Soil Surveys, Field Experiments and Soil Management in Iowa

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Iowa State College

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SOIL SURVEYS, FIELD EXPERIMENTS AND SOIL MANAGEMENT IN IOWA

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

AGRONOMY SECTION
SOILS

Ames, Iowa
SOIL SURVEYS, FIELD EXPERIMENTS AND SOIL MANAGEMENT IN IOWA

By W. H. Stevenson and P. E. Brown.

The complete survey and study of the soils of Iowa which is now being carried on by the Soils Section of the Iowa Agricultural Experiment station is designed to secure the information which the farmers of the state need to enable them to make their soils satisfactorily productive and to keep them so.

The soil survey and the co-operative field experiments have been under way for only a few seasons and there are many questions constantly arising regarding the work. It is the purpose of this circular to answer some of these questions and to set forth as definitely as possible the plan which is being followed both in the soil survey work and in the fertilizer experiments on the various fields throughout the state. Farmers may wish to conduct tests on their farms similar to those included in the field experiments. County agents may wish to plan for co-operative tests of the needs of the soils in their particular counties. In either case, the information given in this circular will be of material assistance in planning, laying out and carrying through accurate and reliable soil experiments. Farmers are urged to encourage and aid in such tests, for it is impossible for the Soils Section to increase to any extent the work which is now under way. The more experiments carried out under different soil and farm conditions, the sooner will it be possible to accumulate the data necessary to permit of definite recommendations regarding the particular fertilizers needed and their value on all the soils in the state.

Much general information regarding Iowa soils has already been secured and is published in the various bulletins, which may be obtained without charge upon request to the Agricultural Experiment station. There are included in these publications the results of a plant food survey of the soils of the state, a report on the need, use and value of lime on Iowa soils, the data secured in studies of the special needs of peat soils, "alkali" soils, "push" soils and "gumbo" soils and other experimental data dealing with the use and value of manure, the rotation of crops, the inoculation of legumes and the control of erosion.

A summary of the information contained in these bulletins and of the recommendations made for soil treatment is included in this circular.

THE SOIL SURVEY AND FIELD EXPERIMENTS

THE SOIL SURVEY

The survey of the soils of the state is being carried out in cooperation with the Bureau of Soils of the United States Department of Agriculture and consists in the preparation of a soil map of each county. These maps show all the soil types in the county and the area which each type covers, and they also show the exact location of every road, stream and railroad.

When the survey is completed, samples of all the soils in the county are taken and examined physically and chemically to determine their character and composition and to learn something regarding their needs.
The physical analysis gives the exact percent of clay, silt, sand and gravel in each soil and thus shows definitely the texture of the soil and of the underlying subsoil. Such information regarding the character of soils has an important bearing on drainage problems and gives information regarding the adaptation of soils to particular crops.

The chemical analysis shows the total plant food and organic matter present in the various soil types and this is an indication of the possible needs of the soils. If the organic matter content is low, applications of farm manure or green manure should be made. If a certain plant food constituent is lacking or present only in small amounts, then a fertilizing material containing that element should be applied. The results from chemical analyses are only indicative, however, of the needs of the soils and should be confirmed by field tests before definite recommendations are made.

Pot experiments are then carried out in the greenhouse with the main soil types in the county and the value of the use of manure, phosphorus fertilizers, lime and a complete fertilizer ascertained.

Finally, field tests are carried out on as many soil types as possible to check the results secured in the greenhouse. The plan of these field tests is discussed later.

The reports giving the results of the surveys and soil studies in the various counties are being published in a special series of bulletins. It is quite impossible to issue these reports as soon as the surveys are completed, for the laboratory and greenhouse studies require much time for their completion. Furthermore, most of the field tests have been started quite recently, and such tests should continue for at least five years before definite conclusions are drawn. Some of the reports are being issued without the field data and in such cases supplementary reports for individual counties will be issued, giving the results of the field experiments.

Nineteen counties have already been surveyed, including Bremer, Pottawattamie, Muscatine, Lee, Webster, Sioux, Van Buren, Mitchell, Ringgold, Scott, Clinton, Clay, Hamilton, Linn, Henry, Wapello, Montgomery, Buena Vista and Black Hawk. The survey work will probably continue at the rate of seven counties each year. The order in which individual counties will be chosen will depend very largely on the interest and demand in the county for the work. Petitions signed by residents and especially by the farmers or members of farmers organizations should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties. The form which may be used in such petitions is as follows:

We, the undersigned citizens of ................. county, are interested in building up and maintaining the fertility of the soils of our section of the state. We, therefore, respectfully petition the Soils Department of the Iowa State College, cooperating with the Bureau of Soils of the United States Department of Agriculture, to make a detailed soil survey of our county as soon as it is possible to do so.

THE FIELD EXPERIMENTS.

Before the survey of the soils of the state was begun, 20 experimental fields were laid out either in co-operation with Individual farmers or with state institutions. These fields were located in 13 counties scattered throughout the state and several of them are in counties which have since been surveyed and the soil types on which the fields are located have been determined. In other cases, however, the fields have not been surveyed. While these fields have been un-
nder way for several years, the results are not yet sufficiently complete
to warrant publication.

In order to extend the study of the lime and fertilizer needs of the
main soil types of the state, 49 fields were laid out in 1917 in counties
which had been surveyed, and they were located with great care on
the predominant soil types in the counties.

