smaller effect on the crop yields. In most cases the differences were too small to be significant. The complete commercial fertilizer with manure and limestone showed somewhat larger effects than the phosphates in some cases, particularly on the alfalfa in 1927 and 1928.
<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn bu. per A.</th>
<th>1919 corn bu. per A.</th>
<th>1920 barley bu. per A.</th>
<th>1921 wheat bu. per A.</th>
<th>1922 oats bu. per A.</th>
<th>1923 oats bu. per A.</th>
<th>1924 timothy and clover tons per A.</th>
<th>1925 oats bu. per A.</th>
<th>1926 oats bu. per A. (1)</th>
<th>1927 alfalfa tons per A. (2)</th>
<th>1928 alfalfa tons per A. (2)</th>
<th>1929 alfalfa tons per A. (2)</th>
<th>1930 alfalfa tons per A. (2)</th>
<th>1931 alfalfa tons per A. (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>77.7</td>
<td>69.6</td>
<td>25.3</td>
<td>33.5</td>
<td>55.4</td>
<td>49.3</td>
<td>31.9</td>
<td>74.4</td>
<td>15.4</td>
<td>0.4</td>
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<td>3.8</td>
<td>3.0</td>
<td>4.9</td>
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<td>Manure</td>
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<td>65.8</td>
<td>28.1</td>
<td>28.4</td>
<td>65.1</td>
<td>54.8</td>
<td>31.0</td>
<td>78.9</td>
<td>17.4</td>
<td>2.0</td>
<td>4.2</td>
<td>3.5</td>
<td>3.1</td>
<td>4.7</td>
</tr>
<tr>
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<td>Manure+limestone</td>
<td>83.3</td>
<td>76.1</td>
<td>24.9</td>
<td>34.9</td>
<td>64.6</td>
<td>61.1</td>
<td>1.08</td>
<td>82.7</td>
<td>15.6</td>
<td>2.5</td>
<td>7.7</td>
<td>3.6</td>
<td>3.0</td>
<td>4.0</td>
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<td>23.1</td>
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<td>4.3</td>
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<td>Manure+limestone+super-phosphate</td>
<td>81.1</td>
<td>72.2</td>
<td>32.7</td>
<td>25.8</td>
<td>71.6</td>
<td>56.1</td>
<td>1.52</td>
<td>96.5</td>
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<td>3.7</td>
<td>3.6</td>
<td>4.6</td>
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<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>75.0</td>
<td>74.4</td>
<td>30.2</td>
<td>32.9</td>
<td>73.6</td>
<td>67.7</td>
<td>1.44</td>
<td>94.9</td>
<td>28.3</td>
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<td>73.1</td>
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<td>25.8</td>
<td>68.8</td>
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<td>1.08</td>
<td>82.1</td>
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<tr>
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<td>Crop residues+limestone</td>
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<td>69.2</td>
<td>34.9</td>
<td>26.7</td>
<td>70.9</td>
<td>62.8</td>
<td>1.31</td>
<td>94.9</td>
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<td>Crop residues+limestone+rock phosphate</td>
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<td>69.2</td>
<td>34.9</td>
<td>26.7</td>
<td>70.9</td>
<td>62.8</td>
<td>1.31</td>
<td>94.9</td>
<td>17.2</td>
<td>3.03</td>
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<td>3.8</td>
<td>3.8</td>
<td>4.8</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>76.6</td>
<td>71.4</td>
<td>32.2</td>
<td>31.3</td>
<td>75.7</td>
<td>69.7</td>
<td>1.44</td>
<td>92.2</td>
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<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>70.5</td>
<td>76.0</td>
<td>32.7</td>
<td>29.1</td>
<td>73.4</td>
<td>61.1</td>
<td>1.56</td>
<td>89.6</td>
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<td>3.8</td>
<td>4.8</td>
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<tr>
<td>13</td>
<td>Check</td>
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<td>67.5</td>
<td>24.5</td>
<td>23.4</td>
<td>66.0</td>
<td>45.8</td>
<td>0.98</td>
<td>73.6</td>
<td>15.6</td>
<td>0.8</td>
<td>3.9</td>
<td>3.0</td>
<td>3.2</td>
<td>4.2</td>
</tr>
</tbody>
</table>

(1) Oats were late and badly lodged at harvest time, also affected with rust.
(2) Most of the check plot yields represent alsike clover and timothy. Total of two cuttings.
(3) Field pastured—no results. Mostly bluegrass.

*The Delmar Field was established in the fall of 1917 on the farm of F. O. Schoder near Delmar in Clinton County. It is located on the N. side of the NE ¼ of the NE ¼ of Section 20, T. 83 N, and R. 3 E. in Bloomfield Township.

and on the oats in 1923, but in most cases the complete commercial fertilizer had about the same effect as superphosphate and rock phosphate.

The crop residues showed small effects on the crop yields in some seasons, but in most cases the differences were too small to be important. Only in the case of the alfalfa in 1927 was there any evidence of the crop residue effect. Limestone applied with the crop residues showed beneficial effects on the crops grown in most seasons, the largest influence appearing on the alfalfa in 1927, 1928, 1929 and 1930, on the timothy and clover in 1924 and on the winter wheat in 1921.

Rock phosphate applied with the crop residues and limestone showed beneficial effects on the crops grown in some seasons, particularly on the alfalfa in 1927 and 1928, the oats in 1923 and the timothy and clover in 1924. In a number of seasons there was very little effect from rock phosphate. Superphosphate with the crop residues and limestone increased the crop yields in most seasons. In some cases the influence was less than that of rock phosphate, especially on the alfalfa in 1927 and 1928, but in 1930 it showed a larger effect on this crop. It had a greater beneficial effect on the timothy and clover in 1924 and on the corn in 1922. In some cases the differences between the effects of the two phosphates were not great. The complete commercial fertilizer with the crop residues and limestone showed less effect than superphosphate in most seasons.
a greater effect on the timothy and clover in 1924 and on the alfalfa in 1928, but in the other years the effects were no greater or even less than those brought about by superphosphate.

THE LETTS FIELD

The results secured in the field experiment on the Muscatine silt loam on the Letts Field, Series I, in Muscatine County are given in table XIV. The application of manure to this soil increased the yield in all but one season. Large increases were noted on the corn in 1923 and 1929, on the barley in 1930 and on the red clover in 1931. In the other seasons, except 1928, there were noticeable increases from the application of manure. Limestone applied with manure increased the crop yields in all seasons, the largest beneficial effects appearing on the oats in 1925, on the corn in 1929 and on the red clover in 1931.

Rock phosphate applied with manure and limestone increased the crop yields in practically all seasons. Appreciable effects were evident on the oats in 1919, on the winter wheat in 1920, on the timothy and clover in 1921, on the oats in 1925, on the corn in 1928 and on the red clover in 1931.

Superphosphate applied with manure and limestone showed slightly larger increases than rock phosphate on the timothy and clover in 1921, on the corn in 1923, 1924 and 1928, and on the oats in 1925. In the other seasons very

TABLE XIV. FIELD EXPERIMENT, MUSCATINE SILT LOAM, MUSCATINE COUNTY, LETTS FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn A</th>
<th>1919 other A</th>
<th>1920 w. wheat</th>
<th>1922 timothy &amp; clover tons per A.</th>
<th>1922 corn A</th>
<th>1923 corn A</th>
<th>1924 corn A</th>
<th>1925 corn A</th>
<th>1926 clover tons per A.</th>
<th>1927 clover A.</th>
<th>1928 corn A</th>
<th>1929 corn A</th>
<th>1930 corn A</th>
<th>1931 red clover tons per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>75.4 57.8 17.1 2.12</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>58.2 65.7 69.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>77.8 58.6 20.6 2.13</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>83.3 71.8 59.9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>72.2 56.6 23.9 2.26</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>81.7 83.0 66.7</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>82.9 62.6 28.5 2.58</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>85.2 81.0 75.4</td>
<td>--</td>
<td>--</td>
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<tr>
<td>5</td>
<td>Manure + limestone + superphosphate</td>
<td>83.7 62.6 27.5 2.73</td>
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<td>--</td>
<td>91.2 87.1 78.7</td>
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<tr>
<td>6</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>84.6 67.4 31.2 2.76</td>
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<td>--</td>
<td>--</td>
<td>83.2 84.5 56.0</td>
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<td>62.2 67.1 57.4</td>
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<td>80.0 57.2 2.16</td>
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<td>--</td>
<td>73.2 63.8 59.1</td>
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<td>Crop residues</td>
<td>88.4 58.4 20.6 2.18</td>
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<td>--</td>
<td>87.7 67.3</td>
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<td>Crop residues + lime</td>
<td>68.8 11.0 26.4 2.49</td>
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<td>78.0 72.0 60.4</td>
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<tr>
<td>11</td>
<td>Crop residues + lime + rock phosphate</td>
<td>74.1 67.4 23.9 2.63</td>
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<td>--</td>
<td>79.0 76.5 62.9</td>
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<tr>
<td>12</td>
<td>Crop residues + lime + superphosphate</td>
<td>75.4 55.0 24.3 2.54</td>
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<td>--</td>
<td>--</td>
<td>80.0 75.6 71.0</td>
<td>--</td>
<td>--</td>
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<td></td>
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<tr>
<td>13</td>
<td>Crop residues + lime + complete commercial fertilizer</td>
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<td>--</td>
<td>79.2 73.6 72.1</td>
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<td>68.5 74.0 16.5 2.12</td>
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<td>--</td>
<td>61.7 65.3 58.8</td>
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</tbody>
</table>

(1) Yield lost on plot 8.
(2) Field was pastured, no results.
(3) Hogs damaged plots 1, 2, 8, 9 and 10.
(4) Corn drilled across plots, difficult to get uniform samples.

The Letts Field was laid out in the fall of 1917 on the John Eliason farm 2 miles north of Letts in Muscatine County. The series is located in the SW corner of the NE ¼ of the NW ¼ of Section 31, T. 76 N. and R. 3 W.
similar increases to those from rock phosphate were evident, and in some cases a smaller effect was secured by the use of superphosphate over that obtained by rock phosphate. The complete commercial fertilizer with manure and limestone showed larger effects than superphosphate in some seasons, particularly on the corn in 1928, and on the clover in 1931. In the latter case, however, it had about the same effect as rock phosphate. In most seasons, the increases were very similar to those brought about by superphosphate, and in some cases were actually less.

The crop residues showed little effect on the crop yields in most seasons. Lime- stone applied with the crop residues increased the crop yields in some seasons, but there were no large effects from this treatment. Rock phosphate applied with the crop residues and limestone increased the crop yields in all seasons, showing particularly large effects on the oats in 1919, on the corn in 1928 and 1929 and on the timothy and clover in 1921. Superphosphate applied with the crop residues and limestone showed somewhat larger effects than rock phosphate in one or two cases, particularly on the oats in 1925, on the corn in 1929 and on the red clover in 1931. In most instances, however, the two phosphates showed very similar effects. In one or two instances, rock phosphate had a larger effect than did superphosphate. The complete commercial fertilizer applied with the crop residues and limestone had much the same effect as superphosphate in most seasons. It had a larger beneficial effect on the corn in 1928 and on the red clover in 1931. In some instances, actually smaller yields were secured than were obtained by the use of superphosphate.

THE AGENCY FIELD

The results secured in the experiment on the Grundy silt loam on the Agency Field, Series I, in Wapello County, are given in table XV. The application of manure proved of value on this soil which is indicated by the increased crop yields secured in practically all seasons. The largest increases were shown on the oats in 1919, 1925 and 1930, on the hay in 1921, 1922 and in 1927, on the corn in 1928 and 1929 and on the wheat in 1931. The use of limestone and manure brought about increases in practically all cases. The beneficial effects of the limestone were particularly evident on the hay crops, but increases were also shown in some cases on the corn and oats.

