Testing Soils in Laboratory and Field

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Abstract
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TESTING SOILS IN LABORATORY AND FIELD

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

AGRONOMY SECTION
Soils

Ames, Iowa
TESTING SOILS IN THE LABORATORY AND FIELD

BY W. H. STEVENSON AND P. E. BROWN

WHAT THE STATION CAN DO TO HELP THE FARMER

The chief aim of the Soils section of the Iowa Agricultural Experiment station is to help the farmer solve his soil problems. This is possible because the work of the section consists not only in the study of soil problems of statewide interest, but also in the application of the results of such general investigations to local conditions.

It may be said, therefore, that there are two distinct divisions of the soil work. First, there is the experimental or investigational part, which consists in the planning and carrying out of experiments on methods of soil treatment and soil management; and second, there is the advisory part. Through this latter function the soils section aims to keep in close touch with the farmers and to help them solve their local problems, often arranging special experiments to aid in the solving of them.

The experimental work in soils during the past few years has included the study of many important questions, chiefly, however, the rotation of crops, the use of fertilizing materials, the drainage of the soil, and the management of certain partially unproductive soils, such as gumbo, peat, alkali and "push" soils. In a general way it may be said that all effort has been directed toward securing the greatest crop production with the least soil depletion.

It is evident therefore that the section has material at hand which 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 Iowa Agricultural Experiment Station, Soils Section, Ames, Iowa.

Where is the land located?
How long has the land been under cultivation?
What system of cropping is practiced?
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.

But there are 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 is now working on a soil survey of the state and analyses are being made of many samples representing typical soil areas. 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 and the soil areas mapped in detail. 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, as will be described, 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.

**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 commer-
cial 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 twenty 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 borings or samplings are then thoroughly mixed and placed in a clean receptacle. A strong muslin sack may be used for mailing or expressing a sample of soil for an analysis or an inspection. The surface samples are usually taken from the surface to a depth of 6-2-3 inches. A second and a third sample are then taken in the same manner, one of the subsurface soil 6-2-3 inches to 20 inches, and one of the subsoil 20 inches to 40 inches.

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 represent definite soil areas. If they are not representative the results of the analyses are of no value whatever.

**SOME TESTS WHICH THE FARMER CAN MAKE**

From the results of the soil survey of the state, which has been mentioned, and the experimental data in connection with it, it will be possible to make many definite recommendations regarding profitable methods of soil treatment, but there are some tests of particular soils which the farmer can very readily make for himself.

**ACIDITY**

In the first place the soil should be tested for acidity. Most crops will not grow satisfactorily in acid soils, and many make no growth whatever.

There is a wide range in the sensitiveness of different crops to acid conditions, the legumes, such as clover and alfalfa, being most readily affected. Beneficial bacterial activities are also inhibited by acidity and the change of insoluble plant food into a soluble form is restricted or absolutely prevented.

There are certain outward indications of soil acidity which are quite evident to any farmer. For instance, if clover or timothy refuse to grow and red top and sorrel appear instead, the soil is usually in need of lime. The presence of moss, or the growth of red top, sorrel, bluets, horsetails, or other similar weeds is evidence of a lack of lime in the soil.

There is, however, a definite test for soil acidity which may be made on any farm. It is known as the litmus paper test and is based on the power of acids to change blue litmus paper to red.
In order to make the test a small sample of soil, free from roots and grass, is put into a clear glass container like a water glass. Two or three strips of blue litmus paper are inserted in the soil so that they are half covered, care being taken that the portion in contact with the soil is not touched with the fingers. Pure water is then added carefully until the soil is thoroughly wet. The test is allowed to stand for several minutes and the paper removed and rinsed thoroughly. If the portion of it which was in contact with the soil has become red, the soil is acid and would be benefited by liming. The litmus paper for this test may be bought at any drug store.

When some lime is present in soils the acidity problem is not so pressing, for as has been pointed out one tenth per cent is satisfactory for most crops and some will grow quite satisfactorily with five one hundredths per cent present. It is the extent of acidity in soils which demands attention: How much lime must be applied to make the soil basic in reaction, or to neutralize the acidity in the soil, is the main problem to be considered.

