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SOIL TESTING

*A Practical System of
Soil Fertility Diagnosis*

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COLLEGE

AGRICULTURAL
EXPERIMENT
STATION

SECTION OF SOIL SCIENCE

EAST LANSING

SOIL TESTING

A Practical System of Soil Fertility Diagnosis

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MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
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SOIL TESTING

A Practical System of Soil Fertility Diagnosis by Means of Chemical Tests

PART I

GENERAL CONSIDERATIONS AND INTERPRETATIONS

OBJECT OF THE BULLETIN

THIS BULLETIN DESCRIBES AN extensive system of soil testing, which involves a coordinated group of several soil tests. This procedure has many advantages over the use of single soil tests because a more complete soil fertility diagnosis is obtained, permitting a more logical and practical interpretation of the results. Any other method of procedure for testing soils that is concerned with only one factor, or at the most, a few factors, of plant growth is exposed to the chance that some important factor may be overlooked. The tests are sensitive and accurate when used under the proper conditions of pure chemicals and clean apparatus. They have been checked with a large number of chemical compounds common to soils and are believed to be specific in each case.

IMPORTANCE OF SOIL TESTING

In fields, gardens, or greenhouses, on lawns, estates, and golf courses, wherever soils are used for the production of crops, the applications of soil testing are virtually unlimited. A pertinent fact concerning soils is that no one can look at a soil or feel it, and by those means determine anything about its active chemical condition. The chemical nature of a soil must be revealed by means of chemical tests. While it is realized that much more can be learned about soil testing and the practical interpretation of the test results, enough progress has been made in this connection to give to soil testing a high degree of usefulness when applied in a logical manner.

Virtually all degrees of fertility are found in agricultural soils. They vary markedly in content of soluble chemical substances that affect plant growth. Generally speaking, either one or more plant nutrients may be found deficient in soils, and toxic or poisonous substances sometimes occur in situations favorable for their development.

Information concerning the chemical composition of soils, particularly of that portion soluble in the soil water and commonly known to affect plant growth, is of practical importance to producers of plants and plant products and to other persons engaged in soils research or educational work. Human experience in the field of soil science and the practical

production of crops has shown conclusively that productive soils always contain an adequate supply of plant nutrients and that they are also characterized by the absence of chemical factors deleterious to plant growth.

Maintaining or increasing the productiveness of soils by suitable methods has been, and still is, one of the main problems of crop growers. Profitable soil management, however, depends on knowledge of what a soil needs in the way of fertilization or other improvements. No one can reach a high degree of efficiency in the management of a soil without information about the chemical conditions in that soil. Systematic soil testing gives definite information concerning soil conditions that can be obtained in no other way and serves as a logical basis for outlining soil improvement practices and treatments.

Teachers of agriculture, in conducting soils classes, will find these rapid soil tests useful for demonstrating the chemical nature of various kinds of soil and the differences that may exist among soils. Many interesting and instructive experiments can be devised, using chemical tests to show the effects of various soil treatments on the solubility or availability of soil constituents. By using the tests themselves, the students' interest in their work is greatly increased.

SYSTEMS OF SOIL ANALYSIS

The three general systems of soil analysis which have been practiced for some time are (1) total analysis, (2) analysis of the soil portions soluble in strong acids, and (3) the analysis of water extracts, salt extracts, or of dilute acid extracts of soils.

The first two systems have given valuable information about the chemical composition of soils, but their results include some portion of the soil constituents not readily soluble in the soil water under the usual crop conditions; hence, the results obtained by these methods do not correlate well with plant growth or the response of plants to fertilizer applications, and their practical usefulness is limited in this respect. In recent times, however, more dependence has been placed on the third system of soil analysis, chiefly because, with respect to the part played by soils in the nutrition of plants, the supply of the easily soluble or available soil constituents in the soil solution and the power of the soil to maintain this supply throughout the life of the plant, or during certain critical periods in the growth of the plant, are the main considerations. In other words, this system of soil testing gives a better idea of the chemical activities of the soil. Testing soils for their content of easily soluble or available constituents, therefore, gives a better understanding of the possible supply of plant nutrients and other soluble soil components more immediately concerned with plant growth.

INTERPRETATION OF SOIL TEST RESULTS

A factor of plant growth is anything that influences the growth of plants. There are many individual factors of plant growth, but they may be classified briefly into three main divisions: (1) climatic factors, (2) soil factors, and (3) factors inherent in the plant itself.

The soil factors may be further subdivided into physical, chemical, and biological factors. A plant grows in a certain coincidence of all of the plant growth factors, each one operating either to aid or hinder growth. This coincidence of all of the plant growth factors is the home of the plant, the environment in which it lives; and from the standpoint of improving plant growth conditions, each one of the many factors assumes more or less importance, as the case may be. Also, a plant grows in a certain coincidence of chemical soil factors, and this coincidence of all the chemical factors, rather than a single factor or a few chemical factors, should be taken as the soil testing unit in the interpretation of the test results; but the chemical test results should be considered in connection with all the other known factors of plant growth applicable to the case. When we realize that normal plant growth is conditioned by many factors, it is certainly fallacious to draw conclusions on the basis of the incidence of a single factor or a single soil test result. Therefore, all of the tests should be applied to each soil sample before an attempt is made to interpret the results, unless from knowledge and experience the operator is sure that a certain test does not apply in the case and may be omitted. The specific applications of certain tests are mentioned in the discussions dealing with them.

Chemical soil tests give us practically no information about the important physical factors of plant growth or of those factors affecting plant growth which are common to soils, such a drainage, water supply, physical condition, tillage methods, and soil temperature. Furthermore, the tests do not show the possible effects of future seasonal conditions on these factors; therefore, the results of the chemical testing of soils do not always correlate with plant growth or the response of plants to fertilization. When all the other factors of plant growth are normal, however, the production of a crop may be limited if the supply of one or more nutrient elements is too low, or if a toxic condition prevails in the soil. Under those conditions, crops usually respond to the application of the limiting element to the soil in the form of fertilizers or to the destruction of the toxic agent present. If, however, one or more of the physical factors of plant growth are limiting, it is illogical to expect a correlation between plant growth and the results of the chemical testing of soils.

To simplify the interpretation of the test results as much as possible, only four divisions of the results are used in this publication—namely,

blank, low, medium, and high. This classification is used comparatively, and is based on general information obtained from the testing of a large number of soil samples. It is a natural classification based on soil test results. A blank test result means that the proper color or precipitate is not obtained in the testing operation and indicates, therefore, that the amount of the substance for which the test is made is so low as to be beyond the sensitivity of the test reaction used. A blank test does not necessarily mean that the substance under consideration is entirely absent from the soil extract, but it does show that this substance is very low in amount. A low test means that the quantity of the substance is sufficient to indicate a test result but that it is comparatively low. In this connection, the words "medium" and "high" have their usual significance; that is, as soils are usually tested, the substances indicating one or the other of these test results are comparatively medium or high in amount. A high test result indicates either that there is an abundant supply of plant nutrient or that too much may be present for normal plant feeding. In the case of chemical substances toxic to plants in comparatively high concentrations, such as nitrates, sulfates, chlorides, manganese, aluminum and others, a high test result should be regarded with suspicion; but a rational interpretation of the test result will depend on other factors which will be considered in more detail later in the special discussions of these substances.

As has been stated, the supply of nutrient elements in soils is but one group of factors contributing to the profitable production of crops; hence, in a logical interpretation of the results of chemical tests on soils, considerable attention must be paid to the other factors of crop production, because they help, in many cases, to define more clearly the soil management problem and to indicate more positively the necessary soil treatment. The appearance of a growing crop is a valuable aid in interpreting the chemical test results obtained from the soil. Any factor of plant growth may become limiting and affect the plant in some way as, for instance, the production of abnormal colors in the foliage, stunted growth, or low yield of product. These conditions are sometimes found in spots associated with other areas of more productive soils. When it can be established that the poor growth of the crop is not due to a poor physical condition of the soil, lack of water, cold soil, plant disease, poor seed, high water table, or the depredations of insects, the reason for the poor condition of plant growth will usually be due to malnutrition of the plants, caused by a lack of one or more nutrients or by the presence of a toxic soil condition. Under conditions of crop production where large amounts of commercial fertilizers are used, a large excess of one or more soluble substances in the soil may also cause malnutrition of the plants. This condition often occurs in greenhouses.

In interpreting chemical test results in respect to plant growth, or response of crops to fertilization or other soil treatments, the extent of the plant root system and the time of occupation of the land by the crop are important matters. Many cultivated crop plants obtain their mineral nutrients almost entirely from the upper layers of the soil because of their shallow root systems, while other plants extend their roots into the soil to a depth of several feet. A deep-rooted crop that occupies the land for a full growing season or longer can draw nutrients from a much larger volume of soil for a longer time than can a shallow-rooted, short-seasoned crop; hence, the former kind of crop can obtain its nutrients from lower nutrient concentrations in the soil.

