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Soil Testing Methods

The Universal Soil Testing System

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THERE ARE many calls for the details of the methods of soil testing used at this Station. The bulletin describing the system, Number 392* (a revision of Bulletin 372) is now out of print and the present circular is issued to meet the demand, pending a more comprehensive publication. Fortunately, extra color chart separates of Bulletin 372 are available in considerable number, and will be distributed with this circular until the supply is exhausted.

Soil testing to determine the nutrient conditions within the soil by means of comparatively simple tests is a relatively new phase of soil science, and has been made possible by the rapid developments in our chemical knowledge during the present century. It promises to be a valuable contribution to the more intelligent management of the soil, helping to forestall crop failure due to improper fertilization and preventing wasteful use of unnecessary fertilizer ingredients.

However, the best fertilizer and liming practices cannot overcome the injurious effects of deficient or excessive moisture conditions, poor soil tilth, weed competition, improper cultural methods, or insect and plant disease troubles. All these factors must be reasonably favorable to plant growth, else the most thoughtful care in providing suitable nutrient conditions will come to naught.

THE SOIL SAMPLE

Samples of soil should be drawn according to the purposes of the tests. If they are to reveal average conditions existing in the field or plot of ground in question, the sample should be a thorough mixture of equal amounts of soil collected at 20 or more points, fairly distributed over the entire area. On the other hand, if there is a special condition to be studied, such as the local soil variation or spot of ground upon which plant growth is abnormal, the sampling should be confined to that area. In such cases a separate sample from the normal part of the field should also be collected.

For sampling cultivated fields an auger is a convenience. It should be bored into the soil about six inches and drawn out with a straight upward pull. The soil may then be stripped from the spiral grooves into a clean pail. If a considerable amount of sampling is to be done, a shank about three feet long with a T-shaped handle of gas pipe should be welded to the auger bit. It is preferable to have screw tip and cutting flanges of the bit removed, so that the cutting face may be beveled downward.

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 for the sample.

In sampling permanent pasture sod and greensward, the surface soil sample should be taken to a depth of only two inches. If desired, separate samples from greater depths may be collected also.

The vessel in which the various sub-samples are collected should then be dumped over a sheet of heavy cloth or tough paper, picked over or run through a one-quarter inch mesh screen for removal of stones and coarse roots, and carefully mixed. The final sample, which need not weigh more than a few ounces, should be drawn from the bulk sample by repeated quartering.

If possible, the sample should be taken when the soil is not abnormally wet and sticky, since it is difficult to mix when in this condition.

The final sample may be brought or sent to the testing laboratory in any clean and reasonably tight container, which has not previously contained drugs, cosmetics, chemicals or fertilizers.

Soil records: In order that soil diagnosis may be as complete as possible, information in regard to past treatment of the field with respect to fertilizers, manure and lime, the performance of previous crops, and the crops to be grown in the immediate future, should be at hand. It is also necessary to know the characteristics of the soil type, especially with respect to texture, drainage and organic content. If the area from which the sample is drawn is shown on a soil map, tests may be most reliably interpreted in relation to the special characteristics of the soil type.

Preparing the soil sample for testing: The entire sample received for testing should be passed through a 2 mm. or 10-mesh screen. If too wet to be screened easily, the soil should be permitted to dry out to a mellow-moist condition first. After screening, it should be mixed thoroughly. The sample should be kept in a room that is free from strong laboratory fumes. It should be tested as soon as possible after collection in the field. Best results are obtained on soils containing some of their natural moisture. However, samples to be reserved for future testing should be carefully air dried before storing in air-tight containers.

THE UNIVERSAL SOIL EXTRACTING SOLUTION

A distinctive feature of the soil testing methods herein described is the employment of a soil extracting solution that permits the development of tests for the various constituents involved in the nutrient status of the soil from a single soil extract. The extracting solution is an 0.5-normal solution of acetic acid buffered with sodium acetate to 4.8 pH. It is suitable for the usual routine tests and for most others with the exception of sodium and chlorine. These require separate extractions with appropriate solutions.

PREPARATION OF SOLUTIONS AND REAGENTS

(All chemicals should be of good C.P. grade)

Universal soil extracting solution: Add 100 gms. of sodium acetate ($\text{NaC}_2\text{H}_3\text{O}_2 \cdot 3\text{H}_2\text{O}$) to 500 ml. of distilled water. After this is dissolved, add 30 ml. of glacial acetic acid and make up to 1 liter.

* Bul. 392. The Universal Soil Testing System, by M. F. Morgan, 1937.

