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SOIL SURVEY OF IOWA JOHNSON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils



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June, 1923
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June, 1923

Soil Survey Report No. 32

SOIL SURVEY OF IOWA

Report No. 23—JOHNSON COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, T. H. Benton
and G. H. Artis



Fig. 1—A typical farmstead in Johnson county.

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JOHNSON COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman,
T. H. Benton and G. H. Artis.

JOHNSON COUNTY is located in eastern central Iowa in the third tier of counties west of the Mississippi river and in the fourth tier north from the Missouri state line. It is partly in the Mississippi loess soil area and partly in the

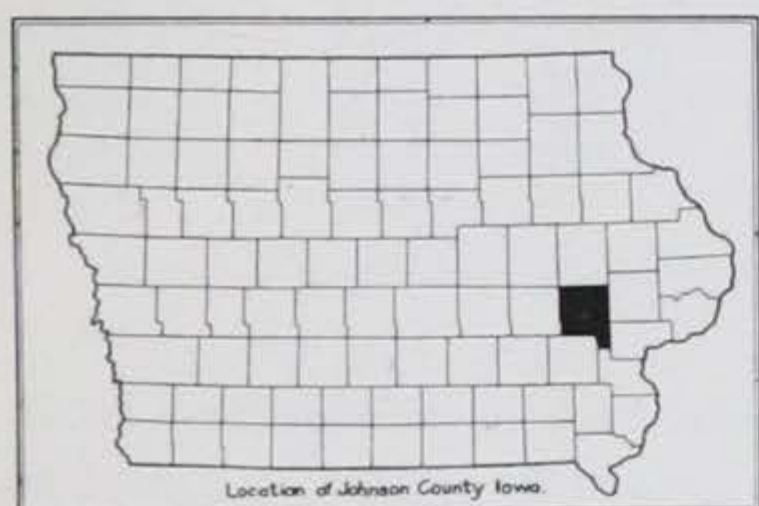


Fig. 2—Location of Johnson county, Iowa.

Iowan drift and the soils are therefore of loessial and glacial origin.

The total area of Johnson county is 390,400 acres and 351,721 acres, or 90 percent, is in farm land. The total number of farms is 2,491 and the average size, 141 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the utilization of the farm land of the county:

Acreage in general farm crops.....	200,096
Acreage in pasture.....	128,477
Acreage in farm buildings, feed lots and public highways.....	13,414
Acreage in waste land.....	4,460
Acreage in crops not otherwise listed.....	419

THE TYPE OF AGRICULTURE IN JOHNSON COUNTY

The type of agriculture practiced in Johnson county is either livestock farming or a system of general farming. The feeding of hogs is the most important livestock industry, but cattle feeding is also practised extensively and the dairy industry is of considerable importance. Some feeding of sheep is also practiced. The livestock industries are more extensively developed in the northern and western townships while general farming is more common in the southern townships, particularly the southeastern townships. Some trucking is practiced, but the industry is not extensively developed. The trucking areas are mainly in the northeastern corner of the county and just south of Iowa City. Melons are the chief crop grown.

There is a considerable area of waste land in the county, much of which might be reclaimed and made productive. General recommendations along this line cannot be given as the causes of infertility are so variable. In a later section of this report, however, attention will be called to the methods which may serve to reclaim unproductive, waste areas of individual soil types. Advice regarding the methods most desirable in special cases will be given by the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE FARM CROPS GROWN IN JOHNSON COUNTY

The general farm crops grown in Johnson county in the order of their importance are corn, hay, oats, potatoes, wheat, alfalfa, rye and barley. The acreage, yield and value of these crops in Johnson county are given in table I.

*See Soil Survey Report of Johnson County, Iowa, by W. E. Tharp of the U. S. Dept. of Agriculture and G. H. Artis of the Iowa Agricultural Experiment Station.

TABLE I. ACREAGE, YIELD AND VALUE OF CROPS GROWN IN JOHNSON COUNTY, IOWA*

Crop	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average Price	Total value of crops
Corn	100,000	28.43	47.0	4,700,000	\$0.30	\$1,410,000
Oats	49,000	13.93	29.0	1,421,000	0.23	326,830
Winter wheat	1,950	0.55	20.0	39,000	0.90	35,100
Spring wheat	370	0.10	14.0	5,180	0.87	4,506
Barley	600	0.17	26.0	15,600	0.42	6,552
Rye	800	0.22	15.0	12,000	0.73	8,760
Potatoes	966	0.27	66.0	63,756	1.40	89,258
Tame hay	45,200	12.85	1.4	63,280	9.08	574,582
Wild hay	950	0.27	1.15	1,092	7.47	8,157
Alfalfa	260	0.07	2.75	715	12.92	9,237
Pasture	128,477	36.52	....	.....	.....	.....

*Iowa Yearbook of Agriculture 1921.

Corn is the most important crop in the county both in acreage and value. Over one-quarter of the total farm land of the county is devoted to this crop. Average yields of 47 bushels per acre are secured, as reported in 1921. Much of the corn produced is used for feed on the farms. In the northern and western townships, probably less than 10 percent is sold. In the southeastern townships more of the crop is sold at the local elevators and shipped out of the county. Some corn is used for silage and in 1921 there were 413 silos in the county.

Hay is the second crop in value in the county, and the third in acreage. It occupies a slightly smaller acreage than oats but has a higher value. Tame hay, consisting mainly of clover and timothy, is the chief hay crop. Only a very small area is in wild hay. Average yields of tame hay amount to 1.4 tons per acre. Some clover is grown alone and some timothy is also grown alone. Clover seed is produced on some farms and occasionally timothy seed is produced.

Oats rank third in value and are grown on practically all farms. Average yields of 29 bushels per acre are reported. As was noted in the case of corn, there is only a small sale of oats in the northern and western townships, but in the southeastern part of the county a much larger portion of the crop produced is sold and shipped out of the county. The oat crop is usually "disced in" on corn ground. The straw is not burned and few farmers make a regular practice of selling it. Most of the straw produced is used for feed or bedding and returned to the land with the manure.

Wheat was formerly grown on a rather extensive area but the acreage in this crop has steadily declined and it is now grown to only a small extent in the county. Winter wheat is produced to a larger extent than spring wheat, yields of the former amounting to 20 bushels per acre and of the latter to 14 bushels. The total value of the wheat crop is not large and practically all of the wheat produced is sold.

Potatoes are grown quite extensively, with average yields of 66 bushels per acre. The major portion of the crop is sold on the local markets or utilized for home consumption.

Alfalfa is being grown on an increasing acreage and very satisfactory yields are usually secured. Average yields reported in 1921 amounted to 2.75 tons per

acre. This crop will undoubtedly become more important in Johnson county as more is learned regarding the methods of preparing the soil and handling the crop. Liming is necessary in most cases and inoculation should be practiced and when the seed bed is well prepared and good seed is used, large crop yields should be secured.

Barley is a minor crop in the county, yielding 26 bushels per acre on the average. Rye is grown on a small area with average yields of 15 bushels per acre. Buckwheat and sorghum are other crops of minor importance. Some sweet corn is grown and truck crops, particularly melons, are raised in the northeastern corner of the county and south of Iowa City. Fruit growing is practiced on a small scale, chiefly to supply the home demand, and is not of commercial importance.

THE EXTENT OF JOHNSON COUNTY'S LIVESTOCK INDUSTRY

The extent to which the livestock industry is developed in the county is indicated in the following figures taken from the Iowa Yearbook of Agriculture for 1921:

Horses, all ages.....	13,298
Mules, all ages.....	1,330
Swine, on farms July 1, 1921.....	144,690
Swine, on farms Jan. 1, 1922.....	109,792
Cattle, cows and heifers kept for milk.....	9,131
Cattle, other cattle not kept for milk.....	34,156
Cattle, all ages.....	43,287
Sheep, all ages on farms Jan. 1, 1922.....	7,780
Sheep, shipped in for feeding, 1921.....	119
Sheep, total pounds of wool clipped.....	63,208
Poultry, total number on farms Jan. 1, 1922.....	346,383
Poultry, number dozen eggs received, 1921.....	1,354,925

The sale of fattened hogs provides the largest source of income on most of the farms and swine feeding is the most extensively developed livestock industry in the county. Cattle raising and feeding is practiced to a considerable extent and sheep feeding is also practiced, but not so commonly.

Dairying is becoming a more important industry, especially in the vicinity of Iowa City. The Holstein is the favorite breed in this section. There are also Hereford, Shorthorn and Angus herds in other parts of the county. The dairy products are disposed of mainly at the local creameries or in Iowa City.

The poultry industry is developing and poultry products are gradually coming to be considered of more importance as sources of farm income. More attention is being given to poultry on the farms and they are being handled more profitably. The poultry products are mainly disposed of on the local markets.

The price of land in Johnson county varies considerably, depending upon the location with reference to towns, railroads and marketing facilities in general and also upon the topography, soil conditions and improvements on the farms. The range in land values is from \$50 up to \$250 or \$300 per acre, and even higher in exceptional cases. The better upland farms average about \$200 to \$250 per acre.

THE SOIL FERTILITY SITUATION IN JOHNSON COUNTY

Crop yields are in general, fairly satisfactory in Johnson county, but they may be increased by better methods of soil treatment and farm incomes may be

made correspondingly greater. Some areas are in need of drainage and in such cases tiling is the first treatment required if large crops are to be secured.

All of the soils in the county are acid in reaction and in need of lime and if the largest possible crops, especially of legumes, are to be grown liming must be practiced. Much farm experience and many experiments have shown very definite profits from the application of lime in necessary amounts, to acid soils. All the soils should be tested for acidity and lime should be applied in amounts shown to be necessary according to the tests.

The need for organic matter and nitrogen is not pronounced in the case of all the soils. In fact some of the types seem to be fairly well supplied with these constituents. In several cases, however, the soils are not properly supplied and fertilizing materials supplying organic matter are very necessary. The application of farm manure is of particularly large value on the soils needing organic matter, but the richer, blacker soils also respond profitably to the use of manure. It is the most valuable fertilizer that can be used in the county and should be considered the basic soil treatment on all livestock farms. Experiments and farm experience demonstrate the importance of the use of manure. Where farm manure is not available for use in sufficient amounts, leguminous green manures may be employed to supply the necessary organic matter and nitrogen. Crop residues should always be carefully utilized to aid in keeping up the supply of these constituents.

The soils of the county are quite generally low in phosphorus and phosphorus fertilizers will certainly be needed in the future if they do not prove of value at the present time. There is evidence, however, that a phosphorus carrier may be profitably employed in many cases now. The supply of available phosphorus in the soils is evidently insufficient in many cases for the best crop growth. Acid phosphate or rock phosphate may be used to supply phosphorus and farmers are urged to test the value of these two materials on a small scale on their farms and thus determine for their own conditions the need of phosphorus and which fertilizer should be employed. The experiments which are under way on the main soil types occurring in the county do not yet show whether the acid phosphate or the rock will prove the most profitable. They do, however, indicate that phosphorus is the limiting factor in crop growth in many instances and that one or the other phosphate may bring about definite increases in crop yields.

Erosion occurs to some extent in the county and several of the soil types are seriously washed and gullied. Care should be taken to prevent and control erosion and to fill gullies, if much farm land is to be kept from a serious reduction in crop producing power. From among the suggestions given later in this report some method may be chosen which will protect the soil from washing and which will reclaim seriously eroded areas.

THE GEOLOGY OF JOHNSON COUNTY

The bed rock underlying the soils of Johnson county is so deeply buried under the deposits of glacial drift and loess that it has no effect on the soil formations. Hence the geological history of the county need be considered only very briefly.

At least twice during the glacial age, great sheets of ice swept down from the

north and covered the county in whole or in part. The earliest glacier, known as the Kansan, extended over the entire surface of the county, and, upon its retreat, left behind a thick deposit of debris or glacial till. This Kansas drift material consists of a blue clay containing numerous boulders of varying size. Thru weathering, the material has been oxidized to a reddish-brown color, to varying depths, below which there is a layer of a yellowish boulder clay merging into the unchanged blue clay of the original drift.

Practically all of the Kansan till, except in the river valleys, is covered by the later deposits of drift or loess, but erosion has occurred extensively in some areas and there has been such a large removal of the surface soil that there are two soil types in the county which are derived mainly from the Kansan drift material. These soils are the Shelby loam and the Shelby silt loam, both minor soil types in the county. There are other areas where the loessial covering has been removed partially and the drift appears in the 3-foot soil section, but these are of local occurrence, and so small in extent that they are included with the loessial types.

The Iowan glacier entered the county from the north in three areas. The first covers Big Grove and Cedar townships and is called the Solon plain. The second extends into the county from the northwestern corner, in a southeasterly direction, passing the town of North Liberty. This is called the North Liberty plain. A third area, smaller in extent, is found in the north central part, including the town of Shueyville. The Iowan drift material is generally a light yellow silty clay to sandy clay, containing some boulders and gravel. The deposit is quite variable in depth but it is relatively thin compared with the underlying Kansan drift.

The soils of the Carrington series are derived from this Iowan drift deposit, two types being mapped, the Carrington silt loam, which is quite extensive in area, and the fine sandy loam, which is of minor occurrence.

The upland soils of the county are mainly derived from the loessial deposit which was made at some previous geological time when climatic conditions were very different than at present. Most of the Kansan till was covered by the loess and much of the Iowan drift likewise has a loessial covering. Over 70 percent of the soils of the county are loessial in origin and in addition the terraces and bottomland soils are made up mostly of loessial material. Only 8.9 percent of the soils are derived from the Kansan and Iowan drift deposits. Along both sides of the Iowa and Cedar rivers the loessial deposits are 10 to 15 feet in depth, generally passing below that point into a yellowish sand which in turn rests upon the drift clay. In many cases the loess rests directly on the glacial clay and the sand is absent. On the smoother areas of the Clinton silt loam and in the Tama silt loam areas west of the Iowa river, the loess is four or five feet in depth on the slopes to 10 feet deep on the tops of flat areas. In the southwestern part of the county the loess is shallower than that in the western and northern parts, and the reddish-brown Kansas till often shows in the road cuts.

The deeper loess is a pale-yellow or buff colored deposit, fine grained, silty and porous. It contains no pebbles or boulders. It possesses the property of

standing in straight cuts, but is subject to some erosion, particularly on steep hillsides. The loess in the southwestern part of the county, often shows mottling at the lower depths, owing to poorer aeration. In other parts of the county in the deeper loess, mottling rarely occurs.

The Clinton, Tama, Muscatine, Knox and Scott soils on the uplands are derived from the loess, the types of the first three series being the most important types in the county. The Knox and Scott soils are very minor in area. The Clinton silt loam has been developed under forested conditions, where there has been a small accumulation of organic matter. The Tama silt loam has been formed on the prairies and organic matter has accumulated so that the soil is dark in color. The Muscatine silt loam occurs where the drainage conditions have been poor on the prairies and there has been a larger accumulation of plant remains and less decomposition.

Terraces or second bottoms are found on a considerable area in the county, occurring along most of the streams. The greater part of these old water-laid deposits is made up of silts and silty clays, but in many areas they are quite sandy. Low mounds of sandy soils occur on the south and east sides of the present flood plains and they often have the appearance of dunes. The higher terraces are classified in the Waukesha, Jackson and Buckner series, while the lower, more recent terraces are included in the Bremer and Chariton series. The latter types show less oxidation in the subsoil and are characterized by mottlings and heavy textures.

The bottomlands in the county are developed in narrow areas along the various streams, the total area amounting to 10.1 percent of the total area of the county. The soils are classified in the Wabash, Cass and Sarpy series. The former have heavy subsoils while the two latter have sandy subsoils. All the bottom soils are subject to overflow and hence are modified in general characteristics by deposits left from the overflow. Wide variations often occur in surface soil conditions among the bottomland types.

PHYSIOGRAPHY AND DRAINAGE

The original surface of Johnson county was a broad smooth plain, sloping gently toward the southeast. The deposits of drift and loess were laid down upon this plain and the topographic features of the county at present are the result of the erosion occurring in these deposits.

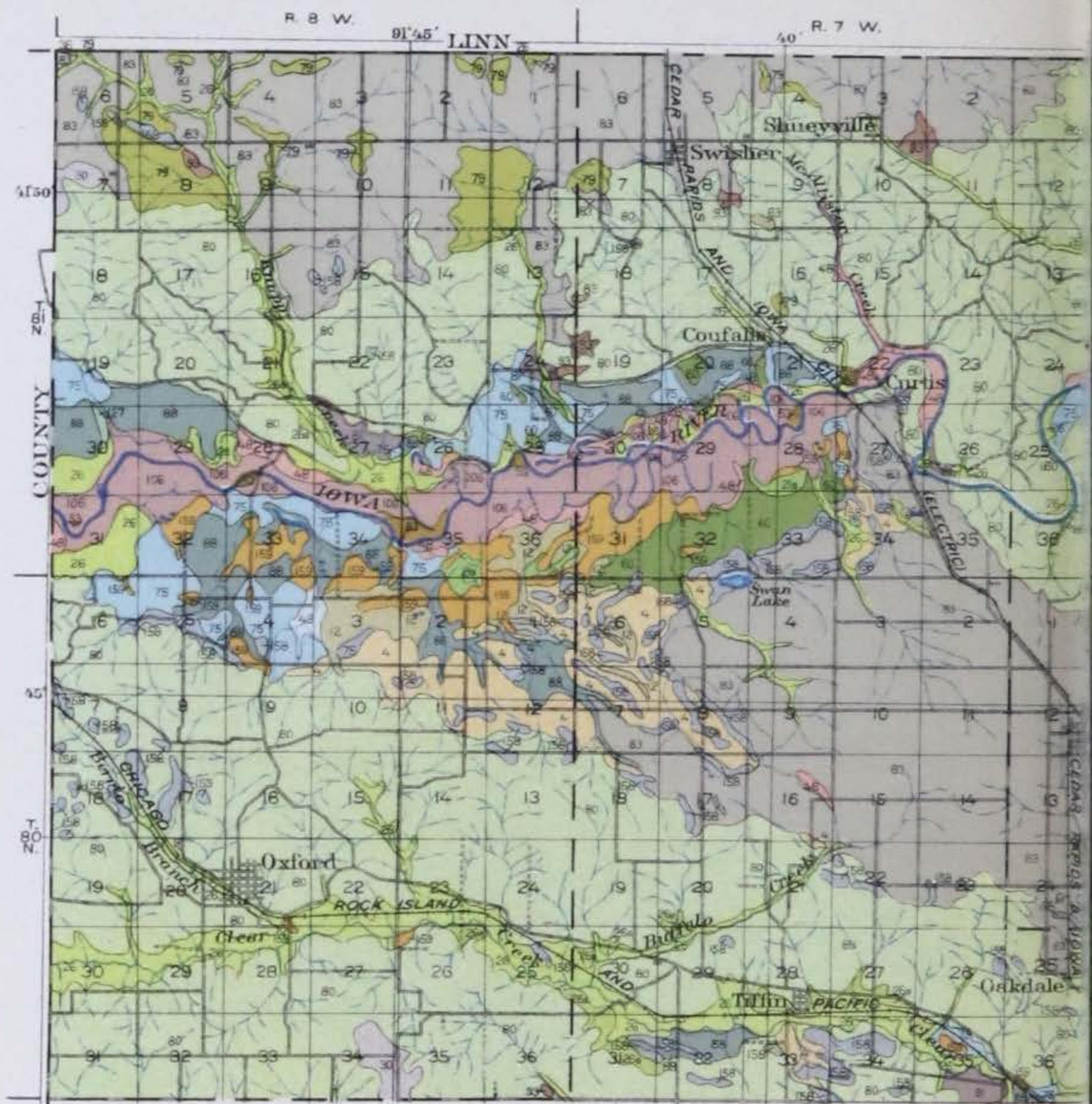
The three areas of Iowan drift soils which have been described are in general comparatively smooth to gently rolling. They are bordered by low ridges. In the northwestern part of Madison township the North Liberty plain is broken by a group of sand hills or ridges, often 50 feet above the drift plain, covering several square miles in area. North of the bottoms along the Iowa river which cuts thru the North Liberty drift plain, the loess hills rise abruptly from the river and the topography is rough for two to three miles until the Iowan drift upland is reached.