Rock phosphate with manure and limestone increased the crop yields in every season, in some cases very large effects being noticed. The hay crops were particularly benefited by rock phosphate, and considerable increases were secured on the oats in 1919 and 1930, on the corn in 1923 and 1929 and on the wheat in 1926 and 1931. Superphosphate showed larger effects than rock phosphate in practically all seasons. There were no strikingly large differences except in the case of the hay crop in 1922. In 1921, 1923, 1928 and 1929 rock phosphate gave somewhat larger effects on the corn and in 1925 on the oats. The complete commercial fertilizer generally showed somewhat smaller effects than superphosphate. Only on the hay crop in 1921, the clover and timothy in 1927, the corn in 1928 and 1929 and the wheat in 1931 were there any great effects from the complete commercial fertilizer. In some cases rock phosphate had larger effects than did the complete commercial fertilizer.
### TABLE XV. FIELD EXPERIMENT, GRUNDY SILT LOAM, WAPello COUNTY, AGENCY FIELD.* SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn per A. (1)</th>
<th>1920 wheat bu. per A.</th>
<th>1921 clover and timothy tons per A. (2)</th>
<th>1922 hay crop</th>
<th>1923 corn per A.</th>
<th>1924 wheat bu. per A. (3)</th>
<th>1925 corn per A.</th>
<th>1926 clover A.</th>
<th>1927 oats per A.</th>
<th>1928 wheat bu. per A.</th>
<th>1929 corn per A.</th>
<th>1930 oats per A. (7)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Check</td>
<td>63.5 44.9 22.7 71.92 2.00</td>
<td>72.7</td>
<td>46.6 62.2 21.7</td>
<td>1.128</td>
<td>83.3 66.8 62.8</td>
<td>20.4</td>
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<td>2</td>
<td>Manure</td>
<td>64.5 62.2 31.5 52.09</td>
<td>2.30</td>
<td>71.8 51.9</td>
<td>19.0</td>
<td>1.196</td>
<td>89.4 72.7 63.7</td>
<td>28.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>66.8 36.3 36.3 72.20</td>
<td>2.20</td>
<td>79.2 62.2</td>
<td>73.8</td>
<td>21.8</td>
<td>100.5 72.6</td>
<td>64.8</td>
<td>20.4</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rock phosphate</td>
<td>68.8 63.6 38.7</td>
<td>2.36</td>
<td>80.6 33.5</td>
<td>2.14</td>
<td>105.4</td>
<td>83.4 80.8</td>
<td>39.3</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>Manure+limestone+superphosphate</td>
<td>70.0 66.6 40.0</td>
<td>2.39</td>
<td>85.4</td>
<td>60.2</td>
<td>77.9</td>
<td>38.9</td>
<td>97.8</td>
<td>83.2</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizers</td>
<td>66.0 34.7 72.52</td>
<td>2.50</td>
<td>83.0</td>
<td>55.4</td>
<td>77.3</td>
<td>30.7</td>
<td>2.47</td>
<td>101.0</td>
<td>85.1</td>
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<td>Check</td>
<td>59.3</td>
<td>18.2</td>
<td>2.30</td>
<td>69.7</td>
<td>43.3</td>
<td>76.8</td>
<td>14.7</td>
<td>1.29</td>
<td>74.4</td>
<td>63.3</td>
<td>50.6</td>
<td>21.0</td>
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<tr>
<td>8</td>
<td>Crop residues</td>
<td>58.5</td>
<td>31.4</td>
<td>18.2</td>
<td>66.3</td>
<td>33.7</td>
<td>64.5</td>
<td>18.7</td>
<td>1.28</td>
<td>76.4</td>
<td>67.6</td>
<td>56.2</td>
<td>21.2</td>
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<td>Crop residues+limestone</td>
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<td>45.8</td>
<td>2.82</td>
<td>71.0</td>
<td>50.7</td>
<td>72.1</td>
<td>18.6</td>
<td>1.69</td>
<td>83.5</td>
<td>73.2</td>
<td>39.5</td>
<td>28.3</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>61.8</td>
<td>36.2</td>
<td>64.3</td>
<td>2.32</td>
<td>65.7</td>
<td>54.7</td>
<td>75.9</td>
<td>20.0</td>
<td>2.14</td>
<td>96.6</td>
<td>77.5</td>
<td>70.8</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>63.5</td>
<td>61.2</td>
<td>36.4</td>
<td>2.19</td>
<td>75.0</td>
<td>57.7</td>
<td>74.6</td>
<td>2.26</td>
<td>93.4</td>
<td>69.0</td>
<td>72.4</td>
<td>36.0</td>
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<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizers</td>
<td>62.5</td>
<td>66.3</td>
<td>35.6</td>
<td>2.17</td>
<td>65.0</td>
<td>54.4</td>
<td>78.4</td>
<td>2.14</td>
<td>93.6</td>
<td>77.3</td>
<td>85.5</td>
<td>38.5</td>
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<tr>
<td>13</td>
<td>Check</td>
<td>52.5</td>
<td>52.0</td>
<td>22.8</td>
<td>56.2</td>
<td>40.4</td>
<td>63.9</td>
<td>42.7</td>
<td>58.8</td>
<td>0.91</td>
<td>67.0</td>
<td>56.6</td>
<td>55.5</td>
</tr>
</tbody>
</table>

1. Corn damaged slightly by hail in July and dry weather in August.
2. Sample No. 7 lost in transit; wheat badly down. Light dressing of manure to all plots by mistake in winter of 1920. Lime applied in November.
3. Pastured after first crop.
4. Pastured after first crop.
5. Wet weather prevented seeding of plots 11, 12 and 13.
6. Mostly timothy.
7. Oats later in maturity on plot 6, damaged by hot winds.

*The Agency Field was laid out in the fall of 1917, on the Johnson Brothers' farm, northeast of Agency, in Wapello County. The series is in the northeastern corner of NW ¼ of the SE ¼ of Section 30, R. 12 W., T. 73 N.

The crop residues showed little effect on the various crops grown. Limestone with the crop residues increased the crop yields in practically every season. Only in the case of the wheat in 1926 was there no increase from the use of limestone. In some cases and on certain of the crops the beneficial effects were very definite. This is particularly true of the hay crop in 1921 and 1922, of the clover in 1927, of the corn in 1928 and 1929 and of the wheat in 1931.

Rock phosphate brought about increases in the crop yields in practically every season. In some instances the increases were very distinct as on the hay crop in 1921, 1922 and 1927, on the wheat in 1926, on the corn in 1928 and 1929 and on the oats in 1930. Superphosphate with the crop residues and limestone showed larger effects than did rock phosphate in several seasons. It had smaller effects than rock phosphate, however, on the clover in 1921, on the oats in 1925, and on the corn in 1928 and 1929, and practically the same effect on the corn in 1923 and on the wheat in 1920. The complete commercial fertilizer gave similar increases to those brought about by superphosphate. Only in one case was there a striking difference. On the corn in 1923, the complete commercial fertilizer showed no effect.
The results secured on the Grundy silt loam on the Mount Pleasant Field, Series 200, in Henry County, are given in table XVI. The beneficial effects of manure are evident in the increased crop yields secured in all but one season. Large increases were noted on the oats in 1921, on the clover in 1926 and 1930, and on the corn in 1927. The application of limestone along with manure increased the crop yields in nearly all seasons. Some considerable crop increases were secured as, for example, with the corn in 1920, 1924 and 1927, 1928 and 1931, and the clover in 1926 and 1930.

Rock phosphate with manure and limestone brought about increases in some seasons, showing up particularly well on the oats in 1921, 1925 and 1929, on the clover in 1922, 1926 and 1930, and on the corn in 1927 and 1928. Superphosphate showed a greater effect than rock phosphate in some seasons, especially on the corn in 1920, on the oats in 1921 and 1929 and on the clover in 1926 and 1930. In other seasons the effects were less or similar to those brought about by rock phosphate. The complete commercial fertilizer had larger effects than superphosphate in one or two cases, notably on the corn in 1920 and on the clover in 1922. In most of the other seasons the effects were less evident than those brought about by superphosphate.

**TABLE XVI. FIELD EXPERIMENT, GRUNDY Silt Loam, Henry County, MT. PLEASANT FIELD*, SERIES 200**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1919 corn bu. per A.</th>
<th>1920 corn bu. per A.</th>
<th>1921 oats bu. per A. (1)</th>
<th>1922 clover tons per A. (2)</th>
<th>1923 corn bu. per A.</th>
<th>1924 corn bu. per A.</th>
<th>1925 oats bu. per A.</th>
<th>1926 clover tons per A. (3)</th>
<th>1927 corn bu. per A.</th>
<th>1928 corn bu. per A. (4)</th>
<th>1929 oats bu. per A. (5)</th>
<th>1930 clover tons per A.</th>
<th>1931 corn bu. per A.</th>
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<td>48.1</td>
<td>36.9</td>
<td>1.6</td>
<td>61.3</td>
<td>49.3</td>
<td>50.9</td>
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<td>38.8</td>
<td>47.3</td>
<td>14.3</td>
<td>30.0</td>
<td>54.1</td>
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<td>Manure</td>
<td>66.3</td>
<td>51.2</td>
<td>46.9</td>
<td>1.9</td>
<td>77.3</td>
<td>58.0</td>
<td>55.0</td>
<td>0.60</td>
<td>44.4</td>
<td>42.3</td>
<td>22.1</td>
<td>11.2</td>
<td>28.5</td>
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<td>69.8</td>
<td>35.3</td>
<td>2.1</td>
<td>185.0</td>
<td>72.7</td>
<td>50.9</td>
<td>1.05</td>
<td>60.0</td>
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<td>42.6</td>
<td>2.4</td>
<td>84.5</td>
<td>70.4</td>
<td>65.9</td>
<td>1.31</td>
<td>76.9</td>
<td>77.0</td>
<td>46.8</td>
<td>1.97</td>
<td>67.2</td>
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<td>77.2</td>
<td>48.9</td>
<td>2.4</td>
<td>77.6</td>
<td>73.3</td>
<td>64.8</td>
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<td>76.6</td>
<td>77.3</td>
<td>52.3</td>
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<td>81.2</td>
<td>44.5</td>
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<td>60.0</td>
<td>65.7</td>
<td>60.4</td>
<td>1.15</td>
<td>65.0</td>
<td>76.3</td>
<td>40.5</td>
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<td>64.9</td>
<td>33.7</td>
<td>2.1</td>
<td>58.3</td>
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<td>47.1</td>
<td>0.52</td>
<td>40.6</td>
<td>47.3</td>
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<td>48.1</td>
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<td>64.6</td>
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<td>0.76</td>
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<td>Crop residues+limestone</td>
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<td>76.3</td>
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<td>2.6</td>
<td>67.3</td>
<td>34.7</td>
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<td>30.5</td>
<td>1.65</td>
<td>51.3</td>
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<td>75.1</td>
<td>43.8</td>
<td>2.5</td>
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<td>38.0</td>
<td>62.5</td>
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<td>33.2</td>
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<td>43.5</td>
<td>2.5</td>
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<td>53.8</td>
<td>64.0</td>
<td>34.7</td>
<td>1.98</td>
<td>57.4</td>
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<td>Crop residues+limestone+complete commercial fertilizer</td>
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<td>90.1</td>
<td>42.2</td>
<td>2.6</td>
<td>74.3</td>
<td>41.3</td>
<td>60.4</td>
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<td>31.1</td>
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<td>47.7</td>
<td>21.0</td>
<td>0.48</td>
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**Yields for 1915-1916-1917-1918 not included due to irregularities.**

(1) Three tons limestone applied, oats lodged in spots.