Reagents for Routine Tests

Nitrate nitrogen reagent: Dissolve 0.05 gm. of diphenylamine in 25 ml. of concentrated sulfuric acid, at a temperature not to exceed 24° C. The resulting solution should have no trace of bluish color, and should give a colorless "spot" when four drops are added to one drop of distilled water. This test should be made frequently since continued exposure to light and accidental contamination may require the preparation of a fresh reagent. The solution is very corrosive, and should not be allowed to come into contact with rubber. Care also should be taken to prevent injury to hands or clothing.

Ammonia nitrogen reagent ("Nessler's reagent"): Dissolve 5 gms. of potassium iodide in 15 ml. of distilled water. Add a saturated solution of mercuric chloride until a slight precipitation occurs. Add 40 ml. of a 50 percent solution of potassium hydroxide. Dilute to 100 ml., allow to settle for one week, decant and keep in a brown glass bottle. Two drops of this reagent, added to 4 drops of the "Universal" leaching solution, should give a practically colorless spot.

Phosphorus reagent "A": Dissolve 12.5 gms. of sodium molybdate, by gentle heating, in 100 ml. of distilled water. Mix 50 ml. of acetic acid and 350 ml. of distilled water in a 600 ml. beaker. Add the above solution of sodium molybdate slowly with constant stirring. Store in a brown glass bottle.

Phosphorus reagent "B": This should be freshly prepared on the day of use as follows: Place 25 ml. of "Universal" extracting solution in a one-ounce dropper bottle. Add .005 to .01 gm. of stannous oxalate (an amount about the size of a match head, conveniently transferred by means of the flattened tip of a thin glass rod) and shake thoroughly.

Potassium reagent "A": Dissolve 5 gms. of $\text{Co}(\text{NO}_3)_2$ and 30 gms. of NaNO_2 in 50 ml. of distilled water acidified with 2.5 ml. of glacial acetic acid. Make up to 100 ml. with distilled water. Let stand 24 hours and filter.

Potassium reagent "B": Iso-propyl alcohol.

Calcium reagent: A saturated solution of sodium oxalate.

Magnesium reagent "A-1": Dissolve .01 gm. of para-nitrobenzene-azo-resorcinol (Eastman Kodak Company) in 2 ml. of 1 percent NaOH. Dilute to 200 ml.

Magnesium reagent "A-2": Dissolve 0.15 gm. of Titan yellow (Dr. G. Grubler & Co. or similar quality) in a mixture of 50 ml. of methyl alcohol and 50 ml. of distilled water. This should be freshly prepared every three or four months.

Magnesium reagent "B": Dissolve 15 gms. of sodium hydroxide in 100 ml. of distilled water.

Aluminum reagent: Dissolve 0.05 gm. of hematein in 100 ml. of 95 percent ethyl alcohol. This should be freshly prepared every two months.

Manganese reagent "A": Dissolve 0.1 gm. of benzidine in 20 ml. of glacial acetic acid. Dilute to 200 ml. and filter.

Manganese reagent "B": Dissolve 15 gms. of sodium hydroxide in 100 ml. of distilled water. This reagent is the same as magnesium reagent "B". (See below.)

Manganese reagent "C": A saturated solution of potassium periodate in the Universal soil extracting solution.

Reagents for Special Tests

Iron reagent "A": Dilute hydrochloric acid of ordinary C.P. concentration (approximately 38 percent HCl) with an equal volume of distilled water.

Iron (ferric and ferrous) reagent "B": Dissolve 10 gms. of potassium ferrocyanide and 0.1 gm. of potassium ferricyanide in 100 ml. of distilled water.

Ferric iron reagent "B": Dissolve 15 gms. of potassium sulphocyanate in 100 ml. of distilled water.

Ferrous iron reagent "B": Dissolve 0.2 gm. of potassium ferricyanide in 100 ml. of distilled water.

Sulfate sulfur reagent: Dissolve 5 gms. of barium chloride in 100 ml. of distilled water.

Nitrite nitrogen reagent: Dissolve 1 gm. of sulphanilic acid, by gentle heating, in 100 ml. of a saturated solution of ammonium chloride. Add 1.5 gms. of phenol and mix thoroughly.

Special sodium soil extracting solution: Mix up 30 ml. of glacial acetic acid to 1 liter, by addition of distilled water. This solution is approximately 0.2 normal in total acidity.

Sodium reagent: Make up two separate lots as follows: (A) Uranyl acetate, 10 gms; acetic acid (30 percent), 6 ml.; distilled water to 65 ml. Dissolve by heating. (B) Zinc acetate, 30 gms.; acetic acid (30 percent), 3 ml.; water to 65 ml. Dissolve by heating. Add (A) to (B) and continue heating until clear. Let stand several days and filter out the sediment.