These fields, laid out in 1917, are listed below:

<table>
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<tr>
<th>County</th>
<th>Co-operator</th>
<th>Post Office</th>
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<tbody>
<tr>
<td>Scott</td>
<td>E. B. Calderwood</td>
<td>Eldridge</td>
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<td>Kroeger Bros.</td>
<td>Princeton</td>
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<td>H. C. Schroeder</td>
<td>Blue Grass</td>
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<td>Joe Gaulkler</td>
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<td>Muscatine</td>
<td>C. J. Sheppard</td>
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<td>Wilbur Oxley</td>
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<td>Ralph Walls</td>
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<td>F. C. Schroeder</td>
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<td>Oscar Ekeley</td>
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<td>Wyse Peterson</td>
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<td>Robert Meek</td>
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<td>G. E. Grace</td>
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<td>F. A. Pine</td>
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<td>J. E. Taylor</td>
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<td>Clay</td>
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<td>H. E. Corwin</td>
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<td>J. R. Karr</td>
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<td>Otto Van Roekel</td>
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<td>Linn</td>
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<td>Black Hawk</td>
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<td>Nels Olson</td>
<td>Lundgren</td>
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The fields started prior to 1917 are given in the following list:

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<thead>
<tr>
<th>County</th>
<th>Co-operator</th>
<th>Post Office</th>
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<tbody>
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<td>Green</td>
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<td>Jefferson</td>
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<td>C. H. Comstock Co.</td>
<td>Sulphur Sp'gs</td>
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<tr>
<td>Story</td>
<td>Agronomy Farm</td>
<td>Ames</td>
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<td>Union</td>
<td>Chas. Ramsbottom</td>
<td>Creston</td>
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<td>Montgomery</td>
<td>Rex Davidson</td>
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<td>Emil Harglund</td>
<td>Red Oak</td>
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<tr>
<td></td>
<td>E. A. Bass</td>
<td>Emerson</td>
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</tbody>
</table>
The number of experimental fields which are maintained by the Soils Section is now approximately as large as can be handled with the funds available for the work and it will be impossible to establish field experiments in all the counties which are to be surveyed in the future. The experiments now under way are so well distributed throughout the state, however, that the results secured will be of value not only in the counties where the fields are located, but also in adjoining counties where the same soil types are found.

The Soils Section will be glad to make suggestions to farmers or county agents who wish to carry on tests of various fertilizing materials on special soils in their counties, but it will not be possible to make regular visits to such fields nor to help at harvest time in securing the crop yields.

THE PLAN OF THE SOIL EXPERIMENT FIELDS

An outline of the plan which is being followed by the Soils Section in the experimental fields now under way is given here for the purpose of aiding anyone who may wish to carry out similar tests. It is very important in such work that attention be paid to all details connected with the experiment if the results secured are to be satisfactory and hence complete information is given on various points that may arise in the starting or carrying out of field tests.

THE LOCATION OF PLOTS

The experimental plots are located on land which is thoroughly representative of the soil types which are to be tested. Soils differ widely even on individual farms and great care should be taken in selecting the fields for experimental work.

The plots are always located on fields where a definite system of crop rotation is followed. This is essential because a good rotation system is the basis of all desirable plans of soil management.

A four-year rotation of corn, corn, oats or wheat and clover is a very common one in the state. Another rotation often followed in some sections is corn, oats, winter wheat and clover. Often timothy is seeded with the clover and makes a five or six-year rotation, the timothy serving for pasture or meadow.

THE LAYING OUT OF PLOTS

The plots are laid out accurately with steel tapes and are all of the same size. They may be permanently located by placing stakes at the four corners, setting them 8 to 10 inches below the surface so they will not interfere with tillage operations. The plan which is usually followed, as shown in fig. 1, is to set a permanent iron stake in
the fence row. Measure out about 16½ feet and set a temporary stake to mark the outside corner of the first plot. Then set a second iron stake in the fence row at a distance of 44½ feet from the first. Measure out 16½ feet from this stake and set a temporary stake to mark the outside corner of the last plot. The plots may then be laid out by means of temporary stakes lined up with the corner stakes. This plan may then be followed for the entire series of plots, the exact location of the plots being determined from the stakes at any time either by a mere measurement with a tape or by the use of a level.

There are 13 one-tenth acre plots in each series. Each plot measures 28 feet by 155 feet 7 inches and there is a 7 foot strip between all plots. (See fig. 1.) Permanent borders around the entire series of plots should be at least one-half rod in width.

The soil treatments applied to the plots are as follows:

**LIVESTOCK SYSTEM**

1. Check.  
2. Manure.  
3. Manure and Limestone.  
5. Manure and Limestone and Acid Phosphate.  

**GRAIN SYSTEM**

7. Check  
8. Crop Residues.  
11. Crop Residues and Limestone and Acid Phosphate.  
13. Check.

Two distinct systems of farming are represented in this test, the livestock system and the grain system. The test may therefore include seven plots instead of thirteen, using plots 1 to 7, inclusive, for a test on a livestock farm and plots 7 to 13, inclusive, for a test on a grain farm.

In the livestock system manure is applied at the rate of 8 tons per acre once in a four-year rotation and in proportionate amounts for rotations which cover a shorter or a longer period of time. Whenever possible, the manure should be applied on the clover sod and plowed under for the following crop of corn.

In the grain system crop residues are employed in place of the manure. This treatment means that there is returned to the soil all the products except the grain or seed which are sold off the farm. The second crop of clover is plowed under and in case the soil is very deficient in organic matter, it may be desirable to cut the first crop of clover and leave it on the ground to be plowed under in the fall, together with the second crop. Clover seed may be taken from the second crop when the yield is sufficiently large to warrant the expense of harvesting, and in that case the straw from the hulling machine is returned to the land.

The corn stalks are cut with a disc or stalk cutter and plowed under. The threshed straw from small grain and clover is all returned to the soil. The application of this material is made at some convenient time usually in the fall on young clover. It may be desirable, however, to stack this material in the feed yard and then apply it to the soil after it has served to some extent as a feed and has undergone some decay.

In both systems of farming, rock phosphate is applied at the rate of 2,000 lbs. per acre, usually once in the rotation, provided it is put on the clover or other sod and turned under in the fall. This application is not increased even if the rotation is for a longer period than
four years. In a rotation shorter than four years or for a single crop, 1,000 lbs. per acre are used.

Acid phosphate is applied at the rate of 200 lbs. per acre each year of the rotation. In the case of corn, it is applied in the spring when the seed bed is finally prepared or just before an early cultivation. With small grain or clover, it is applied to the seed bed or early in the spring when the crop is young.

Complete commercial fertilizer is applied at the rate of 300 lbs. per acre in the same manner as the acid phosphate each year of the rotation. A standard 2-8-2 brand is employed.