Through weathering of soil minerals and decay of organic matter the soil elements gradually become dissolved in the soil water, so that the total seasonal supply of dissolved materials is not in solution at one time. As the dissolved or available chemical compounds of the soil are leached out or taken up by plants, more come into solution from the soluble portions of the soil. Chemical test results on soil extracts obtained by means of water or dilute acids rarely show the total quantity of soluble soil substances available in the soil solution for a plant-growing period. They do show, however, the quantity of dissolved or easily soluble substances or of those elements available for a certain period of time. Different soils vary greatly in the amount of dissolved materials they contain and in the rate at which they enrich their solutions in this respect. A low chemical test result on a soil shows a small amount of dissolved substance in the soil extract and also a low power of solution enrichment at that time; hence, in the case of plant nutrients, the need for fertilization.

Whenever possible, it is preferable to test soils in a systematic manner because the comparison of the test results on one soil with those obtained from another soil may lead to important conclusions. Soil test results from samples of different kinds of soil, good and poor spots, knolls and low places, productive and unproductive soils, and soils receiving different fertilizer treatments may be compared with profit. The testing of soil samples from situations that show differences in plant growth can lead to important discoveries about the soil.

Chemical soil tests will give useful information about the supply of available plant nutrients or the presence of toxic elements in a soil within certain limits. They show, for instance, whether a soil is unusually low or is well supplied with available plant nutrients and indicate what plan of fertilization or other soil treatment is likely to be profitable. They are useful for determining the nature of soil management problems with respect to the effect of fertilizers and other chemical compounds on soils. Perhaps the main use of chemical soil tests

is to determine if a soil is unusually low in one or more fertility constituents, or if a toxic condition is present.

SPECIFIC USES OF THE SOIL TESTS

In this section and elsewhere in the bulletin, ppm. means parts per million in the soil extract. (See the sections on "Extracting the Soil" and "Calculations.")

NITRATES

Nitrogen is the nutrient element required by plants in the greatest amounts. It is found chiefly in the organic matter of soils. The nitrogen of the soil organic matter is transformed to ammonia and then nitrite and finally to nitrate by means of the action of soil organisms. In order for a soil to form nitrates naturally, it should have a supply of nitrogen in organic matter, be moist, warm, and aerated, and have the nitrifying organisms present. Soils very low in organic matter content are usually low in nitrate. A productive soil will develop nitrate throughout the growth period of the crop. When a soil does not produce a supply of nitrate sufficient for the crop, nitrogen should be added in the form of organic matter, manure, or fertilizers containing it.

Growing plants obtain most of their nitrogen from the soil as nitrate which is usually present, naturally, in soils mostly as calcium nitrate, although other nitrate compounds may exist in soils under suitable conditions. Nitrates are very soluble in water and, hence, easily lost from soils, especially sandy soils, by leaching. Because nitrates are soluble and dependent on the nitrifying process for development, the nitrate content of soils may fluctuate considerably during a crop growing season. The fact that a soil was fertilized with nitrogen at crop seeding time is no proof that the crop will obtain a sufficient supply of nitrate throughout its growth period. The best use of the nitrate test, therefore, is to make tests at regular periods, at least during the time the crop should make a steady, thrifty, vegetative growth.

Interpretations:

1. As nitrates are soluble in water, the test indicates practically the total quantity of nitrate in the soil.
2. Low nitrate in the soil, either before the crop is planted or while the plants are small, especially if the plants have a yellow-green color and show a slow, stunted growth, indicates nitrate deficiency.
3. Low nitrate soil test results may indicate: (a) Nitrate not produced in the soil, or (b) nitrate taken up by the crop as fast as produced, thus indicating a low reserve supply, or (c) nitrate washed from the soil by rains or heavy watering.

4. Medium nitrate test results indicate a normal nitrate supply.
5. High nitrate test results—100 to 150 ppm. or more—indicate excess nitrate, especially if the plant growth shows a harmful soil condition.
6. The nitrifying power of a soil low in nitrate content may be measured by placing a sample of the moist soil in a covered container in a warm room for a day or two or longer, and testing it for nitrate at regular intervals of time.
7. When the results are to be correlated with plant growth conditions, nitrate tests should be made on fresh soil samples.

PHOSPHORUS

Phosphorus is an important plant nutrient element. It is present in both the organic matter and in the mineral part of soils. It is made soluble in the soil and available to plants by the decay of organic matter and by the weathering of soil minerals. The supply of available phosphorus and the power of the soil to maintain this supply are two main considerations with respect to available soil phosphorus. Many agricultural soils are low in their content of this important plant nutrient element. Many crop growers consider phosphorus to be the element most often deficient in field soils. A soil may test low in phosphorus when growing a heavy crop, as in the case of nitrates, owing to the exhaustion of the available supply by the crop. Excessive quantities of soluble phosphates in greenhouse soils cause injury to plants. The three chief effects of soil phosphorus on plants are (1) it stimulates root growth, (2) hastens the maturity of the crop, and (3) improves the quality of seeds, especially grains.

Soils revert, or make insoluble, some of the phosphorus applied to them in fertilizers, and some soils have this power in greater magnitude than others. In certain soils, therefore, the application of 100 pounds of superphosphate per acre may cause a difference in test results between fertilized and unfertilized soil; but, in other soils, 400 or 500 pounds or more of superphosphate may be required to produce much difference in the test results. In other words, the reverting, or absorbing power of a soil for phosphorus must be satisfied before a considerable amount of phosphorus will be found in the soil extract.

Interpretations:

1. Field soils that test less than 1 ppm. of soluble phosphorus need phosphate fertilization for best crop growth, especially for shallow-rooted plants or young plants. Deep-rooted crops with extended root systems feed better on soil phosphorus.

2. For forced plant growth, as in greenhouses and on lawns or golf courses, a continuous supply of $2\frac{1}{2}$ to 5 ppm. is more suitable.

3. The excess range of phosphorus begins at about 50 ppm., but this is rarely attained even under heavy fertilization.

4. Poor root growth, late maturity in crops, and shrunken seeds all are indications of phosphorus deficiency.

POTASSIUM

Potassium is found in both the organic matter and the mineral matter of soils but occurs chiefly in the mineral matter and becomes available to plants by solution in the soil water. All soils, except mucks and peats, contain relatively large amounts of "total" potassium, but the amount available to plants in any one soil may be low, especially in sand soils.

A limiting quantity of potassium in the soil causes marked disturbances in plants but, unless the potassium supply is very low, the effects are not clearly visible. When potassium becomes limiting to plant growth, the plants may show a stunted, slow growth, the leaves become yellowish or dull-colored at the edges and finally bronze or brown toward the centers. In extreme cases the leaves fall from the plants. A large proportion of small, shrunken, misshaped pods and seeds of legumes, or of fruits, flowers, tubers, and roots may indicate potassium deficiency in the soil. *In all cases, however, one must be sure that an unhealthy or discolored appearance of plants is not due to diseases or insects before attempting to diagnose soil deficiencies or troubles by this means.*

In soil fertility diagnosis, to obtain more information from the use of the potassium test, two forms of potassium in the soil may be recognized; (1) the fixed, replaceable, or reserve potassium, and (2) the soluble, active, or immediately available potassium. The soil supply of active potassium is important to growers of forced, short-season, and high-value crops, and to growers of crops known to respond markedly to potash fertilizers. In the case of long-season field crops having a comparatively low per-acre value, more dependence can be placed on the reserve potassium supply of the soil to furnish potassium to the crop.

Interpretations:

1. Either a low or blank test result for active potassium indicates the need for potash fertilization for intensive crop production, or for forced or high-value crops.

2. A continuous supply of about 10-20 ppm. is suitable for good crop growth in the greenhouse, or for forced crop growth. About 5-10 ppm. is suitable for good growth of field crops.

3. The excess range of potassium in greenhouse soils begins at about 50 ppm. which is rather commonly found where large quantities of potash fertilizers are used.

4. Farm soils showing either a blank, or low, test for active potassium may be tested also for reserve potassium (test described under methods) in order to determine the possible supply of this form for long-season crops. A low test result for reserve potassium emphasizes the need for potash fertilization.

CALCIUM

Calcium performs many important functions in the soil in the growth of plants. It is the plant nutrient element commonly found in relatively large quantities in soil extracts from untreated soils. In some form of "lime", calcium is often used to neutralize the acidity of acid soils and to correct the toxic conditions sometimes caused by soil acidity. Soils seldom lack calcium as a plant nutrient, but a low availability of calcium in an acid soil is usually a sign of low soil productivity, especially for crops that need a good supply of this element. Excessive amounts of calcium carbonate in soils are injurious to crops that require medium to strongly acid soils for their best growth.

Interpretations:

1. A low test result for calcium, about 40 ppm., indicates a low available supply and, if the soil is acid, also emphasizes the need for liming to grow "high-lime" crops.

2. 100-150 ppm. of calcium is considered sufficient for most plants.

3. High-calcium test results, 150-200 ppm. in an alkaline soil indicate excessive amounts for acid-soil plants.

4. The calcium supply should not fall below that of potassium or magnesium for forced plant growth.

CARBONATES

In humid climates with a normal amount of rainfall, soils may contain calcium and magnesium carbonates, naturally, in quantities sufficient to be detected by the carbonate test. Very small quantities of carbonates, however, cannot be detected by means of this test. Large quantities of carbonates indicate an alkaline soil, but a few small scattered particles of carbonate may sometimes be found in acid soils; however, a soil may be slightly alkaline and the test may not indicate carbonates. The chief use of the carbonate test is to determine if limestone is present in the soil.

