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Connecticut Agricultural Experiment Station
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THE INTERPRETATION OF SOIL TESTS

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Following the announcement of details in regard to Soil Testing Service in Circular 89 of this Station, large numbers of soil samples from fields, orchards, lawns and gardens have been examined for the citizens of the State. The results of these tests have been carefully studied in the light of all available information in regard to cultural methods, fertilizer practices and crop conditions, and data has been compared with results on soils of known fertility requirements. It is now possible to present certain interpretations of soil tests which should prove helpful to those who avail themselves of this service.

Soil Reaction

Soils may be acid (below 7 pH), neutral (7 pH) or basic (above 7 pH) in reaction. Most economic crop plants grow best at reactions between 5.8 and 7.6 pH. A slight acidity is rarely harmful, and is to be expected on the most fertile soils of this State. Medium degrees of acidity (5.0 to 5.8 pH) are desirable for crops troubled with diseases which prefer a less acid condition, as in the cases of potatoes and tobacco. Such crops as corn, timothy, oats, rye and tomatoes do well at medium acidity, if other conditions of fertility are favorable. Moderate liming is necessary for more acid-sensitive crops, such as alfalfa, spinach, lettuce, etc.

Very acid soils (below 5.0 pH) require liberal liming for most crops. Strawberries, blueberries, rhododendron, laurel, and azalea may be grown best on such soils, without lime application. Extreme degrees of acidity (below 4.5 pH) usually prove harmful to such lawn grasses as bent and fescue, which do not require liming on fairly acid soils.

It must be kept in mind that there is a considerable seasonal fluctuation in acidity, and heavily fertilized soils may be as much as one pH unit lower in midsummer than in early spring or late fall. Samples taken at the latter seasons may be more satisfactorily used as an index to the true conditions of the soil.

Ammonium and Nitrate Nitrogen

Nitrogen exists in the soil largely in the form of partially decomposed organic residues containing proteins. Micro-organisms (bacteria and fungi) gradually transform this nitrogen into ammonium compounds. Organic nitrogenous fertilizer materials and leguminous crop residues are thus more readily attacked, due to their high protein content. Some fertilizer materials, such as sulfate of ammonia and ammonium phosphates, add ammonium compounds directly to the soil.

Nitrogen in the form of ammonium compounds may be utilized as such by many plants, especially during their early growth period. Under normal field conditions this form of nitrogen is rapidly converted, first into nitrites, and then into nitrates, by certain species of bacteria. Hence soils rarely show high ammonia tests, unless they have been fertilized with nitrogen in this form during the past few weeks. At other times a high ammonia test is an indication of poor nitrification potentialities in the soil, as a consequence of high acidity, of poor soil aeration due to water-logging, or of some other abnormal factor.

Soils showing high ammonia tests cannot be reliably tested for potassium by the usual simple methods, due to interference of the ammonium ion in the chemical reaction.

Nitrate nitrogen, whether formed in the soil from nitrification of ammonia derived from organic residues and fertilizer materials or directly supplied in the fertilizer (as, for example, nitrate of soda), is rapidly assimilated by the roots of living plants, and is readily lost from the soil by the percolating action of heavy rains. Hence high tests for nitrate nitrogen in field soils are to be expected only when the root system of the crop is not yet fully developed.

High tests indicate a large reserve of readily available nitrogen for the use of the crop as it begins to draw heavily upon the soil. Rapidly growing annual crops require a larger reserve during the early part of their life in the soil, since the gradual processes of nitrogen liberation are rarely sufficiently rapid to meet their requirements during the period of most active growth. Crops with perennial root systems, such as sod grasses, shrubs and trees take up nitrogen through a much longer period of the year, and low nitrate tests do not necessarily indicate a lack of available nitrogen.

Low tests are to be expected at the end of the cropping period, during winter and early spring, and after a period of heavy rainfall. Under such conditions, when all other factors are favorable, the absence of nitrates may not indicate poor availability of soil nitrogen, but the crop is apt to respond to the addition of a readily available nitrogenous fertilizer.

In order to give a reliable indication of the amount of readily available nitrogen in the soil, tests may be made on samples which have been kept in "mellow-moist" condition, in a loosely covered vessel at a temperature of 60° F. or above for several weeks. Low nitrate tests on such samples indicate real nitrogen deficiency in the soil.

Abnormally high nitrate nitrogen tests are occasionally encountered in greenhouse and other intensively fertilized soils, and are an indication of possible injury to the crop due to excessive concentration of the nitrate salts. Such a condition may be corrected by leaching the soils with large amounts of water.

