Bulletin 333 January, 1932

MICROCHEMICAL SOIL TESTS

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ERRATA

In *Microchemical Soil Tests,* Bull. **333** of the Connecticut Agricultural Experiment Station—

Page 124, line 3, should read 500 ml., rather than 1000.

Page 128, center, should read .0895, rather than .2465.

MICROCHEMICAL SOIL TESTS

During the early stages of the evolution of soil science, chemical analyses were the chief means of soil diagnosis. De Saussure, Boussingault and Liebig had developed the fundamentals of plant nutrition as indicated by the chemical composition of the plant, during the first half of the nineteenth century. The soil chemists of that period believed that there was a direct relationship between composition of the plant and its ability to extract essential elements from the soil. Hence a knowledge of the chemical composition of the soil was believed to be essential to measurements of soil fertility.

The work of Lawes and Gilbert at Rothamsted established the basic principles of fertilizer practise and emphasized the three essential elements which are now most universally regarded as of importance from a fertility standpoint: nitrogen, phosphorus and potassium. Determinations of the total or strong acid-soluble amounts of these elements were especially stressed.

Unfortunately, much of this work could not be correlated with field results. There was no consistent correlation between the total or acid-soluble constituents of the soil and its response to fertilizers. Soils in general were found to contain amounts of nitrogen and phosphorus sufficient for hundreds of crops, and potassium for more than a thousand crops, yet these elements commonly needed to be applied in manure or fertilizer. The crop appeared to be more sensitive than the chemical methods designed to reveal the availability of these soil constituents.

This interest in soil analysis gradually declined, and more logically attention came to be paid to the physical, biological and physiochemical properties of the soil in relation to plant growth. Both scientists and farmers came to realize that the requirement of a soil for fertilization is no more important than its needs for adequate drainage or irrigation, favorable humus supply, proper cultivation and suitable soil reaction.

Unusual stress has been placed upon the problem of soil acidity or alkalinity. During the past 20 years numerous methods for determining the degree of acidity and the amounts of lime required for its correction have been developed. Many of these are relatively simple, and provide quick means of diagnosing the soil with respect to this important factor in crop growth relationships. Farmers have been greatly served by these soil acidity tests, made on a large scale through the activities of county farm bureau agents, extension specialists, agricultural colleges and experiment stations. Their farm practise has been affected by these soil tests, and they have been able to adjust their use of lime to the needs of their soils and the crops that they produce.

The simplicity and practical value of the acidity tests have suggested the desirability of tests of a similar type that may be used to diagnose other factors of soil fertility. The development of chemical science during the present century has provided a more thorough understanding of the factors that affect the ability of soils to liberate the various elements in the presence of salts and dilute acids. Field and greenhouse experiments with fertilizers and liming materials provide data on numerous soils of which the requirements are definitely established and these may be used as a basis of comparison with the results of chemical soil examination.

In addition to the pH (soil acidity) test, the first simple determination of promise has been the available phosphorus test. The application of the blue coeruleo-molybdate reaction to phosphorus determinations, following the lead of Denigès[1] provided a rapid and simple basis for such a method. Detailed laboratory methods for phosphorus determination, such as those proposed by Atkins[2], Parker[3], and Truog[4], have been followed by at least three field methods. Spurway[5] has tested the water-soluble and dilute nitric acid-soluble phosphorus in the soil by testing a drop of the soil extract with a solution of ammonium molybdate in nitric acid, using a tin pencil to develop a blue color. Bray[6] has tested the phosphorus which is capable of producing a blue color when the contents of a test tube containing soil and a dilute solution of ammonium molybdate and hydrochloric acid are stirred with a tin pencil. This is being sold commercially as the "Hi-Lo Phosphate Test." Truog, in the commercial Truog-Lamotte Test, extracts the soil with dilute sulfuric acid and develops the blue phosphorus reaction of the filtered solution in the presence of stannous chloride and an ammonium molybdate solution in sulfuric acid. All of these tests have been of practical benefit as indicating soils of different degrees of deficiency with respect to phosphorus requirement.

The author became interested in this field through his development of a field technique for estimating the soil acidity or alkalinity in terms of pH[7]. This method included a specially designed porcelain block embodied in a soil testing set which is being sold commercially.

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[1] Denigès, G. Compt. Rend. Soc. Biol., 84: 875-877.

[2] Atkins, W. R. G. Jour. Agr. Sci., 14: 192-197.

[3] Parker, F. W. and Fudge, F. J. Soil Sci., 24: 109-117.

[4] Truog, E. Jour. Amer. Soc. Agron., 22: 874-882.

[5] Spurway, C. H. Mich. Quar. Bul. 9: 64-67.

[6] Bray, R. H. Ill. Agr. Expt. Sta. Bul. 337.

[7] Morgan, M. F. Ecology, 8: 387-388.

The use of this special porcelain block (Figure 15) in the operation of this test, suggested its application to other soil tests of a microchemical character. Elaborations and adaptations of various chemical methods have developed several qualitative or roughly quantitative tests that are believed to expand considerably the possibilities of soil diagnosis through the agencies of simple methods which require a minimum of time and equipment.

This is the first time many of these tests have been described and the methods are given in considerable detail. It is hoped that they will enable those interested in soil testing to develop a somewhat clearer picture of some of the most important chemical relationships of the soil.

However, it must be borne in mind that the results of no one test should be taken as the complete explanation of crop failure or success. The fertility of the soil is something more than a certain number of pounds of plant food material, regardless of the method by which we seek to reveal various features of its manifold aspects. The interpretations of the tests herein presented must be considered in terms of all other known characteristics of the soil in question. A blind adherence to any prescribed rule will often lead to grave error and hasty condemnation of a method of which too much is demanded.

SOIL SAMPLING

In most soil tests, including all of those described in this bulletin, very small amounts, usually less than a teaspoonful of soil, are actually used for any particular determination. When one realizes that the results produced by this quantity of soil are to be used in interpreting an acre or more of soil, containing millions of pounds of material within the plowed depth, the necessity of careful and accurate sampling is readily apparent.