Special chlorine extracting solution: Dilute 13 ml. of nitric acid of ordinary C.P. concentration (70 percent) to one liter, using distilled water. This solution is approximately 0.2 N. in total acidity.

Chlorine reagent: Dissolve 2 gms. of silver nitrate in 100 ml. of distilled water. Store in an amber glass-stoppered bottle.

Boron reagent "A": Dissolve 0.5 gm. turmeric powder in 100 ml. of ethyl alcohol (95 percent). Filter through a "double acid-washed" paper.

Boron reagent "B": Mix 70 ml. of orthophosphoric acid (85 percent) and 30 ml. of concentrated sulfuric acid. Let stand for a few days, and decant the clear liquid.

Zinc reagent "A": Dissolve .0807 g. of Cobalt chloride in 100 ml. of 0.5 N hydrochloric acid solution.

Zinc reagent "B": Dissolve 8 gms. of mercuric chloride and 9 gms. of ammonium thiocyanate in 100 ml. of distilled water. Let stand for three or four days and decant the clear solution.

Zinc reagent "C": Ethyl ether.

Copper reagent: Dissolve 5 gms. of alphanbenzoinoxime in 100 ml. of ethyl alcohol (95 percent).

APPARATUS AND GLASSWARE

The following list itemizes the equipment normally required for conducting the routine tests used in the Universal soil testing system, and provides for testing six samples of soil simultaneously. Where specifications are given, they should be exactly followed. (These items are obtainable from most laboratory supply firms.)

- 1 Large supply bottle for Universal soil extracting solution (1 liter or larger, as desired).
 - 2 Spot plates, for color reactions, with 12 depressions, 20 mm. diameter and 7.5 mm. deep.
 - 12 Glass vials, 50 mm. long, 10 mm. inside diameter.
 - 1 Block, containing 12 holes .5 inch in diameter and 1 inch deep, for supporting test vials.
 - 6 Eyedropper pipettes, with unflattened straight tip of 2 mm. diameter.
 - 6 Funnels, short neck, 4 cm. diameter (or special soil filtering tubes, with funnel mouth.)
 - 6 Erlenmeyer flasks, 50 ml.
 - 1 Filter paper, box of 100 sheets, Munktell No. 0, 9 cm. diameter.
 - 1 Test tube brush, puff-tuft, for .5-inch diameter tubes.
 - 6 Glass rods, 4 inches long.
 - 1 Measuring cylinder, 10 ml.
 - 1 Measuring spoon, teaspoon size.
 - 1 Dropping bottle, glass-stoppered, for nitrate reagent.
 - 3 Dropping bottles, 2 oz. rubber bulb stopper for Universal soil extracting solution, 15 percent NaOH and 1:1 HCl.
 - 9 Dropping bottles, 1 oz. rubber bulb stopper, for other test reagents.
- Additional dropping bottles should be provided for the reagents used in the special tests, if desired.

PROCEDURE FOR CONDUCTING THE TESTS

The soil extraction: Insert the stem of the funnel into the neck of the flask or bottle used for the collection of the soil extract, and fit a folded filter paper of 9 cm. diameter (of Munktell No. O, C. S. and S. No. 589 or similar grade) into the funnel.

Place a level teaspoonful of the soil sample inside the filter cone, and press down gently with the back of the spoon. Measure out a 10 ml. portion of the Universal soil extracting solution, and pour slowly over the soil mass in the filter. If the soil does not readily absorb the liquid, the extraction should be repeated with the soil moistened slightly with distilled water before being measured into the funnel. Permit the filtration to proceed to completion, or until there is no liquid on the soil surface. In removing the filter

cone of soil, squeeze it gently to extract any remaining liquid which may have collected at its tip. Remove the funnel and insert a clean eyedropper pipette into the filtrate vessel. Pump the liquid up and down the pipette two or three times to insure thorough mixing of the soil extract. Each lot of extract should be supplied with an individual pipette for transferring portions for the various tests.

Alternate procedure: Place a teaspoonful of soil, gently packed and leveled, into a 30 ml. beaker. Add 10 ml. of the Universal soil extracting solution. Stir vigorously for one minute and filter through a paper of quality indicated above into a 20 by 75 mm. glass vial or other suitable container. Remove the funnel, and insert a clean eyedropper pipette into the filtrate vessel. Proceed as above directed.

Soils of some areas are not rapidly saturated with the soil extracting solution, when the extraction is conducted directly in the filter cone. This is especially true of heavy clay soils, particularly when they are already partially wet with field moisture. In such cases it is difficult to obtain concordant results on separate determinations of the same sample, and it is preferable to follow the suggested alternate procedure. However, one or the other method should be consistently followed. The results obtained, while usually relatively the same, are not directly comparable.