South of Iowa City, thruout the entire southern part of the county, the topography is characteristic of the Kansan drift areas. The uplands are rolling as they approach the streams but the areas in between the streams are generally gently undulating to almost flat. The slopes to Clear creek and Old Man creek

SOIL MAP OF J NORT

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut in charge Soil Survey

Thomas D. Rice, Ins
Soils surveyed by W. E. Tharp c
in charge, and G. H. Artis of the



LEGE

DRIFT SOILS

- 83 Carrington silt loam
- 4 Carrington fine sandy loam
- 79 Shelby loam
- 93 Shelby silt loam

LOESS SOILS

- 80 Clinton silt loam
- 120 Tama silt loam

- 30 Muscatine silt loam
- 158 Knox sand
- 154 Scott silt loam

TERRACE SOILS

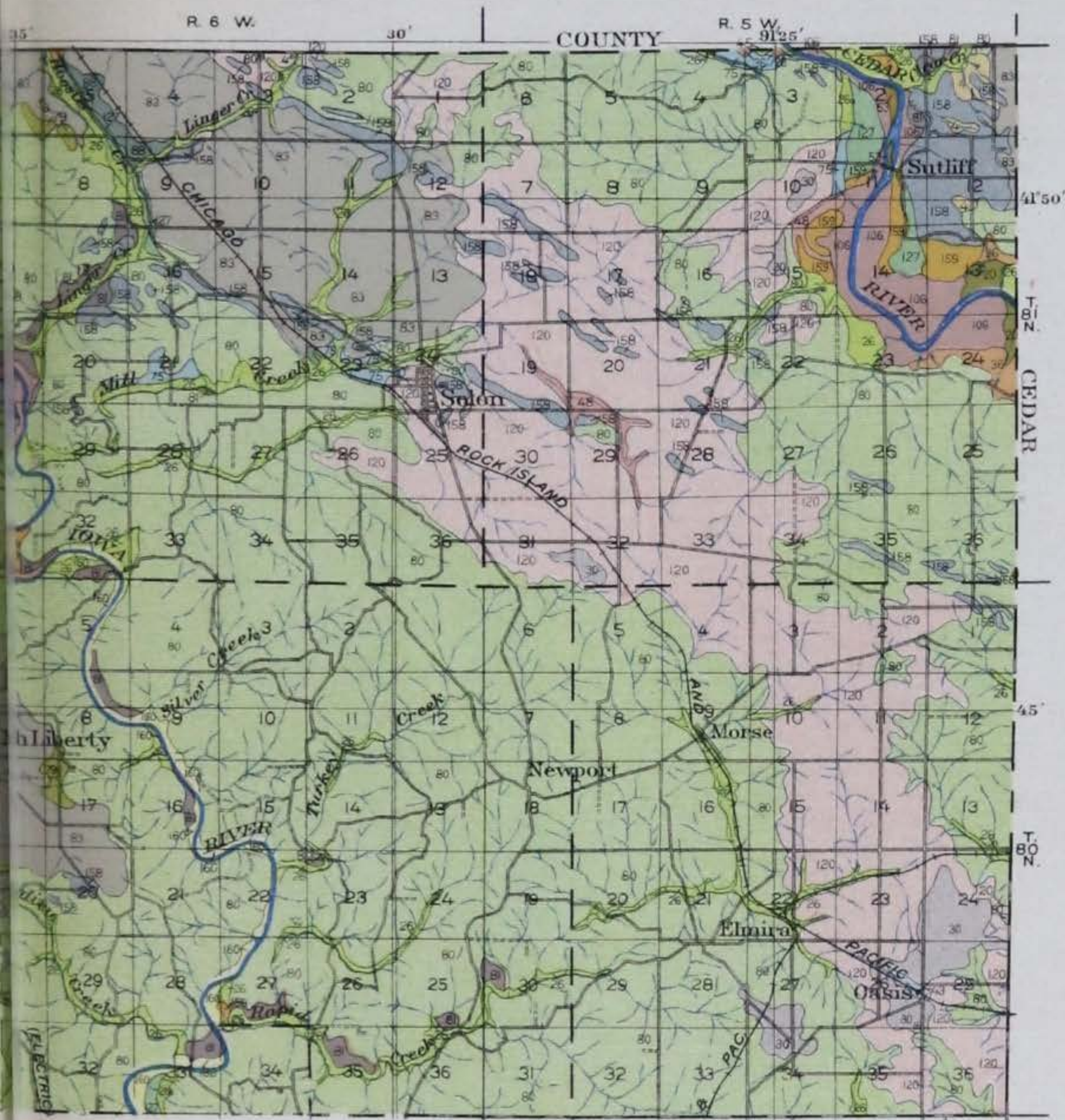
- 75 Waukesha silt loam
- 98 Bremer silt loam
- 43 Bremer silty clay loam
- 159 Buckner loamy sand

Scale: 1

NSON COUNTY IOWA

Northern Division,
U. S. Department of Agriculture,
Soil Conservation Service, Agricultural Experiment Station.

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtis, Director. W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in charge.



A. H. COEN & CO. BALTIMORE

- 81 Jackson silt loam
- 60 Waukesha loam
- 127 Waukesha sandy loam
- 12 Bremer loam
- 36 Buckner silt loam
- 105 Chariton silt loam
- 45 Buckner fine sandy loam

SWAMP AND BOTTOMLAND SOILS

- 26 Wabash silt loam
- 26^A Wabash silt loam (colluvial phase)
- 106 Cass silt loam
- 48 Wabash silty clay loam
- 160 Sarpy sand
- 20 Meadow
- 21^A Muck
- 53 Riverwash

2 1/2 miles

are not so abrupt as in the loess areas north of Iowa City. The greater part of the upland in Sharon and the western part of Washington townships is nearly level in topography. East of the Iowa river in the area south of Iowa City, the uplands are smoother than is the case west of the river. There is a gentle roll near the streams, but the uplands are mainly level to flat.

The loess hills along the Iowa river and west of the Cedar river, along Clear creek and other streams in the county, are probably the most striking in topographic features. These hills rise 40 to 90 feet above the plain level, and much erosion has occurred in them so that the surface is a succession of hills and

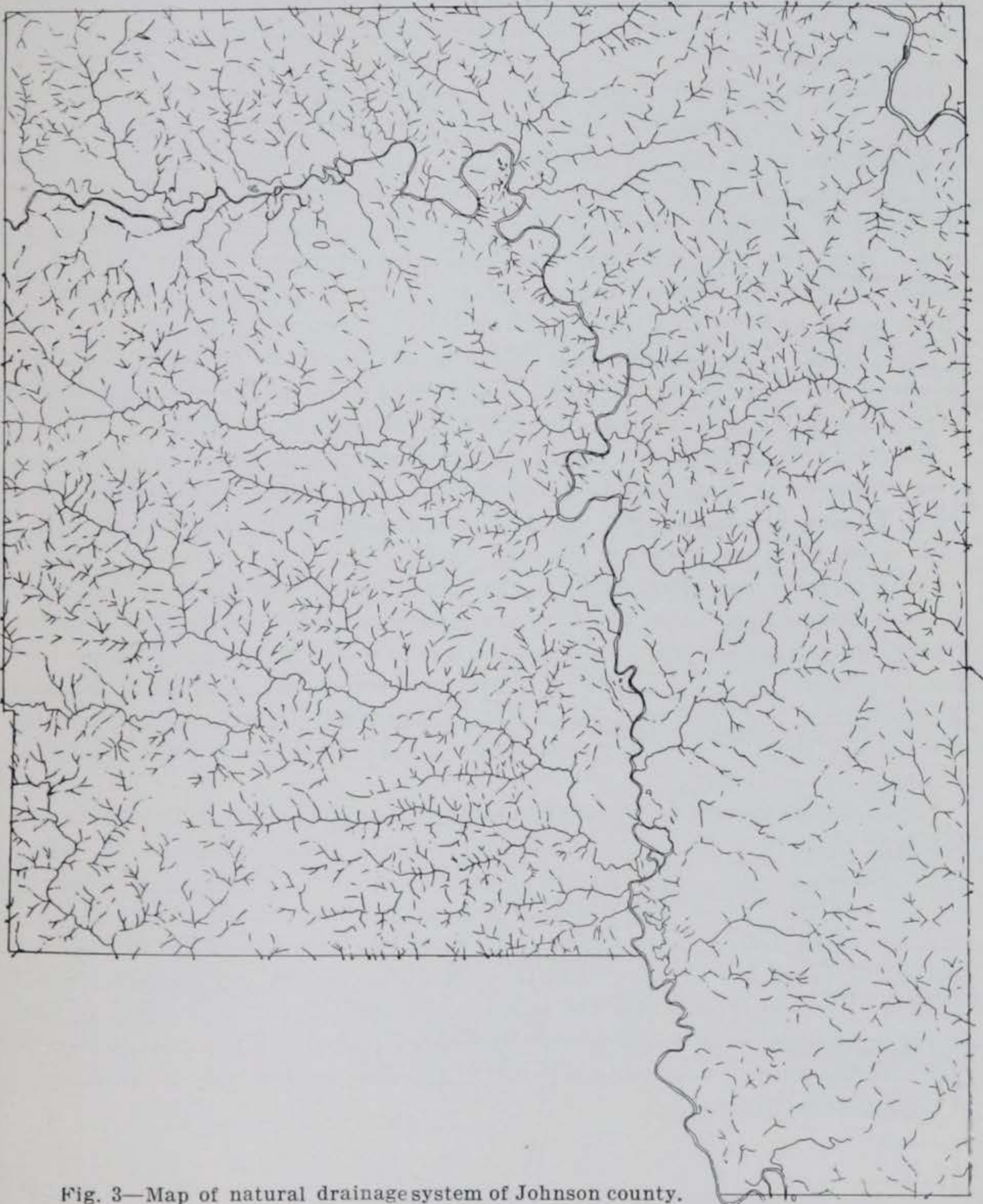


Fig. 3—Map of natural drainage system of Johnson county.

ravines. The hills are sharply defined and the ravines are abrupt and steep sided. They follow the course of the Iowa river from the point where it enters the county, extending as far as Iowa City, and they occur in less pronounced hills and ravines along other streams. Originally these hills were forested but the smoother areas have been cleared and brought under cultivation. Extensive wooded areas remain north of Iowa City and small forests occur on eroded slopes where cultivation is difficult and undesirable because of the serious erosion which is apt to occur.

The drainage of the county is brought about by the Cedar and the Iowa rivers with their tributaries. The Cedar river is the larger stream, but it drains only about 30 square miles in the northeastern corner of the county and has few tributaries.

The Iowa river with its tributaries brings about the drainage of most of the county. It enters the county about six miles south of the northwestern corner, flows almost east as far as Curtis and then turns south and flows in that general direction, with many curves, to the southern boundary of the county. In Monroe and Jefferson townships, the valley of the river is about three miles wide. This valley narrows near Curtis to a gorge about one-fourth of a mile in width. Very small areas of bottomland adjoin the river along its course from Curtis south to Iowa City, but below the city the valley again widens to two or three miles. This bottomland is largely made up of low timbered lands, cut by abandoned channels of the river, which changes its course frequently. The terraces along the river average 10 to 20 feet above the flood plains.

The chief tributaries of the Iowa river are Knapp creek, Lingle creek, Turkey creek, Silber creek, Rapid creek, Pardieu creek, Clear creek, Buffalo creek, Deer creek, Ralstop creek, Old Man creek, North Branch creek, Deep creek, Dirty Face creek, Picayune creek and Snyder creek.

Old Man creek and Clear creek are the largest branches of the river and drain the area to the east. For the first seven or eight miles of its course in the county, Old Man creek has a valley about a mile wide. A fringe of timber borders the channel and the hills to the south are quite generally wooded. East of the junction of this creek with North Branch, the valley is narrower and consists of wooded pasture land. Clear creek valley is rather narrow and west of Tiffin it is more or less timbered.

The drainage system of the county is quite adequate as is indicated on the drainage map, but there are some areas where tiling would be of value. The Muscatine silt loam in the loessial upland is frequently poorly drained and the Bremer and Chariton soils on the terraces are usually in need of tiling. Many of the bottomlands are too wet but they are usually in need not only of drainage but of protection from overflow. There may be some small areas in other soil types where the soils are not drained with sufficient rapidity and in such cases tiling would be very desirable. In general, however, it may be said that the soils of the county are fairly well drained and only in local areas is tiling necessary.

THE SOILS OF JOHNSON COUNTY

The soils of Johnson county are grouped into four classes according to their origin and location. These are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from the materials carried by glaciers and left behind on the surface of the land when the glacier retreated. They are extremely variable in composition and contain numerous pebbles and boulders.

Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were quite different than at present. Terrace soils are old bottomlands which have been raised above overflow by a deepening of the river channel or by a decrease in the volume of the streams which deposited them. Swamp and bottomland soils are those occurring in low, poorly drained areas, along streams, and subject to more or less frequent overflow. The extent and occurrence of these groups of soils in Johnson county are shown in table II.

The drift soils cover only a small proportion of the county, 8.9 percent of the total area. The loess soils are the most extensive, covering nearly three-fourths of the total area, 71.9 percent. Terrace types occupy a similar total area to the drift soils and the swamp and bottomland soils are slightly greater in total area, covering 10.1 percent of the county.

There are 24 individual soil types in the county and these with the colluvial phase of the Wabash silt loam and the areas of meadow, muck and riverwash make a total of 28 separate soil areas. There are four drift types, five loess soils, 11 terrace types and eight areas of swamp and bottomland. The areas of the various soil types in the county are shown in table III.

The Clinton silt loam is the most extensive soil type in the county, as well as the largest loess soil, covering 45.9 percent of the total area. The Tama silt loam is the second largest loess type and the second type in the county, covering 18.9 percent of the total area. The Carrington silt loam is the third type in the county in area and the most extensive drift soil covering 7.4 percent of the county. The Wabash silt loam with the colluvial phase is the next type in total area and the largest bottomland soil, covering 5.6 percent of the county. The Muscatine silt loam stands next in area, covering 5.5 percent of the total area of the county. The remainder of the types are all minor in area, the Cass silt loam covering 2.4 percent, the Waukesha silt loam, the largest terrace type, 2.3 percent, the Wabash silty clay loam, 1.6 percent, the Bremer silt loam, 1.9 percent, the Knox sand and the Bremer silty clay loam, each 1.5 percent, the Buckner loamy sand 1.1 percent of the area of the county and the other types all less than one percent.

There are distinct relations evident between these various soil types and the topographic features of the county. The Carrington silt loam is undulating to

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN JOHNSON COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	34,816	8.9
Loess soils	281,152	71.9
Terrace soils	34,944	9.1
Swamp and bottomland soils.....	39,488	10.1
Total.....	390,400	

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN JOHNSON COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
DRIFT SOILS			
83	Carrington silt loam.....	28,864	7.4
4	Carrington fine sandy loam.....	2,816	0.7
79	Shelby loam	1,920	0.5
93	Shelby silt loam	1,216	0.3
LOESS SOILS			
80	Clinton silt loam	179,456	45.9
120	Tama silt loam	73,984	18.9
30	Muscatine silt loam	21,568	5.5
158	Knox sand	5,696	1.5
154	Scott silt loam	448	0.1
TERRACE SOILS			
75	Waukesha silt loam	9,024	2.3
88	Bremer silt loam	7,232	1.9
43	Bremer silty clay loam.....	5,824	1.5
159	Buckner loamy sand	4,352	1.1
81	Jackson silt loam.....	2,944	0.8
60	Waukesha loam	2,688	0.7
127	Waukesha sandy loam	1,024	0.3
12	Bremer loam	960	0.2
36	Buckner silt loam	448	0.1
105	Chariton silt loam	384	0.1
45	Buckner fine sandy loam.....	64	0.1
SWAMP AND BOTTOMLAND SOILS			
26	Wabash silt loam	20,288	5.6
26a	Wabash silt loam (colluvial phase).....	1,664	
106	Cass silt loam.....	9,344	2.4
48	Wabash silty clay loam.....	6,336	1.6
160	Sarpy sand	768	0.2
20	Meadow	448	0.1
21a	Muck	384	0.1
53	Riverwash	256	0.1
	Total	390,400	

slightly rolling and the Tama silt loam is very similar in topography. The Carrington fine sandy loam is more sharply rolling. The Shelby soils are rolling to hilly or even steep. The Clinton silt loam varies from gently rolling in the majority of the areas to rough eroded slopes in some cases. The Muscatine silt loam is level to flat or depressed in topography. The Knox sand is rolling to knobby, occurring in mounds and ridges. The Scott silt loam is flat to depressed in topography. The terrace types are all more or less level in surface characteristics altho some of the older terraces like the Waukesha and Jackson have been modified by erosion and show a gently rolling topography. The bottomland soils are all level in topography and subject to overflow.

THE FERTILITY IN JOHNSON COUNTY SOILS

Samples were taken for analyses from the most important soil types in the county. The Carrington fine sandy loam, the Shelby silt loam, the Waukesha sandy loam, the Buckner silt loam, the Buckner fine sandy loam, the Sarpy sand and the areas of meadow, muck and riverwash were not sampled, owing to their small extent and relative unimportance. The more extensive types were sampled in triplicate and one sample was taken from each of the minor types.

The samples were all taken with the utmost care that they should be entirely representative of the particular types and that all variations due to peculiar local

conditions or previous soil treatments should be eliminated. Samples were taken at three depths, 0-6 2/3", 6 2/3" to 20", and 20" to 40", representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were run for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were followed in the phosphorus, nitrogen and carbon determinations and the Truog qualitative test was used to determine the limestone requirement. The figures given in the tables are the averages of duplicate determinations on all supplies of each type and they represent, therefore, the results from four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is quite variable, ranging from 471 pounds in the Knox sand to 1,610 pounds in the Wabash silt loam. There is no evidence of any relationship between the phosphorus content and the various soil groups, except that the average of the bottomland soils is higher than the average of the upland types which might be expected as there has been less utilization of all plant food in bottomland soils and little crop growth. There are more striking variations within the various groups, among the individual soil types. Certain definite relations appear between the soil series and the phosphorus supply. The Shelby soils are lower than the Carrington types, the Clinton silt loam is lower than the Tama or the

TABLE IV. PLANT FOOD IN JOHNSON COUNTY, IOWA, SOILS
Pounds per acre of two million pounds of surface soil (0-6 2/3")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
83	Carrington silt loam.....	1,082	4,380	54,509	0	6,000
79	Shelby loam	714	1,620	20,256	0	3,000
LOESS SOILS						
80	Clinton silt loam	1,206	3,180	42,056	0	4,000
120	Tama silt loam	1,495	3,400	40,131	0	6,000
30	Muscatine silt loam.....	1,333	4,090	57,603	0	6,000
158	Knox sand	471	840	12,012	0	2,000
154	Scott silt loam.....	754	2,180	25,935	0	6,000
TERRACE SOILS						
75	Waukesha silt loam.....	1,131	1,260	40,950	0	5,000
88	Bremer silt loam.....	1,455	3,760	47,010	0	5,000
43	Bremer silty clay loam.....	1,489	5,640	72,072	0	2,500
159	Buckner loamy sand	592	840	13,104	0	6,000
81	Jackson silt loam	903	2,640	31,941	0	5,000
60	Waukesha loam	943	2,300	27,027	0	4,000
12	Bremer loam	1,400	4,040	51,051	0	4,000
105	Chariton silt loam.....	1,091	3,140	34,398	0	5,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam.....	1,610	3,660	39,585	0	6,000
26a	Wabash silt loam (colluvial phase)	1,347	3,820	49,959	0	8,000
106	Cass silt loam.....	1,306	3,030	37,538	0	4,500
48	Wabash silty clay loam....	1,105	3,300	43,680	0	8,000

Muscatine and the Scott silt loam is very much lower than the other silt loams in the loess group. The Bremer types are the best supplied of the terrace soils, the Waukesha soils are higher than the Buckner types and the Jackson and Chariton soils are slightly lower than the Waukesha soils. The Wabash soils are better supplied than the Cass types on the bottoms but the differences are not great. All these comparisons reflect to a certain extent the characteristics of color, topography or subsoil conditions which serve to distinguish the various soil series. The relationship between the Shelby and Carrington soils is brought about by the fact that the Shelby types are lighter in color and rougher, more hilly in topography. The Muscatine soils are level in topography and blacker in color than the Clinton types and hence are higher in phosphorus. The Tama soils likewise are darker than the Clinton and gently rolling in topography while the Clinton types are mainly strongly rolling to rough and hence there is more phosphorus in the Tama types. Similar comparisons might be noted in the terrace types but it is evident from the above discussion that the characteristics which serve to distinguish soil series indicate roughly the phosphorus supply.