The carbonate test is useful in discovering marl. Marl is usually gray to white and gives a strong carbonate test. The purity of the marl can

be determined roughly by the amount that goes into solution in making the test. Limestone and ashes also give the carbonate test.

THE SOIL REACTION

The reaction of soils may be acid, neutral, or alkaline. In general agriculture and in the growing of special crops, the soil reaction is important for two main reasons, namely; (1) every cultivated plant has a soil reaction preference, some requiring an acid soil, some a neutral soil, and some preferring the alkaline condition, and (2) strongly acid and strongly alkaline soils are often low in productivity and may contain substances toxic to plants.

Interpretations:

1. A very strong acid test result, with poor crop growth, indicates low fertility or the presence of toxic substances. Soil needs lime for "high-lime" crops. Soil may contain toxic substances.

2. Strongly acid or medium acid test indicates soils suitable for most acid-soil crops. Soil needs lime for "high-lime" crops. Soil may contain toxic substances.

3. Slightly acid or neutral, or slightly alkaline test indicates reaction suitable for "high-lime" crops. Slightly acid soils may need lime, if they test low in calcium. These soils are sometimes made acid for acid-soil crops.

4. Strongly alkaline test, with poor crop growth, may indicate too much alkali. These soils are sometimes made acid to correct this condition. (See "*Soil Reaction [pH] Preferences of Plants.*" Michigan Agricultural Experiment Station, Special Bulletin 306.)

AMMONIA

Virtually all soils contain ammonia in small amounts, rarely exceeding a few parts per million. The ammonia of soils is produced naturally by soil organisms from the nitrogen in soil organic matter and the formation of ammonia is the first step in the production of soil nitrates. Soils high in content of decaying organic matter, freshly manured soils, or soils recently fertilized with ammonium compounds may give comparatively high tests for ammonia.

Interpretations:

1. Low ammonia and low nitrate test results indicate a low supply of nitrogen in the soil.

2. High ammonia with low nitrate test results may indicate that some harmful soil condition is interfering with nitrate formation.

Note: The potassium test is not reliable in the presence of 50 ppm. or more of ammonia.

NITRITES

Nitrites are formed in soils as the second step in the production of nitrates. In well drained, aerated soils nitrites are found, usually in only small quantities. An excess of nitrites in a soil is toxic to plants. This condition may arise from decomposition of nitrates when high in amount in *poorly aerated soils*.

Nitrite toxicity is indicated by poor germination of seeds, slow plant growth, small, light green leaves, root firing and, in extreme cases, the plant roots slough off and the plant wilts and dies.

Excess nitrites may be found in greenhouse soils and other soils after sterilization with steam or by other methods of heating, especially if the soil is high in nitrate content before sterilization. Sterilized soils that develop nitrites should be stirred and allowed to stand for several days, or until the nitrite content has fallen below the toxic limit, before planting a crop.

Interpretations:

1. Nitrite test results of 2 to 5 ppm. indicate toxicity due to nitrites.
2. The chief use of the nitrite test is to determine if sterilization of the soil formed nitrites, and also when the nitrite content becomes low enough for safe planting.

MAGNESIUM

Magnesium is an essential plant nutrient element and is present in chlorophyll, the green coloring matter of plants. When magnesium is deficient in a soil, the plants cannot form chlorophyll properly; hence, the leaves become light colored, sometimes change to a brown, or spotted appearance, and often fall from the plants. In certain localities soils too low in magnesium for good crop growth, particularly special crops, may be found. Soils are very unproductive when deficient in magnesium. Low magnesium is usually associated with low calcium in medium to strongly acid soils.

Interpretations:

1. A blank test result definitely indicates magnesium deficiency.
2. A low test result, 1 ppm. or less, indicates magnesium deficiency, especially when accompanied by a sickly, chlorotic (light colored) appearance of the plants.
3. Five ppm. of magnesium is suitable for most plants.

IRON

Soils usually contain sufficient soluble iron to satisfy the needs of plants. Iron aids in the formation of chlorophyll in plants; hence, iron deficiency in a soil may be shown by chlorosis, a pale-yellow or whitish color in plant leaves, a condition which has been observed on alkaline soils. The pH range of low solubility of iron in soils is about 5.5 to 8.5; consequently, it is within this reaction range that iron deficiency may be found, more especially in the higher portions of this range. Large excesses of soluble iron in a strongly acid soil may be toxic to plants. The condition, however, is of rare occurrence, but may arise from the action on soils of ground waters carrying iron or sulfur, or in other ways.

Interpretations:

1. Most soils give low test results for soluble iron. Chlorotic plants on an alkaline soil may indicate iron deficiency. If iron deficiency is suspected, apply the reserve iron test. A low reserve supply of iron emphasizes the possibility of iron deficiency.

2. Excessively high test results for iron in a strongly acid soil indicate iron toxicity. The high iron test will be accompanied, usually, by a high test for sulfates, nitrates, or chlorides.

ALUMINUM

Soluble aluminum in soils is considered very toxic to plants. Aluminum is rather insoluble in soils through the reaction range of about pH 5.5 to 8.0, hence, soluble aluminum is important in strongly acid soils and ordinarily the test is applied only to acid soils. All strongly acid soils should be tested for soluble or active aluminum. Strongly acid spots in field soils may contain active aluminum, and it may be found in acid soils associated with poor drainage. Soils treated with sulfur, sulfate of aluminum, or other acid substances may develop active aluminum in them if the pH is lowered below 5.5.

Interpretations:

1. A positive test result for active aluminum, 2 to 3 ppm., indicates toxicity to "high-lime" crops. Crops that require strongly acid soils are less affected by active aluminum.

Note: Applications of lime and superphosphate to soils correct aluminum toxicity by changing the active aluminum to insoluble forms.

MANGANESE

Manganese in soils is considered essential to plant growth but a high concentration is harmful to plants. In excessive amounts it injures plant

roots (root firing) and causes stunted growth. A deficiency of manganese is sometimes associated with slightly acid to alkaline soil, pH 6.5 to 8.5, but sandy soils may be found deficient in manganese at lower pH values. Manganese is more soluble in acid soils than in alkaline soils.

Interpretations:

1. Only small quantities of manganese are required by plants; hence, a positive soil test result indicates a sufficient supply.

2. On soils where a deficiency of manganese is suspected from plant symptoms, mainly as stunted growth and chlorotic appearance, apply the reserve manganese test. A blank reserve test result indicates manganese deficiency.

3. Soil test results of about 5 ppm. of manganese may be considered dangerous, because the element may concentrate in spots during dry weather, especially in fields, and injure plant growth. High manganese test results, associated with poor crop growth, indicate manganese toxicity (1).

SULFATES

Plants obtain their sulfur supply from sulfates. Sulfates are present in virtually all soils, although soils may be deficient in sulfur in certain localities. They are not harmful to plants except in unusually high concentrations. A high test for sulfates usually indicates that sulfate compounds or sulfur has been applied to the soil or occurs naturally in the soil. Soils may also test high in sulfate content in the vicinity of brine springs or in dry climates.

The sulfate test is useful for determining excessive or toxic concentrations of soluble salts in soils. The excess range begins at about 450 ppm.

CHLORIDES

Chlorides are present in virtually all soils, but they are injurious to plant growth only when present in comparatively large quantities. A high chloride test result and poor plant growth may indicate plant injury due to chlorides.

The chief use of the chloride test is to determine excessive concentrations of soluble salts, and to indicate the presence of common salt (sodium chloride) in soils. The excess range begins at about 100 ppm.

SODIUM

The sodium test is relatively unimportant in most soils. Certain localities, however, may have soils containing rather large amounts of sodium chloride (common salt). Salt may be injurious to plants when present

in a soil in comparatively large quantities. In small amounts, it may stimulate plant growth.

Strongly alkaline soils, pH about 8.5 or higher, in arid climates or in greenhouses and on other situations where heavy applications of fertilizers containing sodium compounds have been made, and where the plants have been watered with hard water, or softened water, may contain sodium carbonate, which is rather toxic to some kinds of plants. These strongly alkaline soils should be tested for sodium.

Interpretations:

1. High test results for both sodium and chloride indicate the presence of salt in the soil.
2. A high test result for sodium in a strongly alkaline soil may indicate the presence of sodium carbonate.

EXCESSIVE AMOUNTS OF SOLUBLE SUBSTANCES

In the fertilization of small soil areas and the use of hard waters for watering plants, the soil sometimes becomes too rich for normal plant growth or acquires excessive quantities of soluble materials. This condition has been found in gardens, in greenhouses, and on lawns and golf greens. In humid climates the condition often occurs in field soils in small areas, especially during continued dry weather, and in dry climates on extensive soil areas. When excessive quantities of soluble substances occur in soils, they interfere with the nutritional processes of many kinds of plants and the plants show abnormal growth. Unusually high test results for one or more soil constituents, especially when associated with poor plant growth, indicate excessive amounts of soluble substances.

