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Interpreting Your Soil Test Results

The primary goal of soil testing is to inform efficient and effective resource management. Soil testing is the most accurate way to determine lime and nutrient needs. Soil testing is also useful for identifying contaminated sites (e.g., elevated levels of lead).

The results provided on your soil test report reflect the properties of the sample you submitted and the testing procedures used by the University of Massachusetts Soil and Plant Nutrient Testing Laboratory. The analytical methods used by the laboratory were developed for climate and soil types common to New England and the Northeastern U.S.It is important to recognize that the values obtained when a soil sample is analyzed are of little use as raw analytical data. In order to make use of the values in predicting nutrient needs, the test must be calibrated by conducting nutrient response research under local conditions with representative soils ranging from deficient to adequate for each nutrient of concern. The optimum range (or typical range in some cases) is provided in the column to the right of your results. These interpretations, as well as lime and fertilizer recommendations, are based on field and greenhouse trials conducted in Massachusetts and other Northeastern states.Recommendations provided with your soil test report are specific to the crop selection that you identified on your soil sample submission form and are based on the analytical results for your sample. The purpose of this fact sheet is to provide a brief explanation of each of the values provided on your soil test report and how they are used to generate recommendations.

SOIL TEST RESULTS

Modified Morgan Extractable Nutrients:

The lab uses the Modified Morgan extraction procedure, originally developed at the University of Connecticut in the early 1930s for use on New England Soils. It is a *universal* extraction procedure, meaning it is used to determine all major nutrients and many of the micronutrients simultaneously. Nearly all of the New England State Universities and Cornell use the Morgan extraction procedure.

Phosphorus (P) –Among other important functions, phosphorus provides plants with a means of using the energy harnessed by photosynthesis to drive its metabolism. A deficiency of this nutrient can lead to impaired vegetative growth, weak root systems, poor fruit and seed quality, and low yield; however, excessive soil phosphorus levels are a concern due to the potential negative impact on surface water quality. Most phosphorus losses occur with runoff, but where soil levels are extremely high, subsurface losses can occur. Phosphorus enrichment is a leading source of water quality impairment of many lakes, streams, and rivers in New England.

Soil phosphorus exists in a wide range of forms. Some phosphorus is present as part of soil organic matter and becomes available to plants as the organic matter decomposes. Most inorganic soil phosphorus is bound tightly to the surface of soil minerals (e.g., iron and aluminum oxides). Warm, moist, well-aerated soils at a pH level of about 6.5 optimize the release of both of these forms. Plants require fairly large quantities of phosphorus, but the levels of phosphorus available to plant roots at any given time are usually quite low. Soil tests attempt to assess the ability of soil to supply phosphorus from bound forms during the growing season. When a soil test indicates that phosphorus is low and fertilizer is needed, the rate recommended is intended to satisfy immediate crop needs and begin to build soil phosphorus levels to the optimum range (i.e., build and maintain). Phosphorus recommendations are customarily expressed as P_2O_5 to correlate with fertilizer analysis. Once soil test levels are in the optimum range, only a small amount of phosphorus is needed to replace removal and maintain soil levels.

If your soil test results indicate above optimum levels, phosphorus application is unnecessary and should be limited. Where soil phosphorus levels are excessive, phosphorus application should be eliminated, and additional steps should be taken to minimize the risk of surface water contamination by limiting runoff losses.

Potassium (K) – Potassium rivals nitrogen as the nutrient absorbed in greatest amounts by plants. Like nitrogen, crops take up a relatively large proportion of plant-available potassium each growing season. Plants deficient in potassium are unable to utilize nitrogen and water efficiently and are more susceptible to disease. Most available potassium exists as an exchangeable cation (see below). The slow release of potassium from native soil minerals and from fixed forms in clays can replenish some of the potassium lost by crop removal and leaching. This ability, however, is limited and variable. Fertilization is often necessary to maintain optimum yields.

When a soil test indicates that fertilizer potassium is required, the rate of fertilizer recommended is intended to satisfy crop needs and build soil potassium levels to the optimum range. Sandy soils with very low CEC will tend to lose substantial quantities due to leaching and will require more frequent applications of fertilizer. Even when soils test in the optimum range, some potassium generally is recommended to account for a portion of crop removal. By convention, potassium recommendations are expressed as K_2O to correlate with fertilizer analysis.

***Calcium (Ca)* –** Calcium is essential for proper functioning of plant cell walls and membranes. Sufficient calcium must also be present in actively growing plant parts, especially in fruits and roots. Properly limed soils with constant and adequate moisture will normally supply sufficient calcium to plants. If soil calcium levels are less than optimal and lime is not required, gypsum (calcium sulfate) may be recommended.