The relationship among types is also of importance, altho it is not possible to make many comparisons in this county owing to the fact that there are not many types mapped in the same series. The Bremer silty clay loam is higher than the silt loam and the latter is higher than the loam. The Waukesha silt loam is higher than the loam. The Wabash silty clay loam, however, is lower than the silt loam. Bottomland types are not satisfactory for comparison owing to the variations which occur in such soils. In general, soils of finer texture are higher in phosphorus than those coarser in texture. Silty clay loams run higher than silt loams and the sandy types run lower than the loams. The Knox sand in this county gives an indication of how low sandy types may go in plant food constituents.

Considering the analyses of all the soils, it is evident that the phosphorus supply in the soils of Johnson county is not high and in many instances this element may be the limiting factor in crop growth. Even where there is a considerable supply of total phosphorus there is no assurance of a production of available phosphorus rapidly enough to keep crops supplied. Where the total content is as low as is the case in many of the soils in this county, there is almost certain to be insufficient available phosphorus produced. Phosphorus fertilizers may be of value on many of the soils in this county at the present time, to judge from the analytical data and the experimental results obtained in the greenhouse while the field tests on the same soil types in other counties confirm this conclusion. There is no question but that phosphorus carriers will be needed in the near future even if they do not show large effects now.

Rock phosphate or acid phosphate may be employed to supply phosphorus deficiencies, the latter giving more immediate effects. Definite recommendations cannot be made, however, as to when phosphorus should be applied nor which material would prove the more profitable. The experimental work now under way by the Soils Section of the Iowa Agricultural Experiment Station will eventually permit of definite conclusions, but it has not been under way long enough to warrant conclusions yet. The indications are that phosphorus



Fig. 4—Purebred herds are common in the county.

may be used economically in many cases and hence farmers are urged to test the need of phosphorus and which fertilizer should be used on their own soils. They may thus learn the most profitable treatment for their soils and by testing on a small area, may determine whether an extensive application of rock phosphate or acid phosphate will pay.

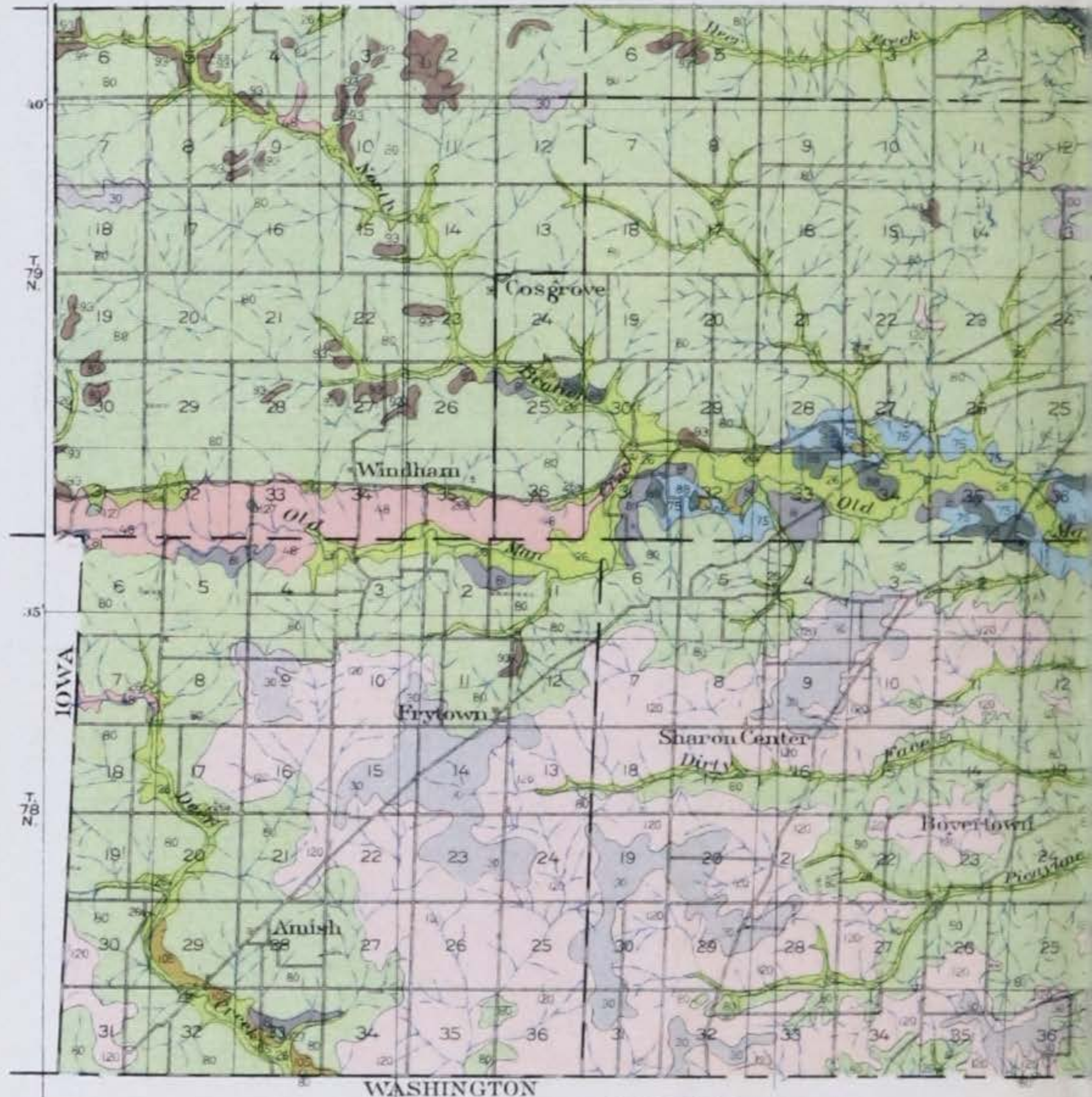
The supply of nitrogen is likewise quite variable, ranging from 840 pounds in the Knox sand and the Buckner loamy sand to 5,640 pounds in the Bremer silty clay loam. As in the case with phosphorus, there seems to be no relation between the soil group and the nitrogen supply except that the bottomland soils average somewhat higher than the other groups. There is a relationship, however, to soil series and to the soil type, just as was noted in the case of phosphorus; again the relations reflect the characteristics of the series. Thus the Carrington soils are higher than the lighter colored, topographically rougher Shelby soils. The Muscatine silt loam is higher than the lighter, more rolling Tama and Clinton types. The Bremer types are higher than the other terrace soils, due to their darker color and more level topography. The Buckner soils run lower than the darker colored terrace soils. Considering type relations, the silty clay loams are higher than the silt loams and the latter surpass the loams. The sandy types are generally poorer in nitrogen than the finer textured types. In general it may be said that dark-colored soils are higher in nitrogen than light colored soils. Level to flat soils are better supplied than rolling types and rough soils are poorest of all. Coarse textured types are lower than fine textured types. Soils like the Clinton which have been developed under forest conditions are lower than soils like the Tama which are formed under prairie conditions. The color, texture and topography, however, are the factors which most readily indicate the nitrogen supply.

The soils of Johnson county as a whole are not deficient in nitrogen, altho in

SOIL MAP OF JOHNSON COUNTY, IOWA

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut in charge Soil Survey

Thomas D. Rice, Insp.
Soils surveyed by W. E. Tharp of the
in charge, and G. H. Artis of the



WASHINGTON

DRIFT SOILS

- Carrington silt loam
- Carrington fine sandy loam
- Shelby loam
- Shelby silt loam

LOESS SOILS

- Clinton silt loam
- Tama silt loam

TERRACE SOILS

- Waukesha silt loam
- Bremer silt loam
- Bremer silty clay loam
- Buckner loamy sand

LEGEND

- Muscatine silt loam
- Knox sand
- Scott silt loam
- Jackson silt loam
- Waukesha loam
- Waukesha sandy loam
- Bremer loam
- Buckner silt loam
- Chariton silt loam
- Buckner fine sandy loam

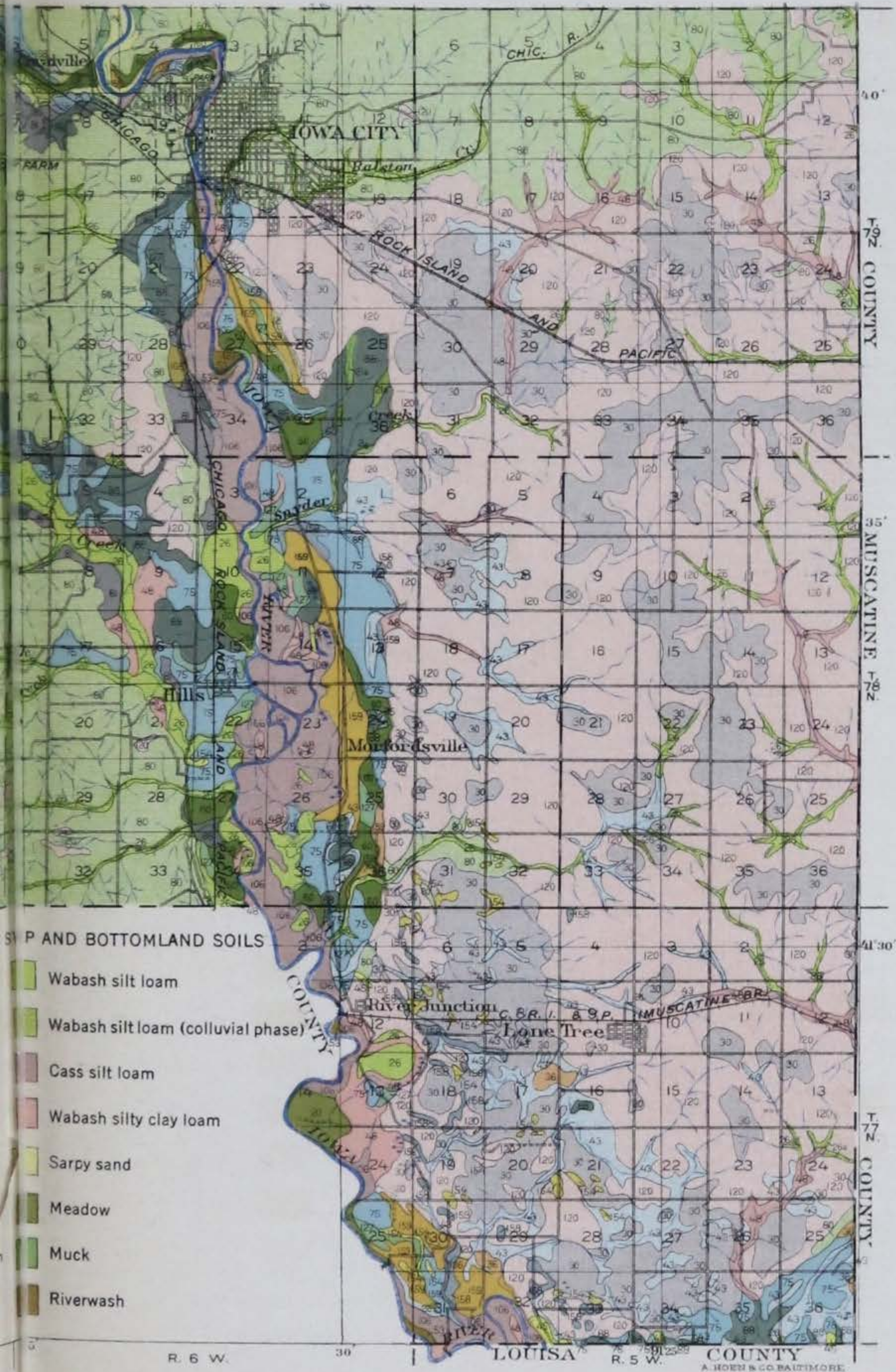
Scale: 1 inch = 2 1/2 miles

R. 6 W.
R. 7 W.

JOHNSON COUNTY SOIL MAP

Northern Division,
U.S. Department of Agriculture,
Agricultural Experiment Station.

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtis, Director. W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in charge.



deficient. Hence the need of nitrogen and organic matter in soils is indicated by the soil color.

The color of the soils in Johnson county is widely different in the various types and hence the content of organic carbon varies just as the nitrogen content has been noted to vary. The amount of organic carbon present ranges from 12,012 pounds in the Knox sand up to 72,072 pounds in the Bremer silty clay loam. These are the same types which showed the lowest and highest amounts of nitrogen, and the relationships among the various types are much the same in the case of the organic carbon as those noted with nitrogen. The Carrington soils are higher than the Shelby types, the Muscatine silt loam is better supplied than the Tama and Clinton soils of the same texture and all three are higher than the Scott and Knox soils. The Bremer types are richer in organic matter than the other terrace soils, the Waukesha and Chariton soils are better supplied than the Buckner. Again there is evidenced a rather distinct relationship between color, topography, soil texture and method of formation of the soils and the carbon content. Dark colored soils, level in topography, heavy in texture and of prairie formation, are the richest in organic matter. Texture relationships are evident. Silty clay loams are higher than silt loams and these types are better supplied than loams. Sandy types are the poorest in organic matter. Level to depressed topographic position leads to a higher content of organic matter. This is evidenced in the case of the Muscatine silt loam. Rough to rolling topography means a low content of organic matter and soils formed under forested conditions are lower than prairie types.

The relation between organic carbon and nitrogen in soils indicates whether or not decomposition processes are proceeding satisfactorily and plant food is being changed into an available form sufficiently rapidly to keep crops supplied. If the relation is not at the best, the production of available food materials may be too slow and crops may suffer. In the soils in Johnson county the relationship is generally quite satisfactory but in a few cases, it might be improved. Farm manure applications are particularly valuable in such cases, and will bring about a desirable increase in the production of available constituents. But farm manure produces desirable results on all the soils in the county and it is the most valuable fertilizing material to use to keep up the supply of organic matter. Some of the soils in the county are too low in organic matter and the amount should be increased. In all of them, however, it is necessary that the supply be kept up. Hence, farm manure should be used on all the soils as far as it is available for use. The ordinary application of 8 to 10 tons per acre will be sufficient on the better soils but larger amounts may be profitably employed on the poorer types. On most farms there is not sufficient farm manure produced to supply all the soils with large amounts and in such cases green manuring must be practiced. On the grain farm green manuring takes the place of farm manure and on many livestock farms it is a desirable practice. Crop residues should always be returned to the soil to aid in maintaining the organic matter content. The proper preservation and use of farm manure, the judicious growing of legumes as green manures and the careful return of all crop residues

TABLE V. PLANT FOOD IN JOHNSON COUNTY, IOWA, SOILS
Pounds per acre of four million pounds of subsurface soil (6 2/3"-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
83	Carrington silt loam.....	1,688	6,360	82,082	0	5,666
79	Shelby loam	836	2,360	25,662	0	3,000
LOESS SOILS						
80	Clinton silt loam.....	1,562	3,290	26,590	0	5,000
120	Tama silt loam.....	1,706	3,840	41,739	0	2,000
30	Muscatine silt loam.....	1,705	5,680	85,051	0	6,666
158	Knox sand	1,240	880	12,544	560	0
154	Scott silt loam	2,424	3,000	28,938	0	5,000
TERRACE SOILS						
75	Waukesha silt loam.....	1,616	4,600	60,060	0	5,000
88	Bremer silt loam.....	2,074	4,360	58,968	0	5,000
43	Bremer silty clay loam.....	1,563	9,260	133,218	980	0
159	Buckner loamy sand.....	2,560	1,560	24,024	0	6,000
81	Jackson silt loam.....	1,734	2,360	27,846	0	6,000
60	Waukesha loam	2,290	2,680	37,674	0	8,000
12	Bremer loam	2,694	2,800	45,318	0	2,000
105	Chariton silt loam.....	2,074	1,880	20,202	0	6,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam.....	2,398	2,560	33,087	0	6,000
26a	Wabash silt loam (colluvial phase)	1,374	5,280	72,618	0	8,000
106	Cass silt loam.....	2,842	3,020	37,019	0	5,500
48	Wabash silty clay loam.....	1,266	4,480	65,520	0	8,000

will permit of keeping up the organic matter content in Johnson county soils and will also serve to increase the supply when necessary. These same materials serve both for this purpose and to maintain and increase the nitrogen supply as already noted.

There is no inorganic carbon present in any of the surface soils in Johnson county and hence it is evident that there is need for liming. All the soils show a definite lime requirement. The subsurface soils and subsoils, with two exceptions are also acid in reaction. In two types there is a small amount of inorganic carbon in the lower soil layers but in neither case is the amount sufficient to be of any significance practically. It will soon disappear and will have little effect on the needs of the surface soils.

All the soils in the county should evidently be tested for lime requirement and lime should be applied if the best crop growth, particularly of legumes is to be secured. The amounts of lime needed as shown in the table are merely indicative of the soil needs and should not be considered to show the exact amount which should be used in any particular case. Soils vary much in lime requirements, even samples of the same type showing wide differences in many cases. Hence all soils should be tested and the proper amount of lime may then be applied. Farmers in Johnson county are urged to test their soils or have them tested and apply lime as needed if they wish to secure the best yields possible of legumes and other general farm crops. One application will not be sufficient for all time and hence tests should be made at least once in the rotation, prefer-

ably preceding the legume, and the content of lime may then be maintained. Larger crop yields are secured on limed land and liming is proving a distinctly profitable farm practice.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

There is no large content of any of the essential plant food constituents in the lower soil layers in Johnson county and hence it is not necessary to discuss these results in detail. Unless the supply of a constituent is very much greater in the subsoil than in the surface there will be no large effect on the fertility of the soil and the analyses of the surface soils will show quite accurately the soil needs. These results may be considered, therefore, merely to support the conclusions drawn in the discussion on the surface soils.