Leaching the soil or mixing with it other untreated soil are methods commonly used in greenhouses to overcome this condition.

APPLICATION OF THE SOIL TESTS

The method of attack for soil testing depends on the nature of the soil problem under investigation, or the objectives to be attained in the practical applications of the soil test results. In the initial investigation of a soil, in order to determine its general fertility condition or the cause of crop injury or failure, it is advisable to make all of the soil tests and also to obtain all other pertinent information about the soil and crop. Results of this preliminary and complete investigation will then point the way for subsequent plans for soil improvement and for the future application of soil testing to check the effects of the soil improvement methods applied.

Because of the chemical nature of soils and the inter-relationships of certain soil constituents, however, the soil testing procedure can be

simplified and better results obtained by applying the test methods in a suitable order. Some pertinent points in this connection are given in the following paragraphs.

Test first for carbonate (limestone). (1) If the soil contains carbonates, it will also be either alkaline or near the neutral point in reaction. Then test for degree of reaction, or pH. A soil well supplied with carbonates changes only slowly in this respect, or in reaction, therefore, no further tests for either carbonates or reaction need be made at least for some time. Then proceed with the other tests. Carbonate soils do not contain toxic amounts of either aluminum, iron or manganese. They are well supplied with calcium, and usually with magnesium. (2) When carbonates are not found, test next for degree of reaction. Then make the other tests, and in strongly acid soils look for low calcium, magnesium, and for soluble aluminum, iron and manganese. Low test results, however, may be found with any soil.

Because nitrates are used by crops in large quantities, and vary considerably in amount in soils during one crop season, periodic tests for nitrates should be made during the season, especially throughout the time of strong vegetative growth of the crop, to insure a sufficient supply.

Potassium is used by crops in quantities second to nitrate, and the supply should also be sufficient for good vegetative growth. In most soils, however, the potassium supply remains rather constant, although it may be found either adequate, low or markedly deficient. Soils found comparatively high in content of available potassium, therefore, will remain in that condition for some time.

The solubility of soil phosphorus is influenced markedly by soil conditions; therefore, always make the phosphorus test unless the soil is found well supplied with phosphorus.

Field soils found comparatively high in content of either active calcium, magnesium, iron, manganese, sulfates, chlorides, or sodium will change only slowly in those respects, naturally, over long periods of time.

The ammonia test may be omitted except (1) for soils containing large quantities of rapidly decaying organic matter, and (2) after the application of organic nitrogen fertilizers and fertilizers containing ammonium compounds. In greenhouses, high ammonia test results may be found (1) after steam sterilization, and (2) in poorly-aerated soils.

Two specific conditions require the application of the nitrite test: (1) To poorly-aerated soils, and (2) after steam sterilization.

Four comparisons may be made on the basis of soil test results: (1) A comparison of the levels of available plant nutrients, or nutrient balance, in any one soil. (2) The fertility content of one soil may be compared with that of another soil. (3) The nutrient supply of a soil may be compared with the needs of a crop. (4) Excesses of nutrients and other substances may be compared with crop tolerances of them.

TESTING PLANT CULTURE SOLUTIONS

The Simplex soil testing system was designed for testing soils. Many requests have been received, however, for information on the application of the test methods to plant culture solutions.

Plant culture solutions contain higher concentrations of nutrients than the soil extract, but not necessarily greater amounts of nutrients than occur in the soil water. In the method of soil extraction for active nutrients given herein, the proportion of soil to water is one-to-six. Assuming that a soil contains 25 per cent of water by volume, then the soil water is diluted 24 times in the extraction method. Multiplying the ppm. in the soil extract by 24 gives the approximate concentration of nutrients in the soil water. The results obtained by this method of calculation from fertile soils will compare favorably with the concentration of nutrients commonly used in culture solutions.

Because the nutrient concentrations of a culture solution are commonly high, the solution must be diluted before making the tests. This procedure is necessary in order to bring the test result color within the range of the color charts. The iron and manganese tests, however, may be made sometimes without dilution.

A 1-ml. pipette and a 100-ml. graduated glass cylinder are convenient for the purpose, because with them any dilution can be made up to one-to-one hundred. The number of times a solution should be diluted depends on the amount contained of the nutrient under test, and this can be determined by trial tests. Since the test result must be multiplied by the number of times dilution to obtain ppm. in the original solutions, large errors are introduced in the results, especially when the times dilution is great. When the test result falls exactly on a chart color, however, the error is much less; therefore, dilutions should be made with this point in mind.

Considering that the nutrient concentrations of culture solutions are not kept on an exact level in the usual practice, nor is this necessary, the soil test methods will be found useful for determining when the nutrient concentrations have fallen below the desired amounts, especially when methods for more accurate analysis are unavailable. The tests are also suitable for determining excesses of sulfates, chlorides, etc., in culture solutions.

TESTING WATER

The soil tests can be used to test water to determine if it contains nitrates, potassium, phosphorus or other plant nutrients which may add fertility to the soil. They will indicate also if the water contains sulfates, chlorides or other substances in quantities great enough to injure plants. All of the tests are applicable to water the same as to the soil extract.

To test water or plant culture solutions for reaction, or pH, take about 1 ml. in a small tube and add a few drops (enough to color the solution) of the Soiltex soil reaction reagent.

PART II

THE SIMPLEX SOIL TESTING SYSTEM

APPARATUS

- A few paper towels and a clean cloth
- 1 spoon—capacity $\frac{1}{2}$ spoonful
 - 1 rack to hold the tubes
 - 1 bottle for distilled water
 - 1 4-inch small glass rod
 - 1 brush for cleaning the shell vials
 - 1 porcelain test plate with 12 cavities
 - 2 glass funnels—2-inch diameter, 2-inch stem
 - 1 box filter paper—100 papers, 9 cm. diameter, analytical grade free from phosphorus and nitrate
 - 3 glass tubes—shell vials, 17 mm. diameter, 100 mm. long, graduated to measure 13 ml.
 - 24 glass tubes—shell vials, 15 mm. diameter, 75 mm. long, graduated to measure 1 and 2 ml. Uniform in diameter and accurately graduated
 - 18 2-ounce dropping bottles for the reagents. Clear glass for reagents No. 1, 3, 8, and 13. Amber or green glass for the other reagents
 - 1 standard medicine dropper. Straight glass tube with 2 mm. opening to deliver 16 drops per ml.
- Total cost about \$9

REAGENTS

Note: All of these solutions must be prepared in resistant, laboratory glassware. The chemicals should be special micro grade or suitable for micro testing. Keep all bottles and droppers upright. (Numbers in parentheses refer to reference list following this section.)

ACETIC ACID SOLUTION

No. 1. Dilute acetic acid—1 part pure, glacial acetic acid and 3 parts distilled water.

NITRATE REAGENT

No. 2. Diphenylamine solution—0.03 gram of diphenylamine dissolved in 25 ml. of pure sulfuric acid free from nitrate. This solution is strongly corrosive and must not contact hands or clothing. A pink, brown or blue color indicates that it is unfit for use. Coat the rubber bottle stopper with paraffin where it contacts the liquid.

PHOSPHORUS REAGENTS

No. 3. *Molybdate solution* (2)—Dissolve 5 grams of ammonium molybdate, free from arsenic and phosphorus, in 50 ml. of distilled water, warming gently to hasten solution. If the solution is turbid, filter. Pour this solution slowly, with stirring, into 50 ml. of pure nitric acid, then add 100 ml. more of distilled water. Coat the stopper with paraffin.

No. 4. *Tin*—Cut clean, bright, thin, pure sheet tin in pieces about 3/16 inch square. Must be clean and bright.

POTASSIUM REAGENTS

No. 5. *Sodium cobalti-nitrite solution* (3)—Solution A: Dissolve 25 grams of cobaltous nitrate in 50 ml. of distilled water in a 500-ml. Erlenmeyer flask and add 12.5 ml. of pure acetic acid. Solution B: Dissolve 120 grams of sodium nitrite in 180 ml. of distilled water, making a volume of about 220 ml. Add 210 ml. of solution B to all of solution A—under a laboratory hood or out of doors. The poisonous, reddish, brown fumes of nitric oxide are then removed from the solution by means of an aspirating bottle and a suction filter pump. The gas must be removed completely from the solution by drawing air through it for three or four hours. The time of the operation can be shortened by placing the solution under low pressure. Filter the reagent before use, and keep in a cool place. Coat the stopper of the dropping bottle with paraffin.

No. 6. *Pure ethyl alcohol, 95 per cent*—Where ethyl alcohol cannot be obtained for scientific purposes, pure, anhydrous iso propyl alcohol may be substituted.

CALCIUM REAGENT

No. 7. *Ammonium oxalate solution*—A saturated solution of ammonium oxalate in distilled water. About 5 grams to 100 ml. of water.

HYDROCHLORIC ACID SOLUTION

No. 8. *Hydrochloric (Muriatic) acid solution*—1 part pure acid free from iron and 3 parts distilled water. Coat stopper of dropping bottle with paraffin.

