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A COMPARISON OF THE SOIL-PLAQUE METHOD WITH THE NEUBAUER AND HOFFER CORNSTALK METHODS FOR DETERMINING MINERAL SOIL DEFICIENCIES

BY LAURA C. STEWART, WALTER G. SACKETT,
D. W. ROBERTSON AND ALVIN KEZER

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A COMPARISON OF THE SOIL-PLAQUE METHOD WITH THE NEUBAUER AND HOFFER CORNSTALK METHODS FOR DETERMINING MINERAL SOIL DEFICIENCIES*

By Laura C. Stewart, Walter G. Sackett, D. W. Robertson and Alvin Kezer

The need for more exact knowledge of the fertilizer requirements of our soils is becoming more urgent each year as the yields from our farms dwindle with the removal of each succeeding crop. It is a recognized fact that some fields are more deficient than others, and that certain plant foods have become reduced while others are still plentiful. We know, for example, that many of our Colorado soils are too low in phosphate for profitable farming, yet these same farms, for the most part, contain ample potash and nitrogen. Neither potash nor nitrogen can take the place of phosphate, and so the only alternative is the addition of some form of phosphate fertilizer. Obviously, we should use the kind of plant food that is called for and apply it where most needed in amounts commensurate with the soil depletion. There is only one way of finding this out and that is by having the soil tested for its deficiencies. Every farmer should have this information about his land for the economic use of both barnyard manure and commercial fertilizer.

Since the fertility of each field, even on the same farm, may be different, depending upon the way the particular tract has been handled and cropped, it follows that a single test from one place on the ranch cannot give reliable information for the whole area, and that each field must be sampled separately. If such a program is to be carried out so that fertilizer can be applied intelligently, we should have a simple, rapid, inexpensive method for making the tests in order to handle expeditiously the large number of samples that would result.

Many methods have been devised for determining the available plant nutrients in soil. Some of these give results that are not reliable while others are so long, laborious and expensive as to be impracticable.

Among the more recent tests that have been described is the bacteriological soil plaque (11) which we have used for the past 3 years very successfully in the routine examination of Colorado soils. In the following study we have compared this method with two of the newer biological ones from the standpoint of reliability, ease of manipulation, time required, expense involved

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and general application to the determination of soil needs for all crops. These are the Neubauer and the Hoffer Cornstalk Methods.

Since any procedure for determining soil requirements, to have a practical value, must give results which can be verified by fertilizer field tests with growing crops, we have conducted parallel fertilizer field experiments in cooperation with the Agronomy Section of the Experiment Station during 1929, 1930 and 1931 on land that we have tested for deficiencies in phosphate, potash and lime. This work was in charge of Dr. D. W. Robertson and is reported elsewhere in this bulletin.

DESCRIPTION OF THE METHODS

THE SOIL PLAQUE*

The principle of the soil plaque as used in this test was originated by Winogradsky (13) in his work on the distribution and activity of nitrogen-fixing organisms in the soil.

In his later investigations in collaboration with Ziemiecka (14), he observed a close correlation between the limiting mineral factors for Azotobacter and those for growing plants. In this connection he states:

> "The method is intended in the first place for the study of fixation in nature which is scarcely commenced. It is clear, however, that the reaction of these microbes so sensitive to limiting mineral factors can serve to indicate these latter in the soil and that with a sensitiveness very superior to chemical methods. Azotobacter have already played this role of indicator in the experiments of Christensen (need of lime) and Gainey (acid). But the old procedure to which these investigators held could not give results as precise as the method of spontaneous cultures."

With Winogradsky's work as a foundation, Sackett and Stewart (11) modified the method for use as a fertilizer deficiency test. The procedure is as follows:

PROCEDURE

The soil is air dried, pulverized and passed thru a 20-mesh screen. A pH determination is next made, using Medalia's (7) colorimetric method. The technique employed has been described previously by Sackett et al (10) and is briefly this:

> "The soil extracts for the hydrogen-ion determinations were prepared by suspending 15 grams of the air-dried soil sample in 70 c.c. of triply distilled conductivity water. These were shaken vigorously for one minute and allowed to settle for 10 minutes, after which 50 c.c. of the supernatant fluid were decanted to centrifuge tubes and centrifuged for 15 minutes. Ten cubic centimeters of the clarified liquid were removed at once with a

*For a more complete description of the Soil-Plaque Method, the reader is referred to Bulletin 375 of the Colo. Exp. Sta., "A Bacteriological Method for Determining Mineral Soil Deficiencies by Use of the Soil Plaque." November, 1931.

pipette for the test, and the readings were made according to the technique of Medalia."

If the soil is acid, of a pH less than 6.8, 8 to 10 percent of precipitated $CaCO_3$ is added. According to Fred and Davenport (2), Johnson and Lipman (6), Gainey (3) and Sackett (10), Azotobacter cells are very sensitive to acid and will not develop in a medium that is more than very slightly acid. The best growth occurs between a pH of 7.0 and 8.0. If the soil is already basic, no $CaCO_3$ is added.

Four 50-gram portions of soil are weighed into separate dishes and thoroly mixed with 5 percent cornstarch (2.5 grams to each portion). With sandy soils, low in anaerobes necessary to convert the starch into forms available for Azotobacter, 1 c.c. of 100 percent solution of sucrose is substituted for the cornstarch. It is important to take into consideration the physical condition of the soil aside from the question of deciding which energy material to use. In the majority of cases it will be found satisfactory and will need no further attention. Very sandy soils, however, are improved by the addition of powdered kaolin. This produces a smooth texture that is more favorable to the development of Azotobacter colonies. In contrast to these sandy soils, heavy clays are sometimes encountered to which the addition of pure quartz sand is very effective in rendering their texture more favorable for aeration and consequently for the development of Azotobacter.

If the soil has been found to be either acid or in a poor physical condition, the chances are that it either contains no Azotobacter or, if present, that they are not in a sufficiently active state to produce spontaneous colonies. In such cases inoculation with a culture of Azotobacter is resorted to, after the unfavorable condition has been corrected.

For inoculation, 1 c.c. of a bacterial suspension, prepared by washing the growth from 1 tube of a 72-hour, mannite agar culture of Azotobacter with physiological salt solution (.85 percent NaCl and diluting it to 100 c.c. is used to each plaque. The majority of Colorado soils are naturally well inoculated with Azotobacter.

The physical condition and reaction having been taken into account and the presence of Azotobacter assured, the soil is then ready for the fertilizer treatments. The first 50-gram portion is used as a check and receives no fertilizer. The second is treated with 0.15 gram K_2SO_4 to test for potash deficiency; the third receives 0.3 gram $Na_2HPO_4 \cdot 12\ H_2O$ for phosphate deficiency, and to the fourth is added 0.15 gram K_2HPO_4 for both potash and phosphate deficiencies. Occasionally soils are encountered so basic in reaction that the addition of sodium salts to the third plaque might increase the basicity to a point where it would suppress growth of Azotobacter. In such cases, H_3PO_4 containing the P_2O_5 equivalent of 0.3 gram Na_2HPO_4 is substituted for the latter. It greatly facilitates the work if the mineral substances are added in solution. For this work 3-percent solutions were made from the K_2SO_4 and K_2HPO_4 and 6-percent solutions from $Na_2HPO_4 \cdot 12\ H_2O$. Five c.c. of each solution thus prepared contain the amounts required per plaque.

Enough distilled water is then added by means of a graduated pipette to each portion of soil to give it the consistency of modeling clay or possibly a little softer. It is thoroly stirred and mixed to insure an even distribution of the mineral substance added. The mass is then transferred to half of a small petri dish with the aid of a spatula and moulded into a plaque. The surface is made smooth and polished by means of a glass microscope slide moistened with distilled water. It is important that an equal amount of liquid (water in the check and water plus solutions in the treated plaques) be added to all four plaques in a set as a variation in the moisture content greatly affects Azotobacter development and would give results that might lead to erroneous conclusions, since the interpretation of results depends on a comparison of the Azotobacter growth on the four plaques. The finished plaques are placed in a large, covered, crystallizing dish on moist blotting paper to prevent them from drying out, and a piece of blotting paper is fitted in the top to prevent the water that condenses from dropping on the plaques. It is desirable to have the four plaques of a set in the same crystallizing dish as this assures the same conditions of humidity for all plaques in each set. They are incubated at 30 degrees Centigrade for 72 hours, at the end of which time Azotobacter will have appeared as starchy, waxy white, raised, moist, glistening circular colonies on all plaques containing the necessary mineral elements. Where the mineral requirement was not met or only partially satisfied, the plaques either remain bare or produce flat, feeble, watery colonies, depending on the degree of deficiency. At this time a comparison is made of the growth on the four plaques of each set.

INTERPRETATION

As has been stated already, soils which produce no colonies of Azotobacter on plaques without the addition of fertilizer manifest a deficiency in some mineral element or elements. In interpreting the results of this test, the check plaque, therefore, is the first to be examined. If there is no growth here, a deficiency is

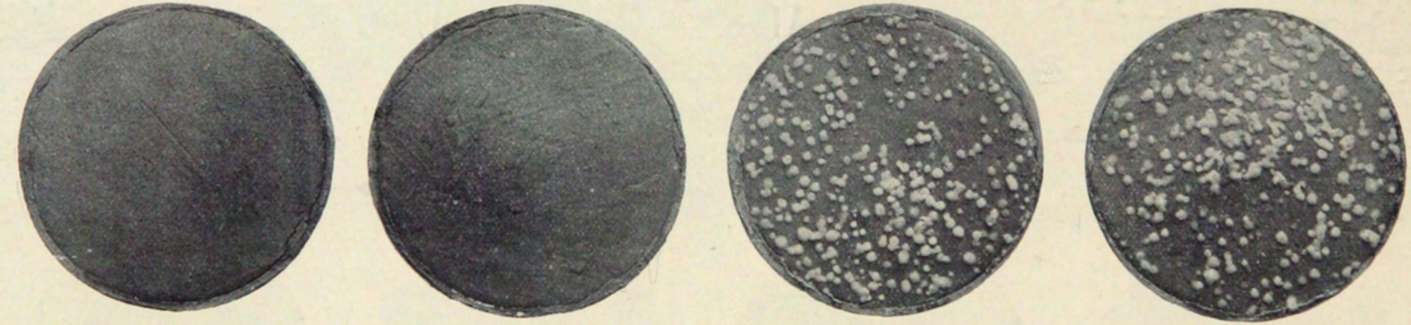

Figure 1.—Soil No. 44. Not deficient in potash, very deficient in phosphate. Reading left to right: Check, nothing added; potash added; phosphate added; phosphate and potash added. Neubauer values: Potash 48.28; phosphate 3.847.

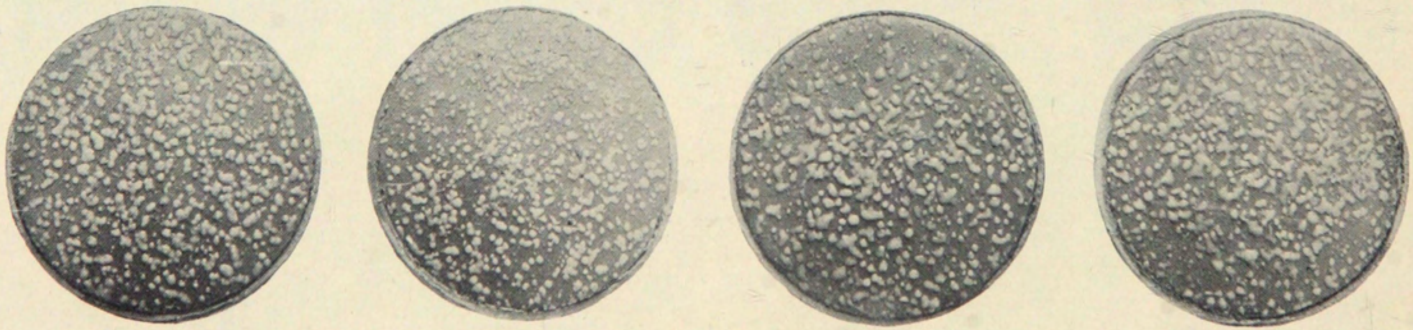

Figure 2.—Soil No. 51. Not deficient in either potash or phosphate. Reading left to right: Check, nothing added; potash added; phosphate added; phosphate and potash added. Neubauer values: Potash 56.912; phosphate 15.270.

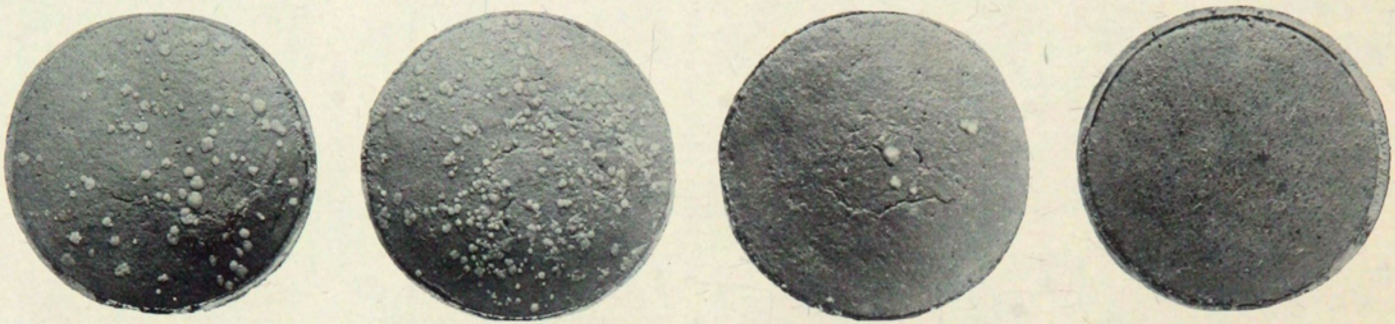

Figure 3.—Soil No. 92. High in both potash and phosphate. Suppression by phosphate. Reading left to right: Check, nothing added; potash added; phosphate added; potash and phosphate added. Neubauer values: Potash 64.229; phosphate 29.911.