Limestone is applied to all the plots except the checks whenever a test for acidity shows a need for the material. The amount to be applied will be indicated by the test, 2 tons additional to that needed to neutralize the actual acidity being added in all cases to insure a proper reaction in the soil for crop growth. The application of lime is made once in the rotation and it is usually applied in the fall or spring after plowing and disced in. It should not be applied before plowing.

The three check plots provided, in case the entire series of plots is used, or the two check plots used when only one part of the series is followed are entirely untreated. The crop on these plots is handled as on the other plots except that no residues are returned in any case.

In beginning an experiment such as has been outlined, the actual procedure to be followed will be somewhat different, depending on the crop of the rotation which occupies the land at the particular time.

If a regular four-year rotation of corn, corn, oats and clover is being followed, the initial treatments in the case of each crop will be as follows:

Corn. If the first crop of corn of the rotation is on the land, 6 tons of manure and 1500 pounds of rock phosphate are applied in the following spring and plowed under. Lime, acid phosphate and a complete commercial fertilizer are also applied in the following spring, the lime being disced in and the other materials applied at the final preparation of the seed bed.

Corn. If the second crop of corn occupies the land, 4 tons of manure and 1000 pounds of rock phosphate are applied in the following spring and disced in and the acid phosphate, complete commercial fertilizer and lime are likewise applied in the spring.

Oats. If the land is in oats, 2 tons of manure and 1000 lbs. of rock phosphate are applied on the surface in the fall and disced in. Lime, acid phosphate and commercial fertilizer are applied in the following spring.

Clover. If the land is in clover, 8 tons of manure and 1 ton of rock phosphate are plowed under in the fall. Lime is applied in the necessary amount either in the fall or spring after plowing and disced in. Acid phosphate and commercial fertilizer are applied at the final preparation of the seed bed for the following crop.

Further suggestions regarding the handling of field tests of fertilizing materials will be given by the Soils Section upon request.

THE TEACHINGS OF THE SOILS SECTION

THE USE OF PHOSPHORUS FERTILIZERS

The analyses of hundreds of samples of typical Iowa soils have shown that there is no large amount of phosphorus present in the soils of the state. As there is a constant removal of this element from the soil by the growing of crops and only a partial return in most cases in farm manure, some commercial phosphorus fertilizer must evidently
be used now or at some time in the future if the soils are to be kept profitably productive.

There are three fertilizers which may be used to furnish phosphorus, namely, bone meal, acid phosphate and rock phosphate. Bone meal is available only in limited amounts at the present time and hence the choice lies between rock phosphate and acid phosphate. There is considerable difference in the cost of the two materials, the latter being much more expensive than the former, but the acid phosphate contains the phosphorus in an available form, while the phosphorus in the rock is only slowly made available for crop use. That material should be chosen, therefore, which will yield the best results economically, or, in other words, which will bring about the greatest increases at the smallest expense.

Tests of the need and value of phosphorus fertilizers on the soils in the state and of the kind which should be used will not yet permit of definite recommendations regarding the use of these materials. The indications are that they may be added with considerable profit to some soils, while on others the increases brought about are not sufficiently large to warrant the application. It will be several years before the experiments now under way will yield definite results and in the meantime farmers are urged to test the value of both the acid and rock phosphate on their own soils. This circular gives an outline of an experiment which may be carried out on any farm and suggestions which should be followed in carrying out such a test are offered. The Soils Section is ready to advise and help farmers who wish to determine the needs of their own soils by this method.

THE USE OF COMMERCIAL FERTILIZERS

Complete commercial fertilizers are materials containing the three essential plant food elements, nitrogen, phosphorus and potassium in varying amounts. Many inquiries are received regarding the use of these materials on Iowa soils and the field experiments now in progress are planned to test the value of a standard brand for ordinary farm crops on some of the more extensive soil types. At the present time, therefore, these materials are not recommended, but neither is it definitely said that they may not prove profitable in some cases. Tests on individual farms are desirable with these materials as well as with phosphorus fertilizers.

The data secured from field experiments should yield definite information regarding the value of complete commercial fertilizers, but at the present time it is felt that definite recommendations should not be made further than to say it is not believed that they will prove profitable for general farm crops on Iowa soils. They may be used, however, if tests prove them to be profitable and with the certainty that they will not injure the land.

The analyses of the soils of the state have shown that most Iowa soils are abundantly supplied with potassium. If proper methods of soil treatment, such as manuring, drainage, etc., are followed, sufficient potassium should be made available to keep crops supplied and the use of a potassium fertilizer is probably not necessary except in special cases.

While nitrogen does not occur in Iowa soils in very large amounts, the application of organic matter, which is so essential in keeping up soil fertility, will add some of this element and the turning under of leguminous green manure crops, when they are inoculated, will add considerable amounts of nitrogen to the soil at a much less expense than is possible by the use of nitrogenous fertilizers. It is not
recommended, therefore, that nitrogenous fertilizers be used generally on Iowa soils for ordinary farm crops. Both potassic and nitrogenous fertilizers may prove of value, however, when used in small amounts as top dressings to encourage the early growth of certain crops. They may also be used in other cases when field tests have proven that they are profitable.

In the case of truck crops, complete commercial fertilizers are often used with much profit and truck farmers may secure from any of the fertilizer companies materials which are specially prepared for individual crops, or they may buy carriers of nitrogen, phosphorus and potassium and make their own mixtures.

THE USE OF LIME

According to extensive tests, the soils in three of the principal soil areas in Iowa, the Mississippi loess, the Southern Iowa loess and the Iowan drift, have been shown to be quite generally in need of lime. Acid soils are also occasionally found in the Wisconsin drift and Missouri loess soil areas.

It is very important, therefore, that all Iowa soils be tested for acidity and, if acid, lime should be applied if satisfactory crop growth particularly of legumes, such as alfalfa and red clover, is to be secured.

Any farmer may test his own soil for acidity according to the litmus paper method described in bulletin 151, or he may send a sample of the soil to the Soils Section of the Iowa Agricultural Experiment station and have it tested more accurately, free of charge. The method of taking a sample of soil for testing is described later. The test which is made not only shows the need of lime, but also the amount which should be applied to remedy the acidity. By submitting a sample of his soil for this test, the farmer will be advised how much lime he should apply to his soil and he will not be in danger of making either too small or too large an application, both of which are undesirable economically.

