UMASS EXTENSION

Results and Interpretation of Soil Test Results

Soil and Plant Tissue Testing Laboratory

The primary goal of soil testing is to provide guidelines for the efficient use of soil amendments, such as lime and fertilizer. Recommendations provided with your soil test are for the crop you have chosen. Problems directly related to disease, insects, and to some extent weather and cultural practices, cannot be addressed by a soil test.

The Soil Sample – One of the most important steps in soil testing is obtaining the soil sample. It should represent the soil in which the plants are or will be growing. Instructions for proper sampling may be obtained by visiting our website. Remember, a poor sample will result in inaccurate recommendations.

Soil pH, Buffer pH, and pH adjustments – **Soil pH** is a measure of the soil's acidity and is a primary factor in plant growth. When pH is maintained at the proper level for a given crop, plant nutrients are at maximum availability, toxic elements are often at reduced availability and beneficial soil organisms are most active. Most plants prefer a soil pH between 5.5 and 7.5. The majority do best in the middle part of this range. Some notable acid-loving exceptions are blueberries, potatoes and rhododendrons.

Due to climate and rock types in New England, soils here tend to be naturally very acidic (4.5-5.5). For this reason, amendments with materials capable of raising pH may be needed. Many products are available to accomplish this, but ground limestone is the most common.

Buffer pH is a measure of the soil's capacity to resist pH change. Two soils with the same soil pH may have quite a different buffer pH and thus one will require significantly more limestone than the other to obtain an optimal soil pH. The extent to which the buffer pH is lower than 6.8 is proportional to the amount of limestone needed. Occasionally soil pH must be lowered, because either the plant requires acid soil or the soil was previously over-limed. Incorporating elemental sulfur is the most effective way to lower soil pH. The sulfur oxidizes in the soil to sulfuric acid. One to two pounds of sulfur will lower the pH of most New England soils about 0.5 units. Unfortunately, sulfur is rarely available in garden centers.

Cation Exchange Capacity and Percentage Base Saturation- Cation exchange capacity (CEC) is an important measure of the soil's ability to retain and supply nutrients. The bulk of this capacity in limed New England soils resides in finely divided soil organic matter. A smaller contribution comes from the soil's clay particles. The basic nutrient cations (positively charged ions) of Calcium (Ca^{++}), Magnesium (Mg^{++}), and Potassium (K^{+}), and the acidic cations of Aluminum (Al^{+++}) and Hydrogen (H^{+}) account for nearly all the absorbed cations in the soil. Very sandy soils low in organic matter commonly have CEC less than 5. New England soils with very high CEC (greater than 40) are invariably rich in organic matter. A CEC between 10 and 15 is typical and usually adequate.

CEC is important because it represents the primary soil reservoir of readily available K, Ca, Mg and several micronutrients. It also helps to prevent leaching of soil nutrients. The ease with which a plant gains access to these nutrients depends somewhat on the relative percentages of the absorbed cations. For this reason it is suggested that percentage saturation levels be held within loosely defined ranges. For example, a soil with a pH of about 6.5 and base saturations of Ca 70%, Mg 12% and K 4% is considered balanced for most crops.

Nitrogen (N) - Nitrogen is essential to nearly every aspect of plant growth. N is absorbed from the soil as nitrate (NO_3^-) and ammonium (NH_4^+). This soil test estimates current nitrate levels. Fertilizer recommendations are not generally made on the basis of these measurements because their levels can fluctuate greatly with soil and weather conditions over short periods of time. Instead, they are used to assess extremes of nitrogen fertility. For example, very high ammonium levels can be toxic to the roots of many plants, particularly if the soil pH is above 7. Very high levels of either form may result in fertilizer "burn." Recommendations are made on the presumption that very little N remains in the soil after the growing season and that most crops require between 1 and 4 lbs of N per 1000 square feet per year. Adjustments are often made for soils recently or continuously supplied with manure or compost. These materials contain N to be released during the growing season.

Phosphorus (P) or Phosphorus Pentoxide (P_2O_5) - 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, and fruit and seed of poor quality and low yield. Soil P exists in a wide range of forms. Some is present as part of soil organic matter and becomes available to plants as the organic matter decomposes. Most inorganic soil P is bound tightly to the surface of soil mineral particles. Warm, moist, well-aerated soils at about pH 6.5 optimize the release of both these forms. Plants require fairly large quantities of P, but the plant-available levels are quite low at any one time. Soil tests attempt to assess the soil's ability to supply P from bound forms during the growing season.