AMMONIA REAGENT

No. 9. *Nessler's solution*—Solution A: Dissolve 5 grams of pure potassium iodide in 15 ml. of distilled water. Solution B: Dissolve 3 grams of pure mercuric chloride in 50 ml. of water with gentle heating. Pour solution B into solution A, slowly, with stirring until a slight, red, permanent precipitate is formed. Filter and add 40 ml. of potassium hydroxide solution (25 grams of potassium hydroxide and 50 ml. of distilled water). Dilute to 100 ml. and allow to settle. (*Poisonous*)

NITRITE REAGENT

No. 10. *Lombard's solution* (4)—Dissolve 1 gram of sulphanilic acid by heating in 100 ml. of a saturated solution of ammonium chloride. Add 1.5 grams of phenol and mix. (*Poisonous*)

MAGNESIUM REAGENTS

No. 11. *Sodium hydroxide solution*—Dissolve 5 grams of sodium hydroxide in 100 ml. of distilled water.

No. 12. *Titan yellow solution* (5)—Dissolve 0.15 gram of titan yellow dye in a mixture of 90 ml. of either ethyl alcohol, or iso propyl alcohol, and 10 ml. of distilled water.

FERRIC IRON REAGENT

No. 13. *Potassium sulphocyanate solution*—Dissolve 20 grams of potassium sulphocyanate in 100 ml. of distilled water. (*Poisonous*)

ALUMINUM REAGENT

No. 14. *Alizarin solution* (6)—Dissolve 0.1 gram of alizarin indicator dye (Schultz No. 778) in 100 ml. of either ethyl alcohol or iso propyl alcohol.

MANGANESE REAGENT

No. 15. *Benzidine solution* (7)—Dissolve 0.2 gram of benzidine in a mixture of 75 ml. of either ethyl alcohol or iso propyl alcohol, and 25 ml. of distilled water.

SULFATE REAGENT

No. 16. *Barium chloride solution*—Dissolve 7 grams of barium chloride in 100 ml. of distilled water.

CHLORIDE REAGENT

No. 17. *Silver nitrate solution*—Dissolve 5 grams of silver nitrate in 100 ml. of distilled water. (*Poisonous*)

SODIUM REAGENT

No. 18. *Magnesium uranyl acetate solution* (8)—Solution A: Dissolve at 70° C., 9 grams of uranyl acetate ($2\text{H}_2\text{O}$) and 6 grams of glacial acetic acid in distilled water to make 100 ml. of solution. Solution B: Dissolve at 70° C., 60 grams of magnesium acetate ($4\text{H}_2\text{O}$) and 6 grams of glacial acetic acid in distilled water to make 100 ml. of solution. Mix solutions A and B, cool to 20° C., let stand, and filter.

SOILTEX SOIL REACTION REAGENT

Dissolve 0.125 gram of aurin and 0.025 gram of bromcresolgreen indicator dye in 100 ml. of either ethyl alcohol or iso propyl alcohol, and

dilute with distilled water to 1000 ml. This solution is extremely sensitive to acids and alkalies and cannot be handled in common glass dropper bottles. Pyrex glass or pure tin tubes are suitable containers for it. The soil reaction test is made on strips of paraffined paper cut $\frac{3}{4}$ x 3 inches.

CHEMICAL SPECIFICATIONS AND APPROXIMATE PRICES ON MINIMUM QUANTITIES

1 lb. Acetic Acid, C. P.* Glacial 99.5%.....	\$0.60
1 gram Alizarin, (Schultz No. 778) Nat. Analine & Chem. Co.....	0.50
$\frac{1}{4}$ lb. Ammonium Molybdate, As and P free.....	0.55
$\frac{1}{4}$ lb. Ammonium Oxalate, C. P.....	0.52
5 grams Aurin, Eastman Kodak Co. 783.....	0.55
$\frac{1}{4}$ lb. Barium Chloride, C. P.....	0.42
25 grams Benzidine, Eastman 33.....	0.65
1 gram Bromeresolgreen, Eastman 1782.....	2.50
1 oz. Cobaltous Nitrate, C. P.....	0.48
100 grams Diphenylamine, Eastman 105.....	0.60
1 lb. Hydrochloric Acid, As and Fe free.....	0.49
5 lbs. Iso Propyl Alcohol, C. P. Anhydrous.....	2.00
$\frac{1}{4}$ lb. Magnesium Acetate, C. P.....	0.72
1 oz. Magnesium Uranyl Acetate, C. P.....	0.50
1 oz. Mercuric Chloride, C. P.....	0.57
1 lb. Nitric Acid, C. P. P free.....	0.55
$\frac{1}{4}$ lb. Phenol, C. P.....	0.47
$\frac{1}{4}$ lb. Potassium Hydroxide, C. P. Pellets.....	0.48
1 oz. Potassium Iodide, C. P.....	0.47
1 oz. Potassium Sulphocyanate, C. P.....	0.39
1 oz. Silver Nitrate, C. P.....	0.87
$\frac{1}{4}$ lb. Sodium Hydroxide, C. P. Sticks, Mg and P free.....	0.41
1 lb. Sodium Nitrite, C. P. Crystals.....	0.87
1 lb. Sulfuric Acid, C. P. As and N free.....	0.49
1 oz. Sulphanilic Acid, C. P.....	0.53
1 oz. Tin Foil, Thick.....	0.25
1 gram Titan Yellow, Eastman P 4454.....	0.40
	<hr/>
	\$17.83

*Chemically pure.

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METHODS

SOIL SAMPLING

The method of taking a soil sample will depend on the nature of the soil problem and the application to be made of the soil test results. A soil sample, however, must represent, as nearly as possible, the soil area or volume to be investigated.

Composite samples are preferable to single soil samples, except that samples from widely different soil locations or soil classes or soil types should not be mixed together for chemical testing. Experience has shown that the soil content of easily soluble chemical constituents varies considerably with soils and soil locations. Usually, marked differences in this respect will be found among soil samples taken from knolls, slopes, and low portions of fields, or among samples representing different kinds of soils. More practical information may be obtained from testing these samples separately.

The dissolved soil components also move readily within the soil. They rise to the soil surface during drying weather and are washed into the soil by rains or by sprinkling. The magnitude of this movement is greater in porous soils than in compact soils. A growing crop also tends to exhaust the soil of its soluble plant nutrients. In sampling soils for chemical testing, therefore, these factors must be considered if the test results are to be correctly interpreted. Soil samples taken directly from the surface of field soils after a period of dry weather will usually test higher in available plant nutrients than samples taken from the same location after a heavy rain that soaks into the soil. Again, samples taken in the fall or early spring or after heavy cropping may test lower than samples taken from the same locations at other times.

In sampling soils that have received fertilizer applications, attention should be given to the position or placement of the fertilizer. Samples of soils taken directly from the positions where fertilizers have been placed will always test higher in content of the substances used in the fertilizer, while samples taken from unfertilized locations will more nearly represent the condition of the soil before fertilization.

In addition to the items already mentioned in this section, many field soils contain unusual conditions that affect rational soil sampling. Good and poor spots of various sizes are of common occurrence. Washing of manure and fertilizers from hillsides denudes the slopes and enriches the depressions. Practices of piling crops, manure, or straw in fields and the burning of log heaps; the droppings of pastured animals; old buildings, and feedlots all sometimes markedly affect the chemical composition of the soil directly beneath these substances or places. Soil samples taken from these locations will not represent the soil of the field as a whole, but tests on such samples will show the effects produced by the treatments involved.

Matters discussed concerning soil sampling refer particularly to surface soils. As the root systems of plants on field soils may occupy the soil to different depths, the supply of easily soluble plant nutrients in the subsoil may be, in some cases, as important as that in the surface soil. Owing to soil weathering processes a soil naturally forms layers, called horizons, having different physical and chemical properties. Three or more of these may be present in a soil in a depth varying from about 2 to 4 feet. The soil horizon directly beneath the surface horizon in many soil types is often low in content of plant nutrients, while the other soil horizons may be low or high in this respect, depending on the many factors involved. Obviously, a soil sample taken from the horizon low in plant nutrients would not represent the true condition of the whole subsoil. Other precautions will become apparent from the brief explanations given here. A thorough study of any field situation before taking soil samples for chemical testing will be found profitable.

The nature of the soil problem under investigation will determine the manner of actually taking a representative soil sample. In sampling local, well-defined soil areas, as after fertilizer placements or where soil and materials applied have been thoroughly mixed together, or from soil surfaces, it is usually sufficient to take up a small amount of soil in the hand or by means of a small scoop or other suitable implement. For taking soil samples from field locations, two methods are commonly used, namely, the soil auger method and the spade method. A soil auger is useful for boring out surface or sub-soil samples, but a spade or shovel is the tool more commonly used for soil sampling. When a spade is used for sampling soils, a vertical slice of the soil is taken, representing the soil to the depth of the plowing, and this soil slice is further mixed before taking from it the final sample for the test. In case a composite sample is taken, the several separate samples should be mixed together thoroughly before the final sampling.