For cultivated fields, an auger provides the best means of sampling. It should be bored intò the soil to about six inches depth and drawn out of the soil with a straight pull. The soil may then be stripped from the spiral grooves of the auger. A bit of from one and one-fourth to one and one-half inches in diameter is most satisfactory. If a considerable amount of soil sampling is to be undertaken, a blacksmith can easily weld the shank of the auger bit to a short rod of iron which may be threaded into a T-shaped handle made of gas pipe. It is preferable to have the screw tip and flanges of the auger bit removed so that the cutting edges may be properly sharpened for boring into the soil.

If an auger is not available, the sample may be taken with a trowel, shovel or spade. A vertical cut is made to the depth of six or seven inches and the face is sliced down thin and collected for the sample.

For soil in permanent sod cover, the sample of most importance is within two inches of the surface, in the zone of feeding roots. A trowel or large knife should be used to obtain small slices through the turf.

Every sample should be a thorough mixture of soil collected from at least six points. If an entire field of one or more acres is to be represented by only one sample it should be collected from at least 20 places well distributed over the area. If there are distinct types of soil or differences in past treatment or crops, these should be represented by their own composite samples from borings or soil slices within a smaller area. Since a half pint of soil is sufficient for all the necessary tests, this amount should be drawn from the composite after it has been thoroughly mixed and, preferably, screened free from stone, hard clods or coarse roots.

A half pint paper carton such as is commonly used as an ice cream container is satisfactory for the transportation and storage of soil samples.

Tests such as those described in this bulletin are preferably made on soil that still contains some of its natural moisture. This means that the samples should be tested within two or three days after they are collected, and should be protected from drying out during the intervening time. Soils that have become "dust-dry" should be slightly moistened with distilled water, in a clean glass vessel or porcelain dish, preparatory to testing.

SOIL RECORDS

In order that soil diagnosis may be as complete as possible, all soil samples should be considered in the light of the type of soil, the past treatment of the field with respect to fertilizers, manure and lime, the results of previous crops and the crops that are contemplated in the immediate future. A form has been drawn to indicate the information required in order to interpret the results of soil tests.

Form for Soil Record

Soil record No. ----------------
Field sample Nos. --------------

Name ---------------------------
Address ------------------------

Soil description

(Underscore terms that apply.)

Topographic location: Level, rolling, steep, in valley, on slope, on hill crest.

Drainage: Excessive, good, fair, poor.

Surface soil: Depth ------ inches.
Color: Black, dark brown, grayish-brown, brown, reddish-brown.
Texture: Coarse sand, loamy sand, sandy loam, fine sandy loam, loam, silt loam, clay loam.
Structure: Soft, loose, crumby, firm, hard, cloddy.
Stone or gravel: Very stony, gravelly, no stone, no gravel.

Subsoil: Thickness ------ inches.
Color: Light brown, yellow brown, yellow, reddish-yellow, yellowish-drab, grayish-drab.
Texture: Sandy, gravelly, loamy.
Structure: Mellow, firm, compact.
Stone or gravel: Very, slightly, stony, gravelly, no stone, no gravel.

Substratum: Loose and stony, compact "hardpan," gravel, sand, clay.
Color: Gray, yellowish-gray, light brown, reddish-gray, brownish-red, drab.

Locate samples by number and direction of north by arrow on outline map of field.

Designation of field . . .

Field history

This season, 19------
Crop ---------- yield ---------
Fertilizer------lbs. per A.-----
analysis in row ☐ or broadcast ☐ ----------------------

Lime----tons per A.
{ hydrated ☐
{ limestone ☐
{ ....
Manure----tons per A.
Kind------------

Last season, 19------
Crop ---------- yield ---------
Fertilizer ------lbs. per A.-----
analysis in row ☐ or broadcast ☐-----------------------
Lime----tons per A.
{ hydrated ☐
{ limestone ☐
{ ....
Manure----tons per A.
Kind------------

Previous treatment:------------

Crops to be grown during next three years:
19----, --------------------
19----, --------------------
19----, --------------------

Is drainage assisted by tile ☐ or open ditches ☐ ?

Special problems: --------------

No form can be devised that will fit all cases, and as much supplemental information as possible should be available to the person making the soil tests.

SOIL TESTING SERVICE

No single agency in this or any other state is in a position to test every field on every farm. This is not necessary, since a few carefully selected tests of representative conditions in any farming community indicate what may be expected under normal conditions. A healthy person does not consult the physician except for an occasional physical examination, and the same principle applies in soil fertility practise. The extension service, through the county agents and agronomy specialists, will help within the limits of their time. Agricultural high school teachers can do much in their communities. Commercial organizations, such as fertilizer and lime producing companies, are giving an increasing amount of this type of service. The state experiment station is interested in diagnosing any unusual soil trouble, and offers its services to all who cannot be served by local soil testing.

It is hoped that as these and similar simple tests become more familiar and readily available, they may be found suitable for home use by the farmer. However, most soil testing requires a somewhat greater familiarity with chemical methods than most persons possess.

OBTAINING SOIL EXTRACTS FOR TESTING

The success of soil testing depends upon a method for obtaining a suitable liquid extract of the soil, that will show by means of certain color reactions the character of the soil with respect to that particular property for which it is being examined. The choice of liquid used for the extraction is determined by the nature of the test. In all methods described in this Bulletin, the special Morgan Soil Test Block, illustrated in Figure 15, is employed. The soil is placed in compartment "A," on the lower side of the perforated partition, firmed with a clean knife, spatula or the finger, and leveled off flush with the sloping face of the block. The narrow groove, "C," should be kept clean, or else partially filled at its upper end, in contact with the soil mass, with clean quartz sand of high purity. (The use of quartz sand in this manner prevents the soil from flowing down into test cup "B," and is recommended in all cases except with the phosphorus test. However, it may be omitted if preferred.)