Potassium (K) or Potash (K2O) – Potassium rivals nitrogen as the nutrient element absorbed in greatest amounts by plants. Like N, crops take up a relatively large proportion of plant-available K each growing season. Plants deficient in K are unable to utilize N and water efficiently, and are more susceptible to disease. Most available K exists as an exchangeable cation (see above). The slow release of K from native soil minerals can replenish some of the K lost by crop removal and leaching. This ability, however, is limited and variable. Fertilization is often necessary to maintain optimum yields.

Calcium (Ca) – Calcium is essential in the proper functioning of plant cell walls and membranes. Sufficient Ca must also be present in actively growing plant parts, especially storage organs such as fruits and roots. Properly limed soils with constant and adequate moisture will normally supply sufficient Ca to plants. High humidity and poor soil drainage hinder Ca movement into these plant parts and should be avoided.

Magnesium (Mg) – Magnesium acts together with P to drive plant metabolism and chlorophyll production, a vital substance for photosynthesis. Like Ca, Mg is ordinarily supplied through liming. Low Mg levels in many soils will not normally cause problems provided the exchangeable cations (see above) are in good balance. If Mg 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 salt (magnesium sulfate) may be incorporated at a rate of 5 – 10 lbs/1000 square feet.

Micronutrients - Micronutrients are essential plants elements that are required in very small amounts. In most properly limed soils they are available in sufficient quantities. Five of these (iron, manganese, zinc, copper, and boron) are tested routinely. Micronutrient fertilizer recommendations are not available. Extremely high values, however, are noted.

Aluminum (Al) - Aluminum is not an essential nutrient for plants. At elevated levels it can be extremely toxic to plant roots and limit the plant's ability to take up P. Extractable Al increases greatly at soil pH below 5.5. Proper liming, however, will lower Al to acceptable levels. Al sensitivity varies greatly with plant type. Acid-loving plants, such as rhododendrons, can tolerate very high Al levels. Lettuce, carrots and beets are very sensitive. Hydrangea, a non-sensitive plant, produces blue flowers at low pH and pink flowers at high pH due to the effect of Al on pigment formation.

Toxic Heavy Metals- This laboratory routinely tests lead (Pb) and cadmium (Cd). Pb is naturally present in soils in the range of 15-40 parts per million (ppm). These levels present no danger to people or plants. Soil pollution with lead-based paints and the leaded fuels of the past have increased soil Pb levels to several thousand ppm in some places. Unless the total Pb level in your soil exceeds 150 ppm, it is simply reported as low and can be considered safe (assuming the sample submitted was representative of the area of concern). Values above 300 ppm are potentially dangerous to people. In such cases consult the separate insert on soil lead levels.

Cadmium is extremely toxic to both plants and animals. It is naturally present in soils at low levels (less than 1 ppm). Industrial discharges of Cd, however, often cause municipal sewage sludge to contain elevated levels of Cd. Composted sludges are often used as soil amendments. Although safe upper limits of Cd for both plants and animals have not been established, monitoring soil Cd levels helps avoid excesses when such materials are used. Unless the Cd in your soil exceeds 1 ppm it is not reported.

Soluble Salts (SS) - Soluble salts (SS) include materials used on roads to melt ice and are present in many fertilizers. SS can cause severe water stress and nutritional imbalances in plants. Generally, seedlings are more sensitive than established plants to elevated SS levels. Also, a great variation exists between plant species. SS levels are determined through a measure of electrical conductivity. Most soils have values between 0.08 and 0.50 dS/m (deciSiemens/meter) by the method used in this lab. The middle of this range is typical of most fertile mineral soils. Values higher than 0.60 dS/m may cause damage to sensitive plants (such as onions, etc.). A SS level can change rapidly in the soil due to leaching so the effects of time and growing conditions must be considered. Excessive SS levels can often be corrected by applying liberal amounts (2- 4 inches) of fresh water. Normal off-season precipitation will usually correct salt problems resulting from over-fertilization.

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For more information regarding soil testing, visit our website at **www.umass.edu/soiltest**

Using Lime and Fertilizer in the Home Landscape

The recommendations provided on your soil test have hopefully been written in a way that is both understandable and convenient for you to use. It is difficult to express these in a way that matches every individual's preference. Some wish to use only natural soil amendments. Others request recommendations in terms of soluble synthetic fertilizers. Most soil tests state the number of pounds of nutrient to apply per given area (to be incorporated through a specified depth). In home gardens the small amounts recommended may be difficult to weigh accurately. It is often much easier to apply a volume of fertilizer (cup, liter, etc.). Your soil test will state the amounts of Nitrogen, Phosphorus, and Potassium recommended for your crop in terms of lbs per specified soil area (or volume). It will then provide you with one way of supplying these nutrients. Use the following tables as an aid in implementing this recommendation or to devise alternatives based on your basic N, P, K soil test recommendation.