SAMPLING GREENHOUSE SOILS

Thoroughly mixed soil materials reduce the errors of sampling to a minimum; therefore, the use of a soil shredder to mix greenhouse soils is a proper start for accurate soil sampling.

When a soil has been mixed uniformly, any method of sampling which takes out a vertical column of soil is satisfactory. A composite sample of eight or ten individual samples from bench, pile, or pots will represent closely the average composition of the whole soil mass.

To obtain the composite sample from a bench or bed, take out a sample of soil from different places by means of a dessert spoon or soil borer, digging from top to bottom of the plant rooting space (push the mulch aside if one is present), and place the separate borings together in a paper sack. Mix the whole together thoroughly by rolling the sack, or by rolling the soil on a sheet of paper. The sample for testing is then taken from the mixed soil.

A soil borer about 5 inches long and $\frac{1}{2}$ inch in diameter, fitted with a plunger to remove the soil core, is a good tool for sampling pot soils.

Sampling soils before watering plants is preferable to sampling soon after watering.

TESTS FOR EASILY SOLUBLE OR "ACTIVE" SOIL CONSTITUENTS

GENERAL DATA AND SUGGESTIONS

Because the soil tests are very sensitive, they are easily affected by contamination; hence, pure chemicals and clean glassware are necessary for good test results. The testing operation should be performed carefully and neatly.

For brevity, the reagents are designated by numbers. After each addition of reagent the solution should be mixed by shaking the tube gently sidewise for a few seconds. Grasp the top of the tube with the fingers and rotate the wrist for this shaking operation. Because the quantity of reagent must balance the quantity of solution, the reagent must be dropped directly into the solution and not on the inside of the tube.

WASHING APPARATUS

The glass tubes should be emptied soon after use, rinsed with tap water, then with distilled water, and inverted on a paper towel to drain and dry. Should a precipitate adhere to the inside of a tube, it may be cleaned out by brushing in tap water and then rinsing with distilled water. If it becomes necessary to use acids or cleaning powders in the tubes, they must be washed from the tubes completely before using the tubes for soil tests.

The test plate can be cleaned by brushing in tap water, rinsing with distilled water, and then dried with a clean cloth or paper towel.

USE OF COLOR CHARTS

A test result is read by comparing the color, or precipitate, with the proper color chart. Estimate test results between colors. The color charts were developed in ordinary day light; therefore, bright sunlight, dark rooms and other unsuitable lighting conditions should be avoided in reading the soil test results. In comparing the test results with the color charts, *lay the chart flat on a table, face the light source, place the bottom of the tube on the chart as directed in each case, and view the solution in the tube lengthwise.* The light must not enter the tube from below. A color developed on the test plate is compared directly with the color chart. Observe carefully the special directions given with each test method on the accompanying color chart.

DILUTIONS

In case the test result on the original soil extract is higher than indicated by the highest chart color, the soil extract must be diluted the required amount to bring the test result within the range of the color chart for an accurate reading. A convenient method of making the dilutions is as follows:

Use a standard medicine dropper—one with a 2 mm. opening, 16 drops to 1 ml. (the lower mark on a small tube) when held upright.

To dilute the soil extract one-to-two: Take 8 drops of the soil extract and 8 drops of distilled water. The test is then applied as directed.

To dilute the soil extract one-to-four: Take 4 drops of the soil extract and 12 drops of distilled water.

To dilute the soil extract on the test plate: For nitrates—One drop of soil extract plus 4 drops of distilled water gives a one-to-five dilution. One drop of extract and 9 drops of water gives a one-to-ten dilution, etc. For ammonia—Three drops of extract and 3 drops of water gives a one-to-two dilution. Three drops of extract and 6 drops of water gives a one-to-three dilution, etc. For both nitrates and ammonia, take for the tests the number of drops required by the method from the thoroughly mixed dilutions, in a separate, clean test plate cavity. The dilutions are mixed on the test plate by means of the medicine dropper. In measuring solutions for testing with a dropper, always discard the first two drops.

Use the standard dropper also to measure the solution for the "drop tests".

The medicine dropper must be cleaned *each time* before use. Rinse the dropper with distilled water and dry it by contacting the point on a paper towel and wiping the outside with a clean cloth.

To obtain the test result on the original soil extract, the color chart

reading from the test result of the dilution is multiplied by the number of times the soil extract is diluted.

The final testing operation must be made on the diluted extract. Dilutions cannot be made after applying the tests.

In the testing of field soils, the soil extracts rarely require dilution. Extracts of garden and greenhouse soils, however, sometimes require dilution for the nitrate, potassium and magnesium "active" tests. The "reserve" tests frequently require dilution.

CALCULATIONS

The figures on the color charts denote parts per million (ppm.) (or pounds per million pounds, or milligrams per liter), and pounds per A/6 in. (pounds in an acre of soil to the depth of six inches, by volume).

Ppm. are read directly from the color charts. Multiplying ppm. by 8 gives pounds per A/6 in.

Multiplying ppm. by 0.0183 gives pounds per 100 square feet of greenhouse bench or bed to the depth of six inches.

EXTRACTING THE SOIL SAMPLE

Approximately one part of soil to six parts of distilled water is the proportion of soil to water used in extracting the soil sample. The amount of soil extract obtained in the extracting method will be sufficient for ordinary testing. In case the soil extract is insufficient to make all of the required tests, the extracting method may be repeated, or double quantities may be taken in suitable apparatus.

Method: Take a level spoonful ($\frac{1}{2}$ spoon) of the soil to be tested in one of the large glass tubes. Add distilled water, down the inside of the tube to allow air to escape from the soil, to the 13 ml. mark. Then add 1 drop of Reagent No. 1, cover the opening of the tube with the thumb and *shake well for one minute*. Filter the solution into the 1 and 2 ml. graduated tubes, and take drops on the test plate as required for the test. This filtered solution is called the *soil extract*.

For good test results, and especially for duplicating results on the same soil, the extracting method must be followed according to directions. *Shake the soil and extracting solution vigorously for the full time.*

If a noticeable pressure develops under the thumb, the soil contains carbonates.

The following test methods are given in a convenient order of operation.

SOIL TEST PROCEDURES

CARBONATE TEST

To a half spoonful of soil on the test plate, folded Soiltex paper, or small dish (butter chip), add 5 to 10 drops of Reagent No. 8 at the edge of the soil. As the acid is drawn into the soil, a brisk bubbling, or evolution of CO_2 gas indicates the presence of carbonates. If only a few small particles of limestone (carbonate) are present, it will be necessary to look closely in order to observe the test result. The test result may be recorded as either absent, low, medium, or high.

SOILTEX SOIL REACTION TEST

Fold a piece of the paraffined paper lengthwise. Fold over about $\frac{1}{4}$ inch of the outer end and open to form a small paper boat. Place a *small* amount of soil (equal in size to about 3 drops of the testing solution) in the center of the paper boat. Add 8 or 10 drops of the Soiltex solution. Shake the paper endwise until the color of the liquid remains constant—about one-half minute. Then shake the soil to the back end of the paper and run the liquid to the front end. Compare the color of the liquid with the Soiltex color chart for the pH or soil reaction.

The Soiltex test is very sensitive. Avoid testing in a stable or where there may be ammonia or acid fumes to affect the test. Use a clean paper for each test. Follow directions carefully.

NITRATE TEST

To 1 drop of soil extract in a cavity of the test plate add 8 drops of Reagent No. 2. Stir with the corner of a Soiltex paper, or with a glass rod. The full blue color should develop in 5 minutes. If the color develops rapidly and is darker than the darkest color of the color chart, dilute the soil extract one-to-five or one-to-ten, or as required, to bring the final test color within the color chart range. (See the section on dilutions.)

AMMONIA TEST

To 3 drops of the soil extract on the test plate, add 1 drop of Reagent No. 9. The color develops rapidly. If a brown precipitate forms, dilute the soil extract and test again for a more accurate result.

PHOSPHORUS TEST

To 1 ml. of soil extract, in a small glass tube add 1 drop of Reagent No. 11, and shake the tube. Then add 5 drops of Reagent No. 3, shake, and add a piece of clean, bright tin, (Reagent No. 4) and *shake well*. The blue color develops immediately and then gradually fades. Read the test result about one minute after adding the tin. When necessary, a

two to three times dilution of the original soil extract will usually be sufficient. When the color continues to develop in the test, further dilution is necessary. If the solution becomes yellow in color after adding Reagent No. 3, it contains 25 ppm., or more, of phosphorus. (*Precaution*—Arsenic gives the same test color, hence, the test may not be applicable to soils, where large quantities of arsenical spray materials have been used.)

POTASSIUM TEST

Add 3 drops of Reagent No. 5 to 1 ml. of soil extract in a small tube, shake, and add slowly, 3 to 4 drops at a time of Reagent No. 6 to the 2 ml. mark on the tube, shaking tube after each addition of this reagent. Read mark on tube at bottom of the liquid meniscus. A yellow precipitate indicates potassium. Allow about one minute for the precipitate to form. Warm the tube in the hand in cold weather. Read the test result as directed on the Potassium Color Chart. If the yellow precipitate forms immediately after adding Reagent No. 5, 70 ppm. or more of potassium is indicated thereby. A dilution of the soil extract of two to four times may be necessary. (*Precaution*—the test cannot be made in the presence of 50 ppm. or more of ammonia. High ammonia tests, however, are rarely found in soils. Should a high ammonia test be found, dilute the soil extract below 50 ppm. of ammonia for the potassium test.)

