

How to Use a Soil Test

What a Soil Test Tells You

A soil test is a "snapshot" of the chemical status of your soil. The test report shows pH (degree of acidity), and the available amounts of various plant nutrients that were present in your soil at the time of sampling. Some soil tests also report total organic matter present in the soil. *The soil test report is an index of the chemical aspect of soil fertility, and therefore tells only part of the story.* It is a valuable diagnostic tool, but it cannot *alone* tell you the correct way to manage your soil.

Three Aspects of Soil Fertility

Physical – good drainage, aeration, moisture-holding capacity, and ease of penetration by plant roots. A crumbly, deep soil that provides all of these and is easy to work, is said to have good *tilth*, or good physical structure.

Chemical - adequate levels of all essential plant nutrients, favorable pH, favorable nutrient balance, freedom from toxic excesses of any one element.

Biological - diversity of beneficial soil organisms (bacteria, fungi, protozoa, nematodes, tiny insect-like creatures, earthworms, *etc.*) that digest *organic residues* (fallen leaves, manure, crop residues, plant root exudates *etc.*) into *humus* (the decomposed organic matter that makes topsoil dark brown and enhances its capacity to hold water and nutrients. This activity is called the *organic matter cycle*, or the *decay cycle*, and it releases nutrients in plant-available form. In addition, healthy and diverse soil life promotes good tilth and protects plants against soil-borne pathogens.

The Soil Life is the Engine of Soil Fertility

In nature, the organic matter cycle provides all of the nutrients that support the natural vegetation. In agriculture, we remove some organic matter and nutrients in harvest, and therefore we have to "feed" the soil life to maintain fertility. This is done with compost, cover crops, crop residues, manure, organic mulches, and sometimes purchased organic fertilizers.

In a well-balanced, fertile soil, that is receiving adequate organic inputs each year, the organic matter cycle will provide your crops with most or all of the nutrients they need from the soil: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) sulfur (S) and micronutrients such as boron (B), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), molybdenum (Mo) sodium (Na) and silicon (Si). However, in the real world of gardening and farming, some nutrient supplementation is often needed, and occasionally certain nutrients are present in excess. The soil test is a valuable tool for determining what inputs or adjustments are needed.

Important Elements in Crop Production

Element	Symbol	Source
<i>Needed in relatively large quantities:</i>		
Carbon	C	Air
Oxygen	O	Air
Hydrogen	H	Water
Nitrogen *	N	Soil, Air (legumes)
Phosphorus *	P	Soil
Sulfur	S	Soil
Potassium	K	Soil
Calcium	Ca	Soil
Magnesium	Mg	Soil
<i>Needed in small quantities:</i>		
Iron	Fe	Soil
Manganese #	Mn	Soil
Zinc #	Zn	Soil
Copper #	Cu	Soil
Molybdenum	Mo	Soil
Boron #	B	Soil
Silicon	Si	Soil
Sodium #	Na	Soil
Chlorine #	Cl	Soil
<i>Elements toxic to plants, animals or humans:</i>		
Aluminum #	Al	Soil
Lead ##	Pb	Soil, indus. pollution
Cadmium ##	Cd	Soil, indus. pollution
Mercury ##	Hg	Indus. pollution

* Excess can pollute ground or surface waters

Excess can be toxic to plants

Toxic to animal and humans.

The bulk of plant tissue is composed of C, H and O, elements the plant accumulates through photosynthesis. Soil testing focuses mostly on N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo and B – elements that can limit crop production when in short supply. Deficiencies in Na, Si and Cl are extremely rare. Many soil labs offer tests for potentially toxic Al, Pb, Cd and Hg. Crops can also absorb traces of cobalt, chromium, iodine and other trace elements essential to animal and human nutrition.

Soil C is measured indirectly in the soil organic matter test, and is central to the organic matter cycle. The acid form of H (H+) determines soil pH. O is essential to plant roots and soil life, and is provided by maintaining good soil aeration.

Mineral Amendments: which ones, how much?

In addition to compost and other organic matter, the soil often needs certain mineral supplements in order to reach optimum fertility and crop yields. This may occur because:

- past farming practices have depleted some nutrients,
- the soil is naturally low in certain nutrients, or
- the soil is too acid or too alkaline for the crops you are growing.