(2) Two crops on all but crop residue plots. Yields represent only first cutting.

(3) Plots 7 to 13 were partly burned off in April. Check plots badly infested with weeds.

(4) Low yield in plot 2 due to wet spot in field.

(5) Wet season cut oat yield.

(6) Hot, dry season.

*The Mt. Pleasant Field—Series 200—was established in 1914 on the State Hospital farm, at Mt. Pleasant in Henry County. The series is located in the SE 1/4 of the SW 1/4 of Section 14, T. 71 N., R. 6 W., Center Township.*
The influence of crop residues on crop growth was not great in any case. The use of limestone with the crop residues brought beneficial effects on most of the crops. The clover in 1922, 1926 and 1930 was definitely increased. The corn was increased in 1923, 1927, 1928 and 1931. In the other seasons, the effects were small and not definite.

Rock phosphate with the crop residues and limestone proved of value on practically all of the crops grown. Some of the increases were not large and in one or two instances no increases were secured. Superphosphate with the crop residues and limestone showed larger effects than rock phosphate in practically all seasons. The influence was much greater on the corn in 1920, on the oats in 1925 and on the clover in 1926. In the other seasons the effects were about the same or slightly less than those brought about by rock phosphate. The complete commercial fertilizer showed a larger effect than superphosphate in one or two cases, but in general the differences were small and there was no evidence of superiority of complete commercial fertilizer over the phosphates.

THE WEST POINT FIELD

The results secured on the Grundy silt loam on the West Point Field No. 1, TABLE XVII. FIELD EXPERIMENT, GRUNDY SILT LOAM, LEE COUNTY, WEST POINT FIELD,* NO. 1, SERIES I

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<tr>
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<td>44.2</td>
<td>1.87 64.0 80.2 56.0 0.25</td>
<td>46.7 31.6 7.6 48.7</td>
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<td>23.8 0.21</td>
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<tr>
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<td>43.5</td>
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<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizer</td>
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<td>41.9</td>
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<td>26.1 1.24</td>
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<td>2.38 54.4 77.2 39.1 1.30</td>
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<td>20.3 0.70</td>
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</table>

(1) Corn on all plots injured by hot winds.
(2) Corn down badly due to storms in September.
(3) Two tons of limestone, April 11.
(4) Low yields due to a very dry season.
(5) Wireworms and wet weather damaged corn considerably.
(6) Wet spring and hot weather seriously damaged oats.
(7) High yields on plots 2 and 3 probably due to better drainage.
(8) Wet spring, resulted in late planting, which never matured. No results.
*The West Point Field No. 1, Series 1, in Lee County was laid out in the fall of 1917 on the farm of Gerhart Harmeyer & Son, northwest of West Point. It is located on the north side of the NE 1/4 of the SW 1/4 of Section 5, R. 5 W., T. 68 N.
Series I, in Lee County are given in table XVII. The application of manure increased the crop yields on this soil in practically all seasons. Very large beneficial effects were evident on the corn in 1922, 1925 and 1928, and on the clover in 1924. Limestone applied with manure increased the crop yields in practically all seasons. The largest beneficial effect of the limestone appeared on the timothy and clover in 1920 and 1931 and on the clover in 1924. Increases were also shown on some of the corn and oat crops.

Rock phosphate applied with manure and limestone increased the crop yields in some seasons, but no large effects were brought about except on the timothy in 1920. Superphosphate applied with manure and limestone showed larger effects than rock phosphate in some seasons, particularly on the oats in 1929, on the clover in 1924, on the timothy and clover in 1931 and on the corn in 1921. In some seasons, the results secured with superphosphate were very similar to those brought about by rock phosphate. The complete commercial fertilizer with manure and limestone showed very much the same effects as superphosphate in most seasons. It had a larger effect on the timothy and clover in 1920 and a slightly greater effect in other seasons, but in general the differences were not large enough to be of significance.

The crop residues showed little or no effect on the crops grown in most seasons. In one or two cases, there were increases from the crop residues, particularly in the case of the timothy and clover in 1920 and the clover in 1924. Limestone applied with the crop residues increased the crop yields in practically all seasons, the largest beneficial effects appearing on the timothy and clover in 1920 and 1931 and on the clover in 1924. The corn and oats crops were increased considerably in some seasons.

Rock phosphate applied with the crop residues and limestone showed a beneficial effect in some seasons. Most of the increases were small, however, and in one or two cases rock phosphate apparently had no effect whatever. Superphosphate applied with the crop residues and limestone showed a slightly larger effect than rock phosphate in some seasons, but in other cases it had a smaller influence. The differences frequently were of very little significance and there apparently would be very little choice between these two phosphates in the case of this particular field. The complete commercial fertilizer with the crop residues and limestone showed about the same effect as the phosphates on most of the crops grown. In one or two cases somewhat larger increases were secured than were obtained by the phosphates, notably in the case of the timothy and clover in 1920, but in several cases the complete commercial fertilizer showed actually less effects.

THE GREENFIELD FIELD

The results secured in the field experiment on the Tama silt loam on the Greenfield Field, Series I, in Adair County, are shown in table XVIII. The application of manure increased the crop yields on this soil in every season, showing particularly large effects on the corn in 1922, the oats in 1928, and the timothy and clover in 1929. Limestone with manure increased the crop yields in most cases and especially in 1929. No beneficial effects were noted on the oats in 1924 and 1928, or on the corn in 1926.
### TABLE XVIII. FIELD EXPERIMENT, TAMASILT LOAM, ADAIR COUNTY, GREENFIELD FIELD,* SERIES I

| Plot No. | Treatment | 1922 corn bu. per A. | 1923 corn bn. per A. | 1924 oats bu. per A. | 1925 clover and timothy tons per A. | 1926 corn bu. per A. | 1927 corn bn. per A. | 1928 oats bu. per A. | 1929 timothy & clover tons per A. | 1929 | 1928 | 1927 | 1926 | 1925 | 1924 | 1923 | 1922 |
|----------|-----------|---------------------|---------------------|---------------------|-----------------------------------|---------------------|---------------------|---------------------|-----------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1        | Check     | 78.6                | 50.9                | 54.1                | 45.0                             | 41.1                | 70.4                | 3.21                |                                   |         |         |         |         |         |         |         |         |         |
| 2        | Manure    | 84.0                | 53.7                | 57.0                | 50.1                             | 44.3                | 73.5                | 3.49                |                                   |         |         |         |         |         |         |         |         |         |
| 3        | Manure+limestone | 90.4            | 55.9                | 57.0                | 48.8                             | 48.1                | 79.3                | 3.87                |                                   |         |         |         |         |         |         |         |         |         |
| 4        | Manure+limestone+rock phosphate | 84.5            | 60.1                | 57.0                | 44.3                             | 52.9                | 98.1                | 4.24                |                                   |         |         |         |         |         |         |         |         |         |
| 5        | Check     | 85.7                | 51.3                | 46.8                | 43.5                             | 39.2                | 65.9                | 3.72                |                                   |         |         |         |         |         |         |         |         |         |
| 6        | Manure+superphosphate | 78.7            | 59.4                | 58.1                | 49.3                             | 58.4                | 88.6                | 4.20                |                                   |         |         |         |         |         |         |         |         |         |
| 7        | Manure+limestone+superphosphate | 82.9            | 60.2                | 57.0                | 45.9                             | 58.3                | 93.1                | 4.23                |                                   |         |         |         |         |         |         |         |         |         |
| 8        | Manure+limestone+complete commercial fertilizer | 89.4            | 52.4                | 58.4                | 48.8                             | 56.0                | 86.2                | 4.11                |                                   |         |         |         |         |         |         |         |         |         |
| 9        | Check     | 86.6                | 50.6                | 51.8                | 48.2                             | 48.3                | 77.1                | 3.70                |                                   |         |         |         |         |         |         |         |         |         |

(1) Plots were pastured, no results taken.

(2) Total of two cuttings.

*The Greenfield Field, Series I, was established in the fall of 1921 on the Claude Martin farm, northeast of Greenfield in Adair County, and was discontinued in 1929 due to inconvenient location of field. It was located in the SW¼ of the NE¼ of S. 32, T. 76 N., R. 31 W., Grove Township.

Rock phosphate with manure and limestone increased the crop yields in most seasons. The largest effect of the phosphate appeared on the oats in 1928 and on the timothy and clover in 1929. The oats in 1924 and the corn in 1926 showed no beneficial effects. Superphosphate with manure and limestone increased the crop yields in practically all seasons. It showed larger effects than rock phosphate on all of the crops except the oats in 1928 and the timothy and clover in 1929. In these latter cases, there was little difference in the yields under the two treatments. Muriate of potash with limestone and superphosphate increased the oats in 1924 and 1928, and showed a beneficial effect on the corn in 1922. In the other seasons it had no beneficial effects. The complete commercial fertilizer with manure and limestone showed smaller effects than superphosphate in all but one case.
THE NEEDS OF UNION COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The laboratory, greenhouse and field experiments which have been discussed in this report provide some indications of the fertilizer treatments which are most desirable for use on the soils of this county. A few more or less general recommendations for the handling of the more important soil types can therefore be made. In the following pages, there are certain suggestions which are based upon experimental results secured and also upon the experiences of many farmers. Any of the treatments suggested may be put into operation on any farm.

Liming

The soils in Union County are all acid in reaction and in need of lime as has been shown by the results of the analyses given earlier in this report. The surface soils are strongly acid and the acidity extends down into the lower soil layers. The figures given in table IV, showing the lime requirements of the various soil types, indicate roughly the lime needs of these soils. There is, however, a wide variation in the acidity of soils and the needs for lime in soils of the same type from different fields are often quite different. It is important, therefore, that tests should be made of every soil before an application of lime is made. Only by making tests of samples from the particular area will it be possible to apply the proper amount of lime. Farmers may test their own soils for acidity or lime requirements, but usually it will be more satisfactory if they will send a small sample to the Soils Subsection of the Iowa Agricultural Experiment Station, where it will be tested for them without charge.

The most satisfactory yields of general farm crops cannot ordinarily be secured on acid soils. Sweet clover, alfalfa and other legumes are especially sensitive to acidity and frequently such crops fail entirely on acid soils. The application of lime to land on which these crops are to be grown will, therefore, bring about very large increases in yields. Corn and small grain crops are also increased considerably in many cases by the application of lime.

The experiments discussed earlier in this report have indicated the large crop increases which may be obtained from the use of lime on the more extensively developed soils in this county. There have been large increases on the Muscatine silt loam, the Grundy silt loam, the Tama silt loam and the Shelby loam. Other soil types in the county would undoubtedly be benefited to quite as large an extent by the use of lime. The practical experience of many farmers has shown the importance of applying lime to acid soils in this county.

It should be emphasized that one application of lime will not suffice on these soils for an indefinite period. Lime must be applied regularly if the soils are to be kept most satisfactorily productive. It is suggested that the soils be tested for lime needs at least once in the rotation and that if necessary the application be made preceding the growing of the legume crop. Thus it is possible to apply the lime where it is most needed and where it will show the greatest effect on the crops. The influence of the application of lime will appear, however, not only on the legume crop of the rotation but also frequently to a considerable extent on the succeeding grain crop.
Manuring

Some of the soils in Union County are fairly well supplied with organic matter which is indicated by their dark color. Occasionally, however, lighter colored soils are developed and in such cases there is a deficiency of organic matter. Thus, the soils of the Shelby, Lindley, Clinton, Calhoun and Jackson series are rather light in color and hence are particularly in need of organic matter, but even on those types which are darker in color such as the Muscatine, Grundy and Tama soils, there are large benefits from the applications of fertilizing materials supplying organic matter. On all the soils in the county it is important that organic matter be supplied at regular intervals, if the content of the soils is to be kept up. On the lighter colored soils, applications are particularly necessary at the present time.