Magnesium (Mg) – Magnesium acts together with phosphorus to drive plant metabolism and is part of chlorophyll, a vital substance for photosynthesis. Like calcium, magnesium is ordinarily supplied through liming. If magnesium levels are low and lime is required, dolomitic lime (rich in Mg) will be recommended. If Mg is low and lime is not required, Epsom salts (magnesium sulfate) may be recommended.

Sulfur(S) –Sulfur is a component of several enzymes that regulate photosynthesis and nitrogen fixation. The vast majority of sulfur in soil is stored in soil organic matter and is converted to available mineral form by the action of soil microorganisms. In New England, atmospheric deposition resulting from combustion of fossil fuels has historically contributed significant amounts of sulfur to soil each year; however, with improved emissions control and the use of cleaner fuels, sulfur deposition has been reduced. Still, sulfur deficiencies are rare in New England and an optimum range for Modified Morgan extractable sulfur has never been identified. The interpretation of extractable sulfur levels found on your report is based on what is typically found. When sulfur levels are low, several sources of sulfur are available to ensure adequate plant nutrition including: gypsum (calcium sulfate), potassium sulfate (0-0-50) and sul-po-mag (0-0-22-11 Mg-22 S). Moderate applications of animal manure or compost will generally result in adequate soil sulfur levels.

Micronutrients – Micronutrients are elements essential to plants that are required in very small amounts. Five of these (iron, manganese, zinc, copper, and boron) are tested routinely. Micronutrient deficiencies are most likely to occur in sandy, low organic matter soils. High soil pH may also bring about micronutrient deficiencies, especially in sandy soils.Micronutrient deficiencies and response to micronutrient fertilizers are rarely observed in the Northeast. For this reason, optimum ranges have never been defined. Your soil test values are compared to levels normally found in Northeast soils. When levels are well below this range,we recommend collecting a plant tissue sample to determine if a deficiency exists and a micronutrient fertilizer is required.

Aluminum (Al)–Aluminum is not a plant nutrient and at elevated levels it can be extremely toxic to plant roots and limit the ability of plants to take up phosphorus by reducing phosphorus solubility. Aluminum sensitivity varies greatly with plant type. Acid-loving plants, such as rhododendrons and blueberries can tolerate moderately high aluminum levels, whereas lettuce, carrots and beets are very sensitive. Extractable aluminum increases greatly at soil pH below 5.5. Proper liming will lower aluminum solubility to acceptable levels.For some crops, the amount of P_2O_5 fertilizer recommended is adjusted based on extractable aluminum levels.

Lead (Pb)–This laboratory routinely screens all soil samples for elevated levels of extractable lead.The extractable lead level is used to estimate the concentration of total sorbed lead, which is what MassDEP and USEPA guidelines are based on. Lead is naturally present in most New England soils at low concentrations (15-40 ppm total lead). At these levels lead generally is thought to present minimal danger to people or plants. Soil pollution with lead-based paint and the tetraethyl lead of past automotive fuels have increased soil lead levels to several thousand ppm in some places. Unless the estimated total lead level in your soil exceeds 299 ppm (Modified Morgan extractable level of 22 ppm) it is simply reported as low and can be considered safe (assuming the sample submitted is representative of the area of concern). Estimated total lead levels above 300 ppm are a concern. In such cases, consult the separate insert on soil lead levels.

Cation Exchange Capacity and Soil Acidity:

Cation Exchange Capacity–Cation exchange capacity (CEC) is a measure of the soil's ability to retain and supply nutrients, specifically the positively charged nutrient ions called cations. These include the cations calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{1+}), ammonium (NH_4^+), and many of the micronutrients. Cations are attracted to negatively charged surfaces of clay and organic particles called colloids. CEC is reported in units of milli-equivalents per 100 grams of soil (meq/100 g) and can range from below 5 meq/100 g in sandy, low organic matter soils to over 15meq/100 g in finer textured soils and those high in organic matter. Low CEC soils are more susceptible to cation nutrient loss through leaching.

The cations calcium (Ca^{2+}), magnesium(Mg2+), potassium (K^+), hydrogen (H^+) and aluminum (Al^{3+}) account for the vast majority of cations adsorbed on the soil colloids in New England soils. Hydrogen (H^+) and aluminum (Al^{3+}) are considered acidic cations because they tend to lower soil pH while calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+) are considered basic cations and have no direct influence on soil pH. Base saturation is the portion (expressed as a percentage) of the soil's cation exchange capacity occupied by calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+). At one time, many labs provided fertilizer recommendations to achieve very specific *ideal* potassium, calcium, and magnesium saturation ratios. This approach was never well supported by data. Research conducted over the last several decades indicates that an ideal basic cation ratio does not exist and fertilizing to achieve a prescribed level of potassium, calcium, and magnesium saturation is unjustified. Still, base saturation can provide useful information. Your report includes the base cation saturation values observed for your sample and the ranges typically observed in New England soils.