The phosphorus supply is so low that phosphorus fertilizers will certainly be needed in the near future and they might prove profitable for use in many cases at the present time. The evidence from field experiments indicates the desirability of testing the value of phosphorus carriers on the soils of this county. The supply of organic matter and nitrogen is not adequate in some instances and in all cases means must be employed to keep it up. Farm manure, leguminous green manures and crop residues should all be employed for this purpose. Larger utilization of these materials is necessary where the supply

TABLE VI. PLANT FOOD IN JOHNSON COUNTY, IOWA, SOILS
Pounds per acre of six million pounds of subsoil (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
83	Carrington silt loam.....	1,509	3,060	40,084	0	2,333
79	Shelby loam	2,262	2,520	31,449	0	3,000
LOESS SOILS						
80	Clinton silt loam.....	2,900	1,830	21,828	0	6,000
120	Tama silt loam.....	2,451	2,660	27,737	0	6,333
30	Muscatine silt loam.....	2,209	4,760	48,606	0	5,000
158	Knox sand	1,050	960	11,872	1,200	0
154	Scott silt loam.....	2,424	4,200	43,570	0	5,000
TERRACE SOILS						
75	Waukesha silt loam.....	2,142	3,540	45,864	0	5,000
88	Bremer silt loam.....	2,910	2,520	37,837	0	3,000
43	Bremer silty clay loam....	2,061	7,980	103,932	900	0
159	Buckner loamy sand.....	2,424	1,320	24,570	0	5,000
81	Jackson silt loam.....	2,829	2,520	25,225	0	6,000
60	Waukesha loam	2,304	1,320	26,208	0	2,000
12	Bremer loam	2,382	1,980	41,769	0	2,000
105	Chariton silt loam.....	2,061	1,800	24,570	0	8,000
SWAMP AND BOTTOMLAND SOILS						
25	Wabash silt loam	3,897	3,140	41,277	0	6,000
26a	Wabash silt loam (colluvial phase)	3,072	4,680	62,244	0	6,000
106	Cass silt loam	1,859	840	14,906	0	4,500
48	Wabash silty clay loam....	1,848	3,180	49,140	0	5,000

of organic matter and nitrogen is low and ordinary applications will suffice to keep up the supply in the better soils.

There is no large supply of lime in any of the subsoils and only in two cases is there any at all. In those instances the amount present will soon be exhausted and it will have little effect on the needs of the surface soil. Lime rarely moves upward in the soil and hence the requirements of the surface soils indicate quite definitely the amount of lime to use regardless of the supply in the subsoil. Evidently all the soils in Johnson county must be tested for lime requirement and the proper application of lime made if the best crops are to be secured. Only in this way will satisfactory legume growth be secured. Tests are necessary on all soils, in all fields and also at regular intervals if the lime content of all soils is to be kept at the best.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Johnson county in order to learn something regarding the needs of the soils for fertilizers. The soils tested were the Clinton silt loam and the Carrington silt loam, two of the major types. In addition to these tests there are included here the results of the greenhouse experiments on the Tama silt loam from Marshall county, the Muscatine silt loam from Louisa county, the Carrington silt loam from Linn county, and the Clinton silt loam from Wapello county. These experiments are reported here as the soil types are the same as those occurring in Johnson county and the results are applicable to conditions there.

In all the tests, the fertilizers tested were the same and the amounts used identical with the materials and amounts applied in the field experiments. Hence these greenhouse tests may be considered to give fairly accurate indications of the effects of fertilizers which may be secured in the field. The treatments used included manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. Manure was added at the rate of eight tons per acre, lime was applied in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was applied at the rate of 2,000 pounds, acid phosphate at the rate of 200 pounds, and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat and clover were grown on the pots, the clover being seeded about one month after the wheat was up. In the experiments on the Johnson county soils, the wheat yields were not secured and only the clover yields are given.

RESULTS ON CLINTON SILT LOAM

The results secured on the Clinton silt loam from Johnson county are given in table VII, the figures being the averages of the green weights of the clover on duplicate pots. Manure brought about an enormous increase in the clover crop, the yield being almost three times as large as on the untreated pot. Lime with manure gave a further increase which was quite definite. The phosphates and commercial fertilizer all produced large effects on the clover, the rock phosphate showing larger effect than the acid phosphate or the complete fertilizer. The differences, however, are not so large as the increases over the manure-lime treatment. Evidently manure, lime and phosphorus fertilizers



Fig. 5—Wheat and clover on Carrington silt loam, Linn county.

are of large value on this soil and will produce profitable crop increases. Rock phosphate seems to be somewhat preferable in this test, but field trials are necessary before definite conclusions are drawn regarding the relative merits of these two materials. Apparently the complete commercial fertilizer is of less value than the phosphorus carriers, at least, it does not give as large effects as the rock phosphate and its effect is not sufficiently larger than that of the acid phosphate to warrant its use as it is so much more expensive.

RESULTS ON CARRINGTON SILT LOAM

The results of the test on the Carrington silt loam from Johnson county are given in table VIII, again only the green weights of the clover being given. Manure brought about a large crop increase and lime with manure proved of quite as large effect. The phosphates and complete fertilizer all gave increases

TABLE VII. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, JOHNSON COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check	31.75
2	Manure	90.72
3	Manure+lime	99.79
4	Manure+lime+rock phosphate	165.56
5	Manure+lime+acid phosphate.....	140.61
6	Manure+lime+complete commercial fertilizer.....	151.95

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, JOHNSON COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check	29.48
2	Manure	40.82
3	Manure+lime	65.77
4	Manure+lime+rock phosphate	86.18
5	Manure+lime+acid phosphate	74.84
6	Manure+lime+complete commercial fertilizer.....	72.57

in the clover yield, the rock phosphate showing a larger effect than the other two materials. The complete fertilizer was of less effect than the phosphates and hence could not be considered as desirable for use. Apparently the Carrington silt loam will respond to applications of manure, lime and phosphorus and to a profitable extent. Large returns may be secured from the use of manure and lime in the field and a phosphate fertilizer may also be applied profitably in many cases. Whether rock phosphate or acid phosphate should be used must be determined for individual soil conditions as these materials vary in their effects under field conditions. Tests should be made on the farm and then the most profitable material may be applied. Complete fertilizers will probably be less desirable than the phosphates.

RESULTS ON TAMA SILT LOAM

The experimental results on the Tama silt loam from Marshall county appear in table IX, the yields of both the wheat and the clover being given. The effect of manure is shown quite definitely with the wheat but in this instance seems to have no effect on the clover. Other experiments on this type, however, have shown beneficial effects on clover and it would seem that manure is a very desirable fertilizer to use on this soil. Lime applied with manure had little effect on the wheat but gave a distinct increase in the clover. Legumes usually show

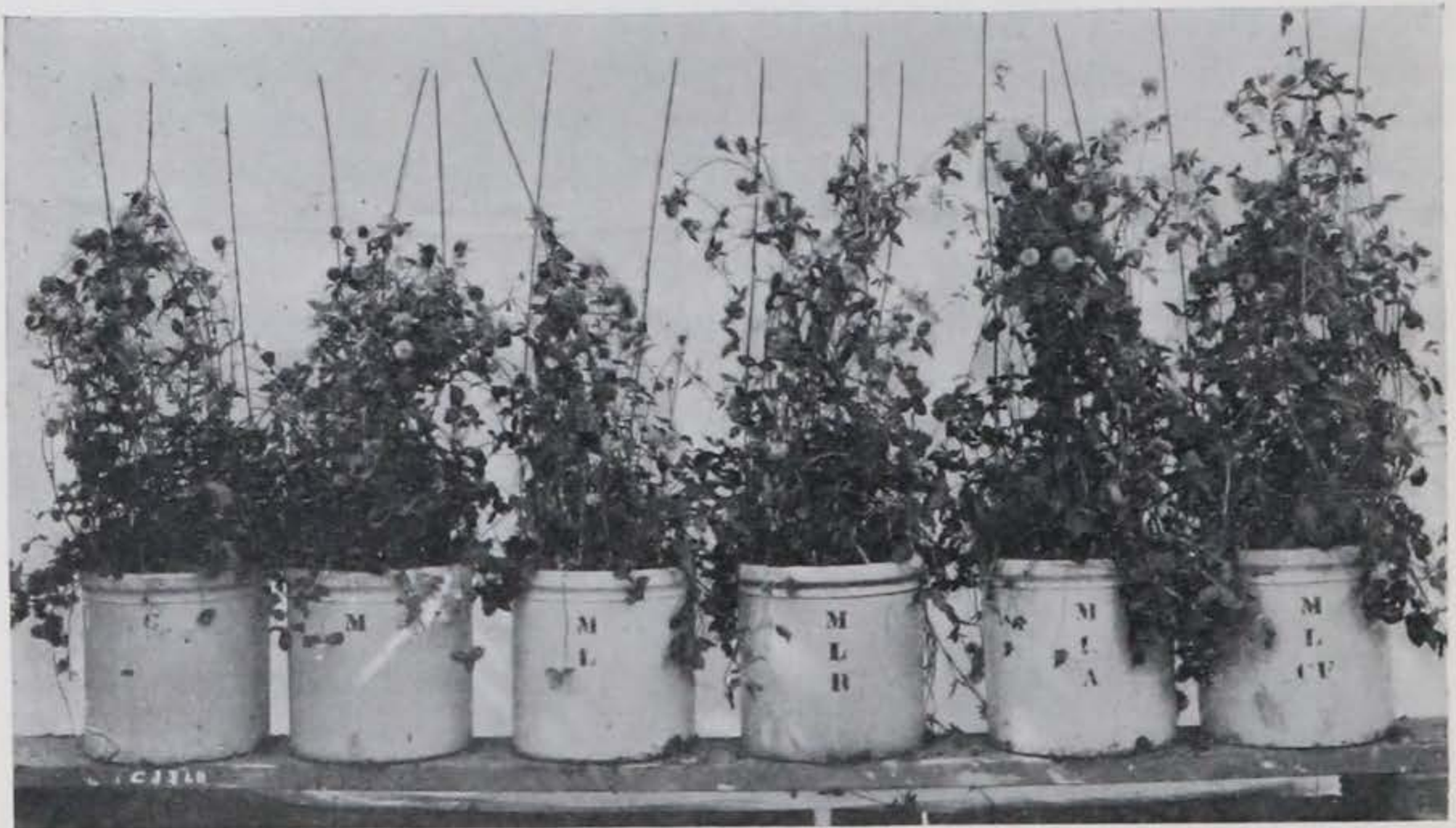


Fig. 6—Greenhouse experiment with clover on Tama silt loam, Marshall county.

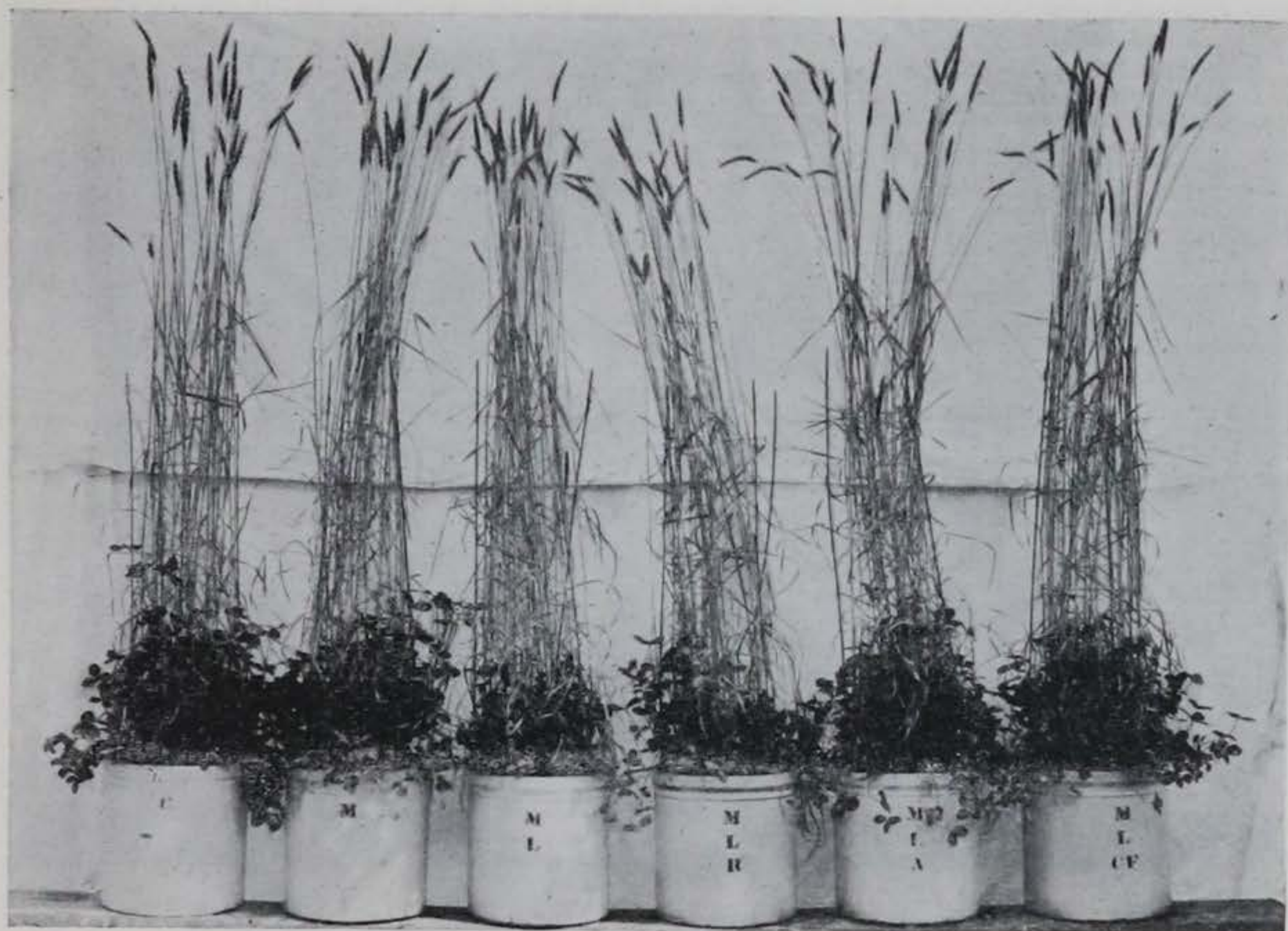


Fig. 7—Wheat and clover on Tama silt loam in Marshall county.

more definite effects from liming than do the grain crops. The rock phosphate and the acid phosphate both gave decided gains in clover but the former had little effect on the wheat. The acid phosphate showed up much better on the clover than the rock phosphate. The complete commercial fertilizer had less effect than the acid phosphate on both crops but showed up better on the clover than did the rock phosphate. There was little effect of the complete fertilizer on the wheat. It would seem that manure and lime should be employed on this soil and that a phosphate fertilizer might give profitable increases. Tests should be carried out in the field, however, before a choice is made between the acid phosphate and the rock. The complete fertilizer seems less desirable for use than the phosphates.

RESULTS ON MUSCATINE SILT LOAM

Table X gives the results secured on the Muscatine silt loam from Louisa county. The beneficial effect of manure on this soil is shown in the results both for the wheat and for the clover, small increases being obtained in both cases.

TABLE IX. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Dry weight clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer.....	24.00	63.50



Fig. 8—Greenhouse experiment on Muscatine silt loam, Louisa county.

Lime with the manure gave further increases in both crops, the wheat showing a distinct gain, as well as the clover. Often the grain crops are increased in yield thru the use of lime altho in general increases are expected only on the legume. The phosphates and complete fertilizer had no effect on the wheat in this case but all brought about increases in the clover. The acid phosphate proved somewhat superior to the rock phosphate but was surpassed by the complete fertilizer. The increase from the latter material over the acid phosphate would hardly warrant the use of the more expensive material, however. Apparently this soil will respond to manure, lime and phosphorus and while the former may be applied with the assurance of profit, phosphorus fertilizers should be tested in the field on small areas before applications are made to large areas.

RESULTS ON CARRINGTON SILT LOAM FROM LINN COUNTY

The results secured in the test on the Carrington silt loam from Linn county are given in table XI.

The addition of manure brought about a distinct increase in both the clover

TABLE X. GREENHOUSE EXPERIMENT, MUSCATINE SILT LOAM, LOUISA COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	22.50	54.43
2	Manure	24.75	56.69
3	Manure+lime	28.00	61.23
4	Manure+lime+rock phosphate	27.25	65.77
5	Manure+lime+acid phosphate	26.75	70.25
6	Manure+lime+complete commercial fertilizer.....	26.25	79.38

TABLE XI. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	16.74	10.5
2	Manure	18.29	16.0
3	Manure+lime	22.00	28.0
4	Manure+lime+rock phosphate	22.50	32.0
5	Manure+lime+acid phosphate.....	23.53	34.5
6	Manure+lime+complete commercial fertilizer.....	21.13	33.0

and wheat grown on this soil. Lime applied with the manure gave further increases in both crops, the effect being particularly evident on the clover but quite definite also in the case of the wheat. The phosphates had slight effects on the wheat, but showed increases in the clover, the acid phosphate proving slightly superior to the rock phosphate in both cases. The differences, however, were not large enough to warrant definite conclusions. The complete commercial fertilizer had no better effects than the phosphates and indeed showed no effect at all on the wheat. Manure and lime are evidently desirable treatments on this soil and a phosphate fertilizer may be used profitably in some cases provided tests in the field show definite results.

RESULTS ON CLINTON SILT LOAM FROM WAPELLO COUNTY

In table XII, the results of the experiment on the Clinton silt loam from Wapello county are given.

Manure showed a distinctly beneficial effect on both crops on this soil, just

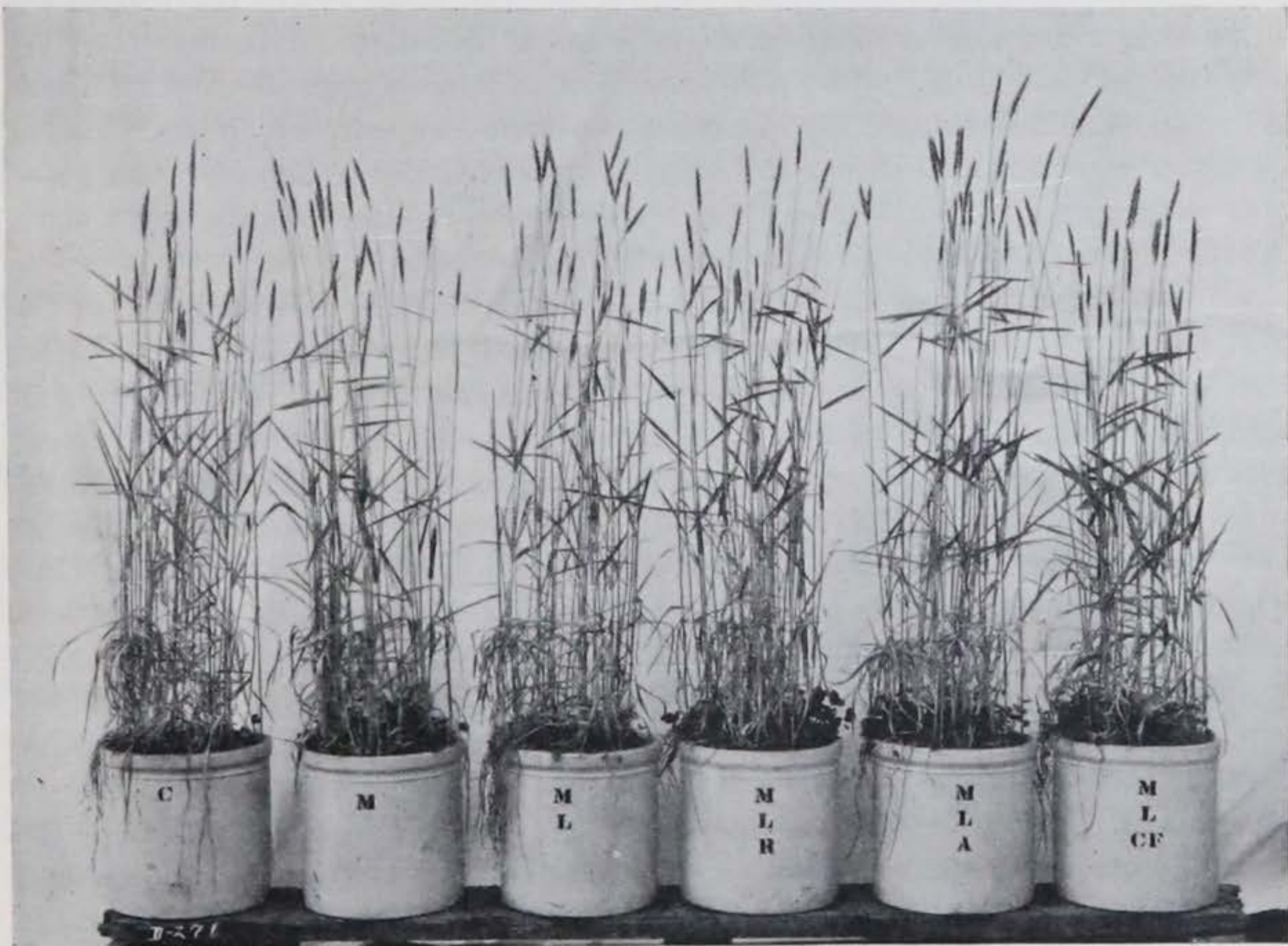


Fig. 9—Manure increased the wheat yield on the Clinton silt loam. Acid phosphate with manure increased the yield more noticeably than did the rock.