The proper handling and application of all the farm manure produced on the farm provides the best means of increasing and maintaining the content of organic matter. Thus, under the livestock system of farming, the use of farm manure will aid materially in keeping up the fertility of the soil. Farm manure brings about large increases in the yields of general farm crops. Experiments which have been described earlier in this report have indicated the large increases in crop yields following the use of farm manure on the Muscatine silt loam, the Grundy silt loam, the Tama silt loam and the Shelby loam. On other soil types in the county there would undoubtedly be as large or even greater effects from the use of manure. The regular application of farm manure to the soils of this county is strongly recommended in order that the most satisfactory crop yields may be secured, and that the land may be kept permanently fertile.

The utilization of all the crop residues will aid materially in keeping up the content of organic matter in the soil. On livestock farms the residues may be used for feed or bedding and returned to the land with the manure. Under the grain system of farming the residues are stored and frequently allowed to decompose partially before being applied, or they may be applied directly to the land. Under both types of farming all residues should be utilized because of their large fertility value.

On grain farms there is little or no production of manure, and on many livestock farms there is insufficient manure produced to permit making a regular application to all the land on the farm. In both cases, therefore, the use of inoculated legumes as green manures is very desirable to permit building up the content of organic matter in the soil. When inoculated legumes are used as green manures they not only supply organic matter to the land, but also add nitrogen which has been taken from the atmosphere. Green manuring would undoubtedly prove of value on many soils in Union County at present. On the lighter colored types, the influence would be particularly great, but the yields of general farm crops may be increased materially by this treatment on most of the soils. Green manuring should be used as a supplement to or substitute for farm manuring. Green manuring should not be followed carelessly, however, as undesirable effects on the soil may occur if the green materials are not properly decomposed. Farmers in Union County may maintain the proper supply of
organic matter in their soils if they will utilize the crop residues and farm manure produced and make a proper use of legumes as green manures.

The Use of Commercial Fertilizers

The supply of phosphorus is rather low in most of the soils in Union County as has been indicated by the results of the analyses of the soils given earlier in this report. It is evident, therefore, that the amount of this necessary plant food constituent present in the soils will not meet the needs of crops over any long period of years. Phosphate fertilizers will certainly be needed on these soils in the near future, and it seems quite possible that the application of some phosphorus fertilizer at the present time might be of very large value.

Phosphorus may be added to the soils through the use of rock phosphate or superphosphate. Rock phosphate is usually applied at the rate of 1,000 pounds per acre once in four years. Superphosphate is added at the rate of 120 pounds per acre annually three years out of four in a 4-year rotation. The phosphorus in rock phosphate is rather slowly available while superphosphate carries the element in a readily available form. Frequently rock phosphate does not show its largest effects until the second year after application, while the results from superphosphate are evident the first year. Superphosphate is more expensive, but the smaller application of superphosphate means that the fertilizer addition is actually less costly. Rock phosphate, therefore, must bring about larger beneficial effects on the crops grown if it is to prove as economically desirable. The beneficial effects of these phosphate fertilizers on some of the more important soil types in Union County have been indicated in some of the experimental results described earlier. Increases in crop yields were shown on the Muscatine silt loam, the Grundy silt loam, the Tama silt loam and the Shelby loam, and it is likely that as large or even larger beneficial effects would appear on various other soil types occurring in the county. In some instances superphosphate seemed to give slightly larger effects, but in other cases rock phosphate was preferable. At the present time it is impossible to choose definitely between these two phosphates for individual soil conditions. A simple test may be carried out with these two materials on any farm, and farmers are urged to make such tests in order to determine for their particular conditions whether the use of a phosphate fertilizer will prove of value and if so which particular phosphate should be employed.

The nitrogen content of the soils in Union County is not low in most cases but neither is it particularly high. In all cases nitrogen must be considered when systems of permanent fertility are planned. Nitrogen is lost from the soil continually in the drainage water and in the crops removed. Some fertilizing material supplying nitrogen must be added to the soils of the county regularly, therefore, if the content of this important element is to be kept up. On those soils where the supply of nitrogen is rather low it is particularly important that some nitrogenous fertilizing material should be used at the present time.

Plowing down the crop residues aids in keeping up the supply of nitrogen in the soil, and the turning under of farm manure supplies a considerable amount
of nitrogen, but the most desirable method of supplying and keeping up the nitrogen content of the soil is by the use of leguminous crops as green manures. Legumes have the ability when well inoculated of taking up the free nitrogen of the atmosphere, and thus when they are turned under in the soil a large increase in the nitrogen content of the soil is brought about. The use of leguminous crops as green manures is therefore of particular value from the nitrogen standpoint in addition to the beneficial effect which is brought about because of the addition of the organic matter to soils. On the lighter colored soil green manuring will be particularly desirable, but it will bring about beneficial effects on many of the soils in the county. The proper growing and handling of leguminous crops for green manuring purposes will permit increasing the nitrogen content of the soil and will make it possible to keep up the supply of nitrogen in the land without the use of the more expensive nitrogenous fertilizers. The latter cannot be recommended for general use on the soils of this county at present. In special cases they may prove of value, but they should never be applied to large areas until tests have been carried out on a small scale, and they have been shown to be profitable.

The supply of potassium is apparently adequate in most of the soils of the county. It seems unlikely, therefore, that commercial potassium fertilizers will be necessary on these soils. If the soils are kept in good condition from the standpoint of drainage, cultivation, supply of organic matter, reaction and plant food content, the production of sufficient available potassium to supply the needs of crops should be insured. The addition of commercial potassium fertilizer to the soils of this county cannot be recommended in general at the present time. On small areas for special crops the use of a commercial potassium fertilizer may be of value. Tests should certainly be carried out with such a material, however, before extensive applications are made.

The use of certain complete commercial fertilizers may be of value in some cases on the soils of this county at the present time. From experiments which have been reported earlier, however, and from the experiences of some farmers, it seems that in most cases a phosphate fertilizer would bring about as large crop increases, and hence the treatment would be more desirable because of the lower cost of the phosphate. Complete commercial fertilizers must have a much larger effect on crop yields than the phosphates if they are to prove as profitable for application to the land. There is no injury to the soil and no objection to the use of complete commercial fertilizers if they prove of value. It is important, however, in all cases where complete commercial fertilizers are to be employed that tests be carried out on small areas comparing the particular fertilizer with superphosphate in order to determine the actual crop effect of the treatment.

Drainage

Most of the upland soils in the county seem to be satisfactorily drained. The larger streams with their tributaries and intermittent drainageways extend into practically all parts of the uplands. There are some small areas, however, of poorly drained land, usually occurring at the heads of drainageways near the small streams and on the flatter or depressed areas in the broad uplands be-
between the streams. The Muscatine silt loam occasionally is poorly drained, and some areas in the Grundy silt loam are not adequately drained. On the terraces, the Bremer, Calhoun and Chariton soils are apt to be poorly drained, and on the bottomlands the Wabash soils are usually in need of drainage. In the case of the latter soils, protection from overflow is necessary before they can be made satisfactorily productive, and this protection should be provided before they can be drained.

Crop yields will not be satisfactory on soils which are too wet. The first treatment needed on such soils, therefore, is the installation of tile. No fertilizer treatments will have any effect on soils which are not properly drained. The expense of tiling may be considerable, but the increased crop yields secured after the land is thoroughly drained will soon pay for the installation. In order to obtain the most satisfactory crop yields and to keep the land productive, adequate drainage should always be provided.

The Rotation of Crops

The fertility of the soil is very quickly reduced by the continuous growing of any one crop. Frequently, however, farmers practice this continuous system of cropping because of the large money value of the particular crop grown. Experiences of farmers and many experiments have shown definitely that under the continuous cropping system yields rapidly decrease and soon the crops become unprofitable. When a rotation of crops is practiced, it has been found that profits are much greater over a period of years in spite of the fact that certain crops are included in the rotation which have actually less money value.

No special rotation experiments have been carried out in Union County, but some rotations may be suggested which will undoubtedly prove valuable. The following desirable rotations may be used in the county. Any of them may serve as a basis upon which suitable rotations may be devised to fit individual farm conditions.

1. SIX-YEAR ROTATION

First year—Corn  
Second year—Corn  
Third year—Wheat or oats (with clover, or clover and grass)  
Fourth year—Clover, or clover and grass  
Fifth year—Wheat (with clover), or grass and clover  
Sixth year—Clover, or clover and grass

This rotation may be reduced to a 5-year rotation by cutting out either the second or sixth year and to a 4-year rotation by omitting the fifth and sixth years.

2. FOUR OR FIVE-YEAR ROTATION

First year—Corn  
Second year—Corn  
Third year—Wheat or oats (with clover, or with clover and timothy)  
Fourth year—Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to 5 years. The last crop will consist principally of timothy.)

3. FOUR-YEAR ROTATION WITH ALFALFA

First year—Corn  
Second year—Oats  
Third year—Clover  
Fourth year—Wheat  
Fifth year—Alfalfa (The crop may remain on the land 5 years. This field should then be used for the 4-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the 4-year system.)
4. FOUR-YEAR ROTATIONS

First year — Wheat (with clover)
Second year — Corn
Third year — Oats (with clover)
Fourth year — Clover

First year — Corn
Second year — Wheat or oats (with clover)
Third year — Clover
Fourth year — Wheat (with clover)
First year — Wheat (with clover)
Second year — Clovers
Third year — Corn
Fourth year — Oats (with clover)

5. THREE-YEAR ROTATIONS

First year — Corn
Second year — Oats or wheat (with clover seeded in the grain)
Third year — Clover (In grain farming only the grain and clover seed should be sold; most of the crop residues such as corn stover should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop.)

First year — Corn
Second year — Oats or wheat (with sweet clover)
Third year — Sweet clover (The clover may be mixed clovers and used largely as pasture and green manure.)
(This may be changed to a 2-year rotation by plowing the sweet clover under the following spring for corn.)
First year — Wheat (with clover)
Second year — Corn
Third year — Cowpeas or soybeans

The Prevention of Erosion

Erosion is the carrying away of the surface soil by the free movement of water over the land. There are two types of erosion, sheet washing and gullying. Sheet erosion is the washing away of the surface soil. Gullying is more striking in appearance since gulches or ravines may be formed.

Erosion occurs to some extent in the soils of Union County. On the drift uplands, the Shelby loam, the Lindley loam and the Lindley silt loam are frequently very badly washed. On the loessial uplands the Clinton silt loam is often seriously eroded. Some areas in the Tama silt loam are affected by the washing away of the surface soil. The shallow phase of the Tama silt loam has been formed by the carrying away of the surface soil by erosion. The same thing has happened in the case of the Grundy silt loam. Wherever erosion occurs, some means of prevention or control should be adopted.

Various methods are followed for the control and prevention of erosion in Iowa. These methods differ somewhat depending upon the type of erosion. Erosion due to "dead furrows" may be controlled by "plowing in," by "staking in" or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven wire dams or concrete dams. They may be prevented from occurring by thorough drainage or by the use of sod strips. Large gullies may be similarly filled or prevented from occurring. Erosion in bottomlands may be prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion may be controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.*

INDIVIDUAL SOIL TYPES IN UNION COUNTY*

There are 16 soil types in Union County, and these with the shallow phase of the Grundy silt loam, the shallow phase of the Tama silt loam and the gray subsoil phase of the Wabash silt loam make a total of 19 separate soil areas. They are divided into four large groups according to their origin and location. The groups are drift soils, loess soils, terrace soils and swamp and bottomland soils.