When base saturation is well outside of these ranges it is typically associated with deficient or excessive potassium or very acidic or alkaline soil conditions. Following the fertilizer and lime recommendations provided with your report will typically result in base saturation values within normal ranges.

Soil pH and Exchangeable Acidity – One of the most valuable pieces of information you can get from soil testing is a measure of soil acidity. Soil pH is an indicator of the soil's acidity which is a primary factor controlling nutrient availability, microbial processes, and plant growth. A pH of 7.0 is neutral, less than 7.0 is acidic, and greater than 7.0 is alkaline. Maintaining proper soil pH is one of the most important aspects of soil fertility management. Most New England soils are naturally acidic and need to be limed periodically to keep the pH in the range of 6.0 to 7.0 desired by most crops and ornamental plants. When the soil is acidic, the availability of nitrogen, phosphorus, and potassium is reduced, and there are usually low amounts of calcium and magnesium in the soil. Under acidic conditions, most micronutrients are more soluble and are therefore more available to plants. Under very acidic conditions aluminum, iron, and manganese may be so soluble they can reach toxic levels. Soil acidity also influences soil microbes. For example, when soil pH is low (below 6.0), bacterial activity is significantly reduced. Acidic soil conditions also reduce the effectiveness of some herbicides

When soil pH is maintained at the proper level, plant nutrient availability is optimized, solubility of toxic elements is minimized, and beneficial soil organisms are most active. While most plants grow best in soil with a pH between 6 and 7, there are some notable acid-loving exceptions, including blueberry and rhododendron, which perform best under soil conditions associated with a lower pH.

Due to the climate and geology of New England, soils here tend to be naturally acidic (4.5-5.5).The most effective way to manage soil acidity is to apply agricultural limestone. The quantity of lime required is determined by the target pH (based on crops to be grown) and the soils buffering capacity. Buffering capacity refers a soil's tendency to resist change in pH. Soil pH is a measure of active acidity, based on the concentration of hydrogen ions (H^+) in soil solution, and is an indicator of the current soil condition. When lime is added to a soil, active acidity is neutralized by chemical reactions that remove hydrogen ions from the soil solution. However, there are also acidic cations (H^+ and Al^{3+}) adsorbed on soil colloids (the CEC) which can be released into the soil solution to replace those neutralized by the lime. This is called exchangeable acidity. Soils such as clays or those high in organic matter have a high cation exchange capacity (CEC) and a potential for large amounts of exchangeable acidity. These soils are said to be well buffered. To effectively raise the soil pH, both active and exchangeable acidity must be neutralized. The lab determines buffering capacity and lime requirement by estimating the exchangeable acidity. Exchangeable acidity, which is reported in units of meq/100 g, is directly related to the quantity of lime required to increase the pH from its current level to the target level determined by the selected crop.

Occasionally soil pH must be lowered, because either the plant requires acid soil or the soil was previously over-limed. Incorporating elemental sulfur (S) is the most effective way to lower soil pH. Once applied, the sulfur oxidizes to sulfuric acid. Applying 5 to 10 lbs. of sulfur per 1000 sq. ft. will lower the pH of most New England soils by approximately half a unit. (Use the lower rate for very sandy soils.) No more than 15 lbs. of sulfur per 1000 sq. ft. should be applied at any one time. Retest the soil after 4 to 6 months to determine if more sulfur is needed.

Additional Optional Tests:
The lab offers several additional optional tests for routine analysis. While each of these tests can provide useful information under certain conditions, results are not directly used to make fertilizer or lime recommendations.

Organic Matter –Soil organic matter (SOM) is composed of materials containing carbon. These materials include plant and animal remains (including bacteria and fungi) in various stages of decomposition, root and microbial exudates and humus. Humus is the end-product of decay and is resistant to further decomposition. Native SOM content of most cultivated or developed areas of New England is almost always less than 8% and typically in the 2 to 4% range. Several factors control the amount of SOM a soil may have, including soil texture and drainage. Well-drained, coarse textured soils tend to naturally have lower levels of SOM. This is due, in part, to the rapid microbial decomposition rates favored by these soil conditions. In fact, it is difficult to maintain high levels of SOM in these soils without drastic, and sometime unsustainable, measures. Despite the low SOM content of many New England soils, it is an important component of soil for nutrient supply, water holding capacity, cation exchange capacity, and soil structure.