Nitrate nitrogen test: Transfer 1 drop of soil extract to the spot plate. Add 4 drops of the reagent; let stand for two minutes; stir with a glass rod and compare the intensity of the resultant blue color with the color chart. The true color is slightly more blue than shown.

Stirring immediately after adding the reagent is not recommended, since the blue color develops most rapidly in the film of contact between the reagent and the extract. Somewhat deeper colors result from prolonged standing in excess of two minutes, but for convenience of operation, the charts are standardized on the basis of this time.

Ammonia nitrogen test: Transfer 4 drops of the soil extract to the spot plate. Add 2 drops of the reagent. Let stand one minute; stir with glass rod and compare the resultant yellow to orange color with the color chart.

Two drops of the reagent are needed to insure neutralization of the acidity of the extract, permitting the development of a permanent color.

Phosphorus test: Transfer 10 drops of the soil extract to the spot plate. Add 1 drop of reagent "A" and 2 drops of reagent "B" (the latter freshly prepared on the day of use). Stir, let stand for one minute and compare the intensity of blue color with the color chart. The true color is a little lighter than shown.

If more than 1 drop of reagent "A" is added, the test is abnormally high. If more than 2 drops of reagent "B" are used, or if that reagent contains more than the designated amount of stannous oxalate, a "dirty" blue or greenish blue color results.

The test should be read in one minute since with a longer period of standing the soil extracting solution, when tested as a blank, develops a definite blue color.

Soils which have been heavily treated with soluble mercury compounds for control of insects or fungous diseases may give a dark precipitate on the addition of reagent "B" in the phosphorus test. Such a result, while valuable in suggesting the presence of mercury, completely prevents identification of phosphorus.

Soils which have been heavily treated with arsenic compounds in the control of insect troubles may give unreliably high apparent tests for phosphorus. Amounts of arsenic entering the soil as spray residues have not appeared to be sufficient to affect the reliability of the test.

Reagent "A" should not show more than a trace of sediment in the bottle in which it is stored. If the molybdate has a definite tendency to precipitate, the reagent is unreliable. This reagent, when carefully prepared, should be stable for six months or more; but unless the directions are carefully followed, it may deteriorate in a much shorter time.

Potassium test: Transfer 10 drops of the soil extract to the test vial (10 mm. inside diameter). Add 1 drop of reagent "A" and 8 drops of reagent "B". Let stand one minute; shake the vial gently and let stand two minutes longer. Estimate the resulting amount of yellow precipitate by the following use of the "line" chart:

Hold the vial vertically, directly over the lines on the chart, with the bottom of the vial one inch above them. Look down through the vial at the different groups of lines, until the set is found which can be barely perceived. The test is read which corresponds to this set of lines. If no perceptible turbidity is obtained, the test is obviously lower than in the case of a very slight turbidity which is not sufficient to obscure the faintest lines on the chart, and should be so recorded.

In general, a soil giving only faint traces of turbidity is recorded as "very low" (100 lbs. per acre), while a negative test, showing no perceptible milkiness, is indicated as "extra low" (50 lbs. per acre). The printed chart is not sufficiently delicate for such differentiations.

Calcium test: Transfer 10 drops of the soil extract to the test vial. Add 1 drop of the reagent, shake vigorously and let stand for five minutes. Compare the resultant white turbidity with the chart, using the following procedure:

Hold the vial vertically over the black background to the left of the gray discs, with the bottom of the vial one inch above the chart. Look down through the vial, comparing it with the various discs on the chart.

Magnesium test: Transfer 10 drops of the soil extract to the spot plate. Add 1 drop of reagent "A-2" and 3 drops of reagent "B". Stir, let stand one minute and compare the resultant light salmon to deep red color with the chart.

If a "high" or "very high" reading is found, it is desirable to repeat the test, using reagent "A-1", which is especially sensitive in this range, in place of reagent "A-2". The procedure is otherwise the same. A deep blue test is read as "very high", while with decreasing amounts of magnesium lavender and pink colors are obtained. No separate chart is included for reagent "A-1". In the lower ranges of magnesium concentration, reagent "A-2" gives more readable tests.

Aluminum test: Transfer 2 drops of the soil extract to the spot plate. Add 2 drops of the Universal soil extracting solution and 1 drop of the reagent. Let stand one minute, and compare the resultant yellow, brownish yellow to lavender color with the chart. The true top color is slightly more blue than shown.

If a "dirty" blue-gray color results from this test, it is indicative of abnormal concentrations of active iron; hence a supplemental test for this constituent should be made.

After completing the reading, add 1 drop of 1:1 hydrochloric acid (equal parts of C.P. hydrochloric acid and distilled water) and shake the block gently before washing it. This prevents the formation of a stain on the porcelain which may interfere with subsequent tests.