The extracting liquid should be added, drop by drop, from a bottle with a pipette stopper, or with an eye dropper, to the upper portion of compartment "A" until the soil becomes saturated, permitting the liquid to flow down the groove into the test cup "B." When the test cup is filled, the liquid is transferred by means of an eye dropper to one of the circular depressions on a porcelain slab of the type commonly used by artists in mixing water colors. The number of drops of extract transferred from the test cup and the subsequent treatment is described under the various tests.

TESTING FOR SOIL REACTION (pH)

Since 1927, when the author proposed a technique for testing the soil reaction in terms of pH values, and arranged for its commercial distribution, a few modifications believed to improve the accuracy of the test have been worked out. The revised method is now being used satisfactorily at this laboratory and by several persons in the extension service.

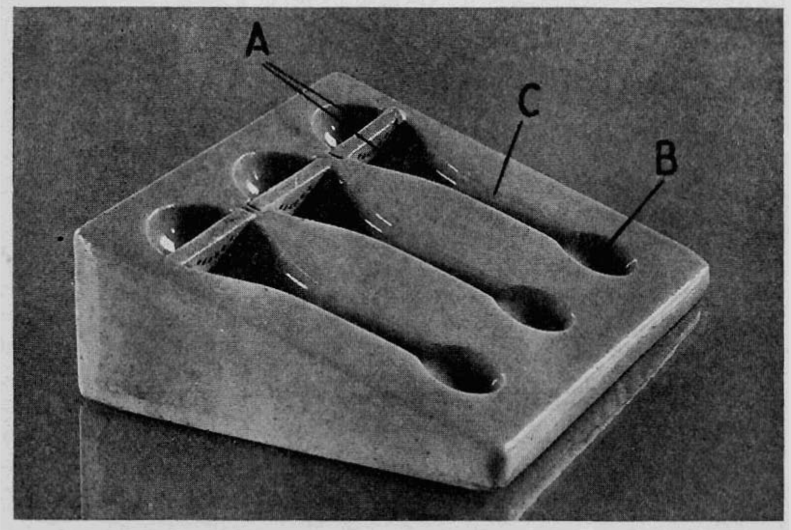

FIGURE 15. Morgan Soil Test Block used in obtaining soil extracts for the tests described in this Bulletin.

Technique

Leaching liquid. Dissolve 3 gms. of sodium chloride (C. P.) in 1000 ml. of distilled water. This solution is approximately 0.05 normal.

Indicators		Range
Bromthymol blue	(0.04 per cent)	6.0-7.6 pH (slightly acid to slightly alkaline)
Chlorphenol red	(0.04 per cent)	5.0-6.6 pH (moderately to slightly acid)
Bromcresol green	(0.04 per cent)	3.8-5.4 pH (strongly to moderately acid)

The list on page 117 covers the range for most soils in the eastern part of the United States. For special studies the following may be added:

Bromphenol blue	(0.04 per cent)	3.0-4.6 pH	(extremely to strongly acid)
Cresol red	(0.02 per cent)	7.2-8.8 pH	(slightly to moderately alkaline)
Thymol blue	(0.04 per cent)	8.0-9.6 pH	(moderately to strongly alkaline)

These indicators are conveniently used from 30 ml. bottles with glass pipettes inserted in rubber bulb stoppers.

All three of the sections of the test block are used for a given sample. The procedure for obtaining the soil extract is substantially as given previously on page 117, except that the indicators are added to the test cups of the soil block before the liquid extract flows down into them. Ordinarily the three dyes are added to the test cups as follows: Left section, bromcresol green; center, chlorphenol red; right section, bromthymol blue. One should touch the tip of the pipette stopper containing the indicator to the bottom of the test cup and squeeze out a "bead" of the colored dye about a quarter of an inch in diameter. (A full drop of indicator dropped free into the test cup is too large a concentration for the liquid capacity of the depression in the test block.) When the leaching liquid has passed through the soil, and flowed down the groove so as to fill the test cup, the resultant color is matched with the color charts for the particular indicator corresponding to the indicator used.[1]

If the resultant color in the bromthymol blue test cup is yellow, a match of color with the chart should be looked for in one of the other two cups. If yellow with chlorphenol red, the bromcresol green usually shows a readable color match.

Special Precautions

The indicators in the bottles from which they are used should show the middle color of their range. Thus both bromthymol blue and bromcresol green should be blue-green, and chlorphenol red should be orange-red. In glass bottles, indicators gradually tend to change color in the alkaline direction, due to the solubility of the glass, so that occasionally a drop of dilute acid (such as the phosphorus leaching liquid described under the phosphorus test) should be added to the indicator to restore its proper color.

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[1] Color charts may be obtained from the La Motte Chemical Products Company or from the Williams and Wilkins Company, both of Baltimore.

If the leaching liquid does not flow freely from the lower edge of the soil in its proper compartment on the test block the fluid may be drawn down by the capillary action of a blunt-pointed glass rod.

Printed color charts should be protected from light as much as possible. It is a good plan to keep each chart in a heavy manila envelope except when it is actually in use.

Interpretations of the pH Test

It must be borne in mind that the pH of the soil is a numerical expression of the hydrogen-ion concentration, in terms of the logarithm of its reciprocal. It measures the degree of acidity or alkalinity on a scale of which 7 pH is the neutral point (neither acid nor alkaline) with lower units indicating increasing acidity and higher ones increasing alkalinity. It does not directly measure the amount of lime required to produce a neutral reaction in a soil that shows a pH value of below 7.

However, on soils of similar type there is a fairly good correlation between lime requirement and pH. These correlations have been determined with reasonable accuracy for such soils as occur in Connecticut.[1]

A neutral or alkaline reaction of soils is not required in the case of most agricultural crops. In many instances it may be undesirable.

Injurious acidity of soils for most acid-sensitive crops cannot be said to exist with pH readings above 6.2. On the other hand, a greater degree of acidity may be needed, as for tobacco, potatoes or other crops that present special disease problems on near-neutral soils.