A NEW TEST FOR ACIDITY

Recently a new test for acidity was devised at the Wisconsin Agricultural Experiment station* and preliminary tests indicate that it may be of considerable value. The principle underlying the method is simple and involving the well-known chemical fact that paper moistened with lead acetate will turn black when subjected to the action of hydrogen sulfide gas. Acid soils when boiled with water and zinc sulfide evolve hydrogen sulfide gas just as would be the case were any acid boiled with zinc sulfide.

To carry out the test, the soil is treated with a solution of zinc sulfide containing some calcium chloride, the mixture boiled for one minute, a paper moistened with lead acetate placed over the mouth of the flask and the boiling continued for two minutes.

If the paper blackens on the lower side, the soil is acid. The amount of blackening will give a rough indication of the extent of acidity in the soil.

That a thorough test for acidity may be made, samples of the surface soil and the subsoil should be taken from several different places in the field. If the soil is shown to be acid by this litmus paper test, then ground limestone should be applied. An application of 2,000 to 3,000 pounds per acre should be sufficient to remedy a moderate degree of acidity for most crops, but if the soil is shown to be strongly acid, and alfalfa or clover are to be seeded, 3,000 to 4,000 pounds per acre should be used.

By application of ground limestone not only is the acidity of some soils corrected, but heavy clay soils which are too wet and improperly aerated are opened up and made more fertile. Light, sandy soils, also, which tend to lose valuable plant food by “burning out” and leaching

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and are apt to dry out too quickly are made more compact and thus more retentive of moisture and plant food.

Finally the lime may remedy an actual deficiency in plant food, calcium. Alfalfa, for example, removes a large amount of calcium from the soil and the succeeding crop may suffer for lack of calcium.

CARBONATES

Acid conditions cannot exist in a soil which contains an abundance of carbonates. A test therefore of the presence of carbonates will give indications of the acidity of the soil. This test is based on the fact that acids attack carbonates with the liberation of carbon dioxide gas. Thus when soils containing carbonates are treated with hydrochloric acid there is a foaming or effervescence indicating that the soil cannot be acid. If no foaming occurs then the soil may be acid or neutral. To make the test, a little concentrated hydrochloric acid is poured on a small sample of moist soil in a clean dish or other receptacle. The extent of foaming is a rough indication of the amount of carbonates present in the soil.

Even although negative results are secured in the surface soil, tests should be made of the subsoil as the presence of carbonates there would be of considerable importance particularly in the case of deep rooted crops.

PHYSICAL CONDITIONS

It is hardly necessary to emphasize the need for proper methods of tillage and cultivation to keep the soil in proper physical condition. Every farmer knows that he may conserve the moisture in his soil during a dry season by keeping it cultivated. The value of the proper preparation of the seed bed for all crops is also a matter of common knowledge. Proper plowing and disking, the killing of weeds, etc., are recognized as essential for satisfactory crop growth.

If the soil is open and porous, dries out too rapidly and is deficient in organic matter, as is often the case due to the "burning out" of this important soil constituent, then applications of barnyard manure or green manure should be made and lime applied. Not only is the physical structure of the soil improved by such treatment, but satisfactory conditions are offered for bacterial activity and there is consequently a sufficient production of plant food to insure good crop growth. The practice of green manuring to build up light soils cannot be too strongly emphasized. Further information regarding green manure crops and methods of green manuring may be found in Circular No. 10, of the Iowa Agricultural Experiment Station.

PRESENCE OF PLANT FOOD

The presence of available plant food in the necessary amount is one of the chief requisites for the best growth of crops. The amounts in available form of the various elements which are necessary for the growth of plants cannot be ascertained by chemical analyses but must
be determined by field experiments such as are described farther on in this circular.

As has been pointed out, chemical analyses merely give indications of plant food deficiencies, showing as they do the total plant food present.

Of the ten chemical elements which have been found to be essential for the growth of plants, five are supplied in sufficient amounts either from the air or soil, and need not be applied to the soil. These five elements are carbon, hydrogen, oxygen, sulphur and iron.