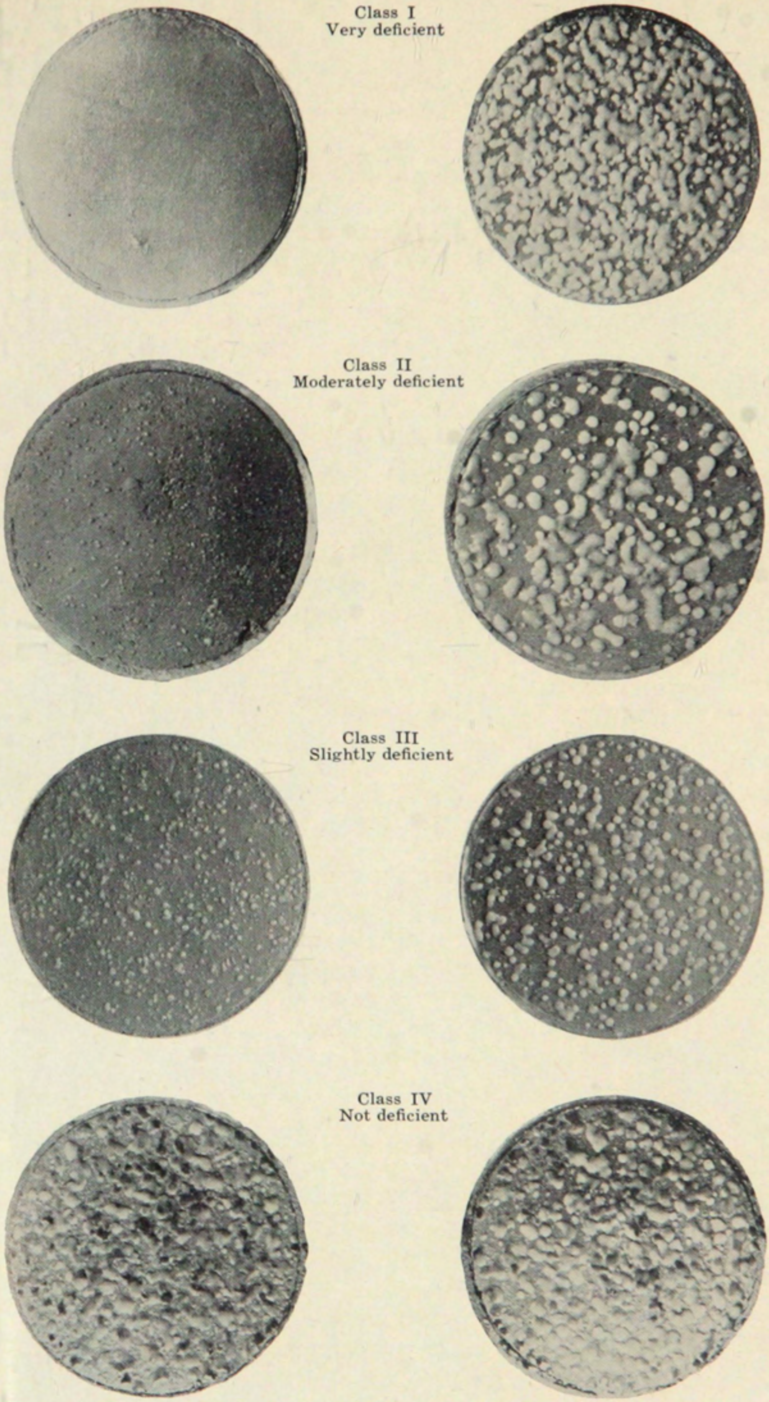

Figure 4.—Type plaques for phosphate deficiency classification. Left row: Checks, nothing added; right row, phosphate added.

indicated which is determined by examining the remaining plaques of the set which have received the various fertilizer treatments. The fertilizer producing the best growth is the one in which the soil is deficient. If the soil is deficient in two factors, say phosphorus and potassium, the best growth will be obtained on the plaque treated with a combination of these two elements. Should there be no deficiency, the untreated plaque will produce colonies as numerous and luxuriant as those on any of the plaques receiving the various fertilizers. (See Figures 1 and 2.) In a few cases soils are so abundantly supplied with mineral nutrients that the addition of more to the treated plaques suppresses the growth of Azotobacter so that in such cases the check plaque gives the most luxuriant growth. (See Figure 3.)

This test is not only qualitative, showing the mineral elements needed, but is also sufficiently quantitative to indicate, for all practical purposes, the amount of fertilizer necessary to supply the deficiency. Most of the soils, on which the test has been carried out, contain an abundance of potassium, so very little work has been done in formulating standards for the quantitative determinations of this element.

In regard to phosphorus, however, four well-defined classes have been established. (See Figure 4). Much of the work along the line of classification has been done by the research division of the Great Western Sugar Company under the direction of Mr. Maxson. The classification is as follows:

CLASSIFICATION

Class 1. Very deficient.

UNFERTILIZED PLAQUE.—Colonies none or few to many extremely small, feeble, pinpoint.

FERTILIZED PLAQUE.—Colonies few to numerous, medium to large, distinct and vigorous.

Class 2. Moderately deficient.

UNFERTILIZED PLAQUE.—Colonies few to as many as fertilized plaque, but very much smaller and weaker in development; none approaching size of colonies on fertilized plaque, pigment often less to none.

FERTILIZED PLAQUE.—Colonies few to numerous, distinct and vigorous.

Class 3. Slightly deficient.

UNFERTILIZED PLAQUE.—Colonies as numerous as fertilized plaque, but smaller and less luxuriant

FERTILIZED PLAQUE.—Colonies few to numerous, distinct and vigorous.

Class 4. Not deficient.
Colonies on both fertilized and unfertilized plaques approximately equal in number and development.

The Neubauer Method

The Neubauer method, already referred to, was devised by Neubauer and Schneider (9) in an effort to overcome the objection common to all chemical methods for the determination of soil deficiencies, namely:—That the results obtained give the nutrients soluble in whatever medium was used in extracting the soil and not what is actually plant available. In order to determine, with certainty, what is available for plants it is necessary that it be extracted by plants. Neubauer and Schneider proceeded on this basis. They claim that seedlings do not wait until the reserve supply of nutrients in the seed is used up, before they start extracting plant food from the soil, but do so as soon as they send out roots. They assert further that 95 to 100 rye seedlings will extract in 14 days all of the available plant food in 100 grams of soil.

Procedure

Growing of Seedlings.—Well-developed, uniform, mature rye seeds, wholly free from damage, are selected and weighed in groups of 100. Each set of 100 seeds should weigh, according to Neubauer, 4 grams. The rye used in this work weighed only 3.45 grams for 100 seeds, as heavier rye could not be obtained. This was secured from the Dresden, Germany, Agricultural Experiment Station. It is not essential, however, that the rye weigh 4 grams as long as all the sets in a series weigh the same, and the rye is in good condition so that it will produce vigorous plants.

The rye is germinated between moist blotting papers in petri dishes in a dark, cool place. Neubauer recommends treating the seeds with 0.125-percent solution of Uspulun before germination to prevent the growth of mould. This treatment was not found necessary in the tests conducted here.

In about 48 hours the seeds should have germinated and attained the proper size for planting. Sprouts of 2-3 m.m. are the best length. This size may be reached in less than 48 hours, depending upon the moisture and temperature conditions.

The planting is done in glass Neubauer dishes 12 centimeters in diameter and 7 centimeters high. The dishes are prepared with a mixture of 100 grams of the soil to be tested, which has been air dried and passed thru a 20-mesh sieve, and 50 grams washed quartz sand. The soil-sand mixture is wet with 24 c.c. of distilled water and spread uniformly on the bottom of the Neubauer dish. One hundred grams of sand wet with 16 c.c. distilled water is spread evenly on top of soil-sand layer. One hundred depressions, to receive the seeds, are made equidistant on the sand layer and a short glass tube for watering is placed in the center. A small wooden disc of a diameter slightly smaller than the Neubauer dish, into which 100 conical upholstering tacks have been placed, is very convenient for making the holes. The seeds are then planted, using only perfectly germinated seeds with both roots and sprouts. If any seeds have not germinated, they are replaced by well-germinated seeds from another dish kept for this purpose. The seeds are covered with another layer of 100 grams quartz sand wet with 16 c.c. of distilled water. This should be spread on smoothly, and pressed down lightly, care being taken not to disturb the seeds. The dish is then weighed, covered with a glass plate, and set on a table near a north window in a cool room. The temperature should remain around 20 C. and should be fairly constant.

All soils should be run in duplicate and a blank, in which 100 grams of quartz sand are substituted for the 100 grams of soil, should be planted on each day of planting. The blank serves as a check on the light, temperature, moisture and other conditions which might influence the growth of the seedlings, as well as a means of determining the amount of nutrients that the plants derive from the seeds. Blanks should also be in duplicate.

In 1 or 2 days, after the seedlings have grown so they touch the glass plate, it is removed, and enough distilled water is added to bring the dish up to weight. This adjustment should be made daily. The watering is done by means of a pipette, the water being introduced into the tube in the center provided for this purpose to prevent the sand from crusting over on the surface and interfering with the proper aeration of the roots. The dishes should be turned each day and moved from place to place in rotation on the table so that all plants in the same series will have as nearly as possible the same light conditions. (See Figure 5.)

After 14 days of growth, when the plants begin to droop and the tips to turn yellow, the vegetative test is discontinued, because according to Zuckerfabrik Kleinwanzleben (15), at this point the assimilation of plant food is over. A prolongation of this period results in losses of nutrients from the seedlings, due to a return of the absorbed mineral material from the roots to the exhausted soil, and to mechanical losses as a result of dying

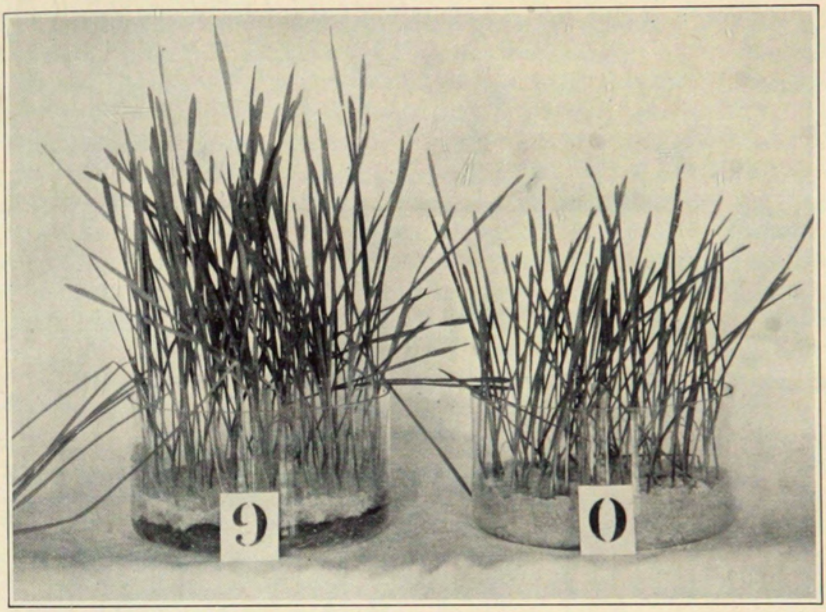

Figure 5.—Neubauer plants. Left, soil; right, quartz. Soil plants: 60.27 mg. K_2O; 27.15 mg. P_2O_5. Quartz plants: 18.01 mg. K_2O; 20.99 mg. P_2O_5.

and subsequent washing away of small roots.

The plants are removed carefully from the Neubauer dish, by inverting it and tapping it gently on the bottom. They are placed in a fine mesh sieve and washed under a stream of tap water for exactly 4 minutes. The matted roots are pulled apart carefully so as to expose them to the action of the water. Rubbing and squeezing should be avoided. After all the soil and sand have been removed the plants are washed in distilled water, counted carefully and placed in numbered porcelain dishes. There should be 95 to 100 plants. Zuckerfabrik Kleinwanzleben (15) found that a variation from 93 to 100 does not affect the analytical results. Any pieces of roots or ungerminated seeds left in the sieve should be collected and added to the plants in the porcelain dishes. All plants should be washed for as nearly the same length of time as possible so that the amounts of nutrients that diffuse into the water will be the same for all the sets in a series. Neubauer recommends cutting the plants from their roots and washing each separately; however, washing the roots without severing them from the plants works out very satisfactorily.

Preparation of Solution.—The plants are dried for a few days at room temperature or in a drying oven and are then ready to be ashed. Neubauer recommends platinum dishes for this. Quartz or porcelain dishes may be used. In our studies porcelain evaporating dishes, 10 cm. in diameter, were employed. It is very important that the plants be ashed slowly. Too high heat must be avoided and the dishes should never reach more than a very dull red color. At higher temperatures the potash will be lost by volatilization or by fusion with the dish. An electric furnace is very convenient for ashing; the door and air vents should be left open to secure better circulation of air and a more rapid oxidation of the carbon present. Two hours are usually sufficient to complete the ashing process. The ash should appear white or it may have a reddish tinge if iron is present. No carbonaceous particles should remain.