Fertilizer Products and Their Properties

Table 1 converts weights to volumes for several fertilizer groups. For example, if your soil test recommendation calls for 3 lbs Bone Meal, under Organic Meals and Blends you find that a one cup measure holds 1/3 lb of Bone Meal. That means 3 cups would hold 1 lb, and 9 cups would hold 3 lbs. One could measure out 9 cups or use a cut-off 2 liter soda container, which also holds 3 lbs of Bone Meal. When measuring volumes scoop the material and level the container top (do not pack).

Table 1. Density Equivalents

	Density Units			
Fertilizer Groups	grams/cc	lbs/cup	lbs/2 liters	lbs/gal (oz/cup)
Organic Meals, Blends, and Wood Ash	0.7	1/3	3	6
Ground Rock Dusts (ex. Lime, Rock Phosphate, Greensand)	1.4	3/4	6	12
Coarse and Medium Granulated Synthetic Blends (ex. 5-10-10 graden fertilizer)	1.0	1/2	4.5	8.5
Fine Granulated and Flaked Synthetic Blends (ex. many turf fertilizers)	0.7	1/3	3	6
Composts	0.35	1/6	1.5	3
Powdered Sulfur	1.0	1/2	4.5	8.5
Urea and Other High Nitrogen Fertilizers	0.80	1/3	3.5	7

Some Convenient Containers for Measuring Fertilizers

12 oz Coffee Can = 1 liter
Dry Wall Compound Bucket = 5 gallons
Kitchen Measuring Cup = Graduated
Cut-off 2 liter Soda Bottle = 2 liters
Cut-off 1/2 gallon Milk Container = 1/2 gallon

SUPPLYING INDIVIDUAL NUTRIENTS

If your soil test calls for a quantity of nitrogen, phosphorus, or potassium expressed in fractions of a pound per 100 square feet, you may use one of the combinations listed below to meet that recommendation.

1/4 lb nitrogen (N):

1 bushel (1.25 cubic feet) well-rotted or composted manure plus 1 lb dried blood (12-0-0)
OR
3 to 4 lbs dried blood (12-0-0)
OR
1/2 lb urea (42-0-0)

1/4 lb phosphorus (P2O5)

3 to 4 lbs bone meal (0-12-0)
OR
1/2 lb triple superphosphate (0-45-0)

1/4 lb potassium (K2O)

4 to 5 lbs wood ash (0-0-5) (use only if soil pH is les than 6.3 and reduce lime recommendation by 3 to 4 lbs)
OR
1/2 lb muriate of potash (0-0-60) or potassium sulfate (0-0-50) (potassium sulfate is preferred but is more difficult to find)

If recommendation calls for 1/2 lb of nutrient, simply double the quantity recommended for 1/4 lb.

For annual flowers use 1/2 the amount recommended for vegetables.

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Soil Lead: Testing, Interpretation, & Recommendations

Soil Lead Contamination Lead is naturally present in all soils. It occurs generally in the range of 15 to 40 parts lead per million parts of soil (ppm), or 15 to 40 milligrams lead per kilogram of soil (mg/kg). Pollution can increase soil lead levels to several thousand ppm; the major cause of soil lead contamination in populated areas is the weathering, chipping, scraping, sanding, and sand-blasting of structures bearing lead-based paint.

In the past, significant causes of soil contamination by lead included the use of tetraethyl lead as an anti-knock ingredient in gasoline and lead arsenate as an insecticide in fruit orchards. Automotive lead emissions have effectively ceased with the phasing out of leaded fuels, and with the development of more effective pesticides and Integrated Pest Management (IPM), lead arsenate is no longer in use. Unfortunately, lead persists in soil for many hundreds of years and past use of these products continues to present problems in some areas.

Soil lead becomes a health risk when directly ingested or inhaled as dust. Garden produce, which has accumulated lead in its tissue or has soil particles adhering to it, can also be a hazard if eaten. Lead poisoning is a particular concern for young children (under 6) because their rapidly developing bodies are very sensitive to the effects of lead, and their play habits tend to increase exposure.