Nitrogen, phosphorus, potassium, calcium and magnesium may be lacking in soils, however, and if lacking, crop yields will be deficient. The two latter elements may be supplied by application of lime as calcic or dolomitic limestone, as has already been shown. If a soil is acid these elements are probably lacking.

NITROGEN

A deficiency in nitrogen in a soil may be safely assumed if there is a lack of humus or organic matter present. Conversely, if a soil is dark in color it is well supplied with humus and will contain a supply of nitrogen, although the absence of satisfactory physical conditions may prevent the proper production of soluble nitrates. In such a case the adjustment of the physical conditions would prove more profitable than an application of sodium nitrate or any other nitrogenous fertilizer.

When soils are deficient in humus and nitrogen, applications of barnyard manure should be made and leguminous crops should be grown and used as green manure. Thus the organic matter and nitrogen content are both increased and the use of any other nitrogenous material is unnecessary for the production of common farm crops such as corn, oats and hay.

In some particular instances it might be worth while to make a small application of sodium nitrate to act as a stimulant to start and encourage the growth of a crop, but in general farming the use of commercial nitrogenous fertilizers on Iowa soils is unprofitable and unnecessary.

In market gardening, however, the application of nitrogenous or other artificial fertilizers is often of considerable value as here abundance of available plant food is necessary for forcing the crops.

POTASSIUM

The potassium content of most soils is considerably greater than the nitrogen or phosphorus content and there is much less danger of a deficiency of that element. That is, the total amount of potassium in soils is large and if conditions are satisfactory for the transformation of the inactive into the active forms, applications of potassium fertilizers are hardly necessary.

Thus, if the humus content of the soil is high, its reaction is not
acid, and if the proper methods of tillage are practiced, the bacterial activities which accomplish the solution of unavailable plant food constituents are facilitated and abundant potassium in proper form is offered to the crop. On soils, however, which show a deficiency in total potassium as is true of some poor, light soils, and many peat soils, especially those which are deep and are underlain with rock or sand, then an application of kainit, potassium chloride or potassium sulphate is to be advocated.

PHOSPHORUS

Phosphorus is the element which is most apt to be deficient in soils, not only in available form but also in insoluble compounds. According to many analyses there is less than 2,000 lbs. of phosphorus per acre to a depth of 6 2-3 inches in Iowa soils. Comparing this with over 30,000 lbs. of potassium per acre to the same depth, it is evident that there is more danger of a phosphorus deficiency in the soils of the State.

This deficiency may be remedied by applying phosphorus to the soil in one of three forms: as fine ground natural rock phosphate, as steamed bone meal, or as acid phosphate. The latter material carries the phosphorus in a form immediately available for plant food, while in the other cases it occurs in an insoluble form and must be transformed to be available. The advocates of rock phosphate recommend, however, that it be applied with barnyard manure or green manure in order that bacterial activities may be enhanced by the latter materials and a more rapid transformation of the phosphorus compounds may occur. They contend also that as the soluble phosphates are transformed into an insoluble form in the soil, when not immediately assimilated, it is of no particular value to use the soluble form. While this change of the soluble form into insoluble does occur in the soil, one important point should not be overlooked—when the soluble material is added to the soil it is immediately dissolved and uniformly diffused through the soil.

Thus, after the change into insoluble form occurs the phosphate is in such physical shape that the bacterial action reproducing the soluble material is considerably greater than it is on the insoluble rock itself.

The rock is much cheaper and hence its use may seem advisable for financial reasons, but it is still a mooted question whether it is not more profitable to apply a soluble phosphate which unquestionably gives quicker returns and probably larger yields even although perhaps not as great percentage returns for the money invested, than to bury a large quantity of rock phosphate in the soil where it becomes slowly available.

The Station is not prepared to make definite recommendations on this point, and if they desire, farmers may test and compare the use of soluble and insoluble phosphorus fertilizers.
FIELD TESTS TO DETERMINE FERTILIZER REQUIREMENTS OF SOIL

Farmers generally recognize the fact that soils differ in productive power. Sometimes soils which differ markedly from each other are found on the same farm or even in the same field.

In many cases the best soil on the farm is not as fertile as it should be, or some portion of the farm is notably unproductive. The farmer may desire therefore to test his soils in a practical manner in order to determine the effect of nitrogen, phosphorus, lime or some other fertilizing material on the crop yields.