The reagent in this test deteriorates slowly, and should be freshly prepared every two months.

Manganese test: Transfer 10 drops of the soil extract to the spot plate. Add 1 drop of reagent "A", stir and add 1 drop of reagent "B". Stir and compare the resultant blue color with the chart as quickly as possible, since the intensity of color fades rapidly after a few seconds. The true color is a slightly greener blue than shown.

If more than 1 drop of reagent "B" is added, or if the tip of the pipette used in transferring that reagent is abnormally large, the test may fail, since too much alkalinity interferes with the test. This test, if properly conducted, is extremely sensitive.

(If the soil contains abnormal concentrations of nitrite nitrogen, a brownish yellow discoloration is to be noted in the routine manganese test. In this case a supplemental nitrite test should be made.)

If no perceptible blue color is detected, add 2 drops of reagent "C". Stir at once with a glass rod and let stand for two minutes. If not more than a faint blue color appears, the test is recorded as "negative", and the soil contains less than 2 pounds of manganese per acre. If there is a strong blue color, without a trace of green or yellow, a "trace" amount is read, representing approximately 2 pounds per acre. If the color is green, gradually changing to yellow, this is recognized as "trace plus", or approximately 3 pounds per acre. If any blue color whatsoever was apparent in the previous stage of testing, a deep yellow to orange-yellow color now develops almost at once.

The above additional procedure is especially useful in differentiating soils suspected of being manganese-deficient.

If a comparatively high reading was originally obtained, it may be desirable to confirm it with a further test involving a separate procedure, as follows:

Transfer 10 drops of the extract to the spot plate and add 2 drops of reagent "C". Stir briskly for two minutes and let stand for two minutes. A rose or lavender color, resulting from the development of permanganate, indicates an abnormally high concentration of active manganese in the soil. No chart for this test is included.

SPECIAL SUPPLEMENTAL TESTS

Iron test (both ferric and ferrous): Transfer 10 drops of the extract to the spot plate. Add 3 drops of reagent "A" and 1 drop of reagent "B". Stir, let stand two minutes. The resultant colors indicate amounts approximately as follows:

Color	Test	Approximate Amount per acre of surface soil
Blue	Very high	500 lbs.
Blue green	High	250 lbs.
Apple green	Medium high	100 lbs.
Pale green	Medium	50 lbs.
Greenish yellow	Low	25 lbs.
Lemon yellow	Very low	10 lbs.

In this and subsequent iron tests, care should be taken to prevent the soil extracting solution or soil extract from coming in contact with any implement or piece of apparatus containing metallic iron.

Ferric iron test: Transfer 10 drops of the soil extract to the spot plate. Add 3 drops of reagent "A" and 1 drop of reagent "B". Stir and let stand two minutes. The resultant colors represent amounts approximately as follows:

Color	Test	Approximate Amount per acre of surface soil
Deep brownish red	Very high	300 lbs.
Medium brownish red	High	200 lbs.
Pale brownish red	Medium high	75 lbs.
Very pale brownish red	Medium	40 lbs.
Slight reddish tint	Low	15 lbs.
Very faint reddish tint	Very low	5 lbs.

Ferrous iron test: Transfer 10 drops of the soil extract to the spot plate. Add 2 drops of reagent "A" and 1 drop of reagent "B". Stir and let stand two minutes. The resultant colors and corresponding tests are the same as indicated for the above general iron test (ferric and ferrous).

Sulfate sulfur test: Transfer 10 drops of the soil extract to the test vial. Add 1 drop of the reagent. Shake vigorously and let stand for five minutes. Compare with the calcium chart. Pounds per acre are approximately one-fifth those indicated for corresponding calcium tests.

Since this test is not sensitive over the range of concentrations existing in most soils of humid regions, except as a result of heavy applications of sulfate materials, it is not conducted as a routine procedure.

Nitrite nitrogen test: Transfer 10 drops of the soil extract to the spot plate. Add 1 drop of the nitrite reagent, 1 drop of hydrochloric acid (1:1) and 4 drops of magnesium reagent "B" (15 percent NaOH). Stir and let stand one minute. The resultant colors represent amounts approximately as follows:

Color	Test	Approximate Amount per acre of surface soil
Yellowish orange	Very High	50 lbs.
Orange yellow	High	25 lbs.
Lemon yellow	Medium	10 lbs.
Pale yellow	Low	5 lbs.
Trace of yellowish tint	Very Low	2.5 lbs.

Soils very rarely show readable nitrite tests under field conditions; hence this test is not used in the routine procedure.