Soils between 5.6 and 6.2 pH may or may not need lime, application of which depends upon the preferences of the crop. In most cases, lime is apt to be beneficial.

A great majority of Connecticut soils falls in the range between 4.8 and 5.6 pH, and although usually capable of growing fair crops of corn and timothy hay, or good tobacco and potatoes, they are seriously in need of lime for all crops that are definitely acid-sensitive.

Below 4.8 pH, soils are so strongly acid that the injurious effects of soil acidity are accentuated by other adverse factors to be expected on such acid soils. Toxic aluminum and manganese, as well as the decreased rate of biological activity, especially in nitrate

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[1] See Bulletin 320, pages 888-889, of this Station.

production and legume nodulation, are to be expected on such soils. Actual lack of calcium or magnesium, or both, may be experienced by some crops, since such a degree of acidity can be attained only when these elements form a low percentage of the soil's capacity to retain these bases in an active form.

PHOSPHORUS AVAILABILITY

As has been already mentioned, fairly satisfactory field methods for estimating the availability of soil phosphorus are now in use. The author has worked out a technique adapted for use in testing the small quantities of soil extract obtained by the use of the Morgan test block, and it is believed that this method possesses the necessary requirements of speed, simplicity and reasonable accuracy.

Reagents

Extracting liquid. Add 1.5 ml. of concentrated nitric acid (C.P.) and 2 ml. of concentrated hydrochloric acid (C.P.) to approximately 100 ml. of distilled water, mix, and dilute to a total volume of 200 ml. This is conveniently used from a 30 to 50 ml. bottle with a pipette stopper.

Test solution. Dissolve 5 gms. of ammonium molybdate of highest purity in 50 ml. of distilled water. Filter to remove undissolved material through a phosphorus-free filter paper. Add this solution slowly, with constant stirring, to a mixture of 100 ml. of distilled water, 50 ml. of hydrochloric acid (C. P.), and 25 ml. of nitric acid (C.P.). Make up the solution to a total volume of 400 ml. by adding distilled water. The reserve stock should be kept in a brown glass bottle in a closed cupboard. A 25 ml. brown glass dropping bottle is a convenient container for the portion required for current use.

Procedure

Extraction of the soil is carried out on the Morgan test block by the method indicated on page 117. Two drops of the liquid that has passed through the soil mass and trickled down the groove into the test cup are transferred to one of the circular depressions on the artist's slab. One drop of the phosphorus test solution is added, and the liquid is stirred with a pointed rod of pure tin for about 30 seconds, until the intensity of the blue color ceases to deepen. The resultant shade of blue is matched with the color chart given in Plate 1, and the corresponding amount of phosphorus is estimated on the terms of parts per million in the soil. Due to the low volume weight and special absorptive properties of peat and forest humus, such materials require a separate scale. The chart also indicates the value corresponding to the different shades of blue, in terms of concentration of a solution or plant extract containing phosphorus, when two drops of it are tested in the above manner.

In case the deepest blue shown by the color chart is produced, it is advisable to repeat the test, transferring one drop of the soil extract to the spot plate and diluting it with four drops of the extracting liquid, then transferring two drops of the diluted extract to another spot plate depression for testing. The amounts of phosphorus corresponding to the shade of blue thus produced would be then multiplied by 5 to obtain the available phosphorus content of the soil.

Precautions

The printed chart is only an approximate match with the true color produced in the coeruleo-molybdate reaction. If more exact comparisons are desired, two-drop quantities of solutions containing standard concentrations of phosphate phosphorus should be tested at the same time and in the same manner. The following procedure will give a series of solutions providing a suitable range.

A stock solution containing 20 parts per million of phosphorus is produced by dissolving 0.0878 gms. of monopotassium phosphate (KH_2PO_4) in 1000 ml. of distilled water.

75 ml.	of	20 p.p.m.	solution diluted to	100 ml.	contains	15	p.p.m.
25 ml.	of	20 p.p.m.	solution diluted to	50 ml.	contains	10	p.p.m.
25 ml.	of	15 p.p.m.	solution diluted to	50 ml.	contains	7.5	p.p.m.
25 ml.	of	10 p.p.m.	solution diluted to	50 ml.	contains	5	p.p.m.
25 ml.	of	5 p.p.m.	solution diluted to	50 ml.	contains	2.5	p.p.m.
10 ml.	of	5 p.p.m.	solution diluted to	50 ml.	contains	1	p.p.m.
25 ml.	of	1 p.p.m.	solution diluted to	50 ml.	contains	0.5	p.p.m.

The concentration in terms of solution may be interpreted on the basis of soil by using the corresponding values given in Plate 1.

Many persons will prefer to make up a hand-colored chart, matched with the colors produced from the standard solutions. The wash crayon Eberhard Faber "Aquarello No. 1075" gives a blue that approximately matches the hue produced in the phosphorus test.

The color should be read at once after stirring with the pointed tin rod. There is some fading of the intensity upon standing.

The tin rod should be kept bright by brisk wiping with a coarse cloth and should be occasionally re-pointed with a pencil sharpener.

The extracting liquid should be occasionally tested. If it gives more than a faint trace of blue color when the test solution is added and stirred with the tin pencil, a fresh lot should be prepared.

The phosphorus test is unreliable when the soil has received applications of arsenic compounds. Soils that have been treated with lead arsenate, as for the control of the Japanese or Asiatic beetle, will give a blue test out of all proportion to the availability of their phosphorus content. It should be remembered that quartz sand should not be used as a clarifier in the test block.