The ash is moistened with 1 c.c. 1-3 HCl, and 10 c.c. hot water are added. It is then evaporated slowly to dryness over a waterbath, to separate the silica, and dried in a drying oven for 3 hours at 110 degrees C. Next the residue is moistened with 1 c.c. concentrated HCl and taken up with hot water. The resulting solution is filtered into a 100 c.c. volumetric flask, cooled and made to volume. In this procedure the dish and filter should be washed carefully with hot water.

The solutions thus prepared are now ready for the phosphate and potash determinations.

DETERMINATION OF PHOSPHATE.—The phosphates were precipitated according to Neubauer (9), and the ammonium phosphomolybdate determined volumetrically as described in the Official Methods (8).

REAGENTS.—*Lorenz Reagent.*—Forty-five hundred c.c. of HNO_3, specific gravity 1.40 at 15 degrees C., are poured over 500 grams $(NH_4)_2SO_4$ and stirred. Fifteen hundred grams of finely crushed $(NH_4)_2MoO_4$ are dissolved with 4 liters of hot water and cooled to 20 degrees C. This is then poured in a thin stream into the HNO_3 and $(NH_4)_2SO_4$ solution. After cooling it is made up to 10 liters and mixed well. It should be kept in brown bottles in a cool, dark place and allowed to stand 48 hours before using.

Nitric Sulphuric Mixture.—One liter HNO_3, specific gravity 1.20, plus 30 c.c. concentrated H_2SO_4.

Wash Solution.—Two-percent solution of NH_4NO_3.

Sodium Hydroxide.—Tenth-normal solution. 1 c.c. = 0.309 mg. P_2O_5.

Nitric Acid.—Tenth-normal solution.

PROCEDURE.—For the phosphate determination 50 c.c. of the solution, prepared from the ash of the plants, are measured into a beaker and evaporated slowly over a waterbath to 25 c.c. Twenty-five c.c. of the nitric-sulphuric-acid mixture are added and heated to boiling. It is removed from the hot plate and 50 c.c. of Lorenz Reagent added slowly with constant stirring to facilitate the precipitation of the phosphomolybdate. The beaker is then covered with a watch glass and allowed to stand 18 to 24 hours at room temperature.

The precipitated ammonium phosphomolybdate is removed from the above solution by filtration and washed with a 2-percent NH_4NO_3 solution until one filling of the funnel will give an alkaline reaction to methyl red with two drops of N/10 NaOH.

The precipitate and filter are transferred to the original beaker in which the precipitation took place and the ammonium phosphomolybdate is dissolved in a small excess of N/10 NaOH. It is titrated with N/10 HNO_3, using phenolphthalein as the indicator. Each c.c. of NaOH is equivalent to 0.309 mg. P_2O_5. This number was multiplied by 2, as only 50 c.c. of the solution were used for each determination. From this value is subtracted the amount of P_2O_5 contained in the blank. This gives the amount of P_2O_5 removed by the seedlings from 100 grams of soil and is the Neubauer value for that soil.

DETERMINATION OF POTASH.—The potassium cobalti-nitrite method was used for the potash determinations. Objection has been raised to the method on the ground that the potassium cobalti-nitrite precipitate which is formed has a variable formula. According to Cunningham and Perkin (1) it may be $K_2NaCo(NO_2)_6$, $K_3Co(NO_2)_6$ or a mixture of these salts, depending upon the temperature at which the precipitate is formed and upon the ratio of sodium and potassium salts.

Another criticism is that the precipitate is not altogether insoluble, so part may be lost in washing. Jarrel (5) found that it gave results that were 2 percent too low as compared with the platinic-chloride method.

However, it is a comparatively inexpensive, rapid method, and if the experimental conditions are carefully controlled, uniform results can be obtained that agree very closely with standard methods for the determination of potassium.

The procedure has been very carefully standardized in the Neubauer analysis so that dependable results can be expected. The test is made as follows:

REAGENTS.—*Potassium Permanganate Solution.*—Prepare N/25 solution by dissolving 1.2642 grams $KMnO_4$ in distilled water and diluting to 1000 c.c. Theoretically, 1 c.c. N/25 $KMnO_4$ solution is equivalent to 0.4709 mg. K_2O, but the actual K_2O value of this solution should be ascertained by determining the potash equivalent in a KCl solution of known strength.

Oxalic Acid Solution.—Prepare N/25 solution by dissolving

2.521 grams crystallized oxalic acid in distilled water and diluting to 1000 c.c.

Determine the value of the oxalic acid in terms of the permanganate by heating to boiling 10 c.c. of the oxalic acid and 100 c.c. of redistilled water with 2 c.c. H_2SO_4 (1-10) and titrating, while still hot, with the standard permanganate to the appearance of a pink color.

Sulphuric Acid.—Ten percent H_2SO_4 containing 0.1 gram $MnSO_4$ per 5 c.c. concentrated acid.

Acetic Acid.—Ten percent CH_3COOH.

Sodium Sulphate Solution.—(Na_2SO_4),—2.5 grams sodium sulphate diluted to 100 c.c. with distilled water.

Sodium Nitrite Solution.—($NaNO_2$),—10 grams sodium nitrite diluted to 100 c.c. with distilled water.

Sodium Chloride Solution.—(NaCl),—saturated solution.

Cobaltous Chloride Solution.—($CoCl_2$),—10 grams cobaltous chloride diluted to 100 c.c. with distilled water.

PROCEDURE.—Twenty c.c. of the solution prepared from the ash of the seedlings are measured into a porcelain evaporating dish and evaporated to dryness over a waterbath to drive off the free HCl. Five c.c. of saturated NaCl, 3 c.c. of 10-percent $CoCl_2$ and 5 c.c. of 10-percent $NaNO_2$ are then added, and once more slowly evaporated to dryness over a waterbath. The dish should be shaken thruout the drying to prevent the formation of a crust. It is during this evaporation process that the precipitation of the potash as $K_3Co(NO_2)_6$ takes place. It is important that the temperature be kept the same for all determinations, as the formula of the potassium cobalti-nitrite is dependent upon the temperature at which precipitation takes place.

After the residue is completely dry, it is cooled, and 5 c.c. of 10-percent acetic acid are added. All lumps should be broken up with a small glass pestle. It is allowed to stand for exactly 15 minutes with the acetic acid. Then 5 c.c. of water are added and filtered immediately thru a Neubauer filter crucible* under medium-high suction. The evaporating dish and precipitate are washed with 18 c.c. of 2-percent Na_2SO_4 solution, using 3 c.c. at a time. It is important that the above-mentioned potash residue stand for exactly 15 minutes with the acetic acid before filtration and that the same volume of wash solution be used in all determinations as standing for a longer time with the acetic acid or using more wash solution would dissolve more of the $K_3Co(NO_2)_6$ and give results that would be too low.

After the precipitate has been washed it is placed with the crucible in a large evaporating dish with 100 c.c. of hot water

*Size 9. Grade 1G-4, obtained from Schott, Jena, Germany.

and 50, 60 or 75 c.c. of standard $KMnO_4$, depending upon the amount of potassium present in the sample. At this point 10 c.c. of 10-percent H_2SO_4 are added. It is heated slowly, with constant stirring, to the simmering point and kept at this temperature for exactly 10 minutes. If the $KMnO_4$ becomes decolorized, more should be added. The $K_3Co(NO_2)_6$ is oxidized by the $KMnO_4$ during the heating process, according to the following equation:

$$5\ K_3Co(NO_2)_6 + 12\ KMnO_4 + 18\ H_2SO_4 \rightarrow 15\ KNO_3 + 5\ Co(NO_3)_3 + 12\ MnSO_4 + 6\ K_2SO_4 + 18\ H_2O.$$

No yellow precipitate should remain in the crucible. Fifty c.c. of standard oxalic acid are then added and heated until the $KMnO_4$ is completely decolorized and no trace of MnO_2 is left in the dish or crucible. The excess oxalic acid is then titrated with standard $KMnO_4$. By deducting the oxalic acid used from the total amount of $KMnO_4$ used, the amount of $KMnO_4$ consumed in the oxidation of the $K_3Co(NO_2)_6$ is determined and from this the amount of K_2O can be computed.

The results obtained are multiplied by 5, as only 20 c.c. of the solution prepared from the ash are used for each determination. From this value is subtracted the blank also multiplied by 5, and the mg. K_2O removed by the seedlings from 100 grams of soil or the Neubauer value in K_2O is thus obtained.

Interpretation

Neubauer classifies phosphate and potash deficiencies as follows:

Phosphate.—Class 1. Soils with less than 4 mg. P_2O_5 per 100 grams of soil. Very deficient.*

Class 2. Soils with 4 to 6 mg. P_2O_5. Moderately deficient.

Class 3. Soils with 6 to 8 mg. P_2O_5. Slightly deficient.

Class 4. Soils with more than 8 mg. P_2O_5. Not deficient.

He regards soils in class 1 as very deficient in phosphate, the deficiency decreasing in classes 2 and 3, respectively, until no deficiency is present in class 4.

Potash.—Class 1. Soils with less than 20 mg. K_2O per 100 grams soil. Very deficient.

Class 2. Soils with 20 to 30 mg. K_2O. Moderately deficient.

Class 3. Soils with 30 to 40 mg. K_2O. Slightly deficient.

Class 4. Soils with more than 40 mg. K_2O. Not deficient

The Hoffer Cornstalk Method

Hoffer (4) developed this method as an aid in interpreting

*The terms "very deficient," "moderately deficient," etc., have been employed by us to designate the different Neubauer classes or values.

symptoms of malnutrition in corn and in diagnosing soil deficiencies in nitrogen, potassium and phosphorus.

The test depends partly upon the appearance of the corn plants with respect to the color, size, accumulation of iron compounds at the nodes, condition of the roots, general health and vigor, and partly, in the case of potash and nitrate deficiencies, upon the results of chemical tests on the plant tissues.

PROCEDURE

Mature corn plants representing the field are selected. The test should be made at the end of the growing season, after the ears are well matured, but before a frost, as freezing breaks down the tissue which allows the potash and nitrates to leach out. The size, color, condition of roots and ears and general appearance of the plant are carefully noted. The stalk is then split lengthwise with a stainless steel knife, and the internal joint tissue is examined for discoloration, due to the presence of iron compounds.

The stalks are now ready for the chemical color tests:

REAGENTS.—*Diphenylamine Solution.*—Dissolve 1.2 grams diphenylamine in 120 c.c. H_2SO_4 prepared by mixing 90 c.c. concentrated H_2SO_4 with 30 c.c. distilled water.

Thiocyanate Solution.—Dissolve 12 grams potassium thiocyanate (KCNS) in 120 c.c. distilled water.

Hydrochloric Acid.—Dilute 1 volume concentrated HCl with 2 volumes distilled water.

The nitrate test is made by applying a few drops of diphenylamine solution to the internode. If nitrates are present, a blue color develops, the intensity of which is dependent upon the amount in the stalk. A high concentration indicates an abundance in the soil, because, according to Hoffer, corn plants take up nitrates in proportion to the amount existing in the soil.

The potash determination is made by testing for iron present, because Hoffer claims that when corn is grown in a soil deficient in available potash, iron accumulates in the joint tissue of the plants, the quantity of iron depending upon the degree of potash deficiency. The test for iron is made by putting a few drops of the potassium thiocyanate solution on the joint tissue of the split stalk, and then by adding a drop or two of the hydrochloric acid. The intensity of the red color produced indicates the relative amount of iron present and indirectly the amount of potash.

A phosphorus need is determined by the appearance of the plants after the other two factors have been eliminated. Stunted growth is usually a symptom of deficiency in available phosphorus.

Interpretation

Hoffer (4) summarizes the interpretation of the results of this test in the accompanying table:

Key to Fertilizer Need Indicated By

Size of Plants	Color produced when stalk tissues are tested with diphenylamine solution		
	If leaves are normal green		If leaves are yellowish green
	Blue	No color	No color
Full size for variety:			
A. Joint tissues normal	None	None	Nitrogen
B. Joint tissues containing iron	Potash	Potash	Nitrogen and Potash
Stunted in growth:			
A. Joint tissues normal	Phosphate	Phosphate	Nitrogen and Phosphate
B. Joint tissues containing iron	Potash and Phosphate	Potash and Phosphate	Nitrogen, Phosphate and Potash

Chemical Test for Nitrates

The soil nitrates are determined by a modification of Whiting's (12) reduction method with Devarda's alloy. One hundred grams of the sample are shaken in a 1000 c.c. glass-stoppered bottle for 4 hours with 500 c.c. of distilled water; after this, 1 gram of NaCl is added to facilitate the flocculation of the colloids; the suspension is allowed to stand over night for further sedimentation. Two hundred and fifty c.c. of the clear supernatant fluid, corresponding to 50 grams of soil, are removed by suction and added to 5 grams Na_2O_2 in an 800 c.c. Kjeldahl flask. This is concentrated to approximately 25 c.c. over a Bunsen flame after which 200 c.c. distilled water and 0.5 gram Devarda's alloy (20 mesh) are added and the flask connected at once with a condenser. Gentle heat is applied and the ammonia resulting from the reduction of the nitrates is distilled into 10 c.c. of N/28 H_2SO_4. The excess of acid is titrated with N/28 NaOH. One c.c. N/28 NH_3 equals 10 p.p.m. N as nitrate nitrogen, when 50 grams of soil are used.