Phosphorus

Phosphorus occurs in unfertilized soils in slowly soluble mineral and organic combinations. It is a component of all mixed fertilizers, and is frequently applied directly as superphosphate.

Under high levels of fertilization, in excess of 800 pounds per acre per year of fertilizers containing as much as 8 per cent of "phosphoric acid", crops remove less phosphorus than is applied to the soil. This element is not leached downward. In soils of only moderate degrees of acidity, applied phosphates remain for long periods in fairly available form. On highly acid soils, containing much active aluminum and iron, more difficultly soluble phosphate compounds are formed with these elements. At low rates of fertilization the phosphorus supplied by the fertilizer results in little or no accumulation, and there may be a net loss when little manure or fertilizer is used. Under such conditions Connecticut soils usually receive no lime, and a high acidity and low phosphorus availability are the rule on most areas of this type.

The phosphorus test indicates the level of more readily available phosphorus in the soil, either native or as a residue from previous applications. There are marked differences in the abilities of various crops to thrive at different degrees of phosphorus availability. Most market garden crops, potatoes, tobacco, and most legumes require the addition of phosphatic fertilizers unless high tests are obtained. Many soils showing only medium tests grow good grass hay, corn, oats and alsike clover with very little phosphorus fertilization when otherwise in a fertile state. Low or very low tests indicate the necessity for proportionally high amounts of "phosphoric acid" in the fertilizer, depending upon the crop grown.

The active phosphorus content of the soil is a fairly stable property, except as affected by recent fertilizer application. Soils which have received direct applications of arsenical materials may give high tests, regardless of their phosphorus content; hence results in such cases are unreliable.

Potassium

Potassium occurs in soils in large amounts in the form of difficultly soluble rock minerals. Their gradual decomposition liberates small quantities of potassium which is loosely combined with colloidal material (clay and humus) capable of being displaced into the soil solution by base exchange reactions. Potassium is also added to the soil in fertilizers containing potash, or as manures or crop residues, and largely goes over into the exchangeable form. Some potassium is removed from the soil by leaching, especially when under cultivation and liberally fertilized.

The active potassium of the soil, capable of nourishing the crop, is that which exists in exchangeable form, or in true solution. This may now be readily determined by the simple soil testing method used by this Station.

Active potassium may be removed from the soil more rapidly than replenished by natural processes, thus tests may be lower at the end of the growing season of a crop with high potash requirements, than after the soil has been fallow or supporting little vegetation for several months. Hence, most reliable tests are obtained in the spring, prior to fertilization.

High potassium tests should be obtained on soils planted to vegetable crops, tobacco and potatoes. Potash fertilization cannot be omitted on such crops, at least for more than one or two seasons, even on soils showing very high potash tests, since the existing favorable conditions cannot long be maintained by natural soil processes.

Legumes and general farm crops, on soils in otherwise favorable degrees of fertility, may require little or no potash fertilization when occasional applications of manure are used, if medium or high soil tests are shown. Soils with low and very low tests usually respond to the addition of potash to the soil, either in the form of fertilizer or manure, for most crops and permanent grass sods.

Calcium

Calcium in soils occurs in the form of undecomposed carbonates (in calcareous soils), rock minerals, as exchangeable calcium (absorbed by the soil colloids), and as soluble calcium salts. Acid soils contain no carbonates, and are depleted in exchangeable calcium. However, many soils which show a considerable degree of acidity by pH tests may have a fair amount of exchangeable calcium. This is especially true of soils high in organic matter or active mineral colloids. In many cases the calcium test is a better indication of lime needs than is the pH test.

Soils with high and very high calcium tests contain adequate amounts of calcium for all crops, and usually do not respond to liming, unless a high active aluminum concentration is indicated. Medium calcium tests on soils near the neutral point may be expected on light sandy soils, but on acid soils a need for lime is revealed, for alfalfa, sweet clover, and lime-loving vegetable crops. A low calcium test on soils with a high aluminum test is a certain indication of lime requirement for all except the most acid-tolerant plants such as blueberries, strawberries, or ericaceous shrubs. When a very low test results, lime should be used in liberal amounts for most crops, unless only moderate applications may be made with safety on account of disease factors, as in the case of tobacco and potatoes.

It must be borne in mind that unless all other tests are satisfactory heavy liming may produce an abnormal soil balance. Thus liming has frequently proven injurious on many sandy soils of the south which are deficient in other elements, such as magnesium, manganese, potassium or iron.

Magnesium

Magnesium occurs in soils in the form of dolomitic carbonates, unweathered minerals, as exchangeable magnesium, absorbed by the soil colloids, and as soluble magnesium salts.