TABLE XII. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM,
WAPELLO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	17.39	38.0
2	Manure	18.69	44.0
3	Manure+lime	19.27	....
4	Manure+lime+rock phosphate	20.46	47.0
5	Manure+lime+acid phosphate	23.38	49.0
6	Manure+lime+complete commercial fertilizer.....	21.89	52.0

as was noted in the experiment on the same type from Johnson county. Lime increased the yield of wheat somewhat but the clover yield was not secured. The phosphates both gave increases in wheat and clover, the acid phosphate showing up more definitely in both cases. The differences, however, were not sufficiently large to permit of very definite conclusions regarding the relative merits of the two materials. The complete commercial fertilizer had slightly greater effects on the clover than did the phosphates but was less effective than the acid phosphate in the case of wheat. It would seem that a phosphate would probably yield more profitable results on this soil than a complete fertilizer. Manure and lime are definitely beneficial and should be used as basic treatments.

FIELD EXPERIMENTS

The experiments which have been started in Johnson county have not been carried out for a long enough time, to permit of conclusions being drawn from them. Field tests must always be run for several years before the results are of value in order to eliminate chance or seasonal variations. The results of the tests in Johnson county will be published later in a supplementary report. There are some field tests under way in other counties, however, which are yielding results of considerable interest and they are included in this report inasmuch as they are located on the same soil types which occur in this county and the results are indicative of the fertilizer needs of these soils.

All these field experiments are laid out on land which is representative of the particular soil type and the value of various soil treatments are tested. The fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer, with manure or with crop residues, thus representing the livestock system of farming and the grain system. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually, and until the last year, the 2-8-2 complete fertilizer has been used at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being used, 267 pounds being applied annually, thus supplying the same amount of phosphorus which is introduced in the 200 pounds of acid phosphate. On the grain system plots, all crop residues are turned under in the soil. The second crop of clover is plowed under and often the first crop is cut and left on the ground to be plowed under with the second. The corn stalks are cut with a disc or stalk cutter and plowed under. The straw from the small grains is

TABLE XIII. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY, SPRINGVILLE FIELD—SERIES I

Plot No.	Treatment	Clover tons per acre 1918	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921	Clover tons per acre 1922
1	Check	2.25	58.6	46.5	44.8	1.37
2	Manure	2.47	64.8	63.3	....	1.35
3	Manure+Lime	2.40	63.7	....	46.9	1.47
4	Manure+Lime+Rock phosphate ...	2.70	60.8	66.1	42.8	2.20
5	Manure+Lime+Acid phosphate....	2.70	67.1	60.8	46.3	2.14
6	Manure+Lime+Complete commercial fertilizer	2.70	64.5	61.0	49.2	1.99
7	Check	1.65	60.0	51.9	36.9	1.35

all returned to the land, application being made at some convenient time. In most of the results reported here the grain system plots are not included as there has not been opportunity as yet for the crop residues to show any definite effects.

All the plots are 155' 7" by 28' in size, making them one-tenth of an acre. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops, that the results may be accurate.

THE SPRINGVILLE FIELD

An experiment is under way on the Carrington silt loam at the Springville Field in Linn county and the results of this experiment to date are given in table XIII.

The yield of corn on the manure-lime plot in 1920 is not given, as it was evidently abnormal, and similarly in 1921 the yield of oats on the manure plot is not included. A small depression runs thru the manure-lime plot and affects the yield on this plot and also on the manure plot.

The results given in the table in general indicate quite definitely the value of manure on this soil. It is the most valuable fertilizer which can be employed and its use in liberal amounts is strongly recommended. The effects of the manure on crop growth are shown at all stages and the yields often do not show the variations which are noted in the field. Lime with manure increases crop yields and is very necessary if the best growth of crops, particularly of legumes, is to be secured.

There are indications in the results of the value of phosphate fertilizers, but it is not possible to decide which material is the most desirable. Sometimes the acid phosphate appears preferable, but in other cases the rock phosphate gave larger effects. The complete fertilizer sometimes gave slightly larger effects than the phosphates, but in no case were the effects sufficiently larger to warrant the use of the more expensive material. Tests of phosphate fertilizers are very desirable on this soil to determine the need of phosphorus and which material should be employed.

THE PRINCETON FIELD

The results secured on the Clinton silt loam on the Princeton Field in Scott county are given in table XIV.

The beneficial effect of manure on this soil is shown on all the crops of the

TABLE XIV. FIELD EXPERIMENT, CLINTON SILT LOAM, SCOTT COUNTY, PRINCETON FIELD

Plot No.	Treatment	Wheat bu. per acre 1918	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921	Clover tons per acre 1922
1	Check*	36.2	63.1	59.6	26.0	1.50
2	Manure	37.4	67.6	68.3	28.4	1.93
3	Manure+Lime	43.0	68.2	70.6	32.1	2.13
4	Manure+Lime+Rock phosphate ..	47.4	67.8	73.5	31.9	2.25
5	Manure+Lime+Acid phosphate ...	45.2	64.0	70.8	35.1	2.29
6	Manure+Lime+Complete commer- cial fertilizer	37.3	68.4	73.6	36.4	2.34

*The check yields are the average of plots 1 and 7.

rotation. Apparently this is a most valuable material for use on this soil and liberal amounts should be used as far as they are available for use. Lime with manure gave a further increase in crop yields, showing effects not only on the legume crop but also on the corn and small grains.

The phosphates generally proved of value, but sometimes the acid phosphate seemed superior and in other cases the rock phosphate had more effect. No definite conclusions can be drawn from these results as to the relative value of the two materials. The results do indicate, however, the possibility of value from the use of phosphorus on this soil and the desirability of testing both materials on individual farms is emphasized. The complete fertilizer proved somewhat better than the phosphates in some cases but the increases secured were not large enough to warrant the use of the more expensive materials.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk county are given in table XV.

The crop yields were not secured in 1921 owing to an oversight on the part of the co-operator but the results are given for 1918, 1919, 1920 and 1922.

The beneficial effects of manure on the Tama silt loam are shown very definitely in these results, large increases being secured in all cases. Lime gave further increases on all the crops, showing the value of this material when applied to acid soils not only on legumes but also on general farm crops. The rock phosphate, acid phosphate and complete commercial fertilizer gave increases in most cases, but the differences were too small to permit of definite conclusions regarding their relative values. Apparently, however, phosphorus may prove of value on this soil and tests of the acid phosphate and the rock are de-

TABLE XV. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Corn bu. per acre 1920	No yield secured in 1921	Oats bu. per acre 1922
1	Check	45.8	47.6	53.2	....	44.8
2	Manure	49.3	54.7	62.8	....	53.1
3	Manure+Lime	54.4	59.2	67.4	....	59.6
4	Manure+Lime+Rock phosphate ...	56.5	64.9	73.3	....	58.1
5	Manure+Lime+Acid phosphate ...	57.4	62.2	73.3	....	53.2
6	Manure+Lime+Complete commer- cial fertilizer	58.5	57.5	72.4	....	62.2

TABLE XVI. FIELD EXPERIMENT, CARRINGTON SILT LOAM, CLINTON COUNTY, CALAMUS FIELD

Plot No.	Treatment	Wheat bu. per acre 1915	Corn bu. per acre 1916	Oats bu. per acre 1917	Clover tons per acre 1918	Clover tons per acre 1919	Corn bu. per acre 1920	Corn bu. per acre 1921	Oats bu. per acre 1922
1	Check	15.9	32.9	28.8	1.45	0.58	57.5	36.0	35.9
2	Manure	26.1	46.7	54.2	3.04	0.74	65.2	43.5	45.4
3	Lime	18.5	47.6	35.6	2.43	0.92	63.2	49.5	43.6
4	Check	19.5	44.1	35.6	2.09	0.70	54.5	39.6	37.2
5	Manure+Lime	24.0	55.5	55.9	3.38	0.74	75.7	50.9	51.8
6	Manure+Lime+Rock phosphate	24.3	60.8	91.6	4.39	1.22	85.1	52.5	63.4
7	Check	21.2	42.2	37.1	3.07	0.90	58.2	44.4	36.3
8	Manure+Lime+Acid phosphate	27.5	61.7	77.8	5.18	2.11	70.4	57.3	57.5
9	Manure+Lime+Com- plete commercial fertil- izer	31.9	63.3	86.6	4.38	1.66	82.2	59.4	66.1
10	Check	20.6	30.1	32.3	1.47	0.52	47.9	33.3	41.4

sirable. The complete fertilizer apparently is less desirable than the phosphates, as it gives about the same effects and costs much more.

THE CALAMUS FIELD

The results secured on the Carrington silt loam on the Calamus Field in Clinton county are given in table XVI.

This field was laid out in 1915 and hence results have been secured for eight years. The results are given on all check plots and averages are not struck. The effect of manure on all crops grown on this soil is shown to be very beneficial. Lime alone had some effect, but less than the manure in most cases. With manure, lime brought about increases over the manure alone and the corn and grain crops were increased as well as the legumes. The rock phosphate, acid phosphate and complete commercial fertilizer all gave increases in the various crops. The results were variable, however, the acid phosphate sometimes giving the best effect, while in other cases the rock showed up the best. The complete fertilizer occasionally gave greater benefits than the phosphates, but the increases were not sufficiently large to warrant its use instead of a phosphate. Evidently phosphorus may be used profitably on this soil in many cases and tests of the two carriers are to be urged. The complete fertilizer seems less desirable than a phosphate. Manure and lime are basic treatments of large value on this soil.

TABLE XVII. FIELD EXPERIMENT, MUSCATINE SILT LOAM, MUSCATINE COUNTY, LETTS FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Wheat bu. per acre 1920	Clover and timothy 1921	Pasture 1922
1	Check	75.4	57.8	17.1	4230	....
2	Manure	77.8	58.6	20.6	4260	....
3	Manure+Lime	77.2	58.6	23.9	4520	....
4	Manure+Lime+Rock phosphate ...	82.9	62.6	28.5	5160	....
5	Manure+Lime+Acid phosphate ...	83.7	62.6	27.5	5460	....
6	Manure+Lime+Complete commer- cial fertilizer	84.8	67.4	31.2	5520	....
7	Check	78.4	51.0	19.9	4200	....

THE LETTS FIELD

The results secured on the Muscatine silt loam on the Letts Field in Muscatine county are given in table XVII.

This field was pastured in 1922, hence crop yields were not secured. From the four crops grown, however, some indications of the value of various fertilizers are given. Manure gave increases in all cases, and lime with manure had some effect, particularly on the clover and timothy but the wheat also showed an increase. The rock phosphate, acid phosphate and complete commercial fertilizer proved of value on all the crops, the complete fertilizer showing up better than the phosphates in every case. It is doubtful if this material would prove profitable on this soil, however, as the increases over the phosphates were hardly large enough to pay for the additional cost of the complete brand. The acid phosphate and the rock gave almost the same results and hence a choice cannot be made between the two materials. It is evident, however, that tests of phosphorus would be very desirable on this soil and phosphorus fertilizers would probably give profitable crop increases.

AVERAGE RESULTS ON CARRINGTON SILT LOAM

The average results secured in all the field tests on the Carrington silt loam are given in table XVIII. The checks are the averages for all the untreated plots and the increases from the various treatments are calculated.

Manure gave an increase in corn, in oats and in clover, the largest effect appearing on the oats. Lime with manure gave a further increase in corn and in clover. There was no effect on the oats in fact the yield was less than with manure, but this result should merely be interpreted to show no gain. There would be no reason for a decrease and as only one oats crop is included, the particular yield was evidently somewhat abnormal. The rock phosphate and

TABLE XVIII. CARRINGTON SILT LOAM
Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*	
	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre
Check	59.2	.....	49.2	.....	1.28	.....
Manure	65.9	6.7	60.3	11.1	1.38	0.10
Manure+Lime	71.4	12.2	56.3	7.1	1.55	0.27
Manure+Lime+Rock phosphate ..	74.6	15.4	61.2	12.0	2.00	0.72
Manure+Lime+Acid phosphate ..	74.5	15.3	61.2	12.0	2.25	0.97
Manure+Lime+Complete commercial fertilizer	74.3	15.1	67.3	18.1	2.16	0.88
Crop residues	60.0	0.8	55.0	5.8	1.36	0.08
Crop residues+Lime	65.1	5.9	50.3	1.1	1.48	0.20
Crop residues+Lime+Rock phosphate	63.5	4.3	61.8	12.6	1.89	0.61
Crop residues+Lime+Acid phosphate	65.0	5.8	59.8	10.6	2.00	0.72
Crop residues+Lime+Complete commercial fertilizer	69.7	10.5	67.3	18.1	1.95	0.67

*Corn yields averaged from 6 crops on 2 fields, oats from 1 crop on 1 field and clover from 3 crops on 2 fields.

TABLE XIX. TAMA SILT LOAM
Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment bu. per acre	Bu. per acre	Increase from treatment bu. per acre
Check	63.3	.....	46.0	.....
Manure	69.6	6.3	49.4	3.4
Manure+Lime	71.8	8.5	56.3	10.3
Manure+Lime+Rock phosphate	77.7	14.4	58.6	12.6
Manure+Lime+Acid phosphate.....	75.3	12.0	56.7	10.7
Manure+Lime+Complete commercial fertilizer..	73.7	10.4	62.9	16.9
Crop residues	69.7	6.4	47.0	1.0
Crop residues+Lime	71.8	8.5	57.9	11.9
Crop residues+Lime+Rock phosphate.....	74.4	11.1	58.9	12.9
Crop residues+Lime+Acid phosphate.....	75.7	12.4	63.3	17.3
Crop residues+Lime+Complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 crops on 2 fields. The oats yields are the averages of 2 crops on 2 fields.

acid phosphate brought about increases in all three crops, giving almost identical effects on the corn and oats. The acid phosphate however showed more effect on the clover than did the rock. The complete commercial fertilizer had the same influence as the phosphates on the corn, gave a greater effect on the oats and a smaller effect than the acid phosphate on the clover.

Crop residues showed slight gains on all the crops. Lime again gave increases in the corn and clover but the yield on the oats plot was abnormal. The rock phosphate and the acid phosphate gave no effect on the corn but both brought about pronounced increases in the oats and clover. The rock seemed somewhat better on the oats while the acid phosphate was slightly superior on the clover. The complete commercial fertilizer gave an increase in corn and larger effects on the oats than the phosphates. It showed no superiority however on the clover.

These results confirm the previous conclusions from the individual fields on the Carrington silt loam. Manure is of distinct value. Lime gives increases in the clover and often also in other crops. The phosphates give increases in yields in practically all cases and the complete commercial fertilizer proves of less value than the phosphates owing to its higher cost. Phosphorus fertilizers would evidently prove profitable for use on this soil.

AVERAGE RESULTS ON THE TAMA SILT LOAM

Table XIX gives the average results secured from all the field experiments on the Tama silt loam.

Manure brought about increases in both corn and oats. Lime with manure had large effects on both these crops. Rock phosphate and acid phosphate showed large increases, the rock apparently being slightly better than the acid phosphate. The complete commercial fertilizer had less effect than the phosphates on the corn but proved somewhat better on the oats.

Crop residues showed slight effects but lime again brought about distinct increases in both crops. The phosphates gave increases in both cases, the acid

phosphate showing larger effects than the rock. The complete fertilizer again had less effect than the phosphates on the corn but gave greater increases in the oats.

These results indicate the value of manure, lime and phosphorus on the Tama silt loam. Rock phosphate seems slightly better than acid phosphate when applied with manure but with crop residues, the reverse is true and acid phosphate is more effective. The complete fertilizer had less effect than the phosphates on the corn but gave larger increases in the oats, not enough larger however, to warrant its use. The testing of phosphorus fertilizers on this soil is evidently very desirable.

THE NEEDS OF JOHNSON COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The fertilizer needs of the soils of Johnson county are indicated by the laboratory, greenhouse and field experiments reported earlier. While the field tests in Johnson county have just been started and no results are as yet available from them, the experiments included in this report are located on soil types in other counties which are the main types found in Johnson county. Hence the conclusions drawn from them may be considered to indicate quite definitely the needs of Johnson county soils. Furthermore they confirm the conclusions from the laboratory and greenhouse tests and they are supported by much practical experience.

It should be emphasized that no suggestions are offered here which are not based on experimental and farm evidence of their value and no treatments are recommended which are not of proven value. In some cases tests on the farm are advised and these tests are only such as may be carried out on any farm with little difficulty. Similar experiments are under way on many farms and are giving information of much value to the farmers who are conducting them and they are also providing valuable data to others who are farming the same types of soil. Such tests also aid in the solution of the problem of profitable farming and permanent fertility on the particular soil. The Soils Section of the Iowa Agricultural Experiment Station will aid any who may wish to test the needs of their own soils and directions which may be followed in carrying out such tests are given in Circular No. 82 of the Experiment Station.

LIMING

All the soils in Johnson county showed acidity and need of lime, according to the tests which are given earlier in this report. Apparently land in this county is quite generally acid and one of the first treatments needed to insure the best growth of all crops is the application of limestone. Legumes such as red clover, and alfalfa are especially sensitive to acidity and frequently such crops refuse to grow at all where the soil is strongly acid. Many times the yields are poor because of acidity. But other crops grown in the general farm rotation are also affected more or less by acid conditions and will not give the best yields unless lime is employed. Corn and small grains often show considerable increases from the use of lime, due probably to its indirect effects on the soil, making conditions

better for crop growth, rather than to any actually injurious effect of the acidity on the crop itself.

Liming benefits soils because of the improvement in the chemical, physical and bacteriological conditions in them. It corrects acidity which is injurious to some crops, particularly legumes. It adds the plant food constituent, calcium, which may be needed, and which is taken up in large amounts by alfalfa, for example. It improves the physical conditions in both heavy and light soils opening up the former, making them better aerated, less cold and moist and better suited for the production of available plant food. It tightens up light, sandy soils, on the other hand, making them less droughty and better able to hold plant food. Bacterial activities are increased by liming as practically all of the desirable bacteria work best in the absence of acid conditions. Greater decomposition of organic matter is brought about and hence there is a more rapid production of nitrates for plant feeding. But the other necessary plant food constituents are also affected and more available plant food of all kinds is produced from the store of unavailable material naturally present in the soil. There is also a greater fixation of nitrogen from the atmosphere both by the free-living organisms and by those living on the roots of legumes, and hence the nitrogen content of the soil may be increased and kept at the most desirable amount. In some cases the value of lime on acid soils may be due to its effect on the chemical, the physical or the bacterial conditions but in most instances the increased crop yields secured may be attributed to a combination of effects on all three groups of factors.