Limestone is the material which should be applied to Iowa soils which are acid, inasmuch as it may be secured quite generally throughout the state, either in the form of screenings or in a ground condition. In either case, to secure the best results the material should consist of 60 to 70 percent dust.

The quantity of lime to apply to Iowa soils which are acid cannot be definitely stated, for there is a great variation in the needs of soils for this material. The best plan is to have the particular soil tested and apply the amount of lime needed.

The value of lime in increasing the growth of legumes on acid soils is well known. Alfalfa and red clover and some other legumes are especially sensitive to acidity and will not do well if lime is not used. It should not be expected, however, that lime will bring about large increases in such crops as corn, oats or wheat. Indeed, these crops are affected only slightly by additions of lime unless the soil is strongly acid. The use of lime in the rotation is warranted by its effect on the clover and alfalfa and if a soil becomes very acid, even grain crops will suffer because of unsatisfactory physical and bacterial conditions in the soil.

The limestone available for agricultural purposes in Iowa is quite variable in composition and varies from 50 to 90 percent pure. The average material contains about 80 percent of lime. If a poor grade of limestone is to be used, a much larger application must be made in order to add the necessary lime. Hence, unless that material may be secured nearby and at a less cost, it is not advisable to use it, for the
freight charges and greater labor in the application of the larger amount of material will make the low grade limestone too expensive. The better limestones in the state, containing about 80 percent lime, should generally be used, and, in fact, they are sometimes cheaper than the poorer materials.

Just where limestone for use on the soil may be secured should be determined for local conditions. Many of the materials are equally valuable and that one should be chosen which may be secured at the lowest cost, figuring in the freight charges and the cost of hauling. The Soils Section issues regularly a list of the concerns supplying limestone and this list may be secured at any time upon application.

THE INOCULATION OF LEGUMES

The value of the inoculation of legumes is shown not only in increased crop production, but in increased fertility in the soil on which the crop is grown. If legumes are well inoculated, as they should always be, they draw upon the nitrogen in the atmosphere and not only do not deplete the soil in that element, but may actually increase the amount present in the soil.

Inoculation may be accomplished by the use of soil from a field where the same legume has previously been grown and well inoculated, or by the use of commercial preparations, called pure cultures, which are now on the market. If soil is used, 300 to 500 pounds should be spread over each acre to be seeded and thoroughly disked in. It should not be allowed to remain on the surface of the soil as in that way the value is lost. The soil should be secured from a field where no plant diseases have been present nor any objectionable weeds have been found. In only one case is cross inoculation possible and that is between alfalfa and sweet clover. Soil from a field where either of these legumes has been grown will inoculate for the other crop.

Several of the pure cultures now on the market are quite satisfactory and give thorough inoculation. Those tested are the Nitragin culture put out by the Nitragin Co. of Waterloo, Iowa; the Farmogerm culture from the National Soil Improvement Co. of Charlottesville, Va.; the Nitrogem culture from the H. K. Mulford Co. of Philadelphia, Pa., and the culture from the Edwards Laboratories at Lansing, Mich. Other cultures on the market may be satisfactory, but they have not been sufficiently tested by us to warrant recommending them. The cultures mentioned are all very similar in value and hence that one should be used which can be secured at the smallest cost.

If soil can be obtained in the immediate vicinity and can be applied with little expense for hauling, then it will undoubtedly be the cheapest material to use. If, however, it must be bought and shipped by freight and hauled a considerable distance, then the use of pure cultures will be cheaper and quite as satisfactory. The price at which some of the commercial preparations are now supplied is so reasonable that they may probably be used to advantage in many cases. The "glue" method is not recommended, as either the soil method or the pure culture method are considered safer and therefore more desirable for general use.

MANURING

Many experiments on Iowa soils and the results of much farm experience have shown very definitely that farm manure is of considerable value in increasing crop production. In fact, the returns secured from the use of farm manure have in most cases proven very much
greater than those obtained by the application of any other fertilizer materials.

Manure is one of the most valuable products on the farm, considered from the standpoint of the fertility of the soil. It contains much of the plant food removed from the soil in the crops and by its use there may be returned to the soil a large portion of the fertility contained in the crops used for feed. Furthermore, it keeps up the organic matter content of the soil and that, as is well known, is extremely important in keeping the soil in the proper physical condition for the best crop production.

Manure is considered a waste product on the average farm and very often care is not taken that it be stored properly and losses of valuable portions be prevented. The farmer should realize that it is worth many times the cost involved in proper storage and in application, because of the increases in crop growth which it brings about and the aid which it gives in maintaining the productive power of the soil. If it is stored in a loose pile and exposed to the weather, as is so often the case, manure may lose as much as 85 percent of its value as a fertilizer. Under proper conditions of storage, this loss may be reduced to 15 percent.

The methods of storing manure in order to prevent losses are variable and no method can be recommended for all farm conditions. In general, it may be said that the method should be such that the manure is protected from leaching and exposure to the weather and that it is kept moist and compact. The liquid portion should not be allowed to leach away and the solid material should be kept mixed with the liquid. Any method which meets these conditions will serve to render the manure of the greatest value when it is applied to the soil. Furthermore, in some cases manure may be applied to the soil as it is produced, and when that is possible, the losses from the manure are reduced to the lowest point. The question of the proper time of application of manure to soil is one which it is impossible to answer definitely for all conditions. In general, it may be said that whenever practicable it is desirable to apply manure to the soil as it is produced. If the manure must be stored, however, then a method should be used which will keep the losses at the smallest possible figure. Circular No. 9 of the Iowa Agricultural Experiment Station discusses these matters in more detail.

In case both of grain farming and livestock farming, crop residues, straw and stover, should be carefully returned to the land in order to aid in the maintenance of the proper organic matter content. Corn stalks and straw should never be burned, for they are too valuable when applied properly to the soil.