Drift Soils

There are 3 drift soils in the county classified in the Lindley and Shelby series. Together they cover 46.0 percent of the total area.

SHELBY LOAM (79)

The Shelby loam is the largest drift soil and by far the most extensively developed soil type in the county, covering 44.6 percent of the total area. It occurs on practically all farms, and extensive areas are found in all parts of the county.

The surface soil of the Shelby loam is a dark brown to black granular loam to a depth of about 10 inches. It is underlaid by a dark brown or brown coarse granular heavy clay loam extending to an average depth of 21 inches. Below this point there is a layer of heavy clay loam or sandy clay containing some pebbles and gravel. This layer is yellowish-brown and is marked with gray and stained with rusty brown or black iron colorations. At about 35 inches the layer is underlaid by a more plastic, stickier and heavier material averaging a sandy clay in texture. The gray markings or black iron spots are more numerous than in the upper layer. Below depths of 3 or 4 feet the soil is not acid in reaction and at depths ranging from 5 to 6 feet there are spots or streaks of lime occurring in many places. A few boulders are found on the surface of the type.

There are many variations in the Shelby loam as mapped, largely due to the fact that it occurs on slopes which are subject to continual erosion, and in many places the surface soil has been very largely carried away. On the lower portions of the slopes a much deeper surface soil has been formed. Narrow strips of very heavy land, known locally as "push soils," commonly occur on slopes occupied by Shelby loam. They are too small, however, to show on the map. Generally the more rolling areas of Shelby along the larger streams are more spotted and variable than the gently rolling areas near the upland divides. An area of this soil in sections 30 and 31 of Platte Township along the east side of the Platte River has a fine sandy loam surface soil and a light sandy clay loam subsoil. This area was not of sufficient size to separate. It is really Shelby fine sandy loam.

*The description of individual soil types given in this section of the report closely follow those in the Bureau of Soils report.
About one-third of the Shelby loam is cultivated, the remainder being in permanent pasture, some in woodland. The principal crops grown are corn, oats and clover and timothy mixed. The yields secured are somewhat lower than those on the Tama, Muscatine and Grundy soils. Corn averages 35 bushels per acre and oats between 25 and 30 bushels and clover and timothy hay three-fourths of a ton per acre.

In the western tier of townships much of the Shelby loam is not so seriously eroded, but on the steeper slopes along the main stream valleys in the eastern part of the county there is very serious erosion, and unless means are taken to prevent the washing away of the soil, crop production is bound to become continually poorer. The checking of the gullies which are forming in the land and the practice of terracing are very necessary if these areas of Shelby are to be cultivated. Many of them are too steep for any cultivated crops and should be kept in pasture. The needs of the Shelby loam on the areas which can be cultivated include the use of farm manure to build up the supply of organic matter and to make the soils more retentive of moisture and less subject to washing, the use of leguminous crops as green manures to supplement the addition of farm manure, the application of lime to correct acidity and to induce satisfactory legume growth and the application of a phosphate fertilizer.

LINDLEY LOAM (65)

The Lindley loam is the second largest drift soil but much less extensively developed than the Shelby loam. It covers 1.3 percent of the total area. The principal areas of the type are on the south slope of Three Mile Valley in Lincoln Township along the Grand River near Monett and Talmage and in sections 12 and 13 of Pleasant Township.

The surface soil of the Lindley loam to a depth of about 4 inches is a gray, friable, somewhat floury loam or very fine sandy loam. When moist the surface soil is more brown or yellowish-brown than gray. Below 4 inches and extending to a depth of about 12 inches there is a friable grayish-yellow or yellowish-brown heavy loam or silt loam. This is underlaid by a dark yellowish-brown silty clay loam which is rather plastic when wet. Below 20 inches the soil is a yellowish-brown heavy, gritty silty clay marked with gray and with rusty brown and black iron stains. Below 40 inches the iron stains are more pronounced and the soil becomes somewhat more friable. To a depth of about 4 feet there are occasional streaks of lime. Stones and a few boulders are found on the surface and mixed in the soil.

The areas in Lindley loam vary considerably especially in the texture of the surface soil and occasionally in the subsoil. On the steeper slopes the surface soil is badly washed and spots of exposed subsoil appear.

The greater part of the Lindley loam is in woodland and utilized for pasture.
cropped, the type produces yields similar to those secured on the Clinton silt loam. Corn averages about 35 bushels per acre, oats between 25 and 30 bushels, and winter wheat about 15 bushels.

The Lindley loam is subject to erosion. Gullying and sheet washing occur to a considerable extent where the areas on the steeper slopes are cultivated. In many cases this type should undoubtedly be left in pasture, and no attempt should be made to cultivate it. It can be protected from erosion, however, through proper methods of treatment. In some cases terracing may be a very desirable practice. The prevention of gully formation can be accomplished by the proper installation of dams. When cultivated the Lindley loam will respond definitely to applications of farm manure which will build up the supply of organic matter and make the soil more retentive of moisture and less likely to be carried away by erosion. Farm manure is of large value on this type, and leguminous crops used as green manures will greatly improve the fertility. The type is acid, and liming is necessary in order to secure the best growth of legumes and also to permit the most satisfactory growth of other general farm crops. The use of a phosphate fertilizer would undoubtedly be of value on this soil, when cultivated, and tests of superphosphate are recommended.

LINDLEY SILT LOAM (32)

The Lindley silt loam is a very minor type in the county, covering 0.1 percent of the total area. Only one small area is mapped on the Ringgold County line in Section 36 of Pleasant Township.

The surface soil of the Lindley silt loam to a depth of about 4 inches is a gray silt loam appearing somewhat brown or yellowish-brown when moist. To a depth of 12 inches the soil is a friable gray or yellowish-brown heavy loam or silt loam. This is underlaid by a dark yellowish-brown silty clay loam. Below 20 inches the soil is a yellowish-brown heavy plastic silty clay containing some markings of gray, rusty brown and black iron stains. Below 40 inches the soil is somewhat more friable but usually resembles rather closely the surface layer. Usually in the lower part of the subsoil below 4 feet there are spots and streaks of lime. The surface soil is strongly acid. Some stones and boulders are found on the surface of the Lindley silt loam and occasionally throughout the soil profile.

As in the case of the Lindley loam, the greater part of this soil is in woodland and used for pasture. It is subject to erosion and when cultivated the soil is likely to wash away and occasionally spots of subsoil may appear. When cultivated, crop yields are very much the same as those secured on the Lindley loam. The treatments recommended for that type are applicable also to this soil. The use of farm manure and leguminous crops as green manures would be of particularly large value. The application of lime is needed, especially if legumes are to be grown. The use of a phosphate fertilizer would be desirable, and tests of superphosphate are recommended. Where the land is to be cultivated it is very desirable that precautions be taken to prevent erosion. Terracing is desirable, but in many cases the land should certainly be kept in pasture and not cultivated.
Loess Soils

There are 4 loess soil types in the county, and these with the shallow phase Grundy silt loam and the shallow phase Tama silt loam make a total of 6 separate loess areas. These soils are classified in the Muscatine, Grundy, Tama and Clinton series.

MUSCATINE SILT LOAM (20)

The Muscatine silt loam is the largest of the loess soils and the second most extensively developed type in the county covering 24.3 percent of the total area. It occurs extensively in all parts of the county, being most largely developed, however, in the western half. Considerable areas of the type are found in all parts of the county.

The surface soil of the Muscatine silt loam is a dark grayish-brown or black mellow silt loam to a depth of about 12 or 14 inches. The subsoil to a depth of about 36 inches is a brown to a grayish-brown heavy silt loam or silty clay loam. When moist this layer is friable, when wet rather plastic. When fairly dry, it is hard and brittle. Below this layer there is a yellowish-brown heavy silt loam which is somewhat more friable and less plastic than the layer above. Rusty brown and black iron stains are found in this layer. Below 5 feet, the soil is similar to that above but is more grayish-brown in color.

In many places the Muscatine silt loam is intermediate between the Tama and Grundy soils and in characteristics rather closely resembles the Tama. The boundaries between these soils are therefore rather arbitrarily drawn. In general, the Muscatine silt loam has a less friable and more plastic subsoil than the Tama soil, but a more friable and less plastic and impervious subsoil than that of the Grundy type.

In the more rolling sections where the type occurs on rather narrow, winding ridge crests, the surface soil is lighter in color than typical and not more than 8 or 10 inches in depth. In places the subsoil shows greater compactness than the typical soil. These areas of lighter colored surface soil and more compact subsoil are usually found near the areas of Clinton silt loam and approach the latter type in characteristics. Most of the narrower ridges on either side of the Grand River valley include soils of this kind. On eroded slopes of valleys small areas of Muscatine silt loam are found within areas of the Shelby and Grundy soils. These are too small to indicate on the soil map.

In topography the Muscatine silt loam is usually gently rolling. In many places, however, it is found on rather level to flat areas. In the western part of the county where the Muscatine silt loam occurs most extensively, the soil is found on many of the slopes below the divides. The natural drainage of the Muscatine silt loam is generally well developed. In some places, however, the
drainage is not adequate and tiling is very desirable if the best crop yields are to be secured.

Practically all of the Muscatine silt loam is in improved farm land and regularly cropped to general farm crops. Yields of corn average about 45 bushels per acre, but yields as high as 75 bushels are frequently reported. Oats and barley average between 35 and 40 bushels per acre, and rye about 25 bushels per acre. Timothy produces from \( \frac{3}{4} \) of a ton to 1 ton of hay per acre, clover and timothy mixed about 1 ton, red clover from 1 to \( 1\frac{1}{4} \) tons and alfalfa about \( 2\frac{1}{2} \) tons per acre.

The Muscatine silt loam is normally a rather productive type, but it will be benefited considerably by certain methods of soil treatment. Manure brings about increased crop yields in all cases on this soil. It is acid and in need of lime especially for the best crops of legumes. The use of a phosphate fertilizer is often of considerable value, and tests of superphosphate and rock phosphate are recommended.

**GRUNDY SILT LOAM (64)**

The Grundy silt loam together with the shallow phase which is rather limited in occurrence, is the second largest loess soil and the third largest type in the county. It occupies 11.3 percent of the total area. It is found on the highest and broadest divides of the uplands. The largest areas are on the divides extending through Creston and Arispe in Highland and Sand Creek townships. Smaller areas are scattered throughout the county in all parts. In the eastern and southern parts the type is found on the flat-topped narrow divides extending down the slopes to the Shelby soils. In other parts, these narrow divides are generally occupied by the Muscatine silt loam or where the Grundy is found on the flat top of the divide the Muscatine occupies the slopes and rounded crests.

The surface soil of the Grundy silt loam to a depth of 16 or 18 inches is a black friable silt loam. Below this point the material becomes heavier and less friable, until at a depth of about 24 inches it is a heavy silty clay. When moist this layer is rather plastic. It is colored by organic matter and is mottled with rusty brown, yellow and gray. At a depth of about 30 inches it is a heavier textured silty clay, tougher and more compact. The color is a dull gray or dull grayish-brown with mottings of rusty brown, yellow and gray. At a depth of about 40 inches the soil becomes lighter textured approaching a heavy silt loam, less plastic, and not nearly so tough as the layer above. The texture becomes less heavy with depth until at about 5 feet it loses its compactness and plasticity. At this depth there is a change of color, the material above being yellowish and that below grayish-brown. Rusty
brown and black iron stains occur throughout the layer to a depth of 40 inches, being usually less pronounced in the grayish-brown layer.