For the best crop production in Johnson county it is essential that lime be applied when needed. The crop increases which may be secured from the proper use of this material are indicated in the results from the greenhouse and field tests which have been discussed. Much farm experience confirms this conclusion and liming is coming to be considered as a fundamental farm practice to insure the best crop growth, especially of legumes and to permit of keeping the soils permanently productive.

The proper amount of lime to use on any soil must be determined by testing the needs of that particular soil. The data given earlier in this report should be considered merely to indicate roughly the type needs. Soils vary widely in extent of acidity and even the same type will show different lime needs, in different fields. The soil from every field should therefore be tested separately if the proper amount of lime is to be applied. Farmers may test their own soils and ascertain quite readily how much lime should be applied to a particular area but it will generally be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

Lime disappears from soils quite rapidly thru leaching and in other ways and hence one test and one application of lime will not be sufficient for all time. It is recommended that soils be tested at least once in a four year rotation and that the lime needed be applied just preceding the legume crop of the rotation. Thus the greatest beneficial effect will be secured. The succeeding crops will be benefited not only by the lime but also by the greater amounts of legume residues which are turned under in the soil.

The farmers of Johnson county should test their soils for lime requirements now and at regular intervals thru the years to come and should apply the necessary amounts of limestone. Thus they may secure the best crop growth and keep their soils permanently productive. Further information regarding the losses of lime from the soil, the use of lime by various crops and other points in connection with liming are given in Bulletin 151 and Circular 105 of the Iowa Agricultural Experiment Station and the Iowa Extension Department.

MANURING

None of the soils of Johnson county are supplied with any large amounts of organic matter altho some contain considerably more than others. The Clinton silt loam, the most extensive type, is not high in this constituent containing only an average amount. The Tama silt loam is not rich in organic matter. The Carrington silt loam and the Muscatine silt loam are better supplied while the minor upland types are much lower. The Bremer soils on the terraces are higher than the other terrace types while the Buckner loamy sand is particularly low. The bottomland soils are all fairly well supplied with organic matter. In general it appears that the light colored, lighter textured soils are lower in organic matter while the dark colored, heavy types are fairly well supplied.

In some of the soils in the county it is evidently necessary to build up the supply of organic matter but in all cases it is necessary to keep up the amount of this material. The value of farm manure on these soils is evident. While its effects are most noticeable and its use most important on the poorer types, large and profitable crop increases are secured by applying manure to the darker colored, apparently richer soils. If the largest crop yields are to be secured and the soils of the county are to be kept permanently productive it is most important that the organic matter supply be built up in some cases and maintained in all instances and that the value of farm manure for this purpose be generally recognized.

Farm manure is one of the most valuable fertilizing materials which can be applied to soils. It improves the chemical, physical and bacteriological soil conditions and as a result increases crop yields. It contains a large part of the essential plant food constituents which have been removed from soils by the crops grown and used for feed and hence it improves soils chemically by supplying these constituents. It actually lengthens the "life" of the soil by prolonging the time when any one element will become deficient. Hence it plays an important part in keeping soils productive. Much organic matter is added to soils in manure and this has an important effect on them chemically and on their fertility. Organic matter also affects the physical condition of soils. It enables light, open soils to hold moisture and plant food better. It opens up tight heavy clays and insures better air and moisture conditions in them. These changes in physical conditions result in a more rapid production of available plant food and hence may have a large effect on crop yields. Manure contains enormous numbers of bacteria and when applied to soils increases its content of these organisms. Bacteria are the active agents making plant food available and hence in manured soils there is a larger and more rapid production of available plant food. The organic matter in manure stimulates bacterial action and

hence there is a further effect on the supply of plant food, suitable for crop use. The bacterial effects of manuring may be the most significant in some cases. On soils high in organic matter beneficial effects of manuring are undoubtedly due mainly to the addition of bacteria. On newly drained, rich black soils this is certainly true. On most soils however, the effects of manuring are probably the result of improved chemical, physical and bacterial conditions.

The value of manure as a fertilizer is often overlooked. Frequently it is stored in loose piles, exposed to the weather where it is sure to lose much of its value. Often 70 to 90 percent of the most valuable portion of the manure may be carried away in the liquid draining from the manure heap. When such losses occur the effect of the manure on crop yields is correspondingly reduced. Losses from manure have therefore a real money value and farmers should take precautions in storing manure to prevent extensive deterioration in value. Manure is sometimes applied to the soil as it is produced and in such cases there is the least possible chance for losses to occur. It is not always practicable, however, to handle the manure in this way and it must be stored. There are various methods which may be followed in storing and they are each the most desirable under certain conditions. No one method is best for all circumstances. Covered yards may be employed; pits are sometimes used; composting is often practiced. Other methods are suggested but in general it may be said that any method will prove desirable if the manure is kept moist and compact and protected from the weather. Even when it is most carefully stored some losses occur but when these are kept to the lowest possible point, as much as 75 percent of the normal value of the manure may be returned to the soil.

Normal applications of manure amount to 8 to 10 tons per acre once in a four-year rotation. This amount gives usually the greatest effect on crop yields per ton of manure applied. It is not economical nor desirable to make large applications of manure where general farm crops are to be grown. Only where soils are particularly deficient in organic matter will large amounts prove as profitable. On the average livestock farm, the amount of manure produced is insufficient to supply a large amount to all the soils on the farm. If one field receives a large application, other areas must go untreated. When more than normal applications are desirable it is not profitable to put on more than 16 to 20 tons except where truck crops are to be grown. For general farming conditions it seems most desirable to apply a reasonable amount of manure to each field once in the rotation. On darker colored, rich soils, the applications may be reduced below the normal and in such cases the application should not be made preceding the small grain crop owing to the danger of lodging.

The effects of manure in increasing crop yields have been indicated in the greenhouse and field tests reported earlier and much farm experience confirms the conclusion that farm manure is a most profitable fertilizing material to use on the soils of Johnson county and wherever it is available for use, it should serve as a basic soil treatment. No other fertilizers will prove of as large value unless manure is used as a basic application.

GREEN MANURING

On grain farms, where manure is not produced, some other material must take its place and on many livestock farms the use of some material to supple-

ment the manure is necessary, as the amount produced is insufficient to meet the needs of the farm. Green manuring is a desirable practice under both these conditions. Either legumes or non-legumes may be used as green manures, but the former are much more desirable because when inoculated they draw their nitrogen from the air and thus, when turned under the soil, they increase the supply of this constituent. They also add organic matter and thus have a double value as green manures. Non-legumes merely supply organic matter and hence it is rarely that legumes are not preferable for use as green manures. Many legumes serve as green manures and one may be chosen which will prove satisfactory under almost any climatic, soil or rotation condition.

Many of the soils of Johnson county might be made more productive thru green manuring. On grain farms the practice is necessary while on many livestock farms it may be desirable if the supply of organic matter is not at the best. The use of green manures is quite generally essential for permanent fertility. The practice should not be followed blindly or carelessly, however, or undesirable effects may result. A heavy green crop turned under in the soil may prove injurious to the subsequent crop if the soil is too dry, because of undesirable effects on the moisture conditions. With proper precautions however, green manuring may often be a most profitable practice. Frequently a part of the clover crop may be turned under and this constitutes a partial green manuring practice. Occasionally the first crop is cut and the second plowed under. If the seed only of the legume is removed the crop becomes mainly a green manure. Sometimes a legume may be seeded in the corn at the last cultivation and serve as a catch crop, producing desirable effects. A legume is sometimes used as a cover crop and may benefit the soil to a large extent. Advice regarding green manuring under special conditions will be given by the Soils Section upon request.

Crop residues returned to the soil aid materially in keeping up the supply of organic matter and they also have some value because of the plant food constituents which they contain. They are frequently burned or destroyed in some way and not turned under in the soil, and in such cases, considerable valuable material is wasted. On the livestock farm, they should be used for feed or bedding and returned to the soil in the manure. On the grain farm they may be applied directly to the soil or the straw may be allowed to decompose partially before being plowed under. The proper use of all crop residues is particularly necessary on the grain farm because farm manure is not produced but they should be thoroly utilized on the livestock farm to supplement the farm manure applied and to aid in keeping up the supply of organic matter and other plant food constituents.

THE USE OF COMMERCIAL FERTILIZERS

The supply of phosphorus is not large in any of the soils in Johnson county and in some instances it is very low. The most extensive upland types are better supplied but the total amount present would not be sufficient for an unlimited number of crops, even if it were made available as rapidly as necessary which would be very unlikely. Furthermore the content of the soils is such that there is grave question whether crops are being properly supplied with

available phosphorus at the present time. Even when considerable amounts of phosphorus are found in soils, there is no assurance that it is being changed into an available form as rapidly as necessary, but where the supply is low, it is practically certain that the availability is proportionately lower. It is evident that phosphorus fertilizers will be needed on the soils in this county in the near future and there is also evidence that profitable results might be secured from the use of such materials at the present time. With some soils the important thing may be to provide some quickly available phosphorus but in all instances it is necessary to consider the building up of the phosphorus content so that crops may be grown satisfactorily in the future. The results given earlier in this report indicate that phosphorus may be a limiting factor in growth in some cases and while definite conclusions cannot yet be drawn from the greenhouse and field tests, indications are certainly given of the desirability of testing the value of phosphorus carriers in Johnson county.

Two phosphorus fertilizers, rock phosphate and acid phosphate, are most commonly applied to soils to supply phosphorus deficiencies. Acid phosphate supplies the phosphorus in an immediately available form while the element in rock phosphate must be made available in the soil. Rock phosphate costs less than acid phosphate but much larger amounts must be applied. It is added at the rate of 2000 pounds per acre once in a four year rotation while acid phosphate is applied at the rate of 200 pounds per acre annually. Thus it is important to decide which material should be applied. The field tests now under way include both materials and eventually it may be possible to say which should be used on a particular soil for the most profitable results. For the present this cannot be done. The results discussed earlier in this report show generally somewhat greater effects from the acid phosphate but in some cases the rock is quite as effective and in a few instances, more so. Different results are secured under different soil conditions. It can only be urged now that farmers test both materials on their own soils and thus determine for their particular condition which material is the most desirable. It is a simple matter to carry out such tests and directions are given in Circular 82 of the Iowa Agricultural Experiment Station. The indications are that one or the other phosphorus fertilizers may give profitable crop increases on many Johnson county soils.

Nitrogen is not low in most of the soils in Johnson county, but neither is it very high and systems of permanent fertility must include methods of supplying this element. In a few cases the supply is low and then the need of nitrogen at the present time is evident. Nitrogen disappears gradually from all soils however thru utilization by crops or thru leaching and some fertilizing material must be used on all soils to make up for these losses and to keep up the supply. Farm manure when carefully stored and applied to the soil adds much nitrogen but in most cases this material alone will not keep up the supply. The ordinary application of manure which has been well cared for will only return to the soil a portion of the nitrogen content but there is still a deficit even where this material is carefully utilized.

Leguminous green manures supply nitrogen in a cheap and most desirable form and by their use to supplement farm manure and crop residues, the nitrogen con-

tent of soils may be increased and maintained. The legumes must be well inoculated or they will not take up nitrogen from the atmosphere and will not serve as nitrogenous fertilizers. If the legume crop is removed as hay, there will be no gain in nitrogen. If a part of the crop is removed there may be some nitrogen added to the soil. If the seed only of the legume is harvested, then there may be a large effect. The greatest influence of a legume as a nitrogenous fertilizer can only be exerted, however, if the entire crop which has been thoroly inoculated is plowed under in the soil. When this is done, no commercial nitrogenous fertilizers is necessary. In general they cannot be recommended for general use on the soils of this county. They may possibly be used in small amounts as top dressings but for general farm crops farm manure, crop residues and leguminous green manures will keep up the nitrogen supply. There is no objection to using a commercial nitrogen carrier if profitable results can be secured but they should not be used until tests have proven their value.

Analyses of many soils of the state made several years ago showed a large content of potassium in practically all cases. It is hardly likely, therefore, that potassium fertilizers would prove profitable for general farm crops. If the organic matter content in soils is good and the general physical conditions are satisfactory potassium should be produced in an available form in sufficient quantities to keep crops well supplied. In individual cases, it might prove desirable to apply a small amount of an available potassium carrier like the muriate or the sulfate to make up for a deficiency in available potassium but in general it seems hardly likely that these materials would prove profitable. Certainly tests should be made on small areas before there is an application to any extensive area. The use of potassium fertilizers in small amounts as top dressings is sometimes of value but again this cannot be generally recommended.

Complete commercial fertilizers are not recommended for general use in Johnson county at the present time. The nitrogen supply in the soils may be more cheaply kept up by the use of legumes as green manure and the potassium supply should be adequate for many years. Phosphorus may be more cheaply supplied in acid phosphate or rock phosphate. The tests reported earlier have shown that complete fertilizers give variable effects on different soils and on various crops. In general however they do not seem to increase crop yields to a sufficient extent above the increase from the use of phosphates to warrant their use. They are much more expensive and must give very much larger crop increases to prove as profitable as the cheaper phosphates. There may be cases in which the complete brands would prove desirable but they should not be extensively used until tests in comparison with phosphates have proven them more profitable. Tests may readily be made on small areas by any who are interested and if the results are satisfactory, there is no objection to their use. When growing truck crops the situation is very different and complete fertilizers especially prepared for such crops may be employed in many cases with distinct profit.

DRAINAGE

The soils of Johnson county as a whole are quite adequately drained. The drainage map given earlier in this report indicates that the natural drainage system of the county is quite complete. There are however, certain areas of

various soil types, where the drainage is poor and tiling is very desirable. If a soil is too wet, satisfactory crops cannot be secured and the first treatment such areas need is tiling if crop yields are to prove profitable. The Muscatine silt loam needs tiling in certain areas. Several of the terrace soils, notably the Bremer types and the Chariton silt loam should be drained. The Wabash soils on the bottoms are also in need of drainage but, of course they also need protection from overflow if they are to be made productive.

The cost of installing tile may be considerable but the expense is more than warranted by the increased crop yields secured. Tiling out small areas of the various soils mentioned and other areas in the county may prove of distinct value in many cases and this drainage should be considered a basic treatment before any fertilizers are tested or conclusions are drawn regarding the value of any special soil treatment.

THE ROTATION OF CROPS

Soils will not continue to produce large yields of the same crop indefinitely but a rotation will keep the soils productive over a much longer period of time. Often, the large value derived from a particular crop will lead to an attempt to grow it year in and year out. Soon yields decrease and eventually the crop refuses to grow. Experiments and much farm experience have shown that, over a period of years the money returns from a rotation are greater than from continuous cropping even altho the rotation includes crops which are less profitable. This is due to the fact that yields do not decrease so rapidly under the rotation. Some rotation should be followed on every soil if the soil is to be kept productive.

In Johnson county, as in all other counties, rotations should be followed. No one rotation can be recommended for use under all conditions but from among those given below some one may be chosen which should be satisfactory. In fact almost any rotation may be followed provided it contains a legume and the "money" crop.

The following rotations are suggested for use in Johnson county:

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.

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 five years. The last crop will consist principally of timothy.)

3. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Corn.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year Alfalfa. (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-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—Clover.

Third Year —Corn.

Fourth Year—Oats (with clover).

. 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 and straw 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 clover).

Third Year —Clover.

First Year —Wheat (with clover).

Second Year—Corn.

Third Year —Cowpeas or soybeans.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials



Fig. 10—Clinton silt loam about a mile north of Coralville.

the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Johnson county erosion occurs to a considerable extent in the Clinton silt loam and occasionally washing occurs in the Carrington silt loam and the Tama silt loam. The Shelby soils are the most seriously eroded however of any of the types and in many cases much of the surface soil has been removed from these soils. Little erosion occurs on the terraces but some of the older higher terraces have been washed to some extent. It is very necessary that means be taken to protect these various soils in the county from the injurious effect of surface washing and from the formation of gullies.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows" to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

“Plowing In.” It is quite customary to “plow in” the small gullies that result from these dead furrows and in level areas where the soil is deep, this “plowing in” process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by “plowing in.” Then it is best to supplement the “plowing in” with a series of “staked in” dams or earth dams.

“Staking In.” The method of “staking in” is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the “staking in” operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in “dead furrows.”

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides, in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

“Staking In.” The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity

of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to 10 feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed up-stream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower end of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or run-off to prevent any cutting back by the water flowing from the tile. The earth

dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up to slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore, reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN JOHNSON COUNTY*

There are 24 individual soil types in Johnson county and these with the colluvial phase of the Wabash silt loam and the areas of meadow, muck and riverwash, make a total of 28 soil areas. They are divided into four groups

*The descriptions given in this section of the report very closely follow those in the Bureau of Soils report.

on the basis of their origin. These groups are drift soils, loess soils, terrace soils and swamp and bottomland soils. (1)

DRIFT SOILS

There are four drift soil types in the county, classified in the Carrington and the Shelby series. Together they cover 8.9 percent of the total area.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the most extensive of the drift soils, covering 7.4 percent of the total area of the county. It occurs in the northern and northwestern parts of the county, the largest area being in Madison and Penn townships around North Liberty. A second area extends along the north county line from the extreme western edge beyond Shueyville varying from one to three miles in width. The third area extends northwest from Solon to the north county line.

The surface soil of the Carrington silt loam is a dark brown to dark grayish-brown silt loam extending to a depth of 20 inches. Below that point the subsoil is a brown or dull yellowish-brown silty clay loam. At depths of 30 to 40 inches there is coarse sand, gravel or small stones mixed with the stiff, yellowish-brown silty clay. In some areas the subsoil is a light-brown silty clay loam. Occasionally the underlying material is a stiff, heavy clay and the drainage of the soil in such areas is not as good. In the area north of Solon there are some variations from the typical soil. Sandy elevations occur here, with areas of a mixture of silt and sand, the surface soil lighter in color than the typical. In the area west of Swisher the soil is a deep silt over a brown or yellowish-brown heavy sandy, gravelly, silty clay. In the more nearly level areas, the surface soil is a deep, black mellow silt loam.

In topography the Carrington silt loam is generally undulating to slightly rolling. In the area north of Solon, the silty areas adjacent to the "paha" ridges are included with this type and lie above the surrounding level. There are a few "paha" ridges in the type. Small areas are nearly level and occasionally there are small sloughs. The drainage of the type is usually quite adequate but in some areas tiling is very desirable. Where the subsoil is heavier, natural drainage is poor and in the level or slough-like spots artificial drainage is necessary.

Practically all of the type is under cultivation corn, oats, clover and timothy being the chief crops grown. Only in the sloughs and on the sandy knolls are the conditions poor for the growth of these crops. Corn yields 50 to 75 bushels per acre, oats give 40 to 80 bushel yields and clover and timothy and bluegrass do well.

The yields of crops on the Carrington silt loam may be increased thru proper methods of soil treatment. Farm manure gives large effects on this soil,

(1) Johnson county adjoins Linn county on the north, Cedar and Muscatine counties on the east, and Louisa County on the south. In certain cases the maps of these counties do not appear to agree along the boundaries. This is due to changes in correlation resulting in part from a fuller understanding of the soils of the state. The Judson silt loam, the Carrington loam, and the Lindley type of Linn county have not been extended into this county on account of their very small area and their close resemblance to larger types in the area. For a similar reason the Bremer silty clay loam of Muscatine county has been mapped as Wabash silty clay loam in Johnson county and the Bremer clay as Bremer silty clay loam. The Muscatine silt loam of Muscatine county has been subdivided in this county into the Muscatine silt loam and the Tama silt loam. The Cass sandy loam and the Cass loam as mapped in Louisa county have been combined in this county with the Cass silt loam, and the Cass sand with the Sarpy sand. (From Bureau of Soils Report.)