Sodium test: Since the Universal soil extracting solution contains sodium, the soil must be extracted with the special sodium extracting solution. The procedure of extraction is not otherwise different.

Transfer 4 drops of the extract, thus obtained, to a test vial. Add 20 drops (1 ml.) of the reagent. Shake vigorously at one minute intervals for 10 minutes and compare with the potassium chart. The amounts in pounds per acre are approximately 10 times those indicated for potassium.

Soils in humid regions, except those receiving overflow water from oceanic tides, rarely show readable tests by this procedure. This test is especially applicable to alkaline conditions existing in arid soils.

Chloride test: Since the Universal soil extracting solution gives a precipitate of silver acetate when tested with the chloride reagent, the soil must be extracted with the special chloride extracting solution, or by distilled water, if clear extracts can be obtained thus. The procedure of extraction is the same in other respects.

Transfer 10 drops of the soil extract, so obtained, to the test vial. Add 1 drop of the reagent. Shake vigorously, and compare the resultant turbidity with the calcium chart. The amounts in pounds of chlorine per acre are approximately as follows, when read on the calcium chart, from top to bottom: 4000-2500-1500-500-250-125.

This test is valuable on saline soils, or when contamination from sea water or sea spray is suspected. Normal soils of humid regions rarely give readable tests, except when recently receiving liberal amounts of fertilizers containing chlorides.

Carbonate test: A soil containing carbonates in appreciable amounts is readily identified by the development of effervescence on the soil surface when the Universal soil extracting solution is filtered through it. This usually results in the development of a convex soil surface at the end of the extraction. No quantitative measurement is attempted.

Soils high in carbonates also give extracts which show white precipitates on the addition of an alkaline reagent (Ammonia reagent or magnesium reagent "B"). Normally this precipitate does not interfere with the color reactions and is due to the formation of calcium hydroxide in excess of its solubility.

Boron test: Extract 1 level *tablespoonful* of soil, in a folded filter cone with 10 ml. of the Universal soil extracting solution. Transfer 4 drops of the extract to a spot plate depression. Add two drops of reagent "A"

and 5 drops of reagent "B". Stir thoroughly until a uniform color is obtained. A clear golden yellow is "negative", representing an amount of boron below the limits of sensitivity of the test. Boron is indicated by increasing depths of a reddish color. When this is just perceptible, the boron content of the soil is about 4 pounds per acre, an amount that should be adequate for normal growth. If a fairly deep red color develops, boron may be present in amounts sufficient to produce injury. It is suggested that the test be calibrated by standard amounts of boron, as boric acid, dissolved in the Universal soil extracting solution.

Zinc test: Prepare the soil extract in the same manner as for the boron test. Transfer 10 drops of the extract to a test vial. Add 4 drops of reagent "A" and 10 drops of reagent "B". Shake thoroughly and let stand for two minutes. Add 20 drops of reagent "C". Shake gently and let stand for 10 minutes. The appearance of a blue color at the film of contact between the ether and the aqueous solution is evidence of zinc. A barely perceptible film of blue indicates approximately 10 parts per million in the extract. Above about 25 p.p.m. a blue precipitate begins to accumulate in the bottom of the vial. The test should be compared with those obtained from standard amounts of zinc as zinc acetate, dissolved in the Universal soil extracting solution. It has not yet been possible to calibrate the above amounts in the extract in terms of that which is active in the soil. However, the presence of considerable zinc, thus shown, is evidence of the accumulation of harmful concentrations, as occasionally found in the vicinity of industrial plants processing zinc ore or metal.

Copper test: Prepare the soil extract as for the boron test. Transfer 10 drops of the extract to the spot plate. Add 2 drops of the above reagent. Stir and let stand for five minutes. A barely perceptible trace of greenish yellow color is observed when approximately 2 p.p.m. of copper are present in the extract. The color deepens in greenish hue, with higher amounts, being quite definite at 5 p.p.m., and at 10 p.p.m. a good apple green color is developed. Readings of the test should be calibrated against standard amounts of copper, as copper sulfate, dissolved in the Universal soil extracting solution.

The copper test is especially useful in examining soils with considerable accumulations of spray residues.

SPECIAL PRECAUTIONS

All glassware, test blocks, stirring rods, etc., should be washed with clean tap water and rinsed with distilled water immediately after being used.

The eyedropper pipettes may be flushed by vigorously pumping water from a beaker in and out of them by intermittent pressure on their bulbs. Any adhering precipitates should be carefully brushed loose from the bottoms of the test vials before final rinsing.

Reagent bottles should be kept clean, and encrustations should not be permitted to accumulate around their caps.

Any reagent that fails to give a satisfactory blank test with the soil extracting solution, or that fails to give high tests on "check" soils consistently giving high results on previous trials for a given constituent, should be rejected and replaced.