For soils containing more than 40 p.p.m. of nitrate nitrogen, 1.0 gram of Devarda's alloy is used. Duplicate determinations are made on all samples.

FERTILIZER FIELD EXPERIMENTS

The final test of any method for the determination of mineral soil deficiencies is the agreement between the deficiencies indicated by the test and the crop yields obtained from field plots treated with the different fertilizers according to the needs shown by the test. If the method possesses merit, the yields should show differences consistent with the fertilizer applications.

In order to ascertain the degree of correlation which existed between the results obtained by the Soil-Plaque and Neubauer methods and the response shown by crops grown on land that had been fertilized according to the needs indicated by the laboratory tests, or in other words, to determine the practical value of the two methods, fertilizer field plots were laid out on 11 farms from which samples had been taken previously for examination.

The farms on which the tests were conducted are all privately owned and are representative of both the better and the poorer classes of soil. These particular tracts were selected for our work after the soil had been tested for deficiencies in phosphate, potash and lime because they presented wide variations in available phosphate. All contained adequate potash and lime, which is true for most of the soils tested in the vicinity of Berthoud, Loveland, Fort Collins and Wellington where the experimental plots were located. The work extended over 3 years: 1929, 1930 and 1931.

In 1929, we had six farms under observation, designated as Nos. 1, 2, 5, 6, 7 and 9. An experimental area was laid off on each of these consisting of 13 plots 17 feet 6 inches wide by 200 feet long, approximately one-twelfth of an acre. This arrangement permitted each treatment to be repeated three times, with every fourth plot as a check where nothing was applied. The fertilizer applications were made according to the following plan, a few days in advance of planting the seed:

Plot No. 1. No treatment.
Plot No. 2. 200 lbs. superphosphate per acre, 40 lbs. P_2O_5.
Plot No. 3. 100 lbs. potassium sulphate per acre.
Plot No. 4. 200 lbs. superphosphate and 100 lbs. potassium sulphate per acre.
Plot No. 5. No treatment.
Plot No. 6. 100 lbs. potassium sulphate per acre.
Plot No. 7. 200 lbs. superphosphate and 100 lbs. potassium sulphate per acre.
Plot No. 8. 200 lbs. superphosphate per acre.
Plot No. 9. No treatment.
Plot No. 10. 200 lbs. superphosphate and 100 lbs. potassium sulphate per acre.
Plot No. 11. 200 lbs. superphosphate per acre.
Plot No. 12. 100 lbs. postassium sulphate per acre.
Plot No. 13. No treatment.

Sugar beets were planted as the test crop, there being 10 rows, 20 inches apart on each plot. Thruout the growing season, they were cultivated, irrigated and otherwise tended by the land owner in the same manner as the balance of his beet fields. At harvest time the samples for sugar tests and the yield data were collected by us. In this connection, it should be mentioned that the 3 outside rows and the 5 feet at each end of each plot were discarded for border effect. From the remaining 4 center rows 3 samples of 20 beets each were taken for sugar determinations, and the remainder of the beets were dug for yield data. The first sugar sample was taken from the first 2 rows, about 20 feet from the end, the beets being picked just as they grew in the row; the second was taken from the 2 center rows near the middle of the plot, and the third, from the third and fourth rows at the opposite end from the first.

The sugar determinations and yield data are presented in Table I.

The general plan of the experiments in 1930 and 1931 was identical with that of 1929 except that only treble superphosphate was used. This was applied at the rate of 100, 200 and 300 pounds per acre, and all treatments were in triplicate with four checks. In all cases the soil had been shown to be deficient in phosphate by the soil-plaque test. In 1930, we had three farms under observation, Nos. 1, 54 and 58, while in 1931 there were four, Nos. 54, 513, 1095 and 1096.

The results of the test are given in Table II.

Table I.—Field Plot Experiments with Sugar Beets, 1929

Year	Sample No.	Treatment															
		200 lbs. superphosphate per acre—40 lbs. P_2O_5				100 pounds potassium sulphate per acre				200 pounds superphosphate and 100 pounds potassium sulphate per acre				Check No treatment			
			Yield per acre				Yield per acre				Yield per acre				Yield per acre		
		Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check
1929	1	12.64	7.03	.867	131.81	11.80	2.83	.333	—10.96	12.52	5.96	.746	99.46	12.43	3.00	.374	0.0
	2	13.57	16.63	2.260	—2.64	13.44	16.00	2.149	—6.96	13.35	17.46	2.346	1.55	13.64	17.00	2.310	0.0
	5	11.96	15.36	1.814	—4.17	12.36	15.25	1.884	—.47	12.30	15.93	1.963	3.69	12.45	15.42	1.893	0.0
	6	15.87	8.73	1.550	—2.08	16.00	9.93	1.593	.63	15.71	9.60	1.434	—9.41	15.74	10.07	1.583	0.0
	7	14.35	10.90	1.566	16.34	14.32	9.33	1.349	.22	14.26	9.43	1.344	—.14	14.30	9.40	1.346	0.0
	9	13.00	13.56	1.760	—10.43	12.87	14.56	1.869	—4.88	13.07	15.03	1.971	.30	15.43	15.20	1.965	0.0

Table II.—Field Plot Experiments with Sugar Beets, 1930 and 1931

Year	Sample No.	Treatment															
		100 lbs. treble superphosphate per acre, 45 percent P_2O_5				200 pounds treble superphosphate per acre				300 pounds treble superphosphate per acre				Check No treatment			
			Yield per acre				Yield per acre				Yield per acre				Yield per acre		
		Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check	Percent sugar	Tons beets	Tons sugar	Percent gain in sugar over check
1930	1	14.83	13.19	1.95	—.51	15.19	14.16	2.15	9.69	15.05	14.94	2.25	14.79	14.89	13.17	1.96	0.0
	54	16.04	15.61	2.51	45.93	15.73	16.42	2.58	50.00	15.90	17.36	2.76	60.46	14.90	11.48	1.72	0.0
	58	17.16	15.58	2.67	17.11	17.07	17.82	3.04	33.33					17.29	13.16	2.28	0.0
1931	54*	16.1	12.58	2.03	41.95	15.60	14.24	2.24	56.64	15.50	16.76	2.59	81.12	15.00	9.57	1.43	0.0
	513	15.7	9.36	1.47	145.00	15.80	10.36	1.64	173.33	15.60	10.96	1.71	185.00	14.00	4.24	.60	0.0
	1095	16.1	14.75	2.58	87.40	15.90	16.51	2.62	106.30	15.70	18.71	2.93	130.71	14.08	8.63	1.27	0.0

*Residual effect from 1930; no fertilizer applied in 1931.

DESCRIPTION OF SOIL SAMPLES

The soils used in this study, with the exception of five from Halle, Germany, and one from North Dakota, were collected from different localities in Colorado. They represent a wide variety of soils, ranging from heavy clays to light sandy loams. The samples were taken to depths varying from 4 to 6 inches. Their composition in regard to the principal plant foods is varied. Some are acid with no lime and a pH of 6.6; others basic with much lime and a pH of 8.2. Some are deficient in nitrates with less than 2 p.p.m., while others contain as much as 60 p.p.m.

The geographical location and crop grown are given below:

Sample No.	Location	Crop grown
1	Wellington, Colorado	Sugar beets
1A	Wellington, Colorado	Sugar beets
2	Wellington, Colorado	Sugar beets
3	Wellington, Colorado	Corn
5	Harmony, Colorado	Sugar beets
6	Berthoud, Colorado	Sugar beets
7	Berthoud, Colorado	Sugar beets
8	Loveland, Colorado	Corn
9	Loveland, Colorado	Sugar beets
21	Wellington, Colorado	Sugar beets
23	Berthoud, Colorado	Alfalfa
25	Campion, Colorado	Sugar beets
32	Ft. Collins, Colorado	Corn
33	McClellands, Colorado	Corn
34	McClellands, Colorado	Corn
35	Ft. Collins, Colorado	Corn
36	Ft. Collins, Colorado	Corn
37	Loveland, Colorado	Corn
38	Loveland, Colorado	Corn
39	Lucerne, Colorado	Corn
40	Eaton, Colorado	Corn
41	Pierce, Colorado	Corn
42	Berthoud, Colorado	Corn
43	Longmont, Colorado	Corn
44	Longmont, Colorado	Corn
45	Hygiene, Colorado	Corn
46	Longmont, Colorado	Corn
47	Windsor, Colorado	Corn
48	Windsor, Colorado	Corn
49	Wellington, Colorado	Corn
50	Wellington, Colorado	Corn
51	Johnstown, Colorado	Sugar beets
52	Ft. Collins, Colorado	Corn
53	Wellington, Colorado	Sugar beets
54	Ft. Collins, Colorado	Sugar beets
58	Ft. Collins, Colorado	Sugar-beets
74	Johnstown, Colorado	Sugar beets
75	Montrose, Colorado	Unknown
76	Montrose, Colorado	Unknown
85	Berthoud, Colorado	Unknown
92	Boulder, Colorado	Flowers
94	Ault, Colorado	Potatoes
99	Paonia, Colorado	Unknown
101	Paonia, Colorado	Unknown
114	Ft. Collins, Colorado	Cherries
117	Montrose, Colorado	Unknown
127	Mesita, Colorado	Unknown
137	Grand Junction, Colorado	Orchard
138	Ft. Collins, Colorado	Unknown
143	Windsor, Colorado	Alfalfa
144	Windsor, Colorado	Sugar beets

Sample No.	Location	Crop grown
146	Ft. Collins, Colorado	Cherries
147	Ft. Collins, Colorado	Garden
174	Monte Vista, Colorado	Potatoes
182	La Jara, Colorado	Potatoes
185	Avon, Colorado	Truck crops
187	Canon City, Colorado	Corn
189	Alamosa, Colorado	Unknown
190	South Fork, Colorado	Potatoes
218	Ft. Collins, Colorado	Raspberries
220	Ft. Collins, Colorado	Strawberries
513	Ft. Collins, Colorado	Beets
517	Fargo, North Dakota	Unknown
1047	Loveland, Colorado	Unknown
1049	Loveland, Colorado	Unknown
1053	Loveland, Colorado	Unknown
1054	Loveland, Colorado	Unknown
1055	Loveland, Colorado	Unknown
81G	Halle, Germany	Unknown
93G	Halle, Germany	Unknown
95G	Halle, Germany	Unknown
101G	Halle, Germany	Unknwon
103G	Halle, Germany	Unknown
1061	Ft. Collins, Colorado	Corn
1062	Ft. Collins, Colorado	Corn
1063	Ft. Collins, Colorado (Lindenmeir Lake)	Corn
1064	Ft. Collins, Colorado (Cherryhurst)	Corn
1065	Ft. Collins, Colorado (Cherryhurst)	Corn
1066	Ft. Collins, Colorado (Plummer School)	Corn
1067	Ft. Collins, Colorado (Plummer School)	Corn
1068	Ft. Collins, Colorado (Plummer School)	Corn
1069	Ft. Collins, Colorado (Plummer School)	Corn
1070	Timnath, Colorado	Corn
1071	Ft. Collins, Colorado	Corn
1072	Ault, Colorado	Corn
1073	Ault, Colorado	Corn
1074	Eaton, Colorado	Corn
1075	Eaton, Colorado	Corn
1076	Eaton, Colorado	Corn
1077	Eaton, Colorado	Corn
1078	Eaton, Colorado	Corn
1079	Ault, Colorado	Corn
1080	Pierce, Colorado	Corn
1081	Ft. Collins, Colorado	Corn
1082	Ft. Collins, Colorado (Terry Lake)	Corn
1083	LaPorte, Colorado	Corn
1084	LaPorte, Colorado	Corn
1085	LaPorte, Colorado	Corn
1086	Loveland, Colorado	Corn
1087	Loveland, Colorado	Corn
1088	Loveland, Colorado	Corn
1089	Loveland, Colorado	Corn
1090	Ft. Collins, Colorado (Brick Plant)	Corn
1091	Ft. Collins, Colorado (Fossil Creek Hill)	Corn
1092	Ft. Collins, Colorado (Near Garbage Farm)	Corn
1093	Ft. Collins, Colorado (5 mi. So. on Shields St.)	Corn
1094	Ft. Collins, Colorado (2 mi. So. on Shields St.)	Corn
1095	Ft. Collins, Colorado (Near Plummer School)	Beets

DISCUSSION OF RESULTS

Comparison of Soil-Plaque and Neubauer Results

SOIL-PLAQUE DETERMINATIONS

In Table No. III are given the detailed results obtained from 108 soils which were tested by the soil-plaque method for deficiencies in potash and phosphate separately and in combination.