GREEN MANURING

In grain farming there is a very limited production of farm manure and in order to keep up the organic matter content of the soil, green manuring must be practiced. This consists merely in turning under some green crop. Legumes are usually chosen for green manures because when they are thoroly inoculated, as they always should be, there is not only an addition of valuable organic matter to the soil, but the content of nitrogen in the soil is increased. Thus the process becomes one of nitrogen fertilization. In some cases non-legumes are used as green manures and may prove quite profitable, but the number and variety of legumes is so great that one can be chosen for almost any condition and the green manuring can be made of double value.

In livestock farming, also, even when farm manure is available in
considerable amounts and properly utilized, green manuring may prove of value. Like many other farm practices, green manuring cannot be recommended for all farm conditions and it must be practiced with understanding. There are times when it is not only valuable, but absolutely necessary for satisfactory crop growth, but in other instances it may prove entirely useless. Suggestions governing the use of green manures, the crop to be chosen, the time of turning under and other questions along this line are given in Circular No. 10 of the Iowa Agricultural Experiment Station.

Definite advice regarding the use of green manure crops under local conditions will be given upon request. If the best results are to be secured from their use, care should be exercised in the choice of a crop, in the conditions under which it is grown and in the general handling of the soil.

THE ROTATION OF CROPS

The rotation of crops is one of the most important farm practices from the standpoint of soil fertility. Crop production gradually decreases if one crop is grown continuously on the same soil, but a good rotation of crops suited to the soil, climatic, farm and market conditions, tends to maintain crop yields. Much experience on the farm has shown the value of the proper rotating of crops and experimental data confirms the farm observations. Bulletin 167 of this station shows the results secured on the experimental plot at Ames with various rotations. Not only is it definitely shown that the continuous growing of one crop is injurious to the soil, but the returns secured from the crops in a rotation are greater than those obtained even by the continuous growth of a so-called "money" crop.

Definite rotations suited to all sections of the state cannot be suggested because of the variations in soil and climatic conditions. Suffice it to say that every rotation should contain a legume in order to aid in keeping up the organic matter and nitrogen content of the soil.

It is quite as important to rotate crops in truck farming as in general farming and indeed it is usually more necessary. Many diseases which attack truck crops and reduce yields can be controlled by the growth of some other crops for several years. Truck farmers should pay special attention to the crop rotation which they follow if satisfactory yields are to be secured.

DRAINAGE

The importance of the proper drainage of soil is so well known that it needs little emphasis at the present time. Land which is entirely non-productive may often be made to produce large crops by the proper installation of tile drains. No amount of care in the treatment of a soil will be of value if the soil is too wet. Many acres of land in Iowa have been reclaimed by drainage and there are still areas where the use of tile would be of value in making the land more productive. The expense involved may be considerable, but it is well warranted by the returns which are secured from the increased crop yields.

PEAT SOILS

There are considerable areas of peat soils in Iowa and special methods of treatment are necessary to reclaim them and make them productive. There are two classes of these peat soils, the shallow and the deep. The shallow peats are usually not over three feet in thickness and the treatments recommended must be understood to
apply only to the shallow peats; they are not at all applicable to the deep peats.

The needs of these shallow peats are for thorough drainage, cultivation and the growing of proper crops upon them. Drainage is the first and most important operation in their reclamation. Sufficient tile of ample size must be provided and proper outlets supplied, and it is usually advisable also to lay special drains to carry away flood waters and prevent the flooding of low-lying peat areas in times of heavy rainfall. The tile should be laid in the underlying subsoil, but not too deeply, as the heavy character of the subsoil may prevent the ready passage of water into the drains. It is often advisable to cover the tile at points a few rods apart with straw, gravel or cinders to permit the water to enter the tile readily.

Fall plowing is desirable for peat soils, as it opens them up during the winter and thus aids in the decay of the peat. Deep plowing is also of value, as it hastens the decomposition of the peat and also improves its physical and chemical condition by bringing up and mixing with it some of the underlying clay which is rich in phosphorus and potassium, elements lacking in the peat itself. The Soils Section has not found the application of chemical fertilizers profitable on shallow Iowa peats, due probably to the presence in the subsoil of those elements which are lacking in the peat.

Corn and small grain crops as a rule do not do well on newly reclaimed peat. A mixture of timothy and alsike clover is the best crop to use on such soils. This may be used for hay or pasture. Many vegetables, such as onions, celery, tomatoes, potatoes, cabbage, etc., give good yields. By a few years of pasturing, or growing vegetables, shallow Iowa peats may be put in a condition which will permit of the successful growth of corn and small grains and, in fact, after such reclamation the soils usually become highly productive.

ALKALI SOILS

So-called "alkali" spots occur in areas varying from one-tenth of an acre to two or more acres in size. They are usually associated with peat deposits and when they appear, crop production is seriously reduced and even entirely prevented. They are due to an accumulation of salts in the soil and the treatment which is necessary to make them productive consists in the use of some method of removing the excess salts.

The first treatment required for the reclamation of such spots is proper drainage. Tile should be laid thru the "alkali" spot as well as thru the low-lying area which it surrounds. If a line of tile is laid around a slough or pond when it is drained as well as thru the center, "alkali" spots may not be formed. If this is not done, however, and the "alkali" spot is fully developed, it may be advisable to change the drainage system in order to hasten the washing away of the salts from the soil.

The addition of large amounts of farm manure will then be advisable, as that material aids in the removal of the excess salts. Straw or any kind of vegetable matter plowed under will also be of assistance. Oats may be sown on such land and when the greatest growth has been attained, the entire crop turned under. With proper drainage, however, and the use of an abundance of farm manure, "alkali" spots may be reclaimed the most readily and in due time made quite as productive as the surrounding soil.
The term gumbo is a popular name applied to certain heavy, "greasy" black clay soils, which occur in various localities in Iowa, either on the upland or in the bottoms. Such soils are difficult to cultivate and if not properly handled they are quite unproductive. If they are plowed when too wet, they ball up before the plow point in such a way that the best implement cannot be made to stay in the ground. On the other hand, if they are too dry, they turn up in clods, which cannot be worked down during the whole season. Freezing and thawing are the only processes which will restore the loose, mealy structure of soils in such a condition.