Interpretation

The amount of phosphorus as phosphates that is sufficiently soluble to be detected by this test is a fairly stable characteristic of any given soil, and is determined by the natural character of the soil and the past use of fertilizers that have supplied amounts of phosphate in excess of crop removal. A majority of old garden soils and fields in a high state of fertility give soil tests in excess of 50 parts per million. Most cultivated crops will be likely to require fertilizers supplying phosphates in excess of crop removal when lower tests are obtained. Pasture fields and old mowing lots in Connecticut usually give tests below 10 parts per million, and phosphate-supplying fertilizers are seriously needed on such soils. It is questionable whether permanent grasses will show much response on soils with tests in excess of 20 parts per million.

The relationship between these phosphorus tests and forest soil productiveness has not been studied sufficiently to merit any statement.

NITRATE NITROGEN

The abundance of nitrate nitrogen in the soil is quite variable, depending upon the stage in the growth of the crop, the temperature of the soil, the occurrence of leaching rainfall, and the kind and amount of fertilizer applied, as well as the general fertility. However, it is believed that it is frequently of great value to be able, by means of a simple test, to form some idea as to the supply of this most available form of nitrogen at critical periods during crop growth.

Reagents

Extracting liquid. Distilled water.

Test solution. Dissolve 0.05 gm. of diphenylamine (C.P.) in 25 ml. of concentrated C.P. sulfuric acid, at a temperature not to exceed 24°C. The resulting reagent should have no trace of bluish color. This is conveniently kept in a 25 cc. "T.K." glass stoppered dropping bottle. When kept stoppered and exposed as little as possible to direct sunlight, it is satisfactory for use for several weeks, but in case it gives any trace of blue color when four drops are added to one drop of distilled water, a fresh quantity should be prepared.

Procedure

Extraction of the soil is carried out on the Morgan test block by the method indicated on page 117. One drop of the liquid that has passed through the soil mass and trickled down into the test cup is transferred by means of a medicine dropper to one of the circular depressions on the artist's slab. Four drops of the test solution are added, and the liquid is stirred with a glass rod. After two minutes the resultant blue color is compared with the chart shown in Plate 2.

If the deepest shade of blue shown on the chart is produced, the test should be repeated. Transfer one drop of the soil extract to the spot plate, dilute it with four drops of distilled water, and transfer one drop of the diluted extract to another cup in the artist's slab for testing in the same manner as before. The amount of nitrate nitrogen corresponding to the shade of blue thus produced must then be multiplied by 5 to obtain the amount in terms of parts per million of soil.

In many cases it is also desirable to test the nitrate nitrogen content of the plant material. Nitrates are most apt to occur at the base of the petioles of the leaves. Small sections of such material, about one-fourth inch long, sufficient to fill the lower portion of depression "A" on the Morgan test block, should be macerated by means of a blunt glass rod with one or two drops of distilled water, and pressing the mass with the rod until the liquid extract flows down into test cup "B." This extract is tested as for soil extracts.

Special Instructions

The printed color chart is only an approximate match of the true color produced in the reaction between diphenylamine and a solution containing nitrates. If more exact comparisons are desired, one-drop quantities of solutions containing standard concentrations of nitrogen should be tested at the same time and in the same manner. The following procedure will give a series of solutions providing a suitable range.

A stock solution containing 20 parts per million of nitrate nitrogen is produced by dissolving 0.0722 gms. of potassium nitrate (KNO_3) in 1000 ml. of distilled water.

75 ml. of 20 p.p.m. solution diluted to 100 ml. contains 15 p.p.m.
25 ml. of 20 p.p.m. solution diluted to 50 ml. contains 10 p.p.m.
25 ml. of 15 p.p.m. solution diluted to 50 ml. contains 7.5 p.p.m.
25 ml. of 10 p.p.m. solution diluted to 50 ml. contains 5.0 p.p.m.
25 ml. of 5 p.p.m. solution diluted to 50 ml. contains 2.5 p.p.m.
10 ml. of 5 p.p.m. solution diluted to 50 ml. contains 1. p.p.m.

The concentration in terms of solution may be interpreted on the basis of soil by using the corresponding values given in Plate 2.

Many persons will prefer to make up a hand-colored chart matched with the colors resulting from the standard solutions. The wash crayon Eberhard Faber "Aquarello No. 1145" gives a blue that approximately matches the hue produced in the nitrate test.

The length of time before reading the test should be accurately measured, since the intensity deepens rapidly during the first minute or so, with subsequent fading.

The test cup "B" should be permitted to fill with soil extract before transferring a drop from it for test.

The reagent should be frequently tested. No trace of blue color should be produced when four drops of the testing solution are added to one drop of distilled water.

Interpretation

The amount of nitrate nitrogen present in the soil varies greatly under different conditions. It is high in a fertile or heavily fertilized soil during late spring or early summer, provided it is not leached from the surface soil by heavy rains or is not removed by a vigorously growing crop or by grass sod. Fertilizers containing much nitrate nitrogen cause an immediate high nitrate nitrogen concentration in the soil, while non-nitrate fertilizers such as sulfate of ammonia, urea, tankage or cottonseed meal require a lapse of a few days to furnish the soil with available nitrates.

Rapidly growing crops that mature in a few weeks usually suffer from nitrogen deficiency very quickly after the nitrate nitrogen content of the soil falls below 25 parts per million, while slowly growing crops which require several months for their development may make normal growth provided the soil never falls below 10 parts per million in nitrate nitrogen. In order that crops may have a good supply of nitrogen at later times, the soil under crops that are not large enough to shade the ground should have a nitrate nitrogen content of from 50 to 100 parts per million. Soils under sod rarely show more than 25 parts per million except for short periods after fertilizers are applied.

Under greenhouse conditions soils should show a nitrate nitrogen test of not less than 50 nor more than 200 parts per million.

AMMONIA NITROGEN

In fertile agricultural soils ammonia nitrogen is rarely present except in small amounts, except during a few weeks following the application of ammonia compounds, such as sulfate of ammonia, or readily available organic nitrogenous materials, such as tankage, cottonseed meal or urea. This is due to the rapid transformation of ammonia into the nitrate form through bacterial activities.

However, on poorly drained or very acid soils, and in most forest soils, nitrates are not readily formed, and strong ammonia tests may be expected.