Table III.—Results of Potash and Phosphate Deficiency Determinations by the Soil-Plaque Method

Soil No.	pH	Description of Plaques				Interpertations	
		Untreated Check	Treated with K_2O	Treated with P_2O_5	Treated with K_2O and P_2O_5	K_2O	P_2O_5
1	7.5	no growth	no growth	many white colonies	many white colonies	not deficient	very deficient
2	7.2	many whitish colonies	few to many whitish colonies	many white colonies	few white colonies	not deficient suppression	not deficient
3	7.5	no growth	no growth	many small white colonies	many small white colonies	not deficient	very deficient
5	7.4	numerous medium-sized white colonies	numerous medium-sized white colonies	many large white colonies	many large white colonies	not deficient	not deficient
6	7.3	many small whitish colonies	many small whitish colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
7	7.5	no growth	no growth	numerous large white colonies	numerous large white colonies	not deficient	very deficient
8	7.3	numerous whitish spreading colonies	numerous whitish spreading colonies	numerous whitish spreading colonies	numerous white spreading colonies	not deficient	not deficient
9	7.4	many small white colonies	many very small white colonies	many large white colonies	few to many large white colonies	not deficient suppression	slightly deficient
21	7.5	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
23	7.3	many small watery feeble colonies	many small watery feeble colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
25	7.2	numerous whitish spreading colonies	numerous whitish spreading colonies	numerous white spreading colonies	numerous white spreading colonies	not deficient	not deficient
32	7.7	numerous small white colonies	numerous white small colonies	numerous small white colonies	numerous small white colonies	not deficient	not deficient
33	7.6	many small white colonies	many small white colonies	few to many small white colonies	few to many small white colonies	not deficient	not deficient slt. suppression
34	7.2	no growth	no growth	few to many white colonies	few to many white colonies	not deficient	very deficient
35	7.4	many very small watery colonies	many very small watery colonies	numerous large white colonies	numerous large white colonies	not deficient	moderately deficient

36	7.2	many small watery colonies	many small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
37	7.4	numerous large white colonies	numerous large white colonies	numerous large white colonies	numerous large white colonies	not deficient	not deficient
38	7.0	no growth	no growth	many small white colonies	many small white colonies	not deficient	very deficient
39	7.5	numerous small whitish colonies	many small whitish colonies	numerous medium, white colonies	numerous medium, white colonies	not deficient	slightly deficient
40	7.2	no growth	no growth	many medium-sized white colonies	many medium-sized white colonies	not deficient	very deficient
41	7.0	very few small watery colonies	very few small watery colonies	very few medium, white colonies	very few medium, white colonies	not deficient	moderately deficient
42	7.4	numerous very small whitish colonies	numerous very small whitish colonies	numerous medium-sized white colonies	numerous medium-sized white colonies	not deficient	moderately deficient
43	7.5	many small watery colonies	many small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
44	7.6	no growth	no growth	many large white colonies	many large white colonies	not deficient	very defeicent
45	7.6	no growth	no growth	very few small white colonies	very few small white colonies	not deficient	very deficient
46	7.1	no growth	no growth	few large white colonies	few large white colonies	not deficient	very deficient
47	7.3	numerous small flat whitish colonies	numerous small flat whitish colonies	numerous large white spreading colonies	numerous large white spreading colonies	not deficient	moderately deficient
48	7.5	many medium-sized white colonies	many medium-sized whitish colonies	many large white colonies	many large white colonies	not deficient	slightly deficient
49	7.7	many small watery colonies	many small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
50	7.7	no growth	no growth	very few small whitish colonies	very few small whitish colonies	not deficient	very deficient
51	7.8	numerous white colonies	numerous white colonies	numerous white colonies	numerous white colonies	not deficient	not deficient
52	7.6	no growth	no growth	few medium, white colonies	few medium, white colonies	not deficient	very deficient
53	7.5	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
54	7.5	no growth	no growth	few large white colonies	few large white colonies	not deficient	very deficient

Table III.—Results of Potash and Phosphate Deficiency Determinations by the Soil-Plaque Method—continued

Soil No.	pH	Description of Plaques				Interpertations	
		Untreated Check	Treated with K_2O	Treated with P_2O_5	Treated with K_2O and P_2O_5	K_2O	P_2O_5
58	7.6	no growth	no growth	many medium-sized white colonies	many medium-sized white colonies	not deficient	very deficient
74	7.6	no growth	no growth	numerous large white colonies	numerous large white colonies	not deficient	very deficient
75	7.5	no growth	no growth	many medium-sized white colonies	many medium-sized white colonies	not deficient	very deficient
76	7.8	no growth	no growth	numerous large white colonies	numerous large white colonies	not deficient	very deficient
85	7.8	no growth	no growth	numerous medium-sized white colonies	numerous medium-sized white colonies	not deficient	very deficient
92	7.3	many large white colonies	many large white colonies	very few small white colonies	no growth	not deficient	not deficient suppression
94	7.5	no growth	no growth	many medium-sized white colonies	many medium-sized white colonies	not deficient	very deficient
99	7.4	numerous large white colonies	numerous large white colonies	numerous large white colonies	numerous large white colonies	not deficient	not deficient
101	7.2	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
114	7.8	numerous small brown colonies	numerous small brown colonies	numerous small brown colonies	numerous small brown colonies	not deficient	not deficient
117	7.1	no growth	no growth	many medium-sized white colonies	many large white colonies	slightly deficient	very deficient
127	7.5	many small watery colonies	no growth	many large white colonies	many large white colonies	not deficient	moderately deficient
137	7.6	many small brown colonies	many small brown colonies	many large brown colonies	many large brown colonies	not deficient	moderately deficient
138	7.6	many small watery colonies	many very small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
143	7.8	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient

144	7.8	many small watery colonies	many small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
146	7.7	no growth	no growth	many large white spreading colonies	many large white spreading colonies	not deficient	very deficient
147	7.8	many medium-sized white colonies	many medium-sized white colonies	many large white colonies	many large white colonies	not deficient	slightly deficient
174	7.0	many very small watery colonies	many very small watery colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	moderately deficient
182	6.8	many brown colonies	many brown colonies	many brown colonies	many brown colonies	not deficient	not deficient
185	6.7	few pin-point watery colonies	few pin-point watery colonies	many large brown colonies	many large brown colonies	not deficient	very deficient
187	7.3	many very small watery colonies	many very small watery colonies	many large brown colonies	many large brown colonies	not deficient	moderately deficient
189	7.2	numerous large white colonies	numerous large white colonies	numerous large white colonies	numerous large white colonies	not deficient	not deficient
190	6.8	many large brownish colonies	many large brownish colonies	many large brownish colonies	many large brownish colonies	not deficient	not deficient
218	7.6	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	not deficient
220	7.8	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	not deficient
513	7.7	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
517	7.6	no growth	no growth	many whitish colonies	many whitish colonies	not deficient	very deficient
1047	7.3	few very small feeble colonies	no growth	many large white colonies	many large white colonies	not deficient	very deficient
1049	7.1	many small watery colonies	many small watery colonies	many large white colonies	many large white colonies	not deficient	moderately deficient
1053	7.0	many large whitish colonies	many large whitish colonies	many large white colonies	many very large white colonies	not deficient	slightly deficient
1054	7.8	many large white colonies	many large white colonies	few to many large white colonies	few large white colonies	not deficient	not deficient
1055	7.5	many small whitish colonies	many small whitish colonies	many very large white colonies	many very large white colonies	not deficient	moderately deficient

Table III.—Results of Potash and Phosphate Deficiency Determinations by the Soil-Plaque Method—continued

Soil No.	pH	Description of Plaques				Interpertations	
		Untreated Check	Treated with K_2O	Treated with P_2O_5	Treated with K_2O and P_2O_5	K_2O	P_2O_5
81G	7.3	no growth	no growth	few flat watery colonies	many large white colonies	moderately deficient	very deficient
93G	7.8	no growth	no growth	few large white colonies	many large white colonies	moderately deficient	very deficient
95G	6.6	no growth	no growth	no growth	many whitish colonies	very deficient	very deficient
101G	7.8	numerous white spreading colonies	numerous whitish spreading colonies	numerous white spreading colonies	numerous white spreading colonies	not deficient	not deficient
103G	7.6	few very small feeble flat colonies	few very small feeble flat colonies	many large white colonies	numerous large white colonies	moderately deficient	very deficient
1061	7.6	many medium watery colonies	many medium watery colonies	many white colonies	many white colonies	not deficient	moderately deficient
1062	7.4	numerous small watery colonies	numerous small watery colonies	many small white colonies	many small white colonies	not deficient	slightly deficient
1063	7.7	few small whitish colonies	few small whitish colonies	few small whitish colonies	few small whitish colonies	not deficient	not deficient
1064	7.7	few feeble watery colonies	few feeble watery colonies	few large whitish colonies	few large whitish colonies	not deficient	moderately deficient
1065	7.2	no growth	no growth	numerous whitish colonies	numerous whitish colonies	not deficient	very deficient
1066	7.7	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
1067	7.7	few whitish colonies	few whitish colonies	numerous large white colonies	numerous large white colonies	not deficient	moderately deficient
1068	6.9	many small flat watery colonies	many small flat watery colonies	many large whitish colonies	many large whitish colonies	not deficient	moderately deficient
1069	7.3	very few small watery colonies	very few small watery colonies	few medium-sized white colonies	few medium-sized white colonies	not deficient	moderately deficient
1070	7.3	no growth	no growth	many watery colonies	many watery colonies	not deficient	very deficient
1071	7.7	no growth	no growth	few medium-large white colonies	few medium-large white colonies	not deficient	very deficient

1072	7.3	many large whitish colonies	many small whitish colonies	many large white colonies	many small white colonies	not deficient suppression	not deficient
1073	6.9	very few feeble watery colonies	no growth	many medium white colonies	many small white colonies	not deficient suppression	very deficient
1074	7.3	numerous small whitish colonies	numerous small whitish colonies	numerous medium white colonies	numerous medium white colonies	not deficient	slightly deficient
1075	7.7	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	not deficient
1076	7.6	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	not deficient
1077	7.4	no growth	no growth	many small white colonies	many small white colonies	not deficient	very deficient
1078	7.5	no growth	no growth	many small white colonies	many small white colonies	not deficient	very deficient
1079	7.6	no growth	no growth	few small white colonies	few small white colonies	not deficient	very deficient
1080	7.2	many watery colonies	many flat watery colonies	many white colonies	many white colonies	not deficient	moderately deficient
1081	7.7	no growth	no growth	numerous small white colonies	numerous small white colonies	not deficient	very deficient
1082	7.6	no growth	no growth	many small white colonies	many small white colonies	not deficient	very deficient
1083	7.6	no growth	no growth	numerous medium-sized white colonies	numerous medium-sized white colonies	not deficient	very deficient
1084	7.4	no growth	no growth	many large white colonies	many large white colonies	not deficient	very deficient
1085	7.5	no growth	no growth	many medium white colonies	many medium white colonies	not deficient	very deficient
1086	7.5	few feeble small watery colonies	few feeble small watery colonies	few larger watery colonies	few larger whitish colonies	not deficient	moderately deficient
1087	7.6	no growth	no growth	few feeble colonies	few feeble colonies	not deficient	very deficient
1088	7.7	no growth	no growth	few feeble colonies	few feeble colonies	not deficient	very deficient
1089	7.0	very small watery colonies	few very small watery colonies	many large white colonies	few large white colonies	not deficient	moderately deficient
1090	7.6	no growth	no growth	very few white colonies	no growth	not deficient	very deficient

Table III.—Results of Potash and Phosphate Deficiency Determinations by the Soil-Plaque Method—continued

Soil No.	pH	Description of Plaques				Interpertations	
		Untreated Check	Treated with K_2O	Treated with P_2O_5	Treated with K_2O and P_2O_5	K_2O	P_2O_5
1091	7.5	no growth	no growth	many whitish spreading colonies	many whitish spreading colonies	not deficient	very deficient
1092	7.3	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	many medium-sized white colonies	not deficient	not deficient
1093	7.6	no growth	no growth	very few whitish colonies	very few whitish colonies	not deficient	very deficient
1094	7.8	no growth	no growth	few medium white colonies	very few small white colonies	not deficient	very deficient
1095		no growth	no growth	many white colonies	many white colonies	not deficient	very deficient
1A	7.5	no growth	no growth	many white colonies	many white colonies	not deficient	very deficient

Of this number, 1, or 0.93 percent, was very deficient in potash; 3, or 2.78 percent, were moderately so; 1, or 0.93 percent, was slightly deficient; and 103, or 95.37 percent, were not deficient. The three moderately and the one very deficient samples were from Germany and were sent to us because of their low potash values.

In four cases, Samples 2, 9, 1072 and 1073, the potash seemed to have suppressed the development of Azotobacter colonies, suggesting that these soils are naturally high in this element, and that the addition of this material might prove harmful under field conditions.

In recommending the use of phosphate fertilizers in the field, it is our practice to place both the very deficient and the moderately deficient soils in one class as "Deficient," and both the slightly deficient and the non-deficient soils in a second group as "Non-deficient," for the reason that the two former respond positively to fertilizer treatments, while the two latter give either insignificant increases or none at all in the majority of cases. If we follow the same procedure in regard to potash fertilizers and divide the 108 soils in this study into two classes, 4, or 3.70 percent, would be deficient in potash, and 104, or 96.30 percent, would be not deficient.

With respect to phosphate, 53, or 49.07 percent, were very deficient; 25, or 23.15 percent, were moderately deficient; 7, or 6.48 percent, were slightly deficient; and 23, or 21.30 percent, were not deficient.

If we divide the 108 soils into the deficient and non-deficient classes, as explained above, 78 of these, or 72.22 percent, would fall into the phosphate deficient group, and 30, or 27.28 percent, into the non-deficient.