CALCIUM TEST

To 1 ml. of soil extract in a small tube add 2 drops of Reagent No. 7 and shake the tube. A white precipitate indicates calcium. Read the test result as directed on the color chart for white precipitates.

MAGNESIUM TEST

To 1 ml. of the soil extract in a small tube add 1 drop of Reagent No. 12, and shake tube. Then add 1 drop of Reagent No. 11 and *shake well*. The magnesium test colors range from light orange to peach red. A yellow color indicates a blank test, or no magnesium. If a red precipitate forms, dilute the extract and retest for a more accurate result.

FERRIC IRON TEST

To 1 ml. of soil extract in a small tube add 3 drops of Reagent No. 13, and shake tube, then add Reagent No. 8 to the 2 ml. mark on the tube.

MANGANESE TEST

To 1 ml. of soil extract in a small tube add 1 drop of Reagent No. 11, shake tube and add 1 drop of Reagent No. 15 and *shake well*. Then add

1 drop of Reagent No. 1. The blue color develops instantly and may be only a pale blue "flash" when the manganese content is low. In most cases the color fades rapidly.

ALUMINUM TEST

To 1 ml. of soil extract in a small tube add 1 drop of Reagent No. 14 and shake tube. Then add 1 drop of Reagent No. 11 and *shake well*. Finally, add 1 drop of Reagent No. 1 and *shake well* again.

SULFATE TEST

Add to 1 ml. of soil extract in a small tube 1 drop of Reagent No. 16 and shake tube. If a white precipitate forms, add 1 to 2 drops of Reagent No. 1, depending on the amount of precipitate, and shake again. A permanent white precipitate indicates sulfates.

CHLORIDE TEST

Add to 1 ml. of soil extract in a small tube 1 drop of Reagent No. 17 and shake tube. If a white precipitate forms, add 1 to 2 drops of Reagent No. 1, depending on the amount of precipitate, and shake again. A permanent white precipitate (curdy when in quantity) indicates chlorides.

NITRITE TEST

To 1 ml. of soil extract in a small tube add 1 drop of Reagent No. 10 and shake tube. Then add 1 drop of Reagent No. 8, shake, and add 3 or 4 drops of Reagent No. 11. A yellow color indicates nitrites.

SODIUM TEST

To 1 ml. of soil extract in a small tube add 1 ml. of Reagent No. 18 and shake tube. Then add 2 ml. of Reagent No. 6 and shake vigorously, or stir briskly with a glass rod, using a down and up motion, and rubbing the inside of the tube. A light yellow precipitate which usually forms slowly indicates sodium. The test result may be recorded as either blank, low, medium, or high.

TESTS FOR "RESERVE" POTASSIUM, PHOSPHORUS, IRON AND MANGANESE

EXTRACTING THE SOIL SAMPLE

Place a level spoonful ($\frac{1}{2}$ spoon) of soil in one of the large glass tubes. Add distilled water half-way to the 13 ml. mark. Then add 5 drops of Reagent No. 8, making about 0.135N acid solution. Shake well for one minute and filter off the soil extract.

RESERVE POTASSIUM TEST

To 1 ml. of the soil extract in a small glass tube add 1 drop of Reagent No. 11 and shake tube. If a precipitate forms, clear the solution by adding 1 to 2 drops of Reagent No. 1 as required. Add 3 drops of Reagent No. 5, shake, and add Reagent No. 6, slowly, with shaking, to the 2 ml. mark on the tube. Read the test result as directed for active potassium. Make dilutions when necessary.

RESERVE PHOSPHORUS TEST

To 1 ml. of the soil extract in a small tube add 1 or 2 drops of Reagent No. 11, with shaking, until a marked precipitate forms in the solution. Then add 5 drops of Reagent No. 3, shake, and add a piece of *clean, bright* tin (Reagent No. 4) and shake again. A blue color indicates phosphorous. Make dilutions when necessary.

RESERVE IRON TEST

To 1 ml. of soil extract in a small tube add 3 drops of Reagent No. 13. Then add Reagent No. 8 to the 2 ml. mark on the tube. (This reserve iron test may be diluted directly with Reagent No. 8, but the solution must be always 2 ml. deep to compare with the Iron Color Chart.)

RESERVE MANGANESE TEST

To 1 ml. of the soil extract in a small tube add 3 drops of Reagent No. 11, with shaking, until a precipitate forms in the tube. Add 1 drop of Reagent No. 15 and *shake well*. Then add 2 drops of Reagent No. 1, with shaking, to form the blue color.

"ACTIVE" AND "RESERVE" TESTS COMPARED

Active test results indicate amounts of easily soluble soil constituents, and the reserve test results denote the amounts of less soluble plant nutrients. Active nutrients may be considered as immediately available to plants, and the reserve nutrients as available over a long period of time. Nitrates, ammonia, nitrites, sulfates, and chlorides are rather soluble in soils, hence, the active test results will show comparatively large quantities of them when present. The solubility of calcium and magnesium in soils is controlled to a considerable extent by CO_2 which is almost always present; therefore, when the active tests for them are low, the reserve supply is low also. Low active test results indicate low solubility, also deficiencies in comparison with higher test results for other nutrients in the same soil. A blank, or low, reserve test result for iron and manganese indicates a marked deficiency of them. The main

value of the active tests compared with the reserve tests is that the active test results show the levels and balance of the immediately available nutrients, and the reserve test results better indicate the reserve supply.

CONDENSED DIRECTIONS FOR RAPID TESTING

(Study the complete directions first)

"ACTIVE" TESTS

CARBONATES

½ spoonful of soil
5 to 10 drops No. 8

Reaction

Small amount of soil
Shaken with Soiltex solution

NITRATES

1 drop extract
8 drops No. 2
Read in 5 minutes

AMMONIA

3 drops extract
1 drop No. 9

PHOSPHORUS

1 ml. extract
1 drop No. 11
5 drops No. 3
1 piece of tin
Read in 1 minute

ALUMINUM

1 ml. extract
1 drop No. 14
1 drop No. 11
1 drop No. 1

SULFATES

1 ml. extract
1 drop No. 16
1 to 2 drops No. 1

CHLORIDES

1 ml. extract
1 drop No. 17
1 to 2 drops No. 1

POTASSIUM

1 ml. extract
3 drops No. 5
To 2 ml. with No. 6

CALCIUM

1 ml. extract
2 drops No. 7

MAGNESIUM

1 ml. extract
1 drop No. 12
1 drop No. 11

IRON

1 ml. extract
3 drops No. 13
To 2 ml. with No. 8

MANGANESE

1 ml. extract
1 drop No. 11
1 drop No. 15
1 drop No. 1
Read immediately

NITRITES

1 ml. extract
1 drop No. 10
1 drop No. 8
3 to 4 drops No. 11

SODIUM

1 ml. extract
1 ml. No. 18
2 ml. No. 6
Stir with glass rod

"RESERVE" TESTS

POTASSIUM

1 ml. extract
1 drop No. 11
1 to 2 drops No. 1
3 drops No. 5
To 2 ml. with No. 6

MANGANESE

1 ml. extract
3 drops No. 11
1 drop No. 15
2 drops No. 1

PHOSPHORUS

1 ml. extract
1 or 2 drops No. 11
5 drops No. 3
1 piece of tin
Read in 1 minute

IRON

1 ml. extract
3 drops No. 13
To 2 ml. with No. 8

SOIL TEST RECORD

Name	Date	No.
------	------	-----

	Kind and Location
Soil	Organic Matter
	Reaction Carbonates

Crop	Kind and Condition
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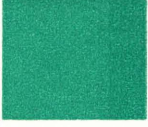



Active Tests

	Ppm.	Lb. a/6 in.	Remarks
Nitrates			
Ammonia			
Phosphorus			
Potassium			
Calcium			
Magnesium			
Iron			
Manganese			
Aluminum			
Sulfates			
Chlorides			
Nitrites			
Sodium			

Reserve Tests

Phosphorus			
Potassium			
Iron			
Manganese			

SOILTEX SOIL REACTION COLOR CHART

Tons Limestone Recommended per Acre		Reaction	pH	Color
Mineral Soils	Muck Soils			
None	None	Very Strongly Alkaline	Up 9.0	
		Strongly Alkaline	8.0	
		Medium Alkaline	7.0	
		Neutral		
		Very Slightly Acid	6.0	
Lime in Special Cases	1 to 2	Slightly Acid		
		Medium Acid		
	Generally None	Strongly Acid	5.0	
2½ to 3	2 to 3	Very Strongly Acid	4.0	
	3 to 6			
	6 to 12	Intensely Acid	3.0 down	

Note: Compare color of test result directly with the chart colors.

NITRATE COLOR CHART

Ppm. = Parts per million in soil extract

Lbs. A/6 in. = Pounds per acre six inches

NITRATES (NO_3)

Ppm.