Fig. 11—Carrington silt loam topography.

as indicated in the results given earlier and liberal applications of this material are recommended. When farm manure is not available for use, then leguminous green manures should be employed. The soil is acid and needs applications of limestone. Large increases in yields of legumes and of all general farm crops follow the use of this material. The content of phosphorus is low and there are indications that phosphorus fertilizers would prove profitable. The tests reported show gains in crop yields from the use of acid phosphate or rock phosphate. Farmers are urged to test these two materials on small areas to determine their relative value. Tiling is needed in a few areas but in general the drainage of the type is good.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county covering 0.7 percent of the total area. It occurs in several small areas, mostly in Oxford and Madison townships, northeast of the town of Oxford. Other small areas are found in the northeastern part of the county. It is associated with the Knox sand and with the Carrington silt loam and the Clinton silt loam, separating the latter from the areas of terrace soils which occur south of the Iowa river.

The surface soil of the Carrington fine sandy loam is typically a dark brown fine sandy loam. The surface soil varies considerably in texture however and generally is a dark brown silty loam containing much medium and fine sand. There are gradations into the Knox sand and hence many small spots are very sandy, a light brown loamy sand or sandy loam, occurring on mounds or slight elevations. The subsoil is generally a dark brown silty clay loam, crumbly or friable. The small areas east of the Cedar river are mostly black loams or sandy loams between sandy ridges.

The Carrington fine sandy loam is nearly all in cultivation except for areas adjacent to the Knox sand where the soil is droughty. General farm crops,

corn, oats and hay are grown. Fair yields are secured. The type is particularly in need of organic matter however, if it is to be made satisfactorily productive. Liberal amounts of farm manure or leguminous green manures should be used. The soil is acid and lime should be applied. Phosphorus fertilizers would undoubtedly prove of value. Truck crops could undoubtedly be most successfully grown on this soil and, when they are, complete brands of commercial fertilizers might be profitably employed.

SHELBY LOAM (79)

The Shelby loam is a minor type in the county, covering only 0.5 percent of the total area. It occurs in numerous small areas in the northwestern part of the county in association with the Carrington silt loam. The largest areas occur in Monroe township.

The surface soil of this type varies from a brown loam containing some stones to a very dark colored silty sandy loam, free of coarse material to a depth of 18 to 20 inches. The subsoil is usually a stiff, coarse textured loam, often grading into a reddish-brown sandy loam. In many cases the loam occurs only on the higher and steeper slopes while on the lower slopes and on the tops of the ridges, the surface soil is dark colored and silty, resembling the Carrington silt loam with which it is associated.

The type is rolling to somewhat hilly in topography with some areas which are steep. Drainage is good to excessive and in the areas with the more sandy subsoils the soil is inclined to be droughty. The type washes badly and protection from erosion is very necessary if the soil is to be kept productive.

General farm crops are grown on this soil and yields are quite variable depending on seasonal conditions. The crops often suffer from drought especially on the higher, light colored knolls, where the soil and particularly the subsoil are gravelly, sandy or stony. On the more silty areas good crop yields are usually secured of corn, oats and clover.

This type needs first of all protection from erosion and then applications of organic matter, if crop yields are to be increased. Liberal amounts of farm manure should be applied and legumes should be used as green manures to improve the water holding power of the soil. The soil is acid and needs lime. It is low in phosphorus and should undoubtedly receive an application of a phosphorus fertilizer.

SHELBY SILT LOAM (93)

The Shelby silt loam is small in area covering but 0.3 percent of the total area of the county. It occurs in many small areas in the northern and western part of the county. Most of the areas are found in Hardin township, northwest of Cosgrove, in association with the Clinton silt loam.

The surface soil of the Shelby silt loam is a brown silt loam, quite variable in depth, usually less than 10 to 15 inches. The subsoil is a stiff clay loam or sandy clay reddish-brown in color, usually containing much gravel and many small stones. Occasionally on the steepest slopes stones occur in the surface soil. There is a gradual change from the Clinton silt loam to the Shelby and no sharp boundaries can be drawn. Where any glacial till occurs

in the subsoil, the soil is mapped as the Shelby and this is often the only means of separation.

In topography the Shelby silt loam is sharply rolling to steep or rough and drainage is good. The type is subject to erosion and may be seriously washed if cultivated. Most of the areas mapped are used only for pasture. If they are to be cultivated it is necessary that they be protected from erosion, large applications of manure should be made or some legume should be turned under as a green manure and lime should be applied. Response would also undoubtedly be secured from the use of a phosphorus fertilizer.

LOESS SOILS

There are five loess soils in the county classified in the Clinton, Tama, Muscatine, Knox and Scott series. They make up the most important group of soils in the county, covering 71.9 percent of the total area.

CLINTON SILT LOAM (80)

The Clinton silt loam is the largest loess type and it is by far the most extensive individual soil in the county, covering 45.9 percent of the total area. It occurs in large areas thruout the county, particularly in the northern and western townships where it is the most important upland soil. It does not occur however, east of the Iowa river, south of Iowa City except in one or two very small areas. The chief upland soils in the southeastern township, Fremont, Lincoln, Pleasant Valley, East Lucas and most of Scott township are the Tama silt loam and the Muscatine silt loam.

The surface soil of the Clinton silt loam is a light grayish-brown or brown very friable silt loam becoming a light yellowish at a few inches and a pronounced yellow at 8 to 10 inches. The upper subsoil is a yellowish-brown heavy silt loam to silty clay loam, friable to crumbly. The lower subsoil is a light yellowish-brown or pale yellowish silt loam, friable and crumbly. When dry the surface of cultivated areas which are fairly level, has an ashy gray color. On hillsides where much of the surface soil has been removed, the surface color is yellow to yellowish-brown. On level areas the surface color is somewhat darker than typical, owing to a greater accumulation of organic matter. On some of the small flat areas, there is a dark colored surface soil underlain at a few inches by a gray or ashy silt loam, which at 18 to 20 inches changes to a stiff silty clay, more or less mottled with gray and pale yellow. Near the rivers there are high points of sandy material resembling the Knox sand. In the areas near the Iowa river in Jefferson and Big Grove townships, there is often a sandy layer below the subsoil, which is exposed in gullies, and the soil on the slopes is more or less sandy. In the areas adjacent to the Tama silt loam there is a gradual change from one type to the other and boundaries are difficult to draw. The soil included with the Clinton in these areas is much darker than the typical.

In topography the Clinton silt loam is undulating to strongly rolling. In the western part of the county the surface is smoother in topography than the typical Clinton altho there is much of the land which is strongly rolling. On the south slopes to the streams the type is rougher while the north slopes



Fig. 12—Level upland soil south of Lone Tree.

are more gradual. Some areas are much eroded and here the topography ranges from strongly rolling to rough. Near the heads of many of the natural drainage channels, there are deep ravines with narrow ridges between. North of Iowa City along the river, the topography includes high, rounded ridges, with deep cut areas separating them.

Practically all of the rougher areas of the type were forested. White oaks generally predominated with more bur oaks as the distance from the river increased. On the more level areas the original forest growth was light and consisted of bur oak groves and hazel brush patches with an occasional area of mixed timber. In the southern and western parts of the county, much of the smoother areas were in prairie at the time of settlement.

Roughly about one-half of the more rolling land has been cleared but only a small part of it is regularly cultivated. This land is used mainly for pasture and bluegrass does well. On the larger areas of the smoother variation of the type general farm crops are grown. Corn yields about 40 bushels but where the land has been manured 60 to 70 bushels are frequently obtained. Variations in yield are wide on the different areas of the type which vary considerably in fertility. Oats yield from 25 to 75 bushels per acre, the late varieties being somewhat preferred. Wheat is grown to a small extent, the winter varieties yielding 20 to 30 bushels per acre. Clover grows well on this soil and alfalfa makes good yields if proper precautions are taken to secure a good stand.

The rougher areas of the type should undoubtedly be kept in pasture owing to the erosion which occurs in such areas. One of the first treatments needed by much of this soil is protection from injurious washing. The prevention of erosion, the filling of gullies and the proper cropping to protect the slopes are most important in the case of this type. The soil is generally low in organic matter and applications of farm manure are very desirable. Large crop increases are always secured, as are indicated in the experiments reported earlier. When farm manure is not available for use, legumes should be turned under as green manures. The soil is acid in reaction and limestone should be ap-

plied especially for legumes. Other crops are also benefitted by liming as experiments and experience on the farm have demonstrated. Phosphorus is low in the soil and phosphorus fertilizers should undoubtedly be used in many cases. Experiments have indicated the value which may come by the use of a phosphate. Either rock phosphate or acid phosphate may be used but tests should be carried out before either material is employed. Some indications point to a superior value for the acid phosphate but the rock might prove as good, at least on the areas better supplied with organic matter.

TAMA SILT LOAM (120)

The Tama silt loam is the second largest soil type in the county, covering 18.9 percent of the total area. It occurs chiefly in the southeastern townships between Iowa City and Lone Tree, east of the Iowa river. In this area, it is the chief upland type in association with the Muscatine silt loam. Extensive areas also occur however in the southwestern townships, Washington and Sharon, from Sharon Center west and south to the county line. A large area also extends from Solon east and south thru Cedar and Graham townships to Oasis and the county line. Other smaller areas are found scattered thruout the eastern and central townships.

The surface soil of the Tama silt loam is a dark brown to black silt loam, loose and mellow. At about 18 inches there is a change to a lighter brown heavy silt loam. The lower subsoil is a light yellowish-brown silt loam or silty clay loam. The depth of the surface soil is quite variable. On the more rolling areas it is 8 to 10 inches in depth. On the more level, broad divides, the dark surface soil extends to a depth of 18 to 20 inches. In these areas the subsoil is heavier and slightly mottled.

In topography the Tama silt loam is undulating to gently rolling. Near the Clinton silt loam it is strongly rolling but it never becomes hilly or broken. Drainage is adequate in most of the type and only in a few flat areas would tiling be necessary.

Practically all of the type is under cultivation and general farm crops are grown. Corn yields 50 bushels per acre on the average and may yield as high as 75 or 80 bushels. Good yields are secured for oats and barley and hay crops do well. Clover is grown extensively and some alfalfa is produced.

The crop yields secured on the Tama silt loam are generally quite satisfactory but the experiments reported earlier indicate that proper treatment will give greater returns from the soil. Manure produces large effects on this type and liberal applications are very desirable. Lime is needed as the soil is acid and gives profitable crop increases. The use of a phosphate fertilizer would often be desirable according to the experiments reported. Tests of the value of rock phosphate and acid phosphate on the farm are very desirable and should precede the large use of either material on this soil.

MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the third largest loess soil in the county, covering 5.5 percent of the total area. It occurs mainly in the southeastern part of the county associated with the Tama silt loam, occupying the level uplands between the areas of more rolling Tama. It is also found in several areas



Fig. 13—A fine farm home in Johnson county.

with the Tama in the southwestern townships, and in association with the same type in the northeastern townships. Small isolated areas occur in the Clinton silt loam west of Iowa City between Old Man creek and Clear creek. These latter areas are hardly typical of the true Muscatine.

The surface soil of the Muscatine silt loam is a dark brown to almost black silt loam, extending to a depth of 18 to 20 inches. The texture becomes somewhat heavier with increasing depth. The subsoil is a brown heavy silt loam changing at varying depths to a more or less mottled gray and yellowish-brown heavy silty clay loam. In some of the more poorly drained areas, the surface black soil extends to a depth of 30 inches and the subsoil is a gray or drab sticky, heavy silty clay loam.

In topography the type is level to flat. Natural drainage is poor and for the most satisfactory crop production, tiling is very necessary.

All of the Muscatine silt loam is under cultivation and general farm crops are grown. Yields of corn amounting to 75 bushels per acre are often secured. Average yields of this crop are lower. When well drained, however, good yields of corn and other crops are secured.

The type may be made more productive in some cases by proper treatments as has been indicated in the experiments described earlier in this report. Small applications of farm manure are often desirable particularly on newly drained areas. Manure should not be applied just preceding the small grain crop, however, owing to the danger of causing it to lodge. Liming is necessary as the soil is acid in reaction and the application of a phosphate fertilizer might prove distinctly profitable in many cases and tests are very desirable. Experiments have indicated some value from the use of these materials.

KNOX SAND (158)

The Knox sand is a minor type in the county covering 1.5 percent of the total area. It occurs in numerous small areas thruout the northern part of the county. The largest area is in the extreme northeast corner, east

of the Cedar river. Here the sand hills rise 50 to 75 feet above the valley. The sand occurs in mounds and is variable in depth. In the northwestern part of Madison township ridges of Knox sand are numerous. Most of them have a northwest to southeast trend. Some are nearly a mile in length but rarely are they more than one-fourth of a mile in width. Many are simply low sandy swells covering a few acres. In general however, they are 20 to 50 feet above the surrounding area. Dune-like areas of this sand occur near Oxford and southeast beyond Tiffin. Small areas occur south of Clear creek. Numerous ridge-like areas occur east and north of Solon in association with the Tama silt loam and the Carrington silt loam. The elevations thruout the northern part of the county which are known as "pahas" are made up of Knox sand or of sandy material which while not typical is mapped with this type. South of River Junction in the southern part of the county there are several small areas of Knox sand occurring as ridges on the uplands.

The Knox sand is chiefly a mixture of fine and medium sand with some coarse material. It is found in mounds and ridges ranging from a few acres to several hundred in size and from a few feet to 50 and 75 feet in height above the surrounding area. The depth of the sand is therefore extremely variable. On the sides of the mounds or ridges there is a gradual change with depth to a shallow silty, sandy loam with a stiff, silty clay subsoil. The lighter ridges consist of a loose, gray to grayish-brown sand with a small content of silt. The lower subsoil is generally a loose brown sand containing more silt than the surface soil. Lower areas of the sand are sometimes darker in color, more silty and less likely to "blow." In the areas east of the Cedar river, the sand is often thin and the underlying brown silt is exposed. Loose, brown sand makes up the areas south of River Junction. In the typical "paha" ridges, the soil is a dark gray or brownish-gray medium to fine sand often containing much silt. The subsurface is a brown sand and the subsoil a loose lighter colored sand.

The areas in Madison township are thinly wooded in places but most of the hills are treeless pastures, generally in blue grass, sometimes in prairie vegetation. "Blow-outs" or spots where vegetation has been destroyed occur and here the loose gray sand drifts badly in dry windy weather. Very few of the areas in this section are cultivated. Corn makes a low yield and other crops grow poorly. No truck crops are now grown but such crops might do very well. In the area east of the Cedar river a light forest growth of black oak chiefly, was formerly common on the lightest sand while elsewhere dense woods of oak, hickory, walnut, elm, ash and wild cherry occurred. Poplars grew in the seepy spots and cottonwood, willow, and sycamore surrounded small ponds. Much of this area is not in cultivation. On the ridges, poor yields are secured when crops are grown, but in the lower slopes, fair crops are secured. Melons and early truck crops do well on many areas and fruit trees prove profitable on the shallower areas. South of River Junction the areas are mainly blue grass pastures with a few bur oak trees. Low areas are cultivated and give fair crops of corn, small grains and clover.

Much of the Knox sand should undoubtedly be kept in pasture. When cultivated, it should be heavily manured and legumes should be turned under as green manures. It should be limed when acid, and phosphorus fertilizers

should be applied. When truck crops are grown, and the soil is particularly adapted to such crops, more organic matter is needed and complete commercial fertilizers may be applied with profit, using brands especially prepared for certain truck crops.

SCOTT SILT LOAM (154)

The Scott silt loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas in the southeastern part of the county northeast of River Junction and to the southeast for several miles. It is found in depressions usually in the Muscatine and Tama silt loams and marks the location of former ponds.

The surface soil of the type is a gray silt loam, light colored and ashy when dry. Usually the surface soil extends to a depth of 18 to 20 inches without change but sometimes there is a subsurface layer slightly more compact and lighter colored than the surface soil. The subsoil is a light silty clay loam drab or light gray in color, often showing yellow and brown mottlings. In topography the type is depressed and drainage is poor.

Corn, oats, timothy, millet and sorghum are grown on the type. When well drained good crops are secured but if drainage is inadequate poor crops are secured. Millet and sorghum prove profitable late forage crops. The type needs principally to be thoroly drained for good crop growth. Liberal amounts of farm manure would prove of value. Lime should be added when the soil is acid and phosphorus fertilizers would probably prove of value.

TERRACE SOILS

There are eleven terrace types in the county classified in the Waukesha, Bremer, Buckner, Jackson and Chariton series. Together they cover 9.1 percent of the total area of the county.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest of the terrace soils, but it covers only 2.3 percent of the total area. It occurs in numerous areas along the Iowa river, Old Man creek, Clear creek and other streams in the county. The largest areas are found south of Iowa City, near Hills and Morfordsville and in the northwestern part of the county in Monroe and Oxford townships.

The surface soil of the Waukesha silt loam is a dark grayish-brown to black friable silt loam. Below 5 to 7 inches the soil becomes somewhat darker colored and heavier in texture. At 25 to 30 inches the subsoil is a brown silt loam or silty clay loam. Small sandy spots, slightly elevated above the soil level, are included with the type. These areas are a loam or sandy loam. In some areas north of River Junction small patches of Bremer soils are included with the type. On some low terraces extending to the river banks the type includes low swales and sandy mounds.

The Waukesha silt loam is level to slightly undulating in topography, sometimes being marked by the low sandy mounds mentioned above. Natural drainage of the type is good. It is found usually on high terraces and the character of the subsoil indicates good drainage and oxidation. On the low terraces oxidation has not been so extensive in the subsoil.



Fig. 14—Farm feed lot.

Practically all of the type is in cultivation and general farm crops are grown. Yields are very much the same as on the Tama silt loam. The type would be benefitted by liberal amounts of manure, the use of lime and probably also by the application of a phosphorus fertilizer.

BREMER SILT LOAM (88)

The Bremer silt loam is the second largest terrace type in the county, covering 1.9 percent of the total area. It occurs in numerous areas along the Iowa river and some of the tributary streams, occupying low terraces. The largest areas are found just south of Iowa City and in the northwestern part of the county in Monroe township.

The surface soil is a black silt loam, extending to varying depths and resting on a light-colored silty clay subsoil, usually mottled. There are many variations from the typical soil. In the areas north of the Iowa river in Monroe township the soil often resembles very closely the Waukesha silt loam, but it has usually a black surface soil with a grayish or mottled subsoil. South of the Iowa river in the same section of the county the surface soil is usually a black friable silt or silty sandy loam, extending to a depth of 20 or 30 inches. Mucky areas occur on the surface in small spots, and there are also small ponds in which shallow muck occurs. The subsoil is heavy and impervious. In the area in the northeastern corner of Oxford township the surface soil is quite variable, but it is usually a black silt loam.

All the areas north of the Iowa river in Monroe township are cultivated and produce good crops of corn, clover and timothy. The areas are usually above overflow, altho some are reached during high floods. Much of the land in Bremer silt loam, south of the Iowa river in this section of the county, is used for pasture or the production of wild hay as the drainage is so poor. Some of the areas have been drained and are growing corn, clover and timothy. In the areas near Morfordsville there are included some ponds and marshes and

much of the land is used for pasture. Good corn is produced on the type in general when it is well drained as is evidenced by yields secured on areas along Old Man creek.

The Bremer silt loam is a rich soil and may be made very productive. It needs first of all, thoro drainage. When this is accomplished, small applications of farm manure would prove helpful. Lime is needed to remedy acidity and phosphorus fertilizers might prove of value.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor type, covering 1.5 percent of the total area of the county. It occurs chiefly in the southeastern part of the county in the wide, flat basins and along drainage lines. The most common occurrence is near Lone Tree, but areas occur from Iowa City, southward. A few small areas are found in other parts of the county.