NEUBAUER DETERMINATIONS

Referring next to Table No. IV, we find the potash and phosphate data for the Neubauer determinations made on 66 of these same 108 soils. An examination of these results shows that 1, or 1.52 percent, was very deficient in potash; 9, or 13.64 percent, were moderately so; 14, or 21.21 percent, were slightly deficient; and that 42, or 63.64 percent, were not deficient.

In regard to phosphate, 28 soils, or 42.42 percent, were very deficient; 17, or 25.76 percent, were moderately so; 4, or 6.06 percent, were slightly deficient; and 17, or 25.76 percent, were not deficient.

By combining the very deficient soils with the moderately deficient into a deficient class and the slightly deficient with the non-deficient into a non-deficient group, as was done with the

Table IV.—Results of Deficiency Determination by the Neubauer Method

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
Blank Control*	95.5	20.99	....	18.01	....
7a	97	22.80	1.09	56.42	38.41
7b	93	23.24	2.25	56.42	38.41
Average	95	23.02	2.02	56.42	38.41
8a	99	33.28	12.29	70.60	52.59
8b	97	34.02	13.03	69.52	51.51
Average	98	33.65	12.66	70.06	52.05
9a	96	27.53	6.54	62.74	44.73
9b	95	26.78	5.79	57.81	39.80
Average	95.5	27.15	6.16	60.27	42.26
Blank Control	98	21.93	....	17.39	....
1a	94	24.19	2.26	66.00	48.61
1b	96	23.02	1.09	70.28	52.89
Average	95	23.60	1.67	68.14	50.75
21a	97	24.97	3.04	64.28	46.89
21b	99	24.47	2.54	63.97	45.58
Average	98	24.72	2.79	64.12	46.23
23a	97	26.28	4.35	64.28	46.89
23b	97	26.28	4.35	63.97	46.58
Average	97	26.28	4.35	64.13	46.74
25a	95	34.82	12.89	61.66	44.27
25b	96	36.14	14.21	68.60	51.21
Average	95.5	35.48	13.56	65.13	47.74
Blank Control	96.5	20.08	....	19.11	....
32a	97	39.53	19.45	68.44	49.33
32b	90	37.04	16.96	67.67	48.56
Average	93.5	38.29	18.21	68.05	48.94
33a	96	31.39	11.31	52.25	33.14
33b	98	31.67	11.59	54.10	34.99
Average	97	31.53	11.45	53.18	34.07
34a	100	23.08	3.00	47.63	28.52
34b	95	21.96	1.88	46.70	27.59
Average	97.5	22.52	2.44	47.17	28.06
35a	96	25.10	5.02	55.64	36.53
35b	97	24.95	4.87	54.56	35.45
Average	96.5	25.02	4.94	55.10	35.99

*All blank controls are the average of duplicate determinations.

Table IV.—Results of Deficiency Determination by the Neubauer Method—continued

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
36a	94	24.28	4.20	51.02	31.91
36b	96	24.04	3.96	45.78	26.67
Average	95	24.16	4.08	48.40	29.29
37a	95	37.14	17.06	62.43	43.32
37b	95	35.78	15.70	64.28	45.17
Average	95	36.46	16.38	63.35	44.24
38a	91	Discarded beca	use of poor stan	d.	
38b	95	22.68	2.60	57.81*	39.59
Average	95	22.68	2.60	27.81	39.59
40a	95	24.07	3.99	53.79	34.89
40b	89	Discarded beca	use of poor stan	d.	
Average	95	24.07	3.99	53.79	34.68
Blank Control	97	20.71	....	19.23	....
42a	92	24.22	3.51	54.56	35.33
42b	96	25.43	4.72	52.41	33.18
Average	94	24.82	4.11	53.49	34.26
43a	95	25.09	4.38	67.20	47.97
43b	97	25.05	4.34	66.18	46.95
Average	96	25.07	4.36	66.69	47.46
44a	96	24.56	3.85	69.21	49.98
44b	100	24.56	3.85	65.82	46.59
Average	98	24.56	3.85	67.51	48.28
46a	99	22.95	2.24	56.41	37.18
46b	95	22.89	2.18	53 79	34.56
Average	97	22.92	2.21	55.10	35.87
47a	96	22.26	1.55	47.94	28.71
47b	95	22.26	1.55	43.93	24.70
Average	95.5	22.26	1.55	45.93	26.70
48a	95	26.69	5.98	48.71	29.48
48b	96	23.54	2.83	45.47	26.24
Average	95.5	25.12	4.40	47.09	27.86
49a	95	22.71	2.00	64.74	45.51
49b	98	22.80	2.09	59.96	40.73
Average	96.5	22.75	2.04	62.35	43.12
53a	95	21.93	1.22	59.39	40.16
53b	94	21.75	1.04	53.79	34.56
Average	94.5	21.84	1.13	56.41	37.18

*Potash blank 18.22

Table IV.—Results of Deficiency Determination by the Neubauer Method—continued

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
54a	96	22.00	1.29	66.13	46.90
54b	98	22.03	1.32	65.66	46.43
Average	97	22.01	1.30	65.89	46.66
Blank Control	95	20.85	....	17.85	....
1047a	99	24.64	3.79	55.03	37.18
1047b	94	24.41	3.56	51.02	33.17
Average	96.5	24.52	3.67	53.02	35.17
1049a	95	26.04	5.19	62.92	45.07
1049b	95	25.80	4.95	62.24	44.39
Average	95	25.92	5.07	62.58	44.73
51a	94	36.16	15.31	77.22	59.37
51b	95	36.09	15.24	72.29	54.44
Average	94.5	36.12	15.27	74.76	56.91
1053a	93	28.36	7.51	52.32	34.47
1053b	96	27.81	6.96	57.82	39.97
Average	94.5	28.08	7.23	55.07	37.22
1054a	94	41.83	20.98	75.24	57.39
1054b	95	41.65	20.80	75.58	57.73
Average	94.5	41.74	20.89	75.41	57.56
1055a	95	26.57	5.72	62.12	44.27
1055b	95	26.11	5.26	57.49	39.64
Average	95	26.34	5.49	59.81	41.96
74a	93	23.48	2.63	62.24	44.39
74b	97	23.54	2.69	56.77	38.92
Average	95	23.51	2.66	59.50	41.65
76a	98	23.42	2.57	55.40	37.55
76b	99	23.70	2.85	59.85	42.00
Average	98.5	23.56	2.71	57.62	39.77
85a	93	23.38	2.53	51.48	33.63
85b	98	21.83	.98	60.27	42.42
Average	95.5	22.60	1.75	55.87	38.02
92a	98	51.35	30.50	85.15	67.30
92b	97	50.18	29.33	79.00	61.15
Average	97.5	50.76	29.91	82.08	64.23

Table IV.—Results of Deficiency Determination by the Neubauer Method—continued

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
Blank Control	99	25.05	....	23.86	....
75a	99	28.67	3.62	57.96	34.10
75b	99	28.24	3.19	56.88	33.02
Average	99	28.40	3.35	57.42	33.56
99a	99	40.04	14.99	61.04	37.18
99b	96	39.42	14.37	60.42	36.56
Average	97.5	39.73	14.68	60.73	36.87
101a	99	29.16	4.11	66.00	42.14
101b	98	29.47	4.42	62.24	38.38
Average	98.5	29.32	4.27	64.12	40.26
117a	95	27.68	2.63	47.78	23.92
117b	97	27.31	2.26	50.71	26.85
Average	96	27.50	2.45	49.25	25.39
127a	99	29.54	4.49	66.86	43 00
127b	100	29.41	4.36	67.20	43.34
Average	99.5	29.47	4.42	67.03	43.17
137a	99	29.91	4.86	61.73	37.87
137b	100	29.54	4.49	62.75	38.89
Average	99.5	29.72	4.67	62.24	38.38
138a	99	30.09	5.04	76.30	54.44
138b	98	29.72	4.67	76.61	52.75
Average	98.5	29.91	4.86	76.45	52.59
146a	100	28.73	3.68	51.02	27.16
146b	98	28.18	3.13	59.96	36.10
Average	99	28.45	3.40	55.49	31.63
Blank Control	93	25.64	....	18.22	....
58a	93	27.13	1.49	66.86	48.64
58b	98	27.62	1.98	74.38	56.16
Average	95.5	27.37	1.73	70.62	52.40
143a	98	29.04	3.40	59.28	41.06
143b	99	28.61	2.97	56.96	38.74
Average	98.5	28.82	3.18	58.12	39.90
144a	99	29.10	3.36	62.76	44.54
144b	95	29.07	3.43	56.52	38.30
Average	97	29.09	3.45	59.14	40.32

Table IV.—Results of Deficiency Determination by the Neubauer Method—continued

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
147a	97	30.83	5.19	69.08	50.86
147b	98	30.83	5.19	66.00	47.78
Average	97.5	30.83	5.19	67.54	49.32
182a	93	33.31	7.67	61.32	43.10
182b	98	35.53	9.89	64.80	46.58
Average	95.5	34.42	8.78	63.06	44.84
185a	97	29.29	3.65	54.03	35.81
185b	99	29.47	3.83	68.40	50.18
Average	98	29.38	3.74	61.21	42.99
189a	99	36.53	10.89	68.40	50.18
189b	98	36.53	10.89	82.08	63.86
Average	98.5	36.53	10.89	75.24	57.02
190a	96	37.85	12.21	80.71	62.49
190b	98	37.38	11.74	87.03	68.81
Average	97	37.62	11.98	83.87	65.65
218a	95	38.64	13.00	67.72	49.50
218b	96	39.16	13.52	82.42	64.20
Average	95.5	38.90	13.26	75.02	56.80
517a	95	27.47	1.83	42.43	24.21
517b	95	27.13	1.49	43.88	25.66
Average	95	27.30	1.66	43.16	24.94
220a	97	41.28	15.64	70.61	52.39
220b	96	40.97	13.33	60.15	41.93
Average	96.5	41.12	15.48	65.38	47.16
187a	93	31.73	6.09	64.51	46.29
187b	98	30.86	5.22	67.41	49.19
Average	95.5	31.30	5.66	65.96	47.74
94a	96	30.28	4.64	76.86	58.64
94b	98	30.28	4.64	76.28	58.06
Average	97	30.28	4.64	76.57	58.35
114a	95	34.17	8.53	61.75	43.53
114b	93	33.68	8.04	60.30	42.08
Average	94	33.97	8.33	61.03	42.81
174a	97	32.13	6.49	62.47	44.25
174b	96	30.12	4.48	57.96	39.74
Average	96.5	31.13	5.49	60.22	42.00

Table IV.—Results of Deficiency Determination by the Neubauer Method—continued

Soil No.	No. plants analyzed	P_2O_5		K_2O	
		mg. P_2O_5 in seedlings	Neubauer value	mg. K_2O in seedlings	Neubauer value
2a	97	31.70	6.06	73.53	55.31
2b	99	32.32	6.68	76.95	58.73
Average	98	32.01	6.37	75.24	57.02
3a	95	28.61	2.97	76.78	58.56
3b	97	29.41	3.77	89.26	71.04
Average	96	29.01	3.37	83.02	64.80
5a	96	36.58	10.94	65.30	47.08
5b	98	36.21	10.57	63.93	45.71
Average	97	36.39	10.75	64.61	46.39
6a	95	29.91	4.27	59.13	40.91
6b	93	28.98	3.34	59.12	39.90
Average	94	29.42	3.78	58.62	40.40
81G*	....	....	7.00	....	21.00
93G	....	....	5.50	....	23.00
95G	....	....	2.40	....	19.00
101G	....	....	13.2	....	43.00
103G	....	....	1.0	....	26.00

*—The results of the Neubauer analysis for soils 81G to 103G inclusive, were furnished by Zuckerfabrik Stobnitz, Stobnitz, Post Mucheln, Bez, Halle, Germany.

soil-plaque results, we find that 10 samples, or 15.15 percent, were deficient in potash, while 56, or 84.85 percent, were not deficient; and that 45 soils, or 68.18 percent, were deficient in phosphate, while 21, or 31.82 percent, were not deficient.

COMPARATIVE STUDIES

In Table V, is given a comparison of the potash and phosphate-deficiency determinations made by both the soil-plaque and Neubauer methods on the same 66 soils that are described in Tables III and IV.