SOM supplies nutrients through the process of mineralization, which is the decomposition of organic compounds by microbial action into carbon dioxide and mineral constituents. Soil microbes are most active in warm soils (over 70°F) that are moist, but well aerated, with a pH between 6 and 7. Mineralization of nutrients will proceed rapidly under these conditions. Three of the macronutrients are made available to plants by mineralization: nitrogen (N), phosphorus (P), and sulfur (S). SOM has a direct influence on water holding capacity due to its ability to absorb large amounts of water, and indirectly by improving soil structure, which creates more pore space for water storage. Soil structure is enhanced by SOM because in the process of decomposition sticky compounds are produced by microorganisms. The cation exchange capacity of soils is controlled by the clay content and the SOM content with both materials supplying negatively charged sites for adsorption of cations. In most New England soils, the humus portion of SOM accounts for the vast majority of the cation exchange capacity.

The optimum range for SOM for soil health varies across soil types. Generally, lower levels of SOM are sufficient, and practical to achieve, in coarse textured, sandy soils as compared to finer soils with more clay content. For example, 2.5% SOM in a loamy sand soil might be considered ideal while 2.5% could be considered marginal in a silt loam soil where 3 to 5% is more common.

Nitrate Nitrogen (NO_3- N) –Nitrogen is **essential** to nearly every aspect of plant growth. Nitrogen is absorbed by plants as nitrate (NO_3^-) and ammonium (NH_4^+). Soil $NO_3^-$and NH_4^+levels can fluctuate widely with soil and weather conditions over very short periods of time. For this reason, soil nitrogen testing is not generally useful for predicting fertilizer need in our humid environment. Nitrogen recommendations are based on crop need with the assumption that very little available N remains in the soil after the growing season. Adjustments should be made based on soil organic matter content and where soils were recently amended with manure or compost or where legumes are grown in the rotation.

Nitrate (NO_3-N) analysis is offered as an additional optional test for routine analysis; however, these results are not directly used to make fertilizer recommendations. In general, a soil NO_3-N concentration of 30 ppm or higher during the active growing season is sufficient for most plants. Interpretation of soil NO_3-N levels below 30 ppm is somewhat nebulous because soil nitrogen is so dynamic. When the concentration of soil NO_3-N is less than 30 ppm, additional fertilizer may or may not be needed.

Under certain specific conditions soil NO_3 testing can be useful for predicting fertilizer needs. The Pre-sidedress Soil Nitrate Test (PSNT) has been shown to successfully predict sidedress fertilizer N needs for a few crops (e.g., corn, pumpkin, peppers, cabbage), but the PSNT requires stricter sampling (depth and timing) and handling than a standard soil fertility sample. Contact the laboratory or visit the website for more information on this test.

Soluble Salts–Soluble salts, present in many commercial (and some natural) fertilizers and deicing products used on sidewalks and roads, can cause severe water stress and nutritional imbalances in plants. Generally, seedlings are more sensitive than established plants to elevated soluble salts levels, and great variation exists between plant species. Most soils tested by the UMass laboratory have values between 0.08 and 0.50dS/m (mmho/cm) with the middle of the range typical of most fertile mineral soils. When values are greater than 0.60 sensitive plants (such as onions, etc.) may suffer salt damage. The level of soluble salts can change rapidly in the soil due to leaching, so the effects of time and growing conditions are important considerations when evaluating the significance of the soluble salts level. Excessive levels can often be corrected by leaching with liberal amounts (2- 4 inches) of fresh water. Normal off-season precipitation usually will correct salt problems resulting from over-fertilization.

Other information provided on your report:

Scoop Density – The lab uses a calibrated sampling scoop to dispense an exact volume of soil (5 cubic centimeters) used for nutrient extraction. The weight of this sample is recorded and used to calculate nutrient concentration on a mass basis (e.g., mg of nutrient per kg of soil). Scoop density is the mass per unit volume (grams per cubic centimeter). Values typically range between 1.0 and 1.25 with lower values associated with higher organic matter levels.

Sample Information –Important information about your sample is listed at the top right-hand corner of you report.

Sample ID is the five-character name you provided with your sample.

Lab Number is the unique identification number we use to track your sample. If you have questions about your results or would like to request a reprint with a different crop code, reference the *Lab Number* in all correspondence with the lab.

Area Sampled is approximate area (in square feet or acres) that is represented by your sample. This is information you provided with your sample and only used for record keeping.

Received is the date your sample arrived at the lab and *Reported* is the date the report was printed (or re-printed).

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