On the more sloping surface of the narrow divides, the Grundy silt loam is usually thinner than typical and approaches the Muscatine silt loam in character in some areas. The divide between Sand Creek and Twelvemile Creek in the southeastern part of the county is of this character. The boundaries between the two soils are placed rather arbitrarily in some cases. On the broader flats near Creston and Arispe, newly plowed fields in depressed areas show a gray color on drying which seems to indicate poor drainage.

The Grundy silt loam is nearly all under cultivation, being cropped to corn and small grains. In normal seasons, crop yields are high. Corn averages between 40 and 45 bushels per acre, yielding as high as 75 to 80 bushels in some places. Oats average between 30 and 35 bushels per acre and wheat about 20 bushels per acre. Red clover grown separately or mixed usually yields about 1 1/2 tons per acre. Alfalfa hay on the better drained areas averages between 2 1/2 and 3 tons per acre.

Except in depressed areas, the Grundy silt loam is fairly well drained, but in many cases tiling is necessary, especially in the depressed areas of the type, before satisfactory crop yields can be secured. The type is well supplied with organic matter, but applications of farm manure bring about large increases in crop yields. The use of leguminous crops as green manures would be of value on this type in many cases. The soil is acid and in need of lime especially for the best growth of legumes. The application of a phosphate fertilizer has been found to increase crop yields considerably. Tests of superphosphate and rock phosphate on this soil are strongly urged.

GRUNDY SILT LOAM (shallow phase) (248)

The shallow phase of the Grundy silt loam is much less extensively developed than the typical soil, occupying about 2 percent of the total area of the county. It occurs on gentle slopes at the heads of drainage ways which have cut back into the broader flat divides and on some of the narrow divides in Pleasant Township. Most of this phase of the soil is found in Sand Creek and Highland townships in typical areas of Grundy silt loam. The areas in Sand Creek Township are somewhat more sloping in topography than those in Highland Township.

The shallow phase of the Grundy silt loam is very similar to the typical soil, except that the surface soil is much shallower. It is normally a dark brown to black friable silt loam, the actual depth of the surface soil varying widely in the different areas. At about 24 inches it becomes a heavy silty clay, rather plastic, dull grayish-brown in color and mottled with rusty brown, yellow and gray. Below 30 inches the soil is a heavy textured silty clay, with more mottling, and a somewhat lighter color. At about 40 inches the soil is somewhat lighter in texture, becoming almost a heavy silt loam but less plastic and tough than the layer above. The texture becomes less heavy at the lower depths until at a depth of about 5 feet it loses its compactness. Here the color changes from a yellowish-brown to a grayish-brown with rusty brown and black iron stains.

The shallow phase of the Grundy silt loam is cultivated with the typical soil,
and yields of general farm crops are slightly lower because of the shallower
surface soil. The needs of the soil are very similar to those of the typical
Grundy. Applications of farm manure are of particularly large value, and the
turning under of leguminous crops as green manures is also of large value. The
soil is acid and in need of lime especially for the best growth of legumes, and
the use of a phosphate fertilizer would undoubtedly be desirable. Tests of super-
phosphate are recommended.

TAMA SILT LOAM (120)

The Tama silt loam with the shallow phase which is less extensively developed
than the typical soil is the third largest loess type in the county, covering 4.3
percent of the total area. It occurs on the tops of the upland divides, being
found, as a rule, on ridges and never on the flat divides. Many areas of this
type are scattered through the county.

The surface soil of the Tama silt loam to a depth of 12 to 18 inches is a mellow
dark colored silt loam. Below this point to a depth of about 36 inches there
is a dark brown or dark yellowish-brown friable heavy silt loam or silty clay
loam. This layer is much less plastic than the corresponding layer in the Mus­
catine silt loam, and the soils are differentiated largely on the basis of this
difference in the character of this layer and also in the fact that the Tama silt
loam has a more yellow subsoil. Below 36 inches the soil is very similar to the
Muscatine silt loam. It is a little lighter in texture and a trifle more open and
porous. The change in color from yellowish-brown to gray generally occurs at
a depth of about 5 feet just as it does in the Muscatine silt loam.

Included with the Tama silt loam as mapped there are some areas where the
surface soil is a little lighter than typical and resembles the Clinton silt loam.
These areas are found on the narrower crests in the more rolling sections of the
county. The type is very well drained and artificial drainage is not necessary.
Some erosion occurs, but the type is not ordinarily seriously eroded.

The Tama silt loam is all under cultivation, and general farm crops are grown.
The yields of corn average around 45 bushels per acre, although yields as high
as 75 bushels per acre sometimes are secured. Oats and barley average between
35 and 40 bushels per acre, wheat between 20 and 25 bushels per acre and rye
about 25 bushels per acre. Timothy and clover hay produce about 1 ton per
acre; red clover from 1 to 11/4 tons and alfalfa about 21/2 tons per acre.

The needs of the Tama silt loam to be made more productive include the
application of organic matter in the form of farm manure and leguminous green
manures. Large increases in crop yields are secured by the application of farm
manure to this soil. The use of lime is necessary as the type is acid in reaction,
and the addition of a phosphate fertilizer would undoubtedly be of value. Rock
phosphate or superphosphate are recommended for application to this soil.
Experiments which have been carried out on the type have indicated very
definitely increased yields of crops from the application of farm manure, lime­
stone and a phosphate fertilizer.

TAMA SILT LOAM (shallow phase) (143)

The shallow phase of the Tama silt loam is minor in area in the county, cov­
ering 1.4 percent of the total area. It is found on rather gently sloping areas
below the ridges of Tama silt loam in the northwestern part of the county. There are no large areas of the type.

The shallow phase of the Tama silt loam is similar to the typical silt loam except that the surface soil is very much thinner. The surface soil is a mellow, dark-colored silt loam varying from a few inches to 10 inches in depth. Below this depth and extending to a depth of 36 inches there is a dark brown or dark yellowish-brown friable heavy silt loam or silty clay loam. Below 30 inches there is a considerable variation in the character of the subsoil. In most places it is a heavy sandy clay very similar to the subsoil of the Shelby which is developed from drift material. In a few areas there is a dense "blue clay" found in some places to a depth of 30 inches but generally at greater depths than this. In some areas, on the shoulders of slopes, the surface soil is entirely removed and the pebbly sandy clay layer is exposed. At the base of the slopes the silt loam is as deep or deeper than the typical soil, having been washed down from the land above.

The shallow phase of the Tama silt loam has been formed through the washing away of much of the surface soil by erosion and hence crop yields on the type are somewhat lower than those secured on the typical soil. The areas are usually farmed along with the areas of the typical silt loam in spite of the greater erosion which has taken place on them. The needs of the phase are very much the same as those of the typical soil except that more emphasis should be placed upon the incorporation of organic matter with this soil. The use of farm manure and the turning under of leguminous green manures in order to build up the supply of organic matter and reduce the danger of erosion are essential. It is also important wherever possible to keep these areas in uncultivated crops to a very large extent or when cultivated that terracing be practiced. Some means of prevention of the washing away of the soil by erosion is very necessary if these areas are to be kept from being completely eroded and the underlying Kansan till exposed at the surface. Without proper methods of farming these areas, they will become more and more unproductive and will reach a condition from which it will be very difficult to reclaim them.

**CLINTON SILT LOAM (80)**

The Clinton silt loam is the fourth of the loess soils developed in the county, occupying 1.2 percent of the total area. It occurs in a number of areas, being found on the narrower ridge crests in the more rolling sections. Most of the areas of the type are found close to the Grand River Valley. In only a few places does the soil extend to any great distance down the slopes.

The surface soil of the Clinton silt loam is a light grayish-brown or yellowish-brown mellow silt loam extending to a depth of 10 or 12 inches. Below this there is a 4-inch layer of a darker gray, more granular soil. Below 18 inches and extending to a depth of about 30 inches there is a light brown heavy silt loam which is friable when moist, somewhat plastic when wet but rather compact when dry. With increasing depth the soil becomes lighter in color with markings of rusty brown, yellow and gray. Between 4 and 5 feet the soil material is much less compact, being a friable silt loam. The color is a light grayish-yellow or light yellowish-brown, mottled with gray, rusty black, brown and
yellow iron stains. Where they adjoin the Grundy soils, the areas of Clinton silt loam
have a heavier texture, more plastic subsoil and the surface soil is darker in color than
typical.

About one-fourth of the total area of the Clinton silt loam is in woodland pasture
which has not been cleared of the native hard-wood growth. On the cultivated areas gen­
eral farm crops are grown, the yields being somewhat lower than those secured on the
Tama, Muscatine and Grundy soils. Corn averages 35 bushels per acre, oats 25 to 30 c
bushels and winter wheat about 15 bushels per acre.

The Clinton silt loam is well drained,
but it is subject to considerable erosion and
on the areas which have been cleared and brought under cultivation, erosion
has frequently occurred to a very harmful extent. Probably some of the rougher
areas of the Clinton should not be cultivated but should be kept in pastures
and perhaps reforested. On the cultivated areas it is very desirable that care
be taken to prevent the occurrence of erosion which is very likely to take place
to a considerable extent. The terracing of Clinton areas to prevent erosion
would undoubtedly be very desirable if cultivated crops are to be grown. Under
a proper system of terracing, the incorporation of organic matter in the soils,
and proper handling, there is no reason why the erosion of this type should not
be cut down to a considerable extent, perhaps even prevented entirely. The
addition of farm manure to the soil and the turning of leguminous crops as
green manures would be of very large value, building up the fertility of the
soil, improving the water holding capacity and reducing the injury through
washing. The soil is acid in reaction and lime is necessary, especially for the
best growth of legumes. The use of a phosphate fertilizer would be very desir­
able on this type, and tests of superphosphate are strongly recommended.

Terrace Soils

There are five terrace soils in the county, together covering 1.4 percent of
the total area. They are classified in the Bremer, Jackson, Calhoun, Chariton
and Waukesha series.

**BREMER SILT LOAM (88)**

The Bremer silt loam is the largest of the terrace types, covering 1.3 percent
of the total area of the county. It is generally found on the sloping or bench­
like terraces from 5 to 10 feet above the bottomlands. The larger areas occur
along the Grand River and Twelvemile Creek in Pleasant Township and in
sections 30 and 31 of New Hope Township. An area on a high terrace is found
in sections 25 and 26 of Pleasant Township.

The surface soil of the Bremer silt loam is an almost black, rather heavy silt
loam which when wet is apt to be a little difficult to handle, but when dry or
moist, is easily plowed and cultivated. Between depths of 8 and 17 inches the soil is heavier and less friable than the surface soil, becoming somewhat plastic in the deeper part when wet, the color changing to a dark gray. Between depths of 17 and 25 inches the soil is a plastic heavy silty clay loam, becoming somewhat tough and compact when dry. The dark gray color is faintly stained with rusty brown iron spots. The soil between 25 and 40 inches is a stiff, plastic, heavy silty clay or clay which on drying forms tough soil masses which are hard to break. The color is dark gray with numerous spots of lighter gray and bluish-gray as well as rusty brown and black iron stains. Below 40 inches the color is a mottled mass of these stainings. The texture of this layer shows a change from clay to silty clay loam. The soil is not so stiffly plastic as the layer above. Small areas of the Chariton soils having distinctly gray subsurface layers and subsoils even more tough and compact, more waxy when wet, than the Bremer subsoils are included with the Bremer silt loam because of their small size.