A study of these data shows that with potash the correlation between the two methods is good, but it is not as marked as in the case of phosphate. Unfortunately, most of the soils used in this investigation were high in potassium, so that an opportunity to study different degrees of deficiency in this element was not afforded. There seems to be a tendency in a few instances, as will be noted in Table V, Soils Nos. 34, 36, 47 and 48, for the soil plaque to show no improvement by the addition of K_2O fertilizers to soils that are slightly to moderately low in this substance, according to the Neubauer analysis. This would seem to indicate that Azotobacter are not as sensitive to potash defi-

Table V.—Comparison of Potash and Phosphate Deficiency Determinations by the Soil-Plaque and Neubauer Tests

Sample No.	Potash		Phosphate	
	Soil Plaque	Neubauer	Soil Plaque	Neubauer
1	not deficient	not deficient	very deficient	very deficient
2	not deficient	not deficient	not deficient	slightly deficient
3	not deficient	not deficient	very deficient	very deficient
5	not deficient	not deficient	not deficient	not deficient
6	not deficient	not deficient	moderately deficient	very deficient
7	not deficient	not deficient	very deficient	very deficient
8	not deficient	not deficient	not deficient	not deficient
9	not deficient suppression	not deficient	slightly deficient	slightly deficient
21	not deficient	not deficient	very deficient	very deficient
23	not deficient	not deficient	moderately deficient	moderately deficient
25	not deficient	not deficient	not deficient	not deficient
32	not deficient	not deficient	not deficient	not deficient
33	not deficient	slightly deficient	not deficient slight suppression	not deficient
34	not deficient	moderately deficient	very deficient	very deficient
35	not deficient	slightly deficient	moderately deficient	moderately deficient
36	not deficient	moderately deficient	moderately deficient	moderately deficient
37	not deficient	not deficient	not deficient	not deficient
38	not deficient	slightly deficient	very deficient	very deficient
40	not deficient	slightly deficient	very deficient	very deficient
42	not deficient	slightly deficient	moderately deficient	moderately deficient
43	not deficient	not deficient	moderately deficient	moderately deficient
44	not deficient	not deficient	moderately deficient	very deficient
46	not deficient	slightly deficient	very deficient	very deficient
47	not deficient	moderately deficient	moderately deficient	very deficient
48	not deficient	moderately deficient	slightly deficient	moderately deficient
49	not deficient	not deficient	slightly deficient	very deficient
51	not deficient	not deficient	not deficient	not deficient
53	not deficient	slightly deficient	very deficient	very deficient
54	not deficient	not deficient	very deficient	very deficient
58	not deficient	not deficient	very deficient	very deficient
74	not deficient	not deficient	very deficient	very deficient

Table V.—Comparison of Potash and Phosphate Deficiency Determinations by the Soil-Plaque and Neubauer Tests—continued

Sample No.	Potash		Phosphate	
	Soil Plaque	Neubauer	Soil Plaque	Neubauer
75	not deficient	slightly deficient	very deficient	very deficient
76	not deficient	not deficient	very deficient	very deficient
85	not deficient	slightly deficient	very deficient	very deficient
92	not deficient	not deficient	not deficient suppression	not deficient
94	not deficient	not deficient	very deficient	moderately deficient
99	not deficient	slightly deficient	not deficient	not deficient
101	not deficient	not deficient	very deficient	moderately deficient
114	not deficient	not deficient	not deficient	not deficient
117	slightly deficient	moderately deficient	very deficient	very deficient
127	not deficient	not deficient	moderately deficient	moderately deficient
137	not deficient	slightly deficient	moderately deficient	moderately deficient
138	not deficient	not deficient	moderately deficient	moderately deficient
143	not deficient	not deficient	very deficient	very deficient
144	not deficient	not deficient	moderately deficient	very deficient
146	not deficient	slightly deficient	very deficient	very deficient
147	not deficient	not deficient	slightly deficient	moderately deficient
174	not deficient	not deficient	moderately deficient	moderately deficient
182	not deficient	not deficient	not deficient	not deficient
185	not deficient	not deficient	very deficient	very deficient
187	not deficient	not deficient	moderately deficient	moderately deficient
189	not deficient	not deficient	not deficient	not deficient
190	not deficient	not deficient	not deficient	not deficient
218	not deficient	not deficient	not deficient	not deficient
220	not deficient	not deficient	not deficient	not deficient
517	not deficient	moderately deficient	very deficient	very deficient
1047	not deficient	slightly deficient	very deficient	very deficient
1049	not deficient	not deficient	moderately deficient	moderately deficient
1053	not deficient	slightly deficient	slightly deficient	slightly deficient
1054	not deficient	not deficient	not deficient suppression	not deficient

Table V.—Comparison of Potash and Phosphate Deficiency Determinations by the Soil-Plaque and Neubauer Tests—continued

Sample No.	Potash		Phosphate	
	Soil Plaque	Neubauer	Soil Plaque	Neubauer
81G*	moderately deficient	moderately deficient	very deficient	slightly deficient
93G	moderately deficient	moderately deficient	very deficient	moderately deficient
95G	very deficient	very deficient	very deficient	very deficient
101G	not deficient	not deficient	not deficient	not deficient
103G	moderately deficient	moderately deficient	very deficient	very deficient
1055	not deficient	not deficient	moderately deficient	moderately deficient

*—The results of the Neubauer analysis for soils 81G to 103G inclusive, were furnished by Zuckerfabrik Stobnitz, Stobnitz, Post Mucheln, Bez, Halle, Germany.

ciencies as they are to phosphate deficiencies. But, as this study included no very deficient soils, and only a few that were either moderately or slightly so, even by the Neubauer determination, it would be unfair to draw more than a tentative conclusion on this point.

Another explanation of this apparent disagreement between the soil-plaque and Neubauer tests, might be found in the following statement concerning the Mitscherlich and Neubauer methods, taken from the publication of Zuckerfabrik Kleinwanzleben:

"According to Wiessmann the numerical values found by the two methods are only comparable with one another when the absolute Neubauer numbers are considered in relation to the limiting values which are valid for the soil which is being considered. This can be very different according to the cultural condition of the soil. For example, the limit number for potash on a very light sandy soil may be 20 mg., but on a heavy fertile soil this limit may lie at 40 mg. A finding of 20 mg. of K_2O would then represent a sufficient potash supply on the first soil, but would represent a great shortage of potash on the second soil. For this reason the absolute Neubauer number is a comparative measure for fertilizer requirement only for those soils which under the same conditions are capable of yielding the same maximum crop. This circumstance has been too little considered in comparisons between Neubauer tests and field experiments, and can be pointed to as an explanation of many cases of disagreement."

Illustrative of this, Soil No. 47, on the one hand, shows no improvement in Azotobacter growth by the addition of K_2O; on the other hand, it has a Neubauer value of 26.69 and would be classified as moderately deficient in potash. However, this is a sandy soil and might be one for which, according to the reference cited, a Neubauer value of 26.69 would indicate sufficient potash. In such a case there would be no disagreement between the soil-plaque and Neubauer indications.

In regard to phosphate, a very close correlation exists between the results of the deficiency determinations by the two methods. In all but nine cases (Soils Nos. 2, 6, 47, 48, 49, 94, 101, 144 and 81G, Table III), the soil-plaque classification corresponded perfectly to the Neubauer. In all but three of the nine, the soil plaque placed the soils one class above the Neubauer, i. e., they were less deficient. For example, Soil No. 144, which was moderately deficient by the soil plaque, was very deficient by the Neubauer, and Soil No. 48, which was slightly deficient according to the soil plaque, was moderately deficient according to the Neubauer classification.

If we classify these soils according to the indications of these tests, into the two groups mentioned, deficient and non-deficient, we note that the soil-plaque and Neubauer methods give results that agree in 91 percent of the cases with respect to potash and in 94 percent with phosphate. In other words, the two methods gave conflicting results with only 6 potash and with 4 phosphate determinations.

Comparison of the Soil-Plaque, Neubauer Method and Chemical Analyses with the Hoffer Cornstalk Test

In Table VI, we have presented the results of the potash and nitrate-deficiency determinations made by the Hoffer Cornstalk test on cornstalks from 54 fields. We have also given the amount of nitrate present in these soils as ascertained by chemical analysis in order to compare the quantity actually present with that indicated by the color reaction in the stalks. An arbitrary amount of 8 parts per million of nitric nitrogen was taken as the minimum for a non-deficient soil. This is equivalent to approximately 200 pounds of nitrate of soda per acre foot.

A comparison of potash and nitrate-deficiency determinations in the above samples as determined by the soil-plaque, Neubauer and Hoffer methods, is given in Table VII.

COMPARATIVE POTASH DETERMINATIONS

By the Hoffer test, none of the 54 samples was deficient in potash. The results of the test were in perfect harmony with the soil-plaque indications, in regard to potash, and agreed quite closely with the Neubauer results. But, as was already stated, most of the soils contained sufficient potassium so that a comparative study of the methods with soils deficient in this element could not be made.

Unfortunately, we have the Neubauer determinations for only 15 of these 54 soils. Of this number, none was very deficient in potash, 3 were moderately so, 7 were slightly deficient

Table VI.—Results of Potash and Nitrate-Deficiency Determinations by the Hoffer Cornstalk Method

Soil No.	Description of Corn Plants				Deficiencies Determined				p. p. m. Nitrate Nitrogen**
					Potash		Nitrate		
	Stalk	Color	Ears	Roots	Results of test	Interpretation	Results of test	Interpretation	
32	tall	normal green	large	healthy	no excess iron	not deficient	medium-blue color	not deficient	16.00
33	tall	normal green	large	healthy	no excess iron	not deficient	medium-blue color	not deficient	17.50
34	tall	normal green	large	healthy	no excess iron	not deficient	pale-blue color	not deficient	9.50
35	short	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	17.50
36	medium	normal green	large	healthy	no excess iron	not deficient	no color	not deficient	10.00
37	small d*	light green	medium	healthy	no excess iron	not deficient	no color	deficient	7.25
38	small d*	yellow green	medium	healthy	no excess iron	not deficient	no color	deficient	1.25
39	medium	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	7.00
40	short	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	12.25
41	tall	normal green	large	healthy	no excess iron	not deficient	medium-blue color	not deficient low	2.25
42	tall	normal green	large	healthy	no excess iron	not deficient	no color	not deficient low	2.25
43	medium	normal green	large	healthy	no excess iron	not deficient	medium-blue color	not deficient low	6.75
44	medium	light green	medium	healthy	no excess iron	not deficient	no color	deficient	5.50

*d=Diameter.
**=Chemical determination.

Table VI.—Results of Potash and Nitrate-Deficiency Determinations by the Hoffer Cornstalk Method—continued

Soil No.	Description of Corn Plants				Deficiencies Determined				p. p. m. Nitrate Nitrogen**
					Potash		Nitrate		
	Stalk	Color	Ears	Roots	Results of test	Interpretation	Results of test	Interpretation	
45	medium	normal green	large	healthy	no excess iron	not deficient	no color	not deficient low	5.25
46	very tall	dark green	large	healthy	no excess iron	not deficient	pale-blue color	not deficient low	5.50
47	short	normal green	medium	healthy	no excess iron	not deficient	no color	not deficient low	5.25
48	medium	normal green	large	healthy	no excess iron	not deficient	medium-blue color	not deficinet	14.25
49	medium tall	normal green	large	healthy	no excess iron	not deficient	pale-blue color	not deficient	11.75
50	tall	normal green	large	healthy	no excess iron	not deficient	deep-blue color	not deficient	9.25
52	medium	normal green	large	healthy	no excess iron	not deficient	deep-blue color	not deficient	9.00
1061	medium	normal green	large	healthy	no excess iron	not deficient	no color	not deficient	21.75
1062	medium	light green	medium	healthy	no excess iron	not deficient	no color	not deficient	28.00
1063	medium	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	34.75
1064	short	normal green	small	healthy	no excess iron	not deficient	deep-blue color	not deficient	26.00
1065	medium	normal green	medium	healthy	no excess iron	not deficient	pale-blue color	not deficient	18.28
1066	short	normal green	large	healthy	no excess iron	not deficient	deep-blue color	not deficient	45.50
1067	medium	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	19.50

**—Chemical determination.

1068	medium	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	18.25
1069	tall	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	76.50
1070	short slender	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	17.00
1071	very short	normal green	small	short	no excess iron	not deficient	deep-blue color	not deficient	18.25
1072	short	normal green	small	healthy	no excess iron	not deficient	deep-blue color	not deficient	28.00
1073	short	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	18.75
1074	med. tall large d*	normal green	large	healthy	no excess iron	not deficient	deep-blue color	not deficient	20.25
1075	med. tall	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	15.50
1076	med. tall	normal green	medium	healthy	no excess iron	not deficient	no color	not deficient	22.50
1077	med. tall	normal green	medium	healthy	no excess iron	not deficient	no color	not deficient	25.50
1078	very short	normal green	small	healthy	no excess iron	not deficient	deep-blue color	not deficient	28.25
1079	med. tall	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	20.75
1080	med. tall	normal green	medium	healthy	no excess iron	not deficient	deep-blue color	not deficient	16.50
1081	tall large	dark green	large	healthy	no excess iron	not deficient	pale-blue color	not deficient	32.21
1082	medium short	normal green	medium	healthy	no excess iron	not deficient	pale-blue color	not deficient	22.75
1083	medium tall	normal green	medium	healthy	no excess iron	not deficient	pale-blue color	not deficient	29.00
1084	tall slender	light green	medium	healthy	no excess iron	not deficient	no color	deficient	8.00

*d=Diameter.

Table VI.—Results of Potash and Nitrate-Deficiency Determinations by the Hoffer Cornstalk Method—continued

Soil No.	Description of Corn Plants				Deficiencies Determined				p. p. m. Nitrate Nitrogen
					Potash		Nitrate		
	Stalk	Color	Ears	Roots	Results of test	Interpretation	Results of test	Interpretation	
1085*	short slender	yellow green	small	healthy	no excess iron	not deficient	pale-blue color	not deficient	26.25
1086	med. tall	normal green	medium	healthy	no excess iron	not deficient	pale-blue color	not deficient	19.25
1087**	short	normal green	small	healthy	no excess iron	not deficient	deep-blue color	not deficient	49.50
1088	short	normal green	medium	healthy	no excess iron	not deficient	medium-blue color	not deficient	28.00
1089	short	normal green	small	healthy	no excess iron	not deficient	medium-blue color	not deficient	20.50
1090**	short	light green	small	healthy	no excess iron	not deficient	medium-blue color	not deficient	22.00
1091	small	light green	small	healthy	no excess iron	not deficient	pale-blue color	not deficient	19.00
1092	medium	light green	medium	healthy	no excess iron	not deficient	very pale-blue color	not deficient	42.75
1093	medium	light green	medium	healthy	no excess iron	not deficient	pale-blue color	not deficient	40.00
1094	medium	normal green	large	healthy	no excess iron	not deficient	pale-blue color	not deficient	40.25

*Matured prematurely due to excessive drouth.
**Hail and dry weather.

and 5 were not deficient. If we place the slightly deficient and non-deficient results in one group, as has been done before, then we have 12 samples in the non-deficient class and 3 in the moderately deficient. Both the soil-plaque and Hoffer test showed all 15 of these to be not deficient in potash.