High and very high tests for magnesium are developed from calcareous soils derived from dolomitic limestones and moderately acid soils resulting from the weathering of rocks high in ferro-magnesian minerals. Medium tests are more common on soils of moderate acidity, on calcareous soils from high calcic limestones, or on soils which have been moderately limed with material of dolomitic origin. Low tests are common on acid soils. Some strongly acid soils give very low or negative tests. This is particularly true of sandy soils. In such cases magnesium should be applied. The cheapest form is in dolomitic lime or limestone. On soils giving high calcium and very low magnesium tests, magnesium sulfate (Epsom salts) is to be preferred. Commercial fertilizers are now available which supply magnesium in these forms.

Aluminum

Aluminum occurs in large amounts in all soils, in the form of undecomposed minerals and in the inorganic colloidal material. In neutral, slightly acid or slightly alkaline soils, the element is in inert combinations which have no direct effect upon plant growth. At greater degrees of acidity, aluminum becomes active, capable of combining as soluble salts and thus exerting a toxic effect upon the growth of many plants, especially those which are benefited by liming when grown on acid soils. A high or very high test is a certain index of an undesirably acid soil, upon which acid sensitive crops are almost certain to fail. A medium test is not so serious, especially with grasses, corn, oats, potatoes, and tobacco. A low or negative test is desirable, except for distinctly acid-tolerant plants.

Manganese

Manganese occurs in small amounts in all soils, chiefly in relatively insoluble combinations. In some calcareous soils and acid soils which have been heavily limed, practically no manganese is present in active forms, and some crops are unable to obtain even the small amounts necessary to meet their requirements. Poor growth and a yellow, chlorotic condition results.

On the other hand, strongly acid soils may contain injurious concentrations of active manganese compounds. Under such conditions liming is a corrective measure.

Manganese is changed by oxidation to less active forms, or may be leached from the soil. Hence tests are of most significance when made just prior to planting or during crop growth. A negative test at such time indicates the desirability of applying manganese. Twenty-five pounds of commercial manganese sulfate per acre is usually adequate to correct any possible deficiency. It is doubtful if manganese is needed if any positive test whatsoever is developed. Medium or moderately low tests are of little significance, except as indicating no manganese deficiency. High or very high tests are undesirable, and indicate a need for lime.

Iron

Iron is an abundant constituent of all soils, existing in the form of iron oxides and many complex mineral combinations. Normally only very small amounts of iron are in active form in the ferric state of oxidation. Under conditions of high acidity, larger amounts are to be found, and under poor drainage conditions, especially in the presence of organic matter, active ferrous iron compounds are developed. Soluble ferrous salts are harmful to plant growth, and are a contributing cause to the infertility of poorly aerated soils.

The presence of very low, yet definite amounts of active iron, as revealed by the test, is desirable for all crops. Higher amounts, on well drained soils, may not be injurious to crops capable of growing under strongly acid conditions. Abnormally high iron tests on poorly drained soils indicate an unfavorable condition.

Negative iron tests may occasionally result on heavily limed soils of excessive sandiness. A chlorotic condition of the leaves may develop in such cases, which is controlled by spraying the plants with iron salts. No case of this sort has been encountered in this State.

Other Tests

Occasionally soils which give poor results contain unusual or harmful concentrations of other chemical constituents. Abnormally high tests for chlorine and sodium show the presence of injurious amounts of common salt. Very high sulfate tests, on soils of unusual acidity, indicate the presence of harmful amounts of sulfuric acid. The presence of more than traces of nitrite nitrogen is likewise injurious, and is occasionally encountered on poorly aerated soils. In all questionable cases these possibilities should be fully investigated.

Other Factors Affecting Crop Growth

Soil testing to determine the nutrient conditions within the soil by means of comparatively simple tests is a comparatively new phase of soil science, and has been made possible by the rapid development 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 favorable nutrient conditions will come to naught.

The form upon which the Soils Department makes its report to persons who have submitted soil samples for analysis is given on the back of this circular.

Connecticut Agricultural Experiment Station

New Haven

Soils Department

REPORT on SOIL TESTS

Name ....

Address ....

....

Date ....

	Sample Designation					
Acidity						
pH						
Concentration of active constituents*..						
Nitrate nitrogen ...						
Ammonia nitrogen..						
Phosphorus........						
Potassium.........						
Calcium						
Magnesium........						
Aluminum						
Manganese........						
Iron						
Other tests........						
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* If numbers are given, these represent approximate pounds per acre to plow depth. Letter significance is as follows: T—trace, L—low, M—medium, H—high, V—very, A—acid, N—neutral, B—basic (alkaline).

Remarks ....

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