Reagents

Extracting liquid. A saturated solution of potassium chloride (C.P.) prepared by dissolving at least 25 gms. of the salt in 100 ml. of distilled water.

Test solution. Nessler's reagent. This is prepared as follows:

Dissolve 5 grams potassium iodide (C.P.) in 15 cc. distilled water. Add a saturated solution of mercuric chloride (C.P.) until a slight precipitate occurs. Add 40 cc. of a 50 per cent solution of potassium hydroxide (C.P.). Dilute to 100 cc., allow to settle for one week, decant and keep in a brown bottle exposed to the light as little as possible. For immediate use a 30 cc. brown glass stoppered dropping bottle is convenient.

Procedure

Extraction of the soil is carried out in the same manner as for previous tests. Four drops of the soil extract are transferred from the test cup to one of the circular depressions on the artist's slab. by means of a medicine dropper. One drop of the Nessler's reagent is added and the liquid is stirred with a glass rod. After one minute the resultant yellow or orange color is compared with the color chart shown in Plate 3. If the deepest shade of orange represented on the chart is produced, the test should be repeated. Transfer one drop of the soil extract to the spot plate, dilute it with four drops of distilled water, and transfer four drops of the diluted extract to another spot plate for testing. The amount of ammonia nitrogen corresponding to the color thus produced must then be multiplied by 5 to obtain the amount in terms of parts per million of soil.

Special Instructions

The printed color chart is only an approximate match of the true shades of yellow and orange produced by the reaction between various amounts of ammonia and Nessler's reagent. The lower concentrations, represented by very pale shades of yellow, could not be shown on the chart. If more exact comparisons are desired, four-drop quantities of solutions containing standard concentrations of ammonia nitrogen should be tested at the same time and in the same manner. The following procedure will give a series of solutions providing a suitable range:

A stock solution containing 50 parts per million of ammonia nitrogen is produced by dissolving 0.236 gms. of ammonium sulfate (C.P.) in 1000 ml. of distilled water.

60 ml. of 50 p.p.m. solution diluted to 100 ml. contains 30 p.p.m.
40 ml. of 50 p.p.m. solution diluted to 100 ml. contains 20 p.p.m.
25 ml. of 30 p.p.m. solution diluted to 50 ml. contains 15 p.p.m.
25 ml. of 20 p.p.m. solution diluted to 50 ml. contains 10 p.p.m.
25 ml. of 10 p.p.m. solution diluted to 50 ml. contains 5 p.p.m.
25 ml. of 5 p.p.m. solution diluted to 50 ml. contains 2.5 p.p.m.
10 ml. of 5 p.p.m. solution diluted to 50 ml. contains 1 p.p.m.
25 ml. of 1 p.p.m. solution diluted to 50 ml. contains 0.5 p.p.m.

The concentration in terms of solution may be interpreted on the basis of soil by using the corresponding values given in Plate 3.

Many persons will prefer to make up a hand-colored chart, matching with the colors resulting from the standard solutions. The wash crayons Eberhard Faber "Aquarello" Nos. 1127 and 1112 may be used for the variations in yellow and orange produced in the ammonia test.

The extracting liquid (saturated KCI solution) should not produce a yellow color when tested with Nessler's reagent, if the materials used are of the proper purity.

Interpretation

A low test for ammonia in agricultural soils is of no significance and is to be expected in a fertile soil unless there has been a recent application of nitrogenous fertilizer in forms other than the nitrate. The rapidity of disappearance of ammonia from the soil in such cases is an indication of the desired transformation of ammonia into the more available nitrate compounds.

In forest soils, especially in the humus layers of "duff" character, ammonia is the most abundant available form of nitrogen, and these organic horizons may produce ammonia nitrogen concentrations ranging from 100 to 500 parts per million, if there is a satisfactory rate of nitrogen transformation.

ACTIVE ALUMINUM

Under conditions of strong acidity, particularly when the soil tests more acid than 5.0 pH, more or less aluminum is brought into an active condition, capable of entering the soil solution and partially taken up by plant roots. Numerous investigators have shown that the presence of aluminum in the soil solution is injurious to the growth of many plants, and believe that this is one of the unfavorable conditions associated with soil acidity.

Soils containing large amounts of phosphorus in readily available form may contain little active aluminum, even though strongly acid. This is due to the effect of phosphates in precipitating aluminum from the soil solution.

It has been common knowledge among soil workers that the intensity of acidity, as measured by pH, often fails to indicate the degree of injury to crop growth that is actually experienced. There is a definite need for a simple test for active aluminum for the purpose of supplementing pH tests particularly on soils in the more acid range. Many acid soils grow good crops, but if there is a high concentration of aluminum as shown by this test, the need for liming is a really serious matter that cannot be ignored.

Reagents

Extracting liquid. This is prepared by diluting 6 ml. of glacial acetic acid (C.P.) to 1000 ml. in which is dissolved 10 gms. of calcium acetate (C.P.). This is an approximately O/N solution of acetic acid, containing 1 per cent of calcium acetate.

Test solution. 0.2 gm. of haematin (a material used in histological staining work) is dissolved in 100 ml. of 95 per cent ethyl alcohol. This should be kept in a brown glass bottle.

Procedure

Extraction of the soil is carried out in the same manner as for the other tests. Four drops of the soil extract are transferred from the test cup to one of the circular depressions on the artist's slab, by means of a medicine dropper. One drop of the test solution is added. At the end of 30 seconds (accurately measured) the resultant color is compared with the color chart shown in Plate 4. If the deepest shade of violet represented on the chart is produced, the test should be repeated. Transfer one drop of the soil extract to the spot plate (artist's slab) dilute it with four drops of the extracting liquid, and transfer four drops of the resultant mixture to another cup on the artist's slab, for testing, as at first. The amount of aluminum corresponding to the color thus produced must be multiplied by 5 to obtain the amount in terms of parts per million of soil.