The first treatment necessary to bring gumbo soils into a productive condition is thorough drainage and this may usually be accomplished without great difficulty whenever an efficient outlet is available. On upland, the tile should usually be laid 8 rods apart, while on lowland gumbo it should be somewhat closer together. Fall plowing is particularly valuable on such soils and should be practiced whenever feasible. The growing and turning under of clover or some other green manure crop is also of value in improving the physical condition of gumbo soils.

Push soils are so called because of the difficulty in plowing and cultivating them. They occur in certain localities in southern Iowa where the surface covering is thin and the underlying heavy subsoil occurs close to the surface. The plow cannot be forced into this subsoil material, but "pushes" along over the surface, turning up only the thin top soil.

Experiments which have been conducted on such soils show that with proper treatment they may be made quite productive. A report of these field studies will be made at an early date in bulletin form.

Thorough drainage has been found to be the treatment first needed by such soils. The drainage system must carry away the surplus water in the soil and the seepage water that as a rule comes to the surface on the hillside. Deep tillage has proven very beneficial on such soils.

The application of farm manure when incorporated with the heavy subsoil material as deeply as possible, has been found to bring about considerably increased crop yields.

The deep tillage and drainage of such soils and the introduction of organic matter into the heavy subsoil will aid materially in making push soils productive. The main point to be considered is the improvement of the physical condition of the subsoil material by opening it up and putting it in a condition which will allow not only for proper plowing and cultivation, but also for the development of plant roots.

SOIL EROSION

Soil erosion is the carrying away of soil thru the free movement of water over the surface of the land. Many soils in Iowa, particularly those that are hilly or rough, are subject to erosion and if it is not prevented or controlled large areas of land may be rendered entirely unfit for the growing of crops.

Various means may be employed to prevent or control erosion and these are considered at length in a bulletin which will soon be issued. Attention will merely be called here to the importance of proper plowing and treatment of soils subject to erosion to prevent its occurrence and to the best method to be employed to reclaim land broken by gullies or badly washed by sheet erosion.
Plowing the land so that the dead furrows run at right angles to the slope is important and fall plowing is of value in preventing the formation of channels through which water will wash. The addition of organic matter aids materially in making the soil more open and better able to absorb the rain water falling upon it. Cover crops used on the land during the winter will protect the soil from erosion. Proper drainage will aid in the rapid removal of water and will therefore lessen the danger of the soil washing away. Land on steep slopes should not be cultivated, but should be kept in meadow or pasture, as in that way the washing away of the surface soil is prevented.

These methods of treatment apply particularly to erosion on hillsides or sheet washing. If gullying has occurred, other methods must be used. "Staking in," straw dams, earth dams, Christopher or Dickey dams, stone dams, concrete dams and rubbish dams are some of the means which may be employed for reclaiming land which is gullied.

The Christopher or Dickey dam or earth dam supplied with a line of tile is probably the cheapest and best method of controlling and filling up both large and small gullies. This consists in the placing of one or more earth dams up the course of the gully, each supplied with a line of tile beneath the dam and extending for some distance above the dam, where it is turned at right angles by a T and brought to the surface. By this arrangement practically all the sediment carried by the water settles out above the dam and the excess water flows out thru the tile under the dam. By this method extensive gullies may be reclaimed and the areas used for cropping purposes. Concrete dams are often used instead of earth dams and serve the same purpose, but they are more expensive and hence they cannot be considered quite as desirable. Other types of dams may be used in some instances and may prove quite satisfactory.

In general, it may be said that it is much cheaper to take all necessary precautions to prevent gullying or sheet erosion of land than it is to bring back into a proper condition, any area which has been subject to extensive washing. Eroded land can be reclaimed, however, and although the expense and labor involved may be considerable, the control and filling up of gullies and the prevention of sheet erosion is well worth while.

WHAT THE STATION CAN DO TO HELP THE FARMER

The studies which the Soil Section has carried on and the work now in hand permits of authoritative statements along many lines of soil management. There are, of course, many questions which it is not yet possible to answer absolutely and completely, because anything like a complete study of the soils of the state will require years of labor and abundant facilities. In so far as investigations have led to conclusive evidence along certain lines, the section is ready and glad to make recommendations regarding the management and improvement of Iowa soils, and to do it free of charge.

In order to advise regarding the proper treatment of any soil, it is necessary, however, that certain facts regarding the lay of the land, the crops grown, the fertilizers added, etc., be in the hands of the station men. It is not merely enough to send in a small sample of soil, although that, of course, is helpful in many cases. It is suggested that the following questions be answered by every farmer who wishes advice. These answers and, if desirable, a sample of
soil carefully taken, as will be described later, should be sent to the Soils Section of the Iowa Agricultural Experiment Station, Ames, Iowa.

Where is the land located? Give township, section and nearest town.
How long has the land been under cultivation?
What system of farming is practiced? Livestock, grain or general.
What rotation of crops is used?
What was the crop yield last year?
What was the crop yield the preceding year?
What crop yields the best?
What crop gives the poorest results?
Has inoculation been practiced for legumes?
Is the land level or rolling?
What is the depth of plowing?
Are there any peculiarities about the soil?
Is the land drained? How?
How much manure has been applied? When?
How much fertilizer has been added? When?
How much lime has been used? When?

WHAT THE STATION CANNOT DO

Certain limitations are imposed upon the work of the Soils Section by the laws under which experiment stations were founded and by the size of the annual appropriations. The section cannot undertake to analyze samples of soil or fertilizers for private parties. Analyses of soils and fertilizers are expensive and tedious operations, and should all the members of the staff, the size of which is limited by the appropriations, spend their entire time on such work, only a small part of the samples annually received could be analyzed. Therefore, such analyses are out of the question for financial reasons.