About two-thirds of the Bremer silt loam in Union County is cultivated, the remainder being in pasture and hay. The crop yields secured on the cultivated areas are a little lower than those obtained on the Grundy silt loam. Corn does better on the type than small grains which are apt to lodge.

The Bremer silt loam is chiefly in need of drainage to be made satisfactorily productive. On some of the sloping areas the drainage is fair while in the flat areas and in the basin-like depressions much water is retained in the soil during a large part of the year, and crop production is limited because of lack of drainage. Tiling is the first treatment needed on most of the type. When it is well drained, the soil must be carefully handled in order that a good seedbed may be prepared for crops. If plowed when too wet, the surface soil is apt to be cloddy, and if it is too dry a crust is formed which is hard to pulverize. Occasionally, when such a crust has developed it has numerous deep surface cracks. It is very important that the type be plowed and cultivated at the right moisture conditions in order that crop yields may be satisfactory. The use of farm manure on the Bremer silt loam is of considerable value in improving the physical conditions of the soil and also in providing better production of available plant food. The use of lime is necessary as the soil is acid in reaction. The application of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

#### JACKSON Silt Loam (81)

The Jackson silt loam, which is the second largest terrace type in the county, covers 1.1 percent of the total area. It occurs on small terraces above the bot-
tomlands of the Grand River, Twelvemile and Threemile creeks. Larger areas are found along the courses of these streams in Jones and Pleasant townships. A few of the higher areas have been eroded and have lost all resemblance to terraces. The larger of these areas is found in Section 29 of Jones Township and Section 14 of Pleasant Township.

The surface soils of the Jackson silt loam to a depth of about 8 inches is a mellow, slightly gritty silt loam which is a light grayish-brown or yellowish-brown silt loam appearing quite grayish-brown when dry. Below this layer the soil material to a depth of 20 inches is a heavy silt loam somewhat lighter in color and less mellow than the surface soil. Between 20 and 34 inches the material is a light brown or yellowish-brown, rather gritty, heavy, compact silt loam which is slightly plastic when wet. Between 34 and 52 inches there is a layer of a yellowish-brown silt loam or silty clay loam containing rusty brown iron stains and some gray spots. Below 52 inches the soil is a yellowish-brown or light grayish-brown friable silt loam showing numerous rusty brown iron stains and spots of gray. On some of the more sloping areas of the type, the soil includes spots having a fine loamy surface soil washed down from the uplands. Occasionally, there is some development of a gray color in the sub­surface of the type, resembling the gray subsurface layer which is characteristic of the Calhoun soil. The type resembles the Clinton silt loam on the uplands in most characteristics, although the subsoil is not so compact as that of the Clinton.

About one-third of the total area of this type is now cleared and in cultivation. Another third is in hay and pasture grasses and the remainder is in woodland and pasture. Native vegetation consists of hardwood trees. On the cultivated areas, general farm crops are grown, and yields are very similar to those secured on the Clinton silt loam. Corn yields about 35 bushels per acre, oats from 25 to 30 bushels per acre, and winter wheat about 15 bushels per acre.

The type is naturally well drained. In some areas the runoff is excessive, and considerable erosion occurs. The type is particularly in need of additions of organic matter in order to be made more productive. The turning under of farm manure and the plowing down of leguminous crops as green manures would be of large value on this type, providing for better retention of moisture and better conditions in the soil for crop growth in general, but especially in dry seasons. The soil is acid in reaction and applications of lime are necessary especially for the best growth of legume crops. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.
The Calhoun silt loam is the third largest terrace type in the county, covering 0.9 percent of the total area. More than half of the type mapped in the county is in Pleasant Township and practically all of the remainder occurs along the Grand River and Twelvemile and Threemile creeks in Union and Jones townships. There is a small area along the East Platte River in Section 26 of Platte Township.

The surface soil of the Calhoun silt loam to a depth of 7 inches is grayish-brown floury silt loam. It is underlaid to a depth of 19 inches by a light gray floury silt loam which is rather compact. A layer of brown silty clay or silty loam, stained with gray in the upper part and with rusty brown in the lower part, is found between 19 and 32 inches. It is the heaviest, most plastic and impervious layer. When dry or moist, the material in this layer breaks into firm, tough particles. Below 32 inches the soil is a dark yellowish-brown heavy silty clay loam stained with rusty brown and iron colorations. Below 40 inches the soil is less plastic and when moist can be broken into a more friable mass. The silt content increases at the lower depths and the texture becomes a heavy silt loam at depths ranging from 4 to 5 feet.

The Calhoun silt loam normally occurs on terraces 20 or 25 feet above the bottomlands. The surface is level or gently sloping. Surface drainage is good, but owing to the impervious subsoil, much of the type and especially those areas which are found in level to depressed sections are in need of tiling in order to be made satisfactorily productive. The Calhoun silt loam is found in association with the Jackson and Chariton soils and includes small spots of these two soils.

Practically all of the type is under cultivation with the exception of a few areas which are in woodland pasture. Originally the land was all woodland. The crop yields are very much the same as those occurring on the Clinton and Jackson soils, sometimes being a little lower where the drainage conditions are particularly unsatisfactory. Normally corn yields about 35 bushels per acre, oats between 25 and 35 bushels, and winter wheat about 15 bushels per acre.

The needs of this soil in addition to adequate drainage, which is the first requirement, include the incorporation of organic matter, the application of lime and the use of a phosphate fertilizer. Liberal amounts of farm manure would be of value on this soil in improving its structure and providing for better physical conditions for the growth of crops. Lime is necessary as the type is acid in reaction and legumes will not grow satisfactorily unless lime is applied. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.
UNION COUNTY SOILS

CHARITON SILT LOAM (105)

The Chariton silt loam is a minor terrace type covering 0.5 percent of the total area. It is found on terraces closely associated with the Calhoun silt loam and the Bremer silt loam. With the exception of a small area in Section 1 in Platte Township, the soil occurs only on terraces along the Grand River and Twelvemile and Threemile creeks in Pleasant, Jones, Union and Sand Creek townships. Most of the areas are small narrow strips lying 18 to 20 feet above the bottoms.

The surface soil of the Chariton silt loam to a depth of 10 inches is a very dark grayish-brown or almost black, smooth, mellow silt loam becoming somewhat more gray when dry. Below this point to a depth of 16 or 18 inches there is a distinctly gray very flouy silt loam, faintly mottled with black organic matter with a few rust colored iron stains. Below this point to a depth of 32 inches there is a very compact impervious silty clay or clay which is sticky and waxy when wet. This layer is dark grayish-brown becoming somewhat more yellowish-brown in color at the lower depths. In the lower part gray and yellow mottlings and rusty brown iron stains occur, and the soil is somewhat less sticky. Below 32 inches there is a slight change toward a softly plastic somewhat more friable and more pervious silty clay loam or silt loam. A gray color replaces the yellowish-brown color in the underlying material and the stains largely disappear.

About one-half of the area of this soil is in cultivated crops, the remainder being in hay and pasture. General farm crops are grown, and yields are somewhat lower than those on the Bremer silt loam and a little higher than those secured on the Jackson silt loam and the Calhoun silt loam. The soil is ordinarily not entirely satisfactorily drained and in most cases tiling is necessary in order to provide for proper moisture conditions. The turning under of farm manure and the plowing down of leguminous crops as green manures would be of value. The soil is acid and in need of lime for the best crop growth, and the use of a phosphate fertilizer would undoubtedly be of value. Tests of superphosphate are recommended.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is minor in extent, covering 0.3 percent of the total area. Small areas of the type are found along the Grand River and along Twelvemile and Threemile creeks. The areas are found on low slopes just above the bottomlands or on land higher than 10 feet above the bottom and less frequently 20 or more feet from the bottoms.

The surface soil of the Waukesha silt loam to a depth of 4 inches is a very dark grayish-brown slightly gritty mellow silt loam. Below this point the color
is almost black to a depth of 16 inches, and dark brown between 16 and 25 inches, the texture being rather uniform. Between 25 and 30 inches the color is a yellowish-brown, the texture a heavy silt loam. At a depth of about 30 inches there is a compact, yellowish-brown heavy silt loam subsoil. At 40 inches a greater sand content is found, making the soil somewhat more loose. The yellowish color at this depth is varied by gray stains. The type is not typical of the Waukesha silt loam mapped in other counties, as here it has a shallower dark colored surface soil and a thicker yellowish-brown subsoil. Within the type as mapped in Union County areas of Judson silt loam occur which were too small to separate on the map. In Section 3 of Platte Township a high terrace having a subsoil similar to that of the Jackson silt loam was included with the Waukesha silt loam because of the dark surface soil.

Practically all of the type is under cultivation and general farm crops are grown. The yields secured are similar to those secured on the Tama silt loam and the Muscatine silt loam. Corn yields average about 40 to 45 bushels per acre, oats and barley between 35 and 40 bushels and wheat about 20 bushels per acre. Timothy and clover hay yield about 1 ton per acre and red clover from 1 to 1 1/4 tons.

The type is normally productive, but crop yields may be increased through soil treatments. The application of farm manure has been found to be of large value on this type, and the turning under of leguminous crops as green manures would also improve the fertility conditions in the soil. The type is acid and in need of lime especially for the growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

**Swamp and Bottomland Soils**

There are 4 swamp and bottomland soil types which together with the gray subsoil phase of the Wabash silt loam, make 5 bottomland areas. Together they cover 8.8 percent of the total area of the county. The soil types are all in the Wabash series.

**WABASH SILT LOAM**

The Wabash silt loam together with the gray subsoil phase, which is very limited in occurrence, is the largest bottomland soil in the county and the fourth largest type. It covers 5.4 percent of the total area. The bottomlands of the Platte River system are composed almost entirely of this soil. In the Grand River system, the Wabash silt loam occurs mainly along the lower courses of Twelvemile Creek and the Grand River.
The surface soil of the Wabash silt loam is a black mellow, rather gritty silt loam 14 inches thick. It is underlaid by a black heavy silt loam or silty clay loam which is somewhat plastic when wet. At a depth of 24 inches the color is somewhat gray, and below this it becomes dark brown, slightly mottled with gray and yellowish-brown with a few rusty brown iron stains. The texture is a heavy silty clay loam or heavy clay which is plastic when wet but becomes friable when dry. In small areas the surface soil varies from a sandy loam to a heavy silty clay loam, and as a rule the subsoil is light or heavy in texture corresponding to the texture of the surface soil. In the small narrow bottomlands there is considerable variation in soil texture, much more so than in the wider flood plains, owing to the wash from the uplands as well as to the sediment deposited by flood waters.

A considerable part of the area in the Wabash silt loam can, in normal seasons, be cropped without overflow damage. The areas of the type are largely in pasture, but the wider bottomlands are cultivated to a considerable extent. Yields of corn and hay are much the same as those secured on the Tama and Muscatine soils on the uplands. Small grains are not grown to any considerable extent, as they are apt to be injured by lodging. The drainage of the type is usually adequate, and the thing which determines whether or not satisfactory crop yields may be secured is largely the matter of overflow. In wet seasons, short season catch crops such as millet, sudan grass, or rape are grown. Corn is planted only in seasons where conditions are favorable.

This type is chiefly in need of protection from overflow to be made satisfactorily productive. It will respond to applications of farm manure and the use of lime is necessary to remedy the acid condition of the soil, especially if legume crops are to be grown. The use of a phosphate fertilizer would be of value, and tests of superphosphate and rock phosphate are recommended.