Special Instructions

The printed color chart is only an approximate match of the true range from yellow to violet produced by the various amounts of aluminum. If more exact comparisons are desired, four-drop quantities of solutions containing standard concentrations of aluminum should be tested at the same time and in the same manner. The following procedure will give a series of solutions providing a suitable range:

A stock solution containing 10 parts per million of aluminum is produced by dissolving 0.2465 gms. of aluminum chloride ($AlCl_3 . 6 H_2O$) in 1000 ml. of distilled water.

50 ml. of	10	p.p.m. solution diluted to	100 ml. contains	5	p.p.m.
30 ml. of	5	p.p.m. solution diluted to	50 ml. contains	3	p.p.m.
20 ml. of	5	p.p.m. solution diluted to	50 ml. contains	2	p.p.m.
25 ml. of	2	p.p.m. solution diluted to	50 ml. contains	1	p.p.m.
25 ml. of	1	p.p.m. solution diluted to	50 ml. contains	0.5	p.p.m.
25 ml. of	0.5	p.p.m. solution diluted to	50 ml. contains	0.25	p.p.m.

The concentration in terms of solution may be interpreted on the basis of soil by using the corresponding values given in Plate 4.

Many persons will prefer to make up a hand colored chart, matching with the colors resulting from the standard solutions. The wash crayons Eberhard Faber "Aquarello" Nos. 1127, 1112, 1103 and 1124 may be used to produce the desired hues.

In case haematin is not readily available, the test solution may be made up from Logwood (haematoxylin), using 0.5 gm. to 100 ml. of 95 per cent ethyl alcohol. However, this must be left in an open beaker in bright sunlight for several hours before it can be used.

Interpretation

The presence of more than 3 parts per million of active aluminum by this test is indicative of distinctly acid soil conditions. Soils showing more than 10 parts per million are apt to produce very poor results except with distinctly acid-tolerant crops. On the other hand, if less than three parts per million is indicated, lime is not a serious need, even though the soil may show a pH test of below 6.

REPLACEABLE CALCIUM

Although lack of available calcium in the soil becomes a direct limiting factor in plant growth in exceptional cases only, the fertility of the soil is closely associated with an adequate supply of this element in order to provide a favorable equilibrium between the various constituents of the soil solution. If there is a deficiency in the replaceable calcium in the soil, the base exchange capacity is incompletely satisfied, and soil acidity of a serious nature is the result. Valuable biological processes are dependent upon the important stabilizing effect of calcium in the soil, and without its beneficial effects the nitrification process would bring about a highly injurious acid condition.

Well-limed soils, those that are not naturally in need of lime, contain an abundance of replaceable calcium. Hence this test can be used to confirm and supplement the interpretation of soil acidity measurements.

Reagents

Extracting liquid. Saturated potassium chloride solution, prepared as described for the ammonia nitrogen test.

Test solution. A saturated ammonium oxalate solution, prepared by dissolving 20 gms. of ammonium oxalate ($(NH_4)_2 C_2O_4 \cdot H_2O$) in 100 ml. of hot distilled water.

Procedure

Extraction of the soil is carried out in the Morgan test block, as in the previously described tests. Five drops of the soil extract are transferred from the test cup to a flat bottomed one-half ounce glass vial five-sixteenths of an inch in diameter. One drop of the test solution is added, and the contents of the vial are shaken gently back and forth. The milky turbidity resulting from the resultant calcium oxalate precipitate is examined by holding one-half inch above a strip of dull black paper, and is compared with the chart shown in Plate 5.

In case the turbidity corresponds to the whitest spot of the chart the test should be repeated. In this case only one drop of the soil extract is transferred to the test vial, and four drops of distilled water are added to it before introducing the test solution. The resulting turbidity as estimated with the chart must then be multiplied by 5 to express the replaceable calcium content of the soil.

Special Instructions

The various degrees of whiteness shown on the printed chart are difficult to reproduce accurately. For more exact estimations, five-drop quantities of solutions containing standard amounts of calcium should be tested at the same time and in the same manner as for soil extracts. The following procedure will give a satisfactory range of concentrations:

A solution of 1.761 gms. of calcium acetate ($Ca(C_2H_3O_2)_2.H_2O$) in 200 ml. of distilled water contains 2000 parts per million of calcium.

25 ml. of a 2000 p.p.m. solution diluted to 50 ml. contains 1000 p.p.m.
25 ml. of a 1000 p.p.m. solution diluted to 50 ml. contains 500 p.p.m.
25 ml. of a 500 p.p.m. solution diluted to 50 ml. contains 250 p.p.m.
20 ml. of a 250 p.p.m. solution diluted to 50 ml. contains 100 p.p.m.
25 ml. of a 100 p.p.m. solution diluted to 50 ml. contains 50 p.p.m.

The corresponding amounts in terms of soil are presented in Plate 5.

A permanent chart may be prepared by matching the resulting turbidities with hand-painted spots, using Chinese white water color on black cardboard.

Interpretation

The amounts of calcium that are replaced from soils by the potassium chloride leaching solutions provide a measure of the amount of calcium contained in the base exchange complex. Soils that have a high percentage of colloidal clay and organic matter give higher values than soils low in humus and clay, unless the former are strongly acid and consequently have most of their calcium replaced by hydrogen-ions.

Normal sandy soils should give 500 p.p.m., clay soils 1000 p.p.m. and humus soils such as peats and forest mold 5000 p.p.m. Lower results indicate that much of the active calcium of the soil has been replaced by hydrogen or other ions, as in acid or highly alkaline soils.

OTHER TESTS

The technique used in these tests described in this bulletin can be adapted to other tests for special soil conditions. Thus, five-drop quantities of distilled water-soil extract can be tested for chlorine, using a drop of a 5 per cent silver nitrate solution, or for sulfate, a 10 per cent Barium chloride solution. These being turbidity reactions, the procedure would be similar to the calcium test, and the chart given in Plate 5 could be used to indicate relative amounts.