The apparent discrepancy between the above Neubauer results and those obtained by the two other methods may be due to the factors mentioned on page 44, and in the light of this explanation, the disagreement may not be as serious as the data suggest.

COMPARATIVE NITRATE DETERMINATIONS

According to the cornstalk test, 50, or 92.59 percent, of the soils examined were not deficient in nitrate, and 4, or 7.41 percent, were deficient.

The results of the chemical determinations for soil nitrates, given in Table VII, show that 43 soils, or 79.6 percent, contained more than 8 parts per million of nitric nitrogen and, therefore, according to our standard of classification, were not deficient. Eleven, or 20.4 percent, were deficient. Four of these 11 soils were also deficient by the Hoffer test; 6 gave low results, as indicated by the pale-blue color or absence of color in normal green stalks, and therefore should be considered on the border line; 1 was not deficient. By placing the 6 border-line soils in the non-deficient group, as was done above, a correlation of 87.04 percent is obtained. If, however, we include these in the deficient group, then we would have 47 not deficient by the cornstalk test, as compared with 43 by the chemical analysis, or a correlation of 92.59 percent.

While there is a high degree of correlation between the results of the Hoffer and chemical determinations, there is a marked disagreement between the intensity of the blue color in the stalks and the actual amount of nitrate present in the soil as determined by chemical analysis. For example, Soils Nos. 1076 and 1077 show no color by the stalk test, yet contain 22.5 and 25.5 p.p.m. nitric nitrogen respectively. Soil No. 52 gives a deep-blue color yet contains only 9.0 p.p.m. nitric nitrogen, while No. 1092 shows a very pale-blue color with 42.75 p.p.m.

All four of these soils are classified as not deficient by both tests, yet the amounts of nitrate present, as indicated by the blue color of the stalk tests, is entirely out of line with chemical findings. Another inconsistency is found in Soil No. 41. Cornstalks from this field produced a medium-blue color when tested by the Hoffer method and the soil was classified as not deficient, yet it contained only 2.25 p.p.m. nitric nitrogen.

Table VII.—A Comparison of Potash and Nitrate-Deficiency Determinations by the Soil-Plaque, Neubauer, Hoffer and Chemical Tests.

Soil No.	Potash			Nitrate	
	Soil Plaque	Neubauer	Hoffer	Hoffer	Chemical Test
32	not deficient	not deficient	not deficient	not deficient	not deficient
33	not deficient	slightly deficient	not deficient	not deficient	not deficient
34	not deficient	moderately deficient	not deficient	not deficient	not deficient
35	not deficient	slightly deficient	not deficient	not deficient	not deficient
36	not deficient	slightly deficient	not deficient	not deficient	not deficient
37	not deficient	not deficient	not deficient	deficient	deficient
38	not deficient	slightly deficient	not deficient	deficient	deficient
39	not deficient		not deficient	not deficient	deficient
40	not deficient	slightly deficient	not deficient	not deficient	not deficient
41	not deficient		not deficient	not deficient low	deficient
42	not deficient	slightly deficient	not deficient	not deficient low	deficient
43	not deficient	not deficient	not deficient	not deficient low	deficient
44	not deficient	not deficient	not deficient	deficient	deficient
45	not deficient		not deficient	not deficient low	deficient
46	not deficient	slightly deficient	not deficient	not deficient low	deficient
47	not deficient	moderately deficient	not deficient	not deficient low	deficient
48	not deficient	moderately deficient	not deficient	not deficient	not deficient
49	not deficient	not deficient	not deficient	not deficient	not deficient
50	not deficient		not deficient	not deficient	not deficient
52	not deficient		not deficient	not deficient	not deficient
1061	not deficient		not deficient	not deficient	not deficient
1062	not deficient		not deficient	not deficient	not deficient
1063	not deficient		not deficient	not deficient	not deficient
1064	not deficient		not deficient	not deficient	not deficient
1065	not deficient		not deficient	not deficient	not deficient
1066	not deficient		not deficient	not deficient	not deficient
1067	not deficient		not deficient	not deficient	not deficient
1068	not deficient		not deficient	not deficient	not deficient
1069	not deficient		not deficient	not deficient	not deficient
1070	not deficient		not deficient	not deficient	not deficient
1071	not deficient		not deficient	not deficient	not deficient
1072	not deficient		not deficient	not deficient	not deficient
1073	not deficient		not deficient	not deficient	not deficient

Table VII.—A Comparison of Potash and Nitrate-Deficiency Determinations by the Soil-Plaque Neubauer, Hoffer and Chemical Tests—continued

Soil No.	Potash			Nitrate	
	Soil Plaque	Neubauer	Hoffer	Hoffer	Chemical Test
1074	not deficient		not deficient	not deficient	not deficient
1075	not deficient		not deficient	not deficient	not deficient
1076	not deficient		not deficient	not deficient	not deficient
1077	not deficient		not deficient	not deficient	not deficient
1078	not deficient		not deficient	not deficient	not deficient
1079	not deficient		not deficient	not deficient	not deficient
1080	not deficient		not deficient	not deficient	not deficient
1081	not deficient		not deficient	not deficient	not deficient
1082	not deficient		not deficient	not deficient	not deficient
1083	not deficient		not deficient	not deficient	not deficient
1084	not deficient		not deficient	deficient	deficient
1085	not deficient		not deficient	not deficient	not deficient
1086	not deficient		not deficient	not deficient	not deficient
1087	not deficient		not deficient	not deficient	not deficient
1088	not deficient		not deficient	not deficient	not deficient
1089	not deficient		not deficient	not deficient	not deficient
1090	not deficient		not deficient	not deficient	not deficient
1091	not deficient		not deficient	not deficient	not deficient
1092	not deficient		not deficient	not deficient	not deficient
1093	not deficient		not deficient	not deficient	not deficient
1094	not deficient		not deficient	not deficient	not deficient

Another criticism of this test is the fact that the results obtained indicate what the current crop was able to take out of the soil during the growing season and not what remains for the next crop. If the results indicate a marked deficiency in the present crop, obviously the soil will be deficient the following one unless the fertility is restored by natural processes or the proper fertilizers. If the test shows an abundance of nitrogen and potash in the plant tissues, the chances are that the soil will be well supplied for the next growing season. If, however, the mineral nutrients have been just adequate to furnish the needs of the present crop, and the interpretation of "not deficient" is made according to Hoffer's recommendations, the soil may not have the necessary plant food to produce a satisfactory crop the following year.

A Comparison of the Soil-Plaque and Neubauer Methods with Field Experiments

A study of the data given in Table VIII shows a very satisfactory correlation between the results of the potash and phosphate determinations by both the soil-plaque and Neubauer methods on the one hand and the crop yields from field plots fertilized according to these indications on the other hand.

In regard to potash, the correlation was 100 percent. None of the soils was deficient in potash by either test and none responded to potash fertilizer in the field. Where both potash and phosphate were employed on the plots, no advantage could be noted over phosphate alone. Two soils, Nos. 2 and 9, showed a suppression of Azotobacter colonies by potash in the soil-plaque determinations (See Table III), and both of these soils gave decreased yields of sugar beets on the plots to which potash had been applied. (See Table I.)

With respect to phosphate, the results of both the soil-plaque and Neubauer determinations were in harmony with the field returns in all cases but one. Soil No. 6 was moderately deficient in phosphate by the soil-plaque test and very deficient by the Neubauer analysis, yet it showed no benefit from the application of phosphate in the field. In fact, the untreated plots averaged better than 1 ton of sugar beets more per acre than those that were fertilized. This disagreement might be accounted for by the fact that leaf spot was rather prevalent on this series and by the further fact that one of the check plots included the remains of an old compost pile. This seeming inconsistency appears to be one of those troublesome cases that one encounters occasionally in experimental work in which some unknown factors have entered in to complicate results. We feel that this has been true here, rather than that both laboratory tests have failed, because the variations among the yields from the triplicate plots were too great to be accounted for otherwise. On the 3 phosphated areas, the sugar-beet tonnages were 11.7, 7.7 and 9.8 per acre, respectively, while on the 4 untreated checks they were 10.8, 9.8 and 8.9, respectively. This irregularity in yield is much greater than we usually observe in similar experiments and suggests a marked variation in the initial fertility and character of the soil in different parts of the tract.

Of the 10 remaining field plots, 7 were very deficient in phosphate by the soil-plaque test and showed a gain in tons of sugar per acre over the untreated checks ranging from 9.69 percent to 173 percent where 200 pounds of treble superphosphate per acre were used. Such fields are shown in Figs. 6 and 7. Of the other

Table VIII.—Results of Deficiency Determinations by Soil-Plaque and Neubauer Methods, compared with Field Tests*

Soil No.	Potash			Phosphate			Phosphate and Potash	
	Soil Plaque	Neubauer	Field Test	Soil Plaque	Neubauer	Field Test	Soil Plaque	Field Test
1	not deficient	not deficient	not deficient	very deficient	very deficient	very deficient	no benefit over P_2O_5	no benefit over P_2O_5
2	not deficient suppression	not deficient	not deficient	not deficient	slightly deficient	not deficient	not deficient	not deficient
5	not deficient	not deficient	not deficient	not deficient	not deficient	not deficient	not deficient	not deficient
6	not deficient	not deficient	not deficient	moderately deficient	very deficient	not deficient	no benifit over P_2O_5	not deficient
7	not deficient	not deficient	not deficient	very deficient	very deficient	moderately deficient	no benefit over P_2O_5	no benefit over P_2O_5
9	not deficient	not deficient	not deficient	slightly deficient	slightly deficient	not deficient	no benefit over P_2O_5	not deficient
54	not deficient	not deficient		very deficient	very deficient	very deficient	no benefit over P_2O_5	
58	not deficient	not deficient		very deficient	very deficient	very deficient	no benefit over P_2O_5	
513	not deficient			very deficient		very deficient	no benefit over P_2O_5	
1095	not deficient			very deficient		very deficient	no benefit over P_2O_5	
1A	not deficient			very deficient		very deficient	no benefit over P_2O_5	

*See Tables I and II for yields.

Figure 6.—Sugar beet field, very deficient in phosphate. Soil No. 1. Left, treble superphosphate added; right, check, nothing added. Neubauer values: Potash 50.75; phosphate 1.67.

three, two were not deficient and one only slightly so. As was to be expected, no increase in yield was obtained from any of these plots. Fig. 8 shows one of our non-deficient fields.

Neubauer determinations were made on 7 of the above 10

Figure 7.—Sugar beet field, very deficient in phosphate. Soil No. 513. Left, check, nothing added; right, 300 pounds treble superphosphate per acre added.

Figure 8.—Sugar beet field. Soil No. 2. Not deficient in either potash or phosphate. Nothing added.

plots. Four of these, corresponding to 4 which were very deficient by the soil-plaque, were also very deficient by the Neubauer test. Of the other 3, corresponding to the 2 not deficient and 1 slightly, by the plaque test, 2 were slightly deficient and 1 not deficient by the Neubauer analysis.

By grouping the slightly deficient soils with the non-deficient, and the moderately with the very deficient, a correlation of 100 percent is obtained between the soil-plaque and Neubauer determinations as applied to these fields, and a 92 percent correlation between the soil-plaque and the field results.

SUMMARY

Brief descriptions are given of the technique employed in making mineral soil-deficiency determinations by the bacteriological soil-plaque, Neubauer and Hoffer cornstalk methods, together with a chemical method for determining soil nitrates.

One hundred eight soils were examined for potash and phosphate deficiencies by the bacteriological soil plaque.

Sixty-six soils were tested for potash and phosphate deficiencies by both the Neubauer and soil-plaque methods.

Cornstalks from 54 fields were subjected to the Hoffer test for deficiencies in potash and nitrate as an indication of corresponding soil deficiencies; chemical analyses for nitrates were made on the respective soils as checks on the cornstalk results,

and deficiency tests for potash and phosphate were made on the same soils by both the soil-plaque and Neubauer procedures.

Fertilizer field experiments were conducted on 11 farms where potash and phosphate fertilizers were applied according to deficiencies indicated by both the soil-plaque and Neubauer tests.

Extensive data are presented giving the results of the tests by the different methods. These are compared with each other and with the field experiments and correlation percentages are given.

CONCLUSIONS

1.—The results of this investigation indicate that the soil-plaque and Neubauer methods are equally reliable for the determination of mineral soil-deficiencies.

2.—The Hoffer Cornstalk method is satisfactory in the majority of cases for the determination of the potash and nitrogen needs of corn when marked deficiencies or abundant supplies exist, but for border-line cases, it is not so dependable.

3.—Close correlations were obtained between the different methods where comparisons were possible.

4.—The soil-plaque method is well adapted to the determinations of phosphate deficiencies and may prove equally valuable in relation to potash.

5.—Taking into consideration reliability, ease of manipulation, time required, expense involved and general application to the determination of mineral soil-deficiencies for all crops, the soil plaque is the most desirable of the three methods investigated.

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