There are, however, further and more important reasons why such analyses are not made. In the first place, samples of soil taken at random, without regard to their representative character, may be so very local in nature that their analyses would be of practically no use to the farmer, and of absolutely no general value. Furthermore, complete chemical analyses of soils give only their total plant food content. Such analyses may show lack of nitrogen, phosphorus or potassium, or an abundance of these elements, but they give no idea of the rate at which they become available, and hence merely indicate the ability of the soil to support plant growth. For instance, nitrogen, phosphorus and potassium may be shown by chemical analyses to be present in abundant amounts, but an application of a nitrogenous, a phosphatic or a potassic fertilizer might yield astonishing returns. On the other hand, very small amounts of these constituents might be present and yet additional applications might give a very small, or even no increase and therefore represent an actual money loss.

The reason for this is simple. All plant food in the soil does not exist in a form available for plants. That is, it must be prepared for them just as human food is prepared in kitchens. The raw materials are acted upon by various agencies and changed into forms which are of use to plants. The bacteria may be called the cooks in charge of the plant kitchens. When these cooks are inefficient there is a decrease in the production of prepared food and the plants are inadequately fed. When the cooks go out on a strike, because of improper working conditions, such as lack of air, water or food (organic matter), no food is prepared and the plants starve.

In all soils there is a certain relation between the raw food known as potential, or total plant food, and the prepared material, known as
active or available plant food, and this relation is determined by the efficiency of the bacteria (the cooks). That efficiency is secured by keeping conditions in soils satisfactory for bacterial growth by providing the proper amount of air, maintaining the best moisture conditions, and supplying food material, or organic matter. These conditions may be kept right by proper tillage, drainage or irrigation, and the addition of manure.

Chemical analyses do not show whether or not conditions are right for bacterial activity. Chemical analyses, as has been pointed out, give only the total or potential plant food content of soils and hence merely indicate the needs of the soil, unless the total food supply is very small, in which case it is safe to assume that more should be added.

It has been well said that "the chief value of a chemical analysis is to serve as an absolute foundation upon which methods of soil treatment can be safely based for the adoption of systems of permanent soil enrichment, not for one crop or one year, but for progressive improvement."

The soils section has made analyses of many samples representing typical soil areas in the state. These samples have been obtained with great care by the station men, using the most accurate means of sampling, and they are representative of definite soil types. Thus, while it is impossible to analyze all the soils of the state, the composition of representative soil types may be ascertained. From these data and experimental results obtained on the different soil areas, information will be available regarding the treatment advisable for any soil, the crops best adapted to it, and the best method of management.

These facts give all the information which the farmers need. The analyses of the typical soil areas give the approximate composition of their soils and the plant food deficiencies may be as closely determined as would be possible from chemical analysis of special samples.

In the case of abnormal soils, however, where no typical analyses are to be found, it may be advisable for the farmer to collect a sample of soil and have an analysis for nitrogen, phosphorus and potassium and possibly for calcium and magnesium, made by a commercial chemist.

Using the analysis as a basis, field tests should then be made to obtain definite information regarding the actual influence of different fertilizing materials.

Samples of fertilizers are analyzed by the state dairy and food commissioner, W. B. Barney, at Des Moines, Iowa, and should be sent to him.

COLLECTING SOIL SAMPLES

In the few cases where samples of soil need to be taken, either to be sent to the station for examination or to be analyzed by a commercial chemist, care should be taken that they are representative of the entire field and not peculiar merely to the spot from which they were taken.

The places from which the samples are to be obtained need to be carefully cleaned of grass and other vegetation. About 20 or more different spots a few rods apart are chosen, all apparently representative of the soil type, and borings are made to the depth of plowing. These borings may be made by means of a regular soil auger, which is about 40 inches long and 1½ inches in diameter, the kind used by the station men, or samples may be taken by means of a trowel or spade.

The surface samples are usually taken from the surface to a depth of 6½ inches. A second and third sample are then taken in the same
manner, one of the subsurface soil 6 1/2 inches to 20 inches, and the other of the subsoil 20 inches to 40 inches.

The surface borings or samplings are then thoroughly mixed, about 1 pint taken and placed in a clean receptacle. The subsurface and subsoil samplings are handled in the same manner. A strong muslin sack may be used for mailing or expressing samples of soil for analysis or inspection.

It is quite essential that all samples be taken as suggested, for soil is very apt to be quite variable in composition and the samples should be truly representative of the soil types. If they are not representative the results of the analyses are of no value whatever.

NOTES

In order to give some idea of the cost of carrying out the tests which have been described, the following notes are appended.

It is recognized, of course, that the cost of fertilizers will vary somewhat from year to year and consequently only the approximate cost is given here. The freight rates on these materials are also exceedingly variable and must be considered in estimating their total cost.

The quotations given here are the average cost of the fertilizers independent of the freight charges.

Fertilizing materials may be purchased from nearly all the leading packing firms and from dealers in commercial fertilizers. The advertisements of many of these firms will be found in agricultural papers and trade journals.

The following firms have indicated that they are prepared to furnish fertilizers, limestone and inoculating material for agricultural purposes.

ROCK PHOSPHATE

Rock phosphate, finely ground, for application to the soil may be obtained from the following concerns:

- Central Phosphate Co., Mt. Pleasant, Tenn.
- Federal Chemical Co., Louisville, Ky.
- Natural Phosphate Co., Nashville, Tenn.
- The Robin Jones Phosphate Co., Nashville, Tenn.
- Ruhm Phosphate Mining Co., Mt. Pleasant, Tenn.

The raw rock phosphate for sale by the above firms contains a minimum of 12 to 14 percent of phosphorus, and costs from $4.00 to $5.60 per ton f. o. b. cars at mines. The freight to various points in Iowa will bring the total cost of the phosphate up to $8.00 to $12.00 per ton in carload lots.

Before purchasing phosphate, firms should be asked to submit a guaranteed analysis showing percentage of phosphorus and fineness of grinding of their rock. Ninety percent of the material should pass thru a 100 mesh sieve.

ACID PHOSPHATE

Acid phosphate is a soluble form of phosphate. It contains from 7 to 9 percent of phosphorus, which, however, is all in an available form and it costs from $23 to $25 per ton.
Acid phosphate may be secured from the following concerns:

Chicago Fertilizer and Chemical Works, Union Stock Yards, Chicago, Ill.
Swift and Company, Chicago, Ill.
Darling and Co., Chicago, Ill.