The writer has made many efforts to devise a simple field test for available potassium (potash) in soils, along similar lines of procedure. The difficulties are obvious to anyone with a knowledge of chemistry. Potassium precipitate or color reactions at the low concentrations readily extractable from the soil by the use of dilute acids or neutral salts without a tedious process of treatment of the extract, are unknown at the present time.

SUMMARY

In general it is of questionable value to make a detailed chemical analysis of a soil in order to predict the value of fertilizers or soil amendments on any particular field.

With the development of our chemical knowledge it is now possible, by means of simple technique which can be used in a few moments in the field, home or office, to make numerous tests of a microchemical character. These tests, when considered in relation to one another, provide means for the diagnosis of several of the more important soil deficiencies or abnormalities.

A revised field method for the colorimetric determination of pH is proposed.

The coeruleo-molybdate blue color reaction in the estimation of phosphorus in soils provides the basis for a new microchemical test for the relatively available phosphorus in soils.

The diphenylamine color reaction in the presence of nitrates has been utilized in the nitrate nitrogen test described herein.

Ammonia nitrogen, not readily soluble in soils, but capable of being displaced by leaching with potassium salts, is readily detected by Nessler's reagent, and a simple technique for thus testing for ammonia nitrogen has been developed.

The presence of aluminum in active form is a toxic property of many strongly acid soils. A simple field test for this important malnutritional factor in soils is believed to provide a means of predicting the severity of injury to be expected on crops grown under acid conditions.

Calcium in active form, as a replaceable base in the soil complex, is capable of being roughly estimated by the methods of extraction and precipitation proposed in this bulletin.

Other simple tests may be made by the general technique employed in all of these methods, but it has not been found practicable to develop any relatively simple test for the available potassium in the soil.

AVAILABLE PHOSPHORUS COLOR CHART

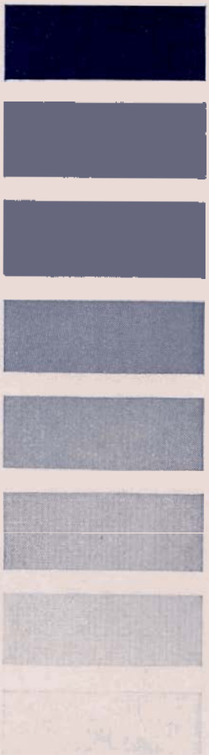
Parts per million			
Peat or forest humus	Liquids	Normal mineral soils	
500	10	100	🟦
375	7.5	75	🟦
250	5	50	🟦
200	4	40	🟦
150	3	30	🟦
100	2	20	🟦
50	1	10	🟦
25	0.5	5	🟦

(For conversion to pounds per acre to 6⅔" depth, multiply by 2 for mineral soils and 0.2 for peat or forest humus.)

This chart is on the basis of 2 drops of a 1 to 1 (by volume) soil extract, or other liquid, treated with 1 drop of test solution and stirred with a pointed tin rod, using the technique presented in this bulletin.

NITRATE NITROGEN COLOR CHART

Parts per million		
Peat or forest humus	Liquids	Normal mineral soils
120	30	24
80	20	16
40	10	8
30	7.5	6
20	5	4
10	2.5	2
4	1	0.8
2	0.5	0.4



(For conversion to pounds per acre to 6⅔" depth, multiply by 2 for mineral soils and 0.2 for peat or forest humus.)

This chart is on the basis of 1 drop of a 1 to 1 (by volume) soil extract, or other liquid, treated with 4 drops of test solution, using the technique presented in this bulletin.

PLATE

AMMONIA NITROGEN COLOR CHART

Parts per million		
Peat or forest humus	Liquids	Normal mineral soils
500	50	80
300	30	48
200	20	32
	15	24
100	10	16
50	5	8
30	3	4
10	1	1.6

(For conversion to pounds per acre to 6⅔" depth, multiply by 2 for mineral soils and 0.2 for peat or forest humus.)

This chart is on the basis of 4 drops of a 1 to 1 (by volume) soil extract, or other liquid, treated with 1 drop of Nessler's reagent, using the technique presented in this bulletin.

PLATE 4

ACTIVE ALUMINUM COLOR CHART

Parts per million			
Peat or forest humus	Liquids	Normal mineral soils	
80	10	15	🟪
40	5	7.5	🟪
24	3	4.5	🟫
16	2	3	🟫
8	1	1.5	🟫
4	0.5	.75	🟨
2	0.25	.375	🟨
0	0	0	🟨

(For conversion to pounds per acre to 6⅔″ depth, multiply by 2 for mineral soils and 0.2 for peat or forest humus.)

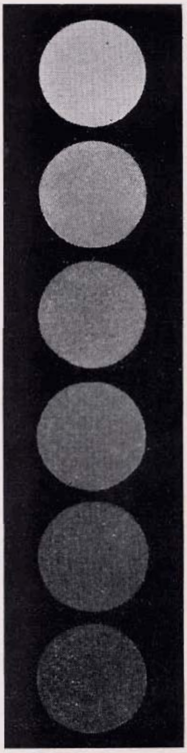
This chart is on the basis of 4 drops of a 1 to [redacted]me) soil extract, or other liquid, treated with 1 drop of test solution (haematin), using the technique presented in this bulletin.

PLATE 5

REPLACEABLE CALCIUM TURBIDITY CHART

Parts per million		
Peat or forest humus	Liquids	Normal mineral soils
10,000	1000	2000
5,000	500	1000
2,500	250	500
1,250	125	250
	50	100
250	25	50

(For conversion to pounds per acre to 6⅔″ depth, multiply by 2 for mineral soils and 0.2 for peat or forest humus.)



This chart is on the basis of 5 drops of a 1 to 1 (by volume) soil extract, or other liquid, treated with 1 drop of test solution, using the technique described in this bulletin.

Note. The chart may be used for chlorine as chlorides, or sulfur as sulfates.