Lbs. A/6 in.

2

Low

16



5

Low

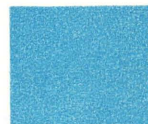
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10

Medium

80



25

Medium

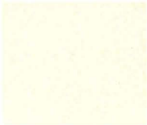
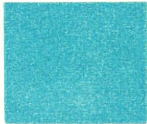


200



Note: Compare color of test result directly with the chart colors.

PHOSPHORUS AND MANGANESE COLOR CHART

Ppm. = Parts per million in soil extract
 Lbs. A/6 in. = Pounds per acre six inches

MANGANESE (Mn)		PHOSPHORUS (P)	
Ppm.	Lbs. A/6 in.	Ppm.	Lbs. A/6 in.
1	8	1/2 Low	4 
2	16	1 Low	8 
5	40	2 1/2 Medium	20 
10	80	5 Moderately high	40 

Phosphorus x 2.3 = P_2O_5 (Phosphoric Acid)









Note: Place bottom of tube on the white paper at the right of the colors and view the solution in the tube lengthwise to match colors.

POTASSIUM COLOR CHART

Ppm. = Parts per million in soil extract

Lbs. A/6 in. = Pounds per acre six inches

POTASSIUM (K)

Ppm.	Lbs. A/6 in.		
Low	No precipitate Less than 24		
5 Medium	40 Slightly cloudy		
10 Medium	80 Slight precipitate		
20 Moderately High	160 Marked precipitate		
Potassium x 1.2 = K ₂ O (Potash)		Base Color	

Note: Hold bottom of tube on base color and match the color seen in the tube with the proper one on the left, being guided also by the amount of precipitate.









To distinguish between a blank test result and 5 ppm.—Set up a blank test by using distilled water in place of soil extract. After adding the reagents, hold the two tubes (blank test and 5 ppm.) together on the black base color. The slightly cloudy effect of the 5 ppm. test result will thereby be visible.

To check the 20 ppm. test result.—Place the bottom of the tube on the heading of this chart. At 20 ppm. the letters will be only faintly visible through the solution in the tube. If the letters are invisible, more than 20 ppm. is indicated.

COLOR CHART FOR WHITE PRECIPITATES

Ppm. = Parts per million in soil extract

Lbs. A/6 in. = Pounds per acre six inches

CHLORIDES (Cl)		SULPHATES (SO ₄)		CALCIUM (Ca)			
Ppm.	Lbs. A/6 in.	Ppm.	Lbs. A/6 in.	Ppm.	Lbs. A/6 in.		
20	160	150	1200	40	320		
50	400	300	2400	100	800		
150	1200 High	600	4800 High	150	1200		
200 or more	1600	800 or more	6400	200 or more	1600 High		
						Base Color	

Note: Hold bottom of tube on the base color and match the color seen in the tube with the proper one on the left.

Lower limit of the tests—White precipitate just visible





Calcium—20 ppm.—160 lbs. A/6 in.

Sulphates—20 ppm.—160 lbs. A/6 in.

Chlorides—5 ppm.—40 lbs. A/6 in.

PHOSPHORUS (P) AND MANGANESE (Mn) COLOR CHART

Ppm = Parts per million in soil extract
Lbs/A = Pounds per acre, 7.87 inches deep
Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

PHOSPHORUS (P)			MANGANESE (Mn)			
Ppm	Lbs/A	Lbs/M	Ppm	Lbs/A	Lbs/M	
1/2	5.3 Low	0.13	1	10.7	0.25	
1	10.7 Low	0.25	2	21.4	0.50	
2 1/2	26.7 Medium	0.63	5	53.5	1.25	
5	53.5 Moderately High	1.25	10	107.0	2.5	

NOTE: Place bottom of tube on the white paper at the right of the colors and view the solution in the tube lengthwise to compare the colors.





Phosphorus (P) x 2.3 equals Phosphoric Acid (P₂O₅)

NITRATE (NO₃) COLOR CHART

Ppm = Parts per million in soil extract

Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

		NITRATES (NO ₃)		
Ppm.		Lbs/A	Lbs/M	
2	Low	21.4	0.50	
5	Low	53.5	1.25	
10	Medium	107.0	2.5	
25	Medium	267.5	6.2	

NOTE:—Compare color of test result directly with the chart colors.

Nitrate (NO₃) x 0.226 equals Nitrogen (N).





SIMPLEX SOIL TEST OUTFIT ♦ ♦ ♦ THE EDWARDS LABORATORY
CLEVELAND, OHIO

MAGNESIUM (Mg) AND ALUMINUM (Al) COLOR CHART

Ppm = Parts per million in soil extract

Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

Magnesium (Mg)			Aluminum (Al)		
Ppm	Lbs/A	Lbs/M	Ppm	Lbs/A	
Blank (Low)			Blank		
2	21.4	0.50	3	32.1	
			Dangerous		
4	42.8	1.0	10	107.	
			High		
6	64.2	1.5	15	160.5	







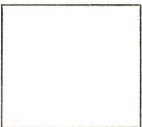

NOTE: Place bottom of tube on the white paper at the right of the colors and view the solution in the tube lengthwise to compare the colors.

COLOR CHART FOR WHITE PRECIPITATES (CHLORIDES, SULPHATES, & CALCIUM)

Ppm = Parts per million in the soil extract

Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

CHLORIDES (Cl)	SULPHATES (SO ₄)	CALCIUM (Ca)				
Ppm	Ppm	Ppm	Lbs/A	Lbs/M		
20	150	40	428.	10		
50	300	100	1070	25		
150 High	600 High	150	1605	37		
200 or more	800 or more	200 or more High	2140	50		
						Base Color

NOTE: Hold bottom of tube on the base color at the right and match the color seen lengthwise through the solution in the tube with the proper one on the left.

Lower limit of the tests—White precipitate just visible.

CALCIUM: 20 Ppm—214 Lbs/A ; 5 Lbs/M

Sulphates: 20 Ppm—214 Lbs/A ; 5 Lbs/M

Chlorides: 5 Ppm—53.5 Lbs/A ; 1.25 Lbs/M

AMMONIUM (NH₄) COLOR CHART

Ppm = Parts per million in soil extract

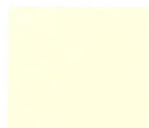
Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

AMMONIUM (NH₄)

Ppm	Lbs/A	Lbs/M
-----	-------	-------

2	21.4	0.50
---	------	------



10	107.	2.5
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25	267.5	6.2
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NOTE: Compare color of test result directly with the color chart.

Ammonium (NH₄) x 3.4 equals Nitrates (NO₃)

Ammonium (NH₄) x 0.78 equals Nitrogen (N)

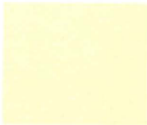




IRON COLOR CHART

Ppm = Parts per million in soil extract

Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

IRON (Fe) (Ferric iron)

Ppm	Lbs/A	Lbs/M	
2	21.4	0.50	
4	42.8	1.0	
6	64.2	1.5	
10	107	2.5	
25	267.	6.2	

NOTE: Place bottom of tube on the white paper at the right of the colors and view the solution in the tube lengthwise to match the colors.




SIMPLEX SOIL TEST OUTFIT ♦ ♦ ♦ THE EDWARDS LABORATORY
CLEVELAND, OHIO

NITRITE (NO₂) COLOR CHART

Ppm. = Parts per million in soil extract.

Lbs/A = Pounds per acre, 7.87 inches deep

Lbs/M = Pounds per 1000 square feet, 7.87 inches deep

Nitrite (NO ₂)			
Ppm	Lbs/A	Lbs/M	
1	10.7	0.25	
2	21.4	0.50	
5 High	53.5	1.25	

NOTE: Place bottom of tube on the white paper at the right of the colors and view the solution in the tube lengthwise to compare the colors.

Nitrites (NO₂) x 1.35 equals Nitrates (NO₃)

Nitrites (NO₂) x 0.3 equals Nitrogen (N)

IRON COLOR CHART

Ppm. = Parts per million in soil extract

Lbs. A/6 in. = Pounds per acre six inches

IRON (Fe)

Ppm.

Lbs. A/6 in.

2

16



4

32



6

48



10

80


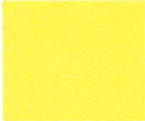



Note: Place bottom of tube on the white paper at the right of the colors and view solution in the tube lengthwise.

AMMONIA COLOR CHART

Ppm. = Parts per million in soil extract
Lbs. A/6 in. = Pounds per acre six inches

AMMONIA (NH₄)

Ppm.	Lbs. A/6 in.	
2	16	
10	80	
25	200 Precipitate	

Note: Compare color of the test result directly with the chart colors.

NITRITE COLOR CHART

Ppm. = Parts per million in soil extract

Lbs. A/6 in. = Pounds per acre six inches

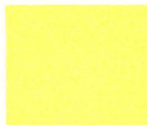
NITRITES (NO_2)

Ppm.

Lbs. A/6 in.

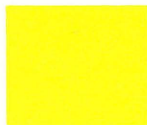
1

8



2

16



5

High

40



Note: Place bottom of tube on the white paper at the right of the colors and view solution in the tube lengthwise.