SOIL REACTION

The degree of acidity or alkalinity, in terms of pH, is not indicated by the tests of the Universal soil testing system. However, a knowledge of at least the approximate reaction of the soil is very desirable. The simple field test kits for pH are usually adequate for practical diagnosis, especially when used in connection with the Universal tests. When more exact results are desired, electrometric measurements, using the quinhydrone or glass electrode procedures, are now reasonably well standardized. These are also much more rapid in manipulation when large numbers of soils are to be tested in routine.

INTERPRETATION OF TESTS

The details of the section on interpretation of tests, printed in Bulletin 392, are omitted. These refer chiefly to Connecticut conditions. It must be clearly recognized that the results of the tests are relative rather than quantitative in the true sense. Those who use soil tests to the best advantage make careful study of the results under a range of soil and crop conditions in a given region, and thus build up a composite picture of the relationships of the tests to various conditions of fertility with respect to the crops with which they are concerned.

It is not economically practicable to build up pasture or general field crop soils to the high plant nutrient level that is desirable in the intensive culture of crops giving large returns per unit area. Naturally poor soils receiving the modest fertilizer treatments needed to obtain profitable yields of general farm crops are rarely built up to a point where high tests for nitrates, phosphorus and potassium can be expected.

PLANT TESTS

It is frequently desirable to verify a case of suspected crop deficiency or nutrient abnormality by means of chemical examination of the plant itself. The visible symptoms produced by the serious deficiency or excess of a given constituent are frequently recognizable by the trained observer, if not modified by the effects of some other factor. But in the field, the plant may be suffering from maladjustment of two or more chemical constituents. Under such conditions, chemical tests of plant tissue are an aid to proper diagnosis.

For plant tissue tests of this sort, the material should be taken from the leaf petiole or from the succulent part of the stem in the portion of the plant most affected by abnormal symptoms. Normal and questionable plants both should be tested simultaneously wherever possible.

Suggested procedure for plant test: Cut up a quantity of the plant tissue to be tested into small cubical sections about 2 mm. in thickness. Mix carefully, and measure a level half-teaspoonful of this material into the filter cone. Extract with 10 ml. of the Universal soil extracting solution and conduct the desired tests in the same manner as previously described for soils.

It is to be noted that reagent "C" must be used for plant material when testing for manganese. It is usually desirable to test for the following constituents: nitrates, ammonia, phosphorus, potassium, calcium, magnesium, manganese and iron.

The color charts should be used for comparative purposes only, as the tests obtained vary widely with the chemical characteristics of the plant. Interpretations of the significance of estimated relative amounts should be based on comparison between normal and affected plants of the species in question.

APPLICATION OF TESTS TO DRAINAGE WATER FROM SOILS

It is frequently desirable to obtain a rough picture of the relative amounts of various soluble chemical constituents in the drainage water from soils, or in the waters of springs or streams. The tests previously described can be applied for this purpose, although a few adjustments are required to compensate for the poor buffer action of such dilute solutions. The following procedures are suggested for the various tests.

Nitrate nitrogen: Proceed as for soil test. Readings, in parts per million, corresponding to the chart colors are approximately as follows, from top to bottom: 15-10-6-3-2-1. If necessary, dilute with distilled water to a definite ratio before testing, and calculate results on basis of dilution used.

Ammonia nitrogen: Proceed as for soil test, except that only one drop of the reagent is added. Readings, in parts per million, corresponding to the chart colors are approximately as follows, from top to bottom: 25-15-10-5-3-2.

Phosphorus: Place in the spot plate depression 5 drops of the water to be tested. Add 5 drops of the Universal soil extracting solution. Proceed as for soil test, except that only one drop of reagent "B" is desirable. Readings, in parts per million, corresponding to the chart colors are approximately as follows, from top to bottom: 3-2-1-0.5-0.3-0.2.

Potassium: Proceed as for soil test. Readings, in parts per million, corresponding to the chart lines are approximately as follows, from top to bottom: 60-50-40-30-20-15.

Calcium: Place in the test vial (10 by 50 mm.) 10 drops of the water to be tested. Add 2 drops of the Universal soil extract and 1 drop of the calcium reagent. Proceed as for soil test. Readings, in parts per million, corresponding to the chart discs are approximately as follows, from top to bottom: 400-300-200-100-75-50.

Magnesium: Place in the spot plate depression 10 drops of the water to be tested. Add 5 drops of the Universal soil extracting solution. Add 1 drop of reagent "A-2" and 2 drops of reagent "B". Proceed as for soil test. Readings, in parts per million, corresponding to the chart colors are approximately as follows, from top to bottom: 40-20-10-5-3-2.