POTASSIUM SALTS

No firms have quoted prices on potassium chloride, potassium sulfate or Kainit for the fall trade.

COMPLETE COMMERCIAL FERTILIZERS

Complete commercial fertilizers may be purchased from the following concerns:

Chicago Fertilizer and Chemical Works, Chicago, Ill.
Swift and Company, Chicago, Ill.

GROUND LIMESTONE

This material may be obtained from the crushing plants listed below:

Burlington Quarry Co., 19 S. 7th St., Keokuk, Iowa.
Quarries at Montrose, Iowa. On C. B. & Q.
H. Dearborn’s Sons, Stone City, Iowa. Quarries at Stone City, Iowa. On C. M. & St. P.
Dolese Bros., 10 S. LaSalle St., Chicago, Ill. Quarries at Buffalo, Iowa, on C. R. I. & P. and C. M. & St. P.
J. A. Green & Sons, Cedar Rapids, Iowa. Quarries at Stone City, Iowa, on C. M. & St. P.
The Hale Roberts Stone Co., Iowa Falls, Iowa. Quarries at Alden, Iowa, on C. & N. W.
Peru Stone and Cement Co., East Peru, Iowa. Quarries at Peru, Iowa, on C. & G. W.
Linwood Quarries Company, Davenport, Iowa. Quarries at Linwood, Iowa, on C. M. & St. P. and C. R. I. & P.
McManus Quarries Company, Keokuk, Iowa. Quarries at Ballinger, Iowa, on C. B. & Q.
Cedar Valley Trap Rock Co., Cedar Rapids, Iowa. Quarry at Glory, Iowa, on W. C. F. & N.

Prices on stone vary from 20 to 75 cents per ton, f. o. b. quarries. For best results, the limestone should consist of at least 60 to 70 percent powder. Stone of the best quality will contain 85 to 95 percent of calcium carbonate.

FERTILIZER AND LIMESTONE DISTRIBUTORS

Distributors for fertilizers and limestone may be secured from the following concerns:

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<th>Name of Distributor</th>
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<tr>
<td>“Hoosier,”</td>
<td>Excelsior Drill Co., Springfield, O.</td>
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<tr>
<td>“Peoria,”</td>
<td>International Harvester Co. of America, Chicago, Ill.</td>
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<td>Peoria Drill and Seeder Co., Peoria, Ill.</td>
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The above firms all make two horse distributors, suitable for applying both fertilizers and limestone. Distributors cost from $40.00 to $90.00.

INOCULATING MATERIAL

Cultures for legumes may be obtained from the following companies: Prices range from 50 cents to $2.00 per acre size, for the cultures supplied by these firms.

<table>
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<tr>
<th>Name of Culture</th>
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<tr>
<td>&quot;Nitrogerm.&quot;</td>
<td>H. K. Mulford Co., Philadelphia, aP.</td>
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<tr>
<td>&quot;Farmogerm.&quot;</td>
<td>National Soil Improvement Co., Charlottesville, Va.</td>
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<tr>
<td>&quot;Nitragin.&quot;</td>
<td>The Nitragin Co., Waterloo, Iowa.</td>
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IOWA AGRICULTURAL EXPERIMENT STATION
Publications Dealing With Soil Investigations in Iowa.

BULLETINS
(Those followed by an * are out of print, but are often available in public libraries.)

78. Drainage Conditions in Iowa*.
82. The Principal Soil Areas of Iowa*.
95. The Maintenance of Fertility with Special Reference to the Missouri Loess*.
98. Clover Growing on the Loess and Till Soils of Southern Iowa*.
119. The Gumbo Soils of Iowa*.
150. The Fertility in Iowa Soils.
151. Soil Acidity and the Liming of Iowa Soils*.
151. Soil Acidity and the Liming of Iowa Soils (Abridged).
157. Improving Iowa's Peat and Alkali Soils.
161. Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa*.
167. Rotation and Manure Experiments on the Wisconsin Drift Soil Area.
177. The Alkali Soils of Iowa.
183. Soil Erosion in Iowa (In press).

CIRCULARS

2. Liming Iowa Soils.
8. The Inoculation of Legumes.
9. Farm Manures.
10. Green Manuring and Soil Fertility.
15. Testing Soils in Laboratory and Field.
43. Soil Inoculation.
51. Soil Surveys, Field Experiments and Soil Management in Iowa.

RESEARCH BULLETINS

2. Some Bacteriological Effects of Liming*.
4. Bacterial Activities in Frozen Soils*.
5. Bacteriological Studies of Field Soils. I*.
8. Bacteria at Different Depths in Some Typical Iowa Soils*.
9. Amino Acid and Acid Amides as Sources of Ammonia in Soils*.
11. Methods for the Bacteriological Examination of Soils*.
17. The Determination of Ammonia in Soils.
25. Bacterial Activities and Crop Production.
34. Studies in Sulfoflcaction.
35. Effects of Some Manganese Salts on Ammonification and Nitrification.
43. The Effect of Sulphur and Manure on the Availability of Rock Phosphate in Soil.
44. The Effect of Certain Alkali Salts on Ammonification.
45. Soil Inoculation with Azotobacter.

SOIL REPORTS

1. Bremer County.
2. Pottawattamie County.
3. Muscatine County.
4. Webster County.
5. Lee County.
6. Sioux County (In press).
7. Van Buren County (In press).
8. Clinton County (In press).
9. Scott County (In press).
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<th>Iron Stake.............16½'.......</th>
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<td>4. Manure, Lime and Rock Phosphate</td>
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<td>10. Crop Residues, Lime and Rock Phosphate</td>
</tr>
<tr>
<td></td>
<td>11. Crop Residues, Lime and Acid Phosphate</td>
</tr>
<tr>
<td></td>
<td>12. Crop Residues, Lime and Complete Commercial Fertilizer</td>
</tr>
<tr>
<td></td>
<td>13. Check</td>
</tr>
</tbody>
</table>

Fig 1. Diagram showing the size, arrangement and fertilizer treatment of soil experiment fields.