A fertility test that has been thoroughly tried out and that includes the application of substances supplying the elements of plant food which are apt to be deficient in Iowa soils, can be made by any thoughtful and careful farmer in the manner described in the following paragraphs:

ESSENTIALS IN A TEST

In the first place, the soil on which the experimental plots are to be located should be truly representative of the soil which it is proposed to test. If this is not the case the experiments will be of little value and they may even prove misleading and induce the land owner to adopt a system of management which will not give satisfactory results.

Again, the land which is devoted to the experimental plots should be kept, through the years, under a definite system of crop rotation. This is essential because a good rotation system is the basis of nearly every satisfactory soil management scheme. No particular type of rotation will, of course, be used in all sections of the state. Each farmer will be compelled to choose a rotation which he believes will give the best results under existing labor, market and soil conditions.

An excellent rotation for many sections of Iowa is the following:
- First year—corn.
- Second year—corn.
- Third year—oats or wheat.
- Fourth year—clover.

This rotation keeps one half of the cultivated portion of the farm in corn. Many grain farmers favor this plan because corn is classed as the chief “money” crop in the state, while the live stock farmers prefer it because the corn crop most nearly meets the requirements of their feeding operations.

Below is given another good rotation which is especially adapted to the southern and western portions of the state:
- First year—corn.
- Second year—oats.
- Third year—clover.
- Fourth year—winter wheat.

This rotation includes winter wheat and therefore will prove particularly satisfactory to the large number of Iowa farmers who are
now growing this crop much more extensively than in former years. Wheat is an excellent crop in a fertility test because it shows quite definitely in yield and quality the effect of soil treatment.

Either of the rotations referred to above may be extended to cover a five or six year period by seeding timothy with the clover and using the crop for pasture or meadow.

**LOCATING AND MARKING OUT THE PLOTS**

After a rotation has been decided upon a series of ten plots should be marked off in that portion of the field which is most nearly representative of the soil which is to be tested.

The plots should all be of the same size. On the average, farm plots which contain one acre each will probably be found to be most satisfactory. They may, however, contain one tenth, one quarter or one half of an acre each. The size of the plot must necessarily be determined by local conditions. A long and narrow plot is usually preferred; for example, a one tenth acre plot which is two rods wide and eight rods long, and plots of other sizes in proportion. It is advisable to separate plots by a division strip seven feet wide. A strip of this width will accommodate two rows of corn or one seven-foot drill.

**FORM FOR PLOT EXPERIMENT DATA**

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil Treatment Applied</th>
<th>1916 Corn</th>
<th>1917 Corn</th>
<th>1918 Oats</th>
<th>1919 Clover</th>
<th>1920 Corn</th>
<th>1921 Corn</th>
<th>1922 Oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure and lime</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure, lime and phosphorus</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>None</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Crop residues</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Crop residues and lime</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues, lime and phosphorus</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues, lime, phosphorus and potassium</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>None</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A satisfactory plan for showing the location of each plot is worked out by setting a stake in the fence row adjacent to the fence, to mark the outside corner of the first plot. The second stake should then be set in line with the corner stake at such a distance as marks off the exact width of the first plot. The third stake should be placed seven feet beyond the second, and thus show the location of the division.
strip between the first and second plots. By following this plan the
exact location of each plot in the series may be shown.

A diagram drawn to scale on paper, should be made of the field
plots which will show the location of the soil under investigation, the
exact length and width of each plot, the width of the division strips,
and the soil treatments. In connection with this diagram, there should
be a record book, in which should be entered the dates of all operations
and other items bearing upon the progress of the experiment. It is
never advisable to trust to memory or to field stakes for the plan
of the experiment.

The following form will be found convenient for keeping the final
data of a field experiment which is continued from year to year:

**RECORD OF THE EXPERIMENT**

Given herewith is an outline of one of the simplest and most prac­tical series of plot experiments, and it is recommended for all normal
types of Iowa soils on which common farm crops are grown.