Soil Lead Levels, Distribution, and Sampling Procedures used by the UMass Soil Testing Lab to screen soils for lead contamination are the same ones used for routine measurement of plant nutrients. The Modified Morgan extracting solution, dilute glacial acetic acid and ammonium hydroxide, removes a reproducible fraction of the total soil lead. The "extractable" lead is a measure of the reactive lead in the soil. A correlation between extractable lead and ESTIMATED TOTAL LEAD has been determined by testing a large number of soils (>300) using both the routine extraction procedure and a more rigorous total soil digestion. Test results report an ESTIMATED TOTAL LEAD level based on this relationship. Information derived from a variety of sources has resulted in classifying soil lead levels as follows:

Lead Level	Extracted Lead	*Estimated Total Lead
	----------mg/kg or ppm----------	
Low	**less than 22**	**less than 299**
Medium	**22 to 126**	**300 to 999**
High	**127 to 293**	**1000 to 2000**
Very High	**greater than 293**	**greater than 2000**

The listed categories are those of the UMass Soil Testing Lab. They are meant to correspond to the recommendations listed below. ***If Estimated Total Lead levels are above 300 ppm, young children and pregnant women should avoid contact with the soil. Estimated Total Lead Levels above 2000 ppm are considered a concern for all users and may represent a hazardous waste situation.** Contact your state's Department of Environmental Protection or your local health department for more information.

The screening test offered by the UMass Soil Testing Lab is only meant to identify areas where lead contamination may be a concern. Soils that are known to be contaminated with higher levels of lead, should be tested for Total Sorbed Lead (using EPA method 3050 or 3051) with appropriate actions taken. There are a number of public and private labs in the Northeast offering this test; contact the soil UMass Soil and Plant Tissue Testing Lab for more information.

Due to the nature of the contamination process, lead in soil may be very unevenly distributed. The lead in paint removed from a structure will generally be concentrated near the source, but levels may vary greatly over small distances (e.g., one foot). Lead arsenate residues in old orchards closely reflect the locations of sprayed trees. *Consider these facts carefully when sampling.* If the purpose of testing is to establish the extent of play area contamination, combine several, small, randomly taken samples from the surface 1- to 2-inches to create one sample for testing. If the concern is for lead uptake by garden vegetables, combine several vertical slices from the top 6- to 8-inches of soil to create a sample.

Good Gardening Practices to Reduce Lead Exposure

1. Locate gardens away from old painted structures and heavily travelled roads.
2. Give planting preferences to fruiting crops (tomatoes, squash, peas, sunflowers, corn, etc.).
3. Incorporate organic materials such as high quality compost, humus, and peat moss.
4. Lime soil as recommended by soil test (a soil pH of 6.5 to 7.0 will minimize lead availability).
5. Wash hands immediately after gardening and prior to eating
6. Discard outer leaves before eating leafy vegetables. Peel root crops. Wash all produce thoroughly.
7. Protect garden from airborne particulates using a fence or hedge (fine dust has the highest lead concentration).
8. Keep dust in the garden to a minimum by maintaining a well-mulched, vegetated, and/or moist soil surface.

Recommendations

Low - Follow the good gardening practices listed above.

Medium - In addition to following good gardening practices:

- Restrict access of children to these soils by maintaining dense cover.
- Do not grow leafy green vegetables or root crops in this soil; instead, grow them in raised beds built with non-contaminated soil and organic amendments.

High - In addition to following good gardening practices:

- Do not grow food crops in this soil and do not allow children access to it.
- Keep soil covered and take steps described above to reduce lead availability.
- Grow food crops in containers filled with growing media or clean topsoil; or create lined, raised beds filled with non-contaminated soil and organic amendments.

Very High

- Contact your local Health Department, Cooperative Extension, or the Department of Environmental Protection office for advice on lead abatement measures that should be taken.

Additional Resources

Lead in residential soils: Sources, testing, and reducing exposure. 1999. Penn State University Cooperative Extension. http://cropsoil.psu.edu/extension/facts/lead-in-soil.pdf

Lead safe yards: Developing and implementing a monitoring, assessment, and outreach program for you community. 2001. U.S. EPA Office of Research and Development. EPA/625/R-00/012. http://www.epa.gov/nrmrl/pubs/625r00012/625r00012.html

Lead contaminated soil: Minimizing health risks. 2010. Rutgers University Cooperative Extension. FS336. http://www.njaes.rutgers.edu/pubs/download-free.asp?strPubID=FS336

Lead in garden soils. University of Connecticut Soil and Nutrient Analysis Lab, Cooperative Extension. http://www.soiltest.uconn.edu/factsheets/LeadGardenSoils.pdf

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