Aluminum: Place in the spot plate depression 4 drops of water to be tested. Add 1 drop of Universal soil extracting solution, and 1 drop of the reagent. Proceed as for soil test. Readings, in parts per million, corresponding to the chart colors are approximately as follows, from top to bottom: 10-5-2-1-0.4-0.2.

Manganese: Place in the spot plate depression 10 drops of water to be tested. Add 1 drop of 1:3 acetic acid (one part glacial acetic acid to three parts of distilled water). Add 1 drop of reagent "A" and 1 drop of reagent

"B". Proceed as for soil test. Readings, in parts per million, corresponding to chart colors are approximately as follows, from top to bottom: 12-7.5-5-2.5-1-0.5.

Iron tests: Proceed as for soil test. Readings, in parts per million, corresponding to color descriptions indicated, are approximately as follows: 50-25-10-5-2.5-1.0.

Sulfate sulfur: Proceed as for soil test. Readings, in parts per million, made on the calcium chart, are approximately as follows, from top to bottom: 200-150-100-50-20-10.

Nitrite nitrogen: Proceed as for soil test. Readings, in parts per million, corresponding to color descriptions, are approximately as follows: 10-5-2.5-1.0-0.5.

Sodium: Proceed as for soil test. Readings, in parts per million, made on the potassium chart are approximately as follows, from top to bottom: 600-500-400-300-200-150.

Chlorine: Proceed as for soil test. Readings, in parts per million, made on the calcium chart, are approximately as follows: 800-500-300-100-50-25.

Boron: Proceed as for soil test. Standardize readings against aqueous solutions of boron, as boric acid, of known concentrations, ranging from 50 to 2 parts per million.

Zinc: Proceed as for soil test. Standardize readings against aqueous solutions of zinc, as zinc chloride, of known concentrations, ranging from 50 to 5 parts per million.

Copper: Place in the spot plate depression 10 drops of the water to be tested. Add 2 drops of Universal soil extracting solution, and proceed as for soil test. Standardize readings against aqueous solutions of copper, as copper sulfate, of known concentrations, ranging from 25 to 2 parts per million.

The above methods have also been found to be very helpful in control of concentrations of various constituents employed in water or sand culture methods of growing plants.

COMPOSITE SOLUTION STANDARDS

The color and turbidity charts prepared for distribution with this circular are the results of the best efforts of the engraver and printer. However, it is very difficult to obtain true reproductions by the photo-engraving process. Hence it is desirable to provide a means of checking them with solutions containing a range of concentrations of the various constituents determined in the routine tests. Hand-colored charts made up by matching tests given by solution standards will serve when printed charts are not available.

The following scheme employs a series of stock solutions containing the various constituents. Aliquot portions are used for the preparation of composites which give approximately the same relative levels of concentration for the various tests.

Preparation of Stock Solutions

Prepare separate stock solutions for each constituent, dissolving quantities of the C.P. chemical shown in the following table in 100 ml. of the *Universal soil extracting solution*:

Constituent	Chemical	Grams per 100 ml. <i>Universal soil extracting solution</i>	Concentration of Constituent p.p.m.
Nitrate nitrogen	Sodium nitrate-NaNO ₃	.607	1,000
Ammonia nitrogen	Ammonium sulfate-(NH ₄) ₂ SO ₄	1.258	1,500
Phosphorus	Mono-sodium phosphate-NaH ₂ PO ₄ ·H ₂ O	.045	100
Potassium	Potassium chloride-KCl	.764	4,000
Calcium	Calcium acetate-Ca(C ₂ H ₃ O ₂) ₂ ·H ₂ O	13.210	30,000
Magnesium	Magnesium acetate-Mg(C ₂ H ₃ O ₂) ₂ ·4H ₂ O	1.766	2,000
Aluminum	Aluminum chloride-AlCl ₃ ·6H ₂ O	1.338	1,500
Manganese	Manganous sulfate-MnSO ₄ ·4H ₂ O	.203	500

Preparation of Composite Solution Standards

ml. of stock solutions

	"High" standard	"Medium" standard	"Very low" standard
Nitrate nitrogen	2	0.6	0.2
Ammonia nitrogen	2	0.6	0.2
Phosphorus	2	0.6	0.2
Potassium	2	1.0	0.6
Calcium	2	1.0	0.6
Magnesium	2	0.6	0.2
Aluminum	2	0.6	0.2
Manganese	2	0.6	0.2

Dilute each standard to a total volume of 200 ml., using the *Universal soil extracting solution*.

Corresponding portions of the above composite solution standards should be tested in the same manner as for soil extracts, in order to familiarize the operator with the true color or turbidity range for each test.