The series of soil treatments listed below really includes two dis­tinct systems of farming. For instance, the treatments recommended
for plots one to four inclusive, represent a live stock system of soil
management, while plots five to eight inclusive, represent a grain
farming system. It is suggested that any farmer who does not wish
to use as many as ten plots may confine his experiments to either the
live stock or the grain system. If this is done, in some cases it may
be advisable to include the treatment suggested for plot nine, and
thus make the test include potassium.

**PLAN FOR PLOT EXPERIMENTS**

a—Fertility test. b—Live stock system. c—Grain farming system.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Soil Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None.</td>
</tr>
<tr>
<td>2</td>
<td>Manure.</td>
</tr>
<tr>
<td>3</td>
<td>Manure and limestone.</td>
</tr>
<tr>
<td>4</td>
<td>Manure, limestone and phosphorus.</td>
</tr>
<tr>
<td>5</td>
<td>None.</td>
</tr>
<tr>
<td>6</td>
<td>Crop residues.</td>
</tr>
<tr>
<td>7</td>
<td>Crop residues and limestone.</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues. limestone and phosphorus.</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues. limestone, phosphorus and potassium.</td>
</tr>
<tr>
<td>10</td>
<td>None.</td>
</tr>
</tbody>
</table>
The following explanations regarding the details of this plan for plot experiments in the field should be carefully noted:

1. Manure of good quality, but fairly representative of that commonly produced on the farm, should be applied at the rate of eight or ten tons per acre, once in a four year rotation and in proportionate amounts for rotations which cover a shorter or longer period of time. When it is possible to do so, the manure should be put on the clover field and plowed under for corn the following year.

2. Ground limestone or limestone screenings should be applied to the land after it has been plowed, at the rate of two or three tons per acre, once in a four year rotation. The application of lime may be made at any convenient time of the year.

3. Phosphorus may be applied in finely ground rock phosphate, steamed bone meal or acid phosphate. The rock should be used at the
rate of 2,000 pounds per acre, the steamed bone meal at the rate of 800 pounds per acre, and the acid phosphate at the rate of 300 to 400 pounds per acre. These applications are made but once in a four year rotation.

4. The soil treatment recommended for plot 6, is designated as “crop residue.” This treatment should be understood to mean that all products except the grain or seed which are sold in grain farming, shall be returned to the land and used as fertilizers. The details of this procedure are as follows:

A. The clover should be clipped once or twice somewhat earlier than the first cutting for hay would ordinarily take place. The clipped material should be left on the land to be plowed under later.

Seed should be taken from the second crop if there is a yield which will justify the expense of the harvest. There is a strong demand in this state for clover seed of good quality and the prices are such as to make yields of even one or two bushels per acre quite profitable.

B. The corn stalks should be cut with a disk or stalk cutter and plowed under.

C. The threshed straw from small grain and clover should be returned to the land. This may be done at some convenient time. Often the straw is stacked in a feed yard for a few months and then applied as a fertilizer. This plan affords the work horses on the farm some feed during the winter and permits the straw to decay to some extent, putting it in a better condition to handle.

5. It should be noted that neither crop residues nor any other fertilizing material are to be applied to plots 1, 5 and 10. All crops are to be removed from these plots, and nothing returned.

6. Potassium may be applied in potassium chloride, potassium sulphate or kainit. The chloride and sulphate should be used at the rate of 200 to 300 pounds per acre, and the kainit at the rate of 1,000 pounds per acre, once in a four year rotation.

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.
ROCK PHOSPHATE

Raw rock phosphate finely ground, for application to the soil, contains from 10 to 14 per cent of phosphorus and costs from $3.50 to $5.00 per ton, f. o. b. cars, at the Tennessee mines. The freight to various points in Iowa will bring the cost of the rock up to $7.50 to $10.00 per ton, in carload lots.

Rock phosphate is quite variable in composition, both physically and chemically, and its value is considerably modified by small differences.

It should be so finely ground that 90 per cent of the material can be washed through a sieve of 100 meshes per inch. The percentage of fine material may easily be tested by washing a certain amount through a sieve and drying and weighing the residue.

ACID PHOSPHATE

Acid phosphate is made by treating the raw ground rock with acid which changes the insoluble calcium phosphate into a soluble form. The material as it is placed on the market is in a finely ground form and contains in addition to the soluble calcium phosphate also some calcium sulphate, a product of the treatment of the rock.