The surface soil is a black, heavy silt loam to silty clay loam which at a few inches depth grades into a stiff silty clay. There is little change in color or texture to a depth of 25 or 30 inches, where the subsoil is encountered. This is a dark bluish-gray tenacious silty clay which at 40 inches may become light colored. Some areas have friable silty soils with black waxy subsoils. Small spots of the Scott silt loam are also included with the type as they are too small to show on the map.

Practically all of the larger areas are cultivated and general farm crops are grown. Numerous small depressions are either marshy ponds or pasture ground, usually in bluegrass. Undrained areas are often shallow ponds filled with cat-tails and other rushes.

This type needs drainage primarily, if it is to be made suitable for general farm crops. When well drained, it is highly productive. It must be cultivated carefully as it will clod if plowed when too wet. There are so-called "gumbo" spots where the waxy clay is near the surface. These areas need special care in handling. Small applications of farm manure would help on newly drained areas, but should not be applied preceding the small grain crop. Oats are apt to lodge on the type and the addition of manure might increase that difficulty. The soil is acid and should be limed for good legume growth. Phosphorus fertilizers will be needed in the future.

BUCKNER LOAMY SAND (159)

The Buckner loamy sand is a minor type in the county, covering 1.1 percent of the total area. It occurs in many areas along the Iowa river, Cedar river and some of the minor streams of the county. The largest individual area is around Morfordsville, extending north and south on the east side of the Iowa river. Other areas occur to the south and to the north as far as Iowa City. In the northwestern part of the county there are several areas of the type south of the Iowa river. Small areas are found on both sides of the Cedar river in the northeast corner of the county. Small isolated areas are found on the terraces in other parts of the county.

The surface soil of the Buckner loamy sand is a dark brown, medium to fine sand, containing some silt and clay. There is little change to a depth of 20 or 30 inches, where the subsoil becomes a yellowish-brown loose sand. In the

areas south of Iowa City the soil is darker colored and somewhat heavier in texture. In slight depressions and where the type joins the Waukesha or Bremer soils, it is a sandy loam. On the terraces along the Cedar river south of Sutliff the soil in this type is a dark brownish-gray to light gray sand, somewhat coarser than the typical—a mixture of medium and coarse sand and fine material. The subsoil is the same in texture and brown in color.

In the areas in the northwestern part of the county, the Buckner loamy sand occurs in low mounds and ridges and most of it is in cultivated crops. Corn yields 30 bushels per acre on the average, but on the more sandy spots the yield is lower. Rye is a good crop on this type, yielding 15 to 20 bushels per acre. Oats and wheat are seldom grown. Clover is grown only on the heavier textured areas. Much of the type in this section of the county is pastured, usually in bluegrass. In the areas south of Iowa City the yields of corn often exceed 30 or 35 bushels per acre. Rye does well and fair yields are secured of other grain crops. Watermelons, Irish potatoes and most garden crops do well on the type in these areas. Clover grows well in favorable seasons. Sorghum, Sudan grass and feterita are well adapted to this soil. In the areas near the Cedar river, melons, sweet potatoes and other truck crops are the chief crops grown and satisfactory yields of these crops are secured.

This type is chiefly in need of organic matter to make it more productive. It should receive liberal applications of farm manure and legumes should be turned under as green manures. The soil needs lime for good legume growth. It should also receive applications of phosphorus fertilizers. Where truck crops are grown, applications of complete commercial fertilizers, brands specially designed for certain crops, could undoubtedly be made in many cases with distinct profit.

JACKSON SILT LOAM (81)

The Jackson silt loam is of minor importance in the county, covering 0.8 percent of the total area. It occurs in numerous small areas on the higher terraces along the Iowa river, Cedar river, Old Man creek, Clear Creek, Lingle creek and other smaller creeks in various parts of the county. It is most extensively developed along Lingle creek and along Old Man creek. One large area is found on the west side of the Iowa river, south of Iowa City.

The surface soil of the Jackson silt loam is a light brownish-gray silt loam. In cultivated fields it often appears ashy in color. The upper subsoil is a light brown silt loam. At 20 to 30 inches the subsoil becomes a compact silty clay loam, mottled with gray and yellowish-brown. Sometimes the subsoil is a yellow, heavy silty clay. In the areas on the small creeks north of Iowa City and west of Solon, the soil is a dark silt loam with a more open subsoil.

The type was formerly timbered chiefly with bur oak and white oak. Nearly all of it is now in cultivation and general farm crops are grown. Corn, oats, bluegrass and clover do well. This type needs chiefly organic matter to make it more productive. Heavy applications of farm manure are very desirable and legumes should be used as green manures. Liming is necessary to grow good legumes and phosphorus fertilizers should be tested. They should yield good profit.

WAUKESHA LOAM (60)

The Waukesha loam is of minor occurrence in the county, covering 0.7 percent of the total area. It is found in small areas mainly along the Iowa river, south of Iowa City and in Jefferson township, along the river southwest from Curtis. Other small areas occur in other parts of the county. The largest area is just north of Swan Lake in Jefferson township.

The surface soil of the type is a dark-brown loam 20 to 30 inches in depth. The subsoil is a brown, well oxidized loam or sandy loam. In the area north of Swan Lake the soil is a stiff black silty loam. In the areas south of Iowa City the soil is variable, but generally is a light brown loam or silty loam.

Practically all of the type is cultivated and good crops of corn, oats and clover are secured. The soil will respond profitably, however, to applications of manure, the use of legumes as green manures, the addition of lime and probably also to the application of a phosphate fertilizer.

WAUKESHA SANDY LOAM (127)

The Waukesha sandy loam is minor in area, covering 0.3 percent of the total area of the county. Small areas of the type occur along the Iowa river just north of Iowa City and south to the county line. Other areas are found along Hoosier creek and Cedar river and a few scattered areas are located in other parts of the county. The largest areas are near Sutliff along the Cedar river.

The surface soil of this type is a brown to dark brown coarse to fine sandy loam. The subsoil is very similar in color and texture to the surface soil. The surface soil color is often a light brown. On the tops of the narrow ridge like areas the color is lighter and the texture approaches a sand. In some places the type resembles closely the Buckner loamy sand, but has a slightly heavier soil and subsoil. Many areas of the type are too small to show on the map.

The areas in this soil are generally under cultivation and general farm crops are grown. Good yields of corn and small grains are secured. The type needs organic matter and should be manured or green manured. It is acid and should be limed. It would also probably respond to phosphorus fertilizers.

BREMER LOAM (12)

The Bremer loam is small in area, covering only 0.2 percent of the total area of the county. It occurs in several areas south of the Iowa river just west of Swan Lake. The largest area is four miles north of Oxford.

The surface soil of the Bremer loam is a black loam. The subsoil is a heavy silt loam or silty clay loam, lighter in color than the surface and mottled with gray and dull-yellow. There is much variation in the surface soil texture and it is occasionally a coarse sandy loam. The subsoil is sometimes sandy, but as a rule is heavier than the surface soil.

Most of the type is cultivated and utilized for general farm crops. Some areas are too wet and are used only for pasture or wild hay. When thoroughly drained, good crop yields are obtained. Tiling is the first treatment this soil needs and the most important treatment. It will respond to small amounts of farm manure. It needs lime and phosphorus fertilizers would also probably prove of value.

BUCKNER SILT LOAM (36)

The Buckner silt loam is small in area and covers only 0.1 percent of the total area of the county. It is found in several small areas, one south of Lone Tree and several along the Cedar river. Other small areas occur on the Muscatine county line in the southeastern corner of the county.

The surface soil of the Buckner silt loam is a dark brown silt loam and the subsoil is a rather open, yellowish-brown silty loam, differing little in texture from the surface soil. In the areas near the Cedar river the surface is lighter in color approaching the Jackson.

General farm crops are grown on this type and good yields are generally secured. Some areas are in need of tiling, but in general the drainage is good. The type should be manured or green manured. It needs lime and phosphorus fertilizers would undoubtedly give larger crops.

CHARITON SILT LOAM (105)

The Chariton silt loam is minor in importance in the county, covering only 0.1 percent of the total area. It is developed on the terraces along the Iowa river, Old Man creek and Deer creek. The largest areas are in the southwestern part of the county along Deer creek. Small areas occur along Old Man creek and one area is found south of Iowa City.

The surface soil of the Chariton silt loam is a moderately dark gray silt loam to a depth of 8 inches. The subsurface layer is a light-gray silt loam, ashy when dry and pasty when wet. Below 18 to 20 inches the subsoil is a tight silty clay mottled with gray, brown and yellow. Occasionally the subsoil is somewhat sandy and less impervious. The surface soil often appears white or ashy when cultivated, owing to the turning up of the ashy layer.

Some of the lower-lying areas are forested and are utilized for pastures. Timothy and bluegrass do well. General farm crops are not very satisfactory except in favorable seasons. The soil needs thoro drainage, with a careful laying of tile, if good crop yields are to be secured. It will respond then to farm manure, lime and probably also to phosphorus fertilizers.

BUCKNER FINE SANDY LOAM (45)

The Buckner fine sandy loam is of little importance in the county, covering 0.1 percent of the total area. It is found in several small areas in the southeastern corner of the county on the Louisa county line.

The surface soil is a dark brown fine sandy loam, ranging from a very sandy loam to a loam. Below 12 inches the subsoil is somewhat lighter in color, but the texture is much the same. The color varies from dark brown to brown. The type occurs on low ridges on the terraces and it is well drained. It is not droughty.

The type is used for general farm crops and fair yields are secured. It is well adapted for truck crops, but this industry has not been developed. The soil needs liberal applications of organic matter, as farm manure or green manures. It should be limed and phosphorus fertilizers would be of value. If truck crops were grown, brands of complete commercial fertilizers might be used with profit.

SWAMP AND BOTTOMLAND SOILS

There are four bottomland types in the county, an area of the colluvial phase of the Wabash silt loam, and areas of muck, meadow and riverwash, making eight areas of swamp and bottomland soils. The soil types are classified in the Wabash, Cass and Sarpy series. The total area of bottomland amounts to 10.1 percent of the area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest bottomland type and with the colluvial phase, which is small in area, it covers 5.6 percent of the total area of the county. It occurs in narrow strips along the Iowa river, Cedar river and the various creeks of the county. It is most extensively developed along Old Man creek and Clear creek.

The surface soil of the type is generally a black silt loam to a depth of 20 to 30 inches. The lower subsoil is quite variable, but it is usually a silty clay, lighter in color than the surface soil. In the areas along Clear creek above Tiffin the soil is a dark gray to nearly black silt loam 12 to 24 inches in depth. The subsoil is a pale yellow or mottled yellow and gray, plastic silty clay loam. In depressions the soil is sometimes a stiff silty clay loam. Sandy spots occur infrequently. The areas on Old Man creek above the junction with North Branch consist of 2 or 3 feet of black, friable silt loam. Back from the streams the texture becomes heavier and merges into the silty clay loam. Below the junction with North Branch the areas of the type are a heavy black silt loam to silty clay loam. In the areas of the type along the minor streams flowing thru the Clinton silt loam the soil is a black friable silt loam overlying a dark-colored silty clay loam. In the areas adjacent to the Tama and Muscatine soils there are spots where the subsoil is a stiff, black, waxy silty clay to clay.

Practically all of the type is subject to overflow, but in many areas good yields of corn are secured in favorable seasons. In the areas along Clear creek much of the type is cultivated and good crops of corn, oats, clover and timothy are secured. Narrow timbered areas occur adjacent to the streams and in these areas and in low spots back from the streams bluegrass does well. Most of the areas along Old Man creek are used for pasture, owing to frequent overflow. Along the smaller streams the type is usually in pasture. Areas at the heads of drainageways are often in cultivation and good yields of corn, oats and clover are secured.

The areas of Wabash silt loam which are suitable for cultivation need to be well drained if the best crop yields are to be secured. Protection from overflow is also necessary if crops are to be sure. Tiling, however, is often desirable. Small amounts of farm manure would help newly drained areas. Liming is necessary for clover. Phosphorus fertilizers will be needed in the future. Much of the type should undoubtedly be kept in pasture.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is small in area, covering 0.4 percent of the total area. It is found in numerous small areas, chiefly along Cedar creek, Knapp creek and some of the smaller streams in the county sep-

arating the loessial uplands from the Wabash bottoms. The largest areas are along Clear creek.

The surface soil is a dark-brown to black rather loose silty loam to a depth of 20 or 30 inches. The subsoil is a yellowish-brown silty loam, more friable and less compact than the subsoil on the adjacent upland. The soil is formed from the wash of silty material from the adjacent uplands and narrow or fan-shaped areas are formed on the bottoms. The areas seldom exceed 20 acres in size.

This phase of the Wabash silt loam is highly productive, giving good yields of corn, clover and timothy. It would be benefitted by farm manure, lime and probably a phosphate fertilizer.

CASS SILT LOAM (106)

The Cass silt loam is the second largest bottomland soil, covering 2.4 percent of the county. It is developed in numerous areas along the Iowa river and the Cedar River, but it not found along the minor streams. The most extensive areas are found south of Iowa City near Morfordsville, from Curtis west along the Iowa river and south of Sutliff along the Cedar river.

The surface soil of the Cass silt loam is quite variable, ranging from a heavy silty loam to a sandy loam. The latter occurs nearer the streams, while further back the soil is heavier in texture. The color is generally a very dark brown to black and the texture a silt loam. At 8 to 10 inches it changes to a brown or grayish-brown sandy material, becoming lighter in texture at lower depths. In many cases it is a loose brown sandy loam or sand. In the "cut-offs" which are flooded when the river is high, the soil is extremely variable in color and texture. In old channels and depressions the soil is a very black, heavy-textured material approaching the Wabash silty clay loam in texture. The type is well drained except in the low-lying areas. The water table is normally below 40 inches, but sometimes rises higher in the soil. The soil is all subject to overflow.

The areas along the Iowa river in the northwestern part of the county are thinly wooded with elm, ash, soft maple, oak, hickory, walnut, sycamore and cottonwood. South of Iowa City the type is more heavily wooded. Most of the soil is in bluegrass pasture. Some of it is cultivated and good crops of corn are secured if late floods do not occur. The type needs protection from overflow if crop yields are to be satisfactory and sure. It would respond to small amounts of manure. It needs lime and would probably be helped by a phosphorus fertilizer. Most of the type should be kept in pasture.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the third largest bottom soil, covering 1.6 percent of the total area of the county. It occurs in numerous areas along Old Man creek south of Windham. Another extensive area is found south of River Junction. Narrow strips are developed along some of the very small tributary streams and in intermittent drainage lines.

The surface soil of the type is a black crumbly to friable silty clay loam, extending to a depth of 20 to 30 inches. The subsoil is a dark bluish-gray clay,

Below 6 to 8 inches the texture is often a stiff silty clay. In areas adjacent to the Tama and Muscatine soils, the surface soil is a black silt to silty clay loam and the subsoil shows more or less mottling. So-called "gumbo" spots occur, but they are not extensive. In the areas of the type north of the Iowa river in Monroe township there are slight elevations where the soil resembles the Waukesha silt loam, but most of the soil is a black silt to silty clay loam.

A part of the type is cultivated and general farm crops, especially corn and tame grasses, are grown. In favorable seasons, when the soil is not overflowed and drainage has been established, 70 to 80 bushels of corn are obtained. Most of the type is in pasture and probably should be kept for this purpose. When cultivated the type needs primarily to be thoroughly drained. It should be protected from overflow if crops are to be sure. It is acid and needs lime and phosphorus fertilizers might help. Care is necessary in cultivating the soil to prevent clodding. Fall plowing is desirable and the soil should not be wet when plowed, neither should it be too dry. Small applications of manure would be of value on newly drained areas.

SARPY SAND (160)

The Sarpy sand is a minor type in the county, covering only 0.2 percent of the total area. It occurs in narrow strips along the Iowa river from Iowa City north to a point just beyond the junction with Lingle creek. Small areas are also found along Clear creek west of Coralville.

The surface soil of the type is a light brown or brownish-gray medium or fine sand, extending to a depth of 10 to 15 inches. The subsoil is usually a light brown sand. There are some light-colored areas where the texture is somewhat loamy. The darker areas contain much silty material. The type is extremely variable, including both heavier and darker colored phases.

Much of the Sarpy sand is cultivated. Corn is the chief crop grown and when conditions are favorable, the yields are excellent. Some sorghum is grown. Clover and bluegrass do well. The soil should be protected from overflow if crops are to be safe from injury by flooding. Farm manure or leguminous green manures should be applied. Lime is needed and phosphorus fertilizers would probably be of value.

MEADOW (20)

There is a small area of meadow in the county, amounting to 0.1 percent of the total. Two areas are found along the Cedar river and two areas along the Iowa river, south of River Junction.

Meadow consists of a mixture of sand, silt and clay so intermingled that no one texture occurs in a sufficiently large area to be mapped. It is darker in color than riverwash. Practically all of the areas are marshy.

Willows grow along the stream channels and there is a luxuriant growth of water grasses and weeds. The soil has no agricultural value except that it furnishes some pasturage.

(MUCK (21a)

There is some muck in the county, the total area amounting to 0.1 percent of the county. It occurs in several small areas southwest of Curtis and south of Iowa City.

Muck is black, finely divided, spongy material, made up of partially decayed vegetation remains. It represents an advanced stage of decomposition of brown peat. The subsoil is a black clay. In some of the larger areas in Madison and Oxford townships there is a rim or bank 10 to 15 feet high on one side, where the muck is several feet deep and quite peaty. On the opposite side of the areas there is a gradual merging into the adjacent soil, and true muck occurs. Small areas of muck are the sites of shallow lakes and in rainy seasons they become marshes and pools. Southeast of Iowa City the muck is shallow and associated with the Bremer soils. The largest area has been drained, but is still subject to overflow.

Muck is utilized chiefly for pasture purposes. It is not suitable for the growth of general farm crops until it has been decomposed further. Corn and small grains do not do well until the areas have been drained and cultivated for several years. Timothy and alsike clover make an excellent crop on newly drained muck and pasturing the crop provides for compacting of the muck and more rapid decomposition. The growing of vegetables of various kinds is often profitable. Thoro drainage is the first treatment needed to make muck areas suitable for cultivated crops. Fall plowing is desirable and deep plowing also aids by mixing the underlying heavy, rich black clay with the lighter soil material. By pasturing or growing vegetables for a few years the muck is brought into a condition which will permit corn and small grain to be grown satisfactorily.

RIVERWASH (53)

There is a small area of riverwash in the county, amounting to 0.1 percent of the total area. It occurs in small areas along the Cedar river and the Iowa river. It consists chiefly of sand and sometimes overlies a black silty soil at depths varying from a few inches to several feet. The wide areas include cut-offs and some mud deposits which are overgrown with willow, birch and cottonwood. All the areas are subject to frequent overflow and are constantly changing in character. Some have value as pasture, but in general the areas are valueless.

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 co-operation 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. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

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 proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and to insure the best crop production.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizers may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the

soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in the soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the ni-

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (NaNO³)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	\$12.00	\$1.52	\$0.84	\$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

trogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about \$30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, 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 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 maintenance 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 summarized here.

CULTIVATION AND DRAINAGE

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

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 production 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 available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, 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 thoro 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.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of heavy drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

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.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes

in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation 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 a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance 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 reason 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 satisfactory 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 nitrogen 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 soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is 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, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. 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 thru 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 acid phosphate 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 Section.

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

period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their 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 soil 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 divisions 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 thoro 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, altho 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, coluvial 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.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	{	All partially destroyed or undecomposed 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.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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 per cent 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 per cent 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 per cent.

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 per cent 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.

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 one 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 of 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 road map of the county.

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