**WABASH SILT LOAM** (gray subsoil phase) (26b)

The gray subsoil phase of the Wabash silt loam is of minor occurrence in the county, covering 0.4 percent of the total area. It occurs on the better drained parts of the first bottoms and appears to be developing into a terrace type. Most of the small areas are found on the first bottom of the Grand River and Twelvemile Creek.

The gray subsoil phase of the Wabash silt loam is similar to the typical soil except that the layer between an average depth of 12 to 34 inches is more gray and somewhat compact. In some places this gray layer approaches the floury character of the similar layer in the Chariton and Calhoun soils. In most places the gray color is sprinkled, stained or coated over the surface of the soil particles. The subsoil below a depth of 28 or 30 inches is a silty clay loam mottled with...
gray or rusty brown iron stains. When dry, the soil in this layer becomes slightly tough and compact.

The areas in this phase of the typical soil are well protected from overflow and most of the type is cultivated. General farm crops are grown and yields are very similar to those obtained on the typical Wabash silt loam. The type will respond to applications of farm manure, the use of lime to correct acidity and the application of a phosphate fertilizer.

**Wabash Loam (49)**

The Wabash loam is the second largest bottomland type, covering 6.1 percent of the total area. Most of the areas of the type are on the bottomlands of the Grand River, Twelvemile and Threemile creeks.

The surface soil of the Wabash loam is a black mellow loam extending to a depth of 8 to 10 inches. Below this point the soil is more silty and less loamy and slightly less black in color. At a depth of about 25 inches the subsoil is a dark brown heavier textured silty clay loam. It is generally much more loamy than the subsoil of the Wabash silt loam. Faint mottlings occur in a few places in this layer. The surface soil and subsoil of the type vary greatly in texture in different areas. In some places the surface soil may be a fine sandy loam and the subsoil rather sandy and porous. In other areas the surface soil and subsoil are both a loam showing little difference in mellowness and structure, but the color of the subsoil is a dark brown.

Most of the type is in pasture, some of it being in woodland. Under cultivation, corn is the chief crop grown and yields are very similar to those obtained on the Wabash silt loam. The soil is well drained, and yields are satisfactory except where the land is subject to frequent overflow. The type is chiefly in need of protection from overflow if it is to be made more satisfactorily productive. It will respond to applications of farm manure or the turning under of leguminous green manures. It is acid and in need of limestone, and the use of a phosphate fertilizer would be very desirable, where cultivated crops are grown.

**Wabash Silty Clay Loam (48)**

The Wabash silty clay loam is a minor type, covering 0.2 percent of the total area. Most of it is found in the bottomlands of the Grand River. The largest area is in Section 2 of Dodge Township. Small areas are found along the Platte River, in Section 30 of Douglas Township, in sections 3 and 33 of Platte Township, along Twelvemile Creek in Section 34 of Union Township and in Section 17 of Pleasant Township.

The surface soil of the Wabash silty clay loam is a very black heavy silty clay loam, somewhat plastic when wet but friable when moist. Below a depth of
10 inches the material is a heavier textured silty clay a little lighter in color than the surface soil and mottled with gray and rusty brown iron stains. When wet the soil is plastic, and when dry it is very tough and difficult to pulverize. Below a depth of 20 inches the mottling is more intense.

A part of the soil is under cultivation, but most of it is in pasture. The yields secured on the type when it is well drained to protect it from overflow are much the same as those secured on the Wabash silt loam. The type is chiefly in need of drainage and protection from overflow to be made productive. The application of farm manure is of value on the drained areas, improving the physical condition of the soil and bringing about better conditions for crop growth. If the land is plowed when too wet, the surface soil is apt to be cloddy. The addition of manure will permit the preparation of a better seedbed, although it is important even under such treatment that the soil be plowed and cultivated when in the proper condition of moisture so that it will not break into clods. The use of lime is necessary on the type as it is acid in reaction and the application of a phosphate fertilizer would undoubtedly be of value.

**WABASH FINE SANDY LOAM (62)**

The Wabash fine sandy loam is a minor type, covering 0.1 percent of the total area. The only area mapped in the county is on the north county line along the Grand River adjoining the area of this same soil in Madison County. Small strips occur in several places along the channels of the Grand River and other main streams, but they are so narrow and of such variable texture that they are included with the Wabash loam or Wabash silt loam on the map.

The surface soil of the Wabash fine sandy loam is a loose, very friable sandy loam, dark colored but not so black as the Wabash silt loam. The only changes in the soil at the lower depth are that there is a somewhat lighter color and heavier texture to the soil. In general the subsoil is in dark brown loam, but in places at a depth of 3 or 4 feet it is somewhat sandy approaching the loose sandy character of the subsoils of the Cass series.

Practically none of this type is under cultivation. It is utilized for pasture, much of it being in woodland pasture. If cultivated, the type would need to be protected from overflow, and when this protection is provided satisfactory crop yields may be secured. The type will respond in a very large way to applications of farm manure and the turning under of leguminous crops as green manures. The use of lime is necessary on the type as it is acid in reaction. The addition of a phosphate fertilizer would also undoubtedly be of value, and tests of superphosphate are recommended.
APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proved value are suggested.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the

Map of Iowa showing the counties surveyed.
fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant
evidence at hand to prove that the best possible yields of certain crops are not being obtained
in many cases because of the lack of necessary plant foods or because of the lack of proper
conditions in the soil for the growth of plants and the production, by bacteria, of available
plant food.

Proper systems of farming will insure the production of satisfactory crops, and the mainta-
ence of permanent fertility and the adoption of such systems should not be delayed until the
crop yields are much lower, for then it will involve a long, tedious and very expensive
fight to bring the soil back to a fertile condition. If proper methods are put into operation while
comparatively large amounts of certain plant foods are still present in the soil, it is
relatively easy to keep them abundant and attention may be centered on other elements likely
to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be sum-
murized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil
in a favorable condition for crop production, largely because they help control the moisture.

The moisture in soils is one of the most important factors governing crop production. If the
soil is too dry, plants suffer for lack of water necessary to bring them their food and also for
lack of available plant food. Bacterial activities are so restricted in dry soils that the produc-
tion of available plant food practically ceases. If too much moisture is present, plants likewise
refuse to grow properly because of the exclusion of air from the soil and the absence of avail-
able food. Decay is checked in the absence of air; all beneficial bacterial action is limited and
accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of
excessive moisture in restricting plant growth by stopping aeration and limiting beneficial
decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess
of water may be removed from the soil by drainage, and the amount of water present in the
soil may be conserved during the periods of drouth by thorough cultivation or the maintaining
of a good mulch. The need for drainage is determined partly by the nature of the soil, but
more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam
will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is
sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and
also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility
out of a soil much more rapidly than a rotation of crops. One of the most important farm
practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis
suited to the soil, climatic, farm and market conditions. The choice of crops is so large that
no difficulty should be experienced in selecting those suitable for all conditions.

There are a number of explanations of the value of rotations. It is claimed that crops in
their growth produce certain substances called “toxic” which are injurious to the same crop,
but have no effect on certain other crops. In proper rotations the time between two different
crops of the same plant is long enough to allow the “toxic” substances to be disposed of in
the soil or made harmless. This theory has not been commonly accepted, chiefly because
of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these
“toxic” substances could be large enough to bring about the effects evidenced in continuous
cropping.

But, whatever the reasons for the bad effects of continuous cropping, it is evident that for
all good systems of farming some definite rotation should be adopted, and that rotations should
always contain a legume, because of the value of such crops to the soil. In no other way can
the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the
use of legumes, either as regular or “catch” crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satis-
factory crops are to be secured. Humus not only keeps the soil in the best physical condition
for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus
may always be considered a reliable indication of the presence of much nitrogen. This nitro-
gen does not occur in a form available for plants, but with proper physical conditions in the
soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus,
is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which
produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of the soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is not possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions and through a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and superphosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Subsection.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials through leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological force which brought about the formation of the various soil areas.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet of earth debris left after the ice of such glaciers melts, is called "glacial till" or "drift," and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "niggerheads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wis-
The principal soil areas of Iowa.

Map showing the principal soil areas in Iowa.

Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different from the present. These loess soils are very porous in spite of the fine texture, and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

The soil survey by counties

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thorough and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.
GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, although some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:

Organic matter — All partially destroyed or decomposed vegetable and animal material.
Inorganic matter —

- Stones — over 32 mm.*
- Gravel — 32—2.0 mm.
- Very coarse sand — 2.0—1.0 mm.
- Coarse sand — 1.0—0.5 mm.
- Medium sand — 0.5—0.25 mm.
- Fine sand — 0.25—0.10 mm.
- Very fine sand — 0.10—0.05 mm.
- Silt — 0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats — Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams — 15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks — 25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays — Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams — 20 to 30 percent clay and more than 50 percent silt.

Clay Loams — 20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams — 20 percent clay and more than 50 percent silt mixed with some sand.

Loams — Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays — 20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams — More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams — More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand — More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand — More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand — More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

* 25mm. equals 1 in. † Bureau of Soils Handbook.
Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.
Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.
Gravels—More than 50 percent very coarse sand.
Stony Loams—A large number of stones over 1 inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact map of the county.
IOWA AGRICULTURAL EXPERIMENT STATION
PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA
(Those followed by a * are out of print, but are often available in public libraries.)

No. BULLETINS
78 Drainage Conditions in Iowa.*
92 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
98 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.*
150 The Fertility in Iowa Soils.*
150a The Fertility in Iowa Soils (Popular Edition).*
151 Soil Acidity and the Liming of Iowa Soils.*
151a Soil Acidity and the Liming of Iowa Soils (Abridged).*
157 Improving Iowa's Peat and Alkali Soils.*
161 Maintaining Fertility in the Wisconsin Drift Soil Areas of Iowa.*
157 Rotation and Manure Experiments on the Wisconsin Drift Soil Areas.*
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191 Reclaiming Iowa's Push Soils.
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242 Inoculation of Non-Legumes.*
242a Inoculation of Non-Legumes (Abridged).
248 The Management of Peat and Alkali Soils in Iowa.
259 Experiments with Fertilizers on Some Iowa Soils.
276 A Soil Management Program for Carrington Loam.
280 A Soil Management Program for Grundy Silt Loam.

CIRCULARS
2 Liming Iowa Soils.*
7 Bacteria and Soil Fertility.*
9 The Inoculation of Legumes.*
9 Farm Manures.*
10 Green Manuring and Soil Fertility.*
15 Testing Soils in Laboratory and Field.*
24 Fertilizing Lawn and Garden Soils.
44 Soil Inoculation.
51 Soil Surveys, Field Experiments and Soil Management in Iowa.*
58 Use of Lime on Iowa Soils.*
92 Iowa Soil Survey and Field Experiments.*
106 The Pasture Problem in Iowa.*
130 The Use of Fertilizers on Iowa Soils.*
102 Inoculation of Legumes.*

RESEARCH BULLETINS
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5 Some Bacteriological Effects of Liming.*
5 Influences of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
9 Bacteria at Different Depths in Some Typical Iowa Soils.*
11 Amino Acid and Acid Amides as Source of Ammonia in Soils.*
11 Methods for the Bacteriological Examination of Soils.*
13 Bacteriological Studies of Field Soils. III.*
17 The Determination of Ammonia in Soils.
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25 Bacterial Activities and Crop Production.*
26 Studies of Sulfonation.
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44 The Effect of Certain Alkali Soils on Ammonification.
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58 Nitrification in Acid Soils.
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159 The Measurement of the Degree of Saturation of Soils with Bases.
144 Methods for Determining Root Carbon Dioxide Production in Soil.
143 Some Chemical and Bacteriological Effects of Various Kinds and Amounts of Lime on Certain Southern Iowa Soils.