Acid phosphate contains about 14 per cent of available phosphoric acid and costs from $14 to $16 per ton f. o. b. cars.

BONE MEAL

Steamed bone meal contains about 12½ per cent of phosphorus and may be obtained for $25 to $30 per ton f. o. b. cars in carload lots.

POTASSIUM SALTS

Muriate of potash, the trade name for potassium chloride, and potassium sulphate contain about 40 per cent of potassium and cost from $40 to $50 per ton f. o. b. cars, while kainit, containing potassium sulphate and some magnesium sulphate, magnesium chloride and sodium chloride, has about 10 per cent potassium and may be obtained for from $12 to $15 per ton f. o. b. cars.

GROUND LIMESTONE OR LIMESTONE SCREENINGS

The following firms in Iowa have indicated that they are prepared to furnish limestone for agricultural purposes; there may be others also.

Bartlett & McFarlane, Waterloo, Iowa, offer material from dust to the size of a pea, at $1 per ton F. O. B. cars their quarry.

Bettendorf Stone Co., Davenport, Iowa, will furnish material 65 per cent fine particles, and 35 per cent from ¼" diameter and smaller particles down to dust at 80c per ton in large quantities or 90c per net ton in small quantities, F. O. B. their quarry which is located at Bettendorf.

Burlington Quarry Co., Keokuk, Iowa, offer screenings at a cost of 75c per ton in carload lots, F. O. B. Montrose, Iowa.

Charles Chilton, Ottumwa, Iowa, will furnish material at 75c per ton.

H. Dearborn's Sons, Stone City, Iowa, offer screenings composed of
50% dust and from this to ½” maximum size, at 25c per ton in car-
load lots, F. O. B. their quarry.

Dolese Bros. Co., 10 South LaSalle St., Chicago, Ill., with quarries
at Buffalo, Iowa, offer a high grade limestone in a fine state of division
for sale in carload or smaller lots. Prices quoted upon application.

Ellsworth Stone Co., Iowa Falls, Iowa, sell limestone screenings con-
sisting of 60% dust at 20c per ton in carload lots, F. O. B. their quarry.

F. Erickson Co., Stone City, Iowa, furnish a material consisting of
screenings, a mixture of particles from ¾” down to a small portion
of stone dust, for 25c per ton in carload lots, F. O. B. their quarry.

The Fort Dodge Portland Cement Corporation, Gilmore City, Iowa,
offer limestone screenings in carload lots from thirty to fifty tons, at
50c per ton, F. O. B. their quarry.

J. A. Green & Sons, Stone City, Iowa, will furnish screenings passed
through a ¾” sieve, the particles of stone being from one quarter of
an inch down to dust, at 50c per ton in carload lots, F. O. B. their
quarry.

The Linwood Quarries Co., Davenport, Iowa, offer screenings passed
through a ¼” sieve, at 35c per ton, F. O. B. their quarry at Linwood,
Iowa.

McManus & Tucker, Keokuk, Iowa, will furnish a material containing
60-65% dust at a cost of 75c per ton, F. O. B. their quarry.

The Peru Stone & Cement Co., East Peru, Iowa, offer screenings at
20c per cu. yd., F. O. B. their quarry in carload lots, and at 20c per
cwt. in less than carload lots.

B. N. Arquitt & Sons, Farley, Iowa, will supply a material at 80c
per ton.

John Boland, Bettendorf, Iowa, will furnish limestone at $1.15 per
ton, F. O. B. their quarry.

Quimby Stone & Fuel Company, Mason City, Iowa, will furnish
material at 90c per ton, F. O. B. their quarry.

Waverly Stone & Gravel Co., Waterloo, Iowa, furnish limestone at
30c per ton, F. O. B. their quarry.

State Reformatory, Anamosa, Iowa, will supply material at 40c per
ton, F. O. B. Anamosa.

The Hale Roberts Stone Company, Alden, Iowa, furnish limestone at
20c per ton, F. O. B. their quarry.

The Earlham Land Co., Des Moines, Iowa, will furnish material at
50c per ton, F. O. B. Earlham, Iowa.