A soil test can help identify the amendments and amounts your soil needs. If the testing laboratory gives recommendations for organic gardens and farms, this is most helpful. Otherwise, you may have to "translate" conventional fertilizer recommendations to organic amendments.

NOTE – *if you are certified organic under the USDA's National Organic Program (NOP), be sure that any soil amendments you purchase are allowed under this program.*

Taking a Soil Sample

Getting a good representative sample is very important for obtaining a meaningful soil test report. Collect a soil sample by taking cores 0-6 inches deep (0 to 8 inches for a garden with deep topsoil) from 12 to 25 points evenly scattered through the field or area you are testing. If you do not have a coring tool, dig a hole about 8 inches deep with a shovel, leaving a smooth nearly-vertical surface. Use a trowel to take a small, even slice of soil from 0-6 inches depth along this surface. Combine and thoroughly mix the cores in a stoneware crock or clean plastic bucket (*not metal*, which can cause false readings for iron, aluminum or zinc). Allow the combined sample to air-dry for a day or two at room temperature (*not in direct sunlight*). Then put a pint of air-dry soil into a sample bag provided by the lab, or a zipper-seal plastic bag, and mail it to the lab along with your mailing address, testing instructions, payment, a brief description of the field and cropping history, and crops to be planted this year. Often, the lab provides a sampling form on which to provide this information.

If you are farming several fields, do a soil test for each. Also, if you know that two or more sections of a given field have different soil types, or widely different cropping histories, take a sample for each section.

Reading the Soil Test Report

Different labs use different procedures for nutrient analysis, so the exact figures for each nutrient in a given soil sample will vary widely among labs. However, most labs give an interpretation relevant to their particular analytical procedures. Usually, the number for each nutrient is followed by a letter code such as: *VL* = very low (critically deficient); *L* = low (likely to restrict

crop yield); *M* = medium (sufficient for most crops, may be limiting to heavy feeders); *H* = high (favorable); and *VH* = very high (ample, possibly excessive). Any nutrients that are rated *VL* or *L* on your soil test usually needs to be supplemented, whereas nutrients rated *VH* may indicate a need to cut back on inputs of those elements. Some labs may use *D* (deficient) to indicate low levels, *S* (sufficient) or *O* (optimum) for desirably high levels, and *E* (excessive) for potentially unfavorable high levels.

Many soil tests do not give a direct measurement of plant-available nitrogen (N). This is because soluble soil N levels normally undergo wide and rapid seasonal fluctuations related to soil biological processes and plant uptake. Soluble N can range from nearly undetectable and excessive levels (that may leach to groundwater) within a single season. Many labs give an *estimated nitrogen release (ENR)* in lb/acre-year, an estimate of the amount of N released annually by soil biological processes, based on soil organic matter content and soil texture. If the ENR is 120 or more, the organic matter cycle will provide most or all of the N needed by most crops. In addition, some labs will provide a *pre-side-dress nitrate test*. This is a measurement of soluble nitrogen taken *at a specific time of year*, usually late spring to early summer when the crop is about half-grown. It is a good indication of whether an application of readily-available N is needed to prevent N-related yield limitation.

Usually, the lab will report each nutrient in parts per million (ppm) or pounds per acre (lb/acre). NOTE: 1 ppm = about 2 lb/acre in the plow layer (6 inches depth). These numbers represent an approximation of the *plant-available* nutrients present, not the total amount of each element in the soil. NOTE: some labs report elemental P and K, and others report phosphate (P₂O₅) and potash (K₂O). 1 ppm P = 2.3 ppm P₂O₅; 1 ppm K = 1.2 ppm K₂O. Some labs give *two* values for P. The first is plant-available P, and the second is a larger number that includes "reserve" P (which is released to crops more slowly, over several seasons).

The soil test will also give soil pH. A pH of 7.0 is neutral; 6.0 is mildly acid, 5.0 is strongly acid, and 4 is extremely acid, while numbers above 7 indicate alkaline soil. Most crops prefer a pH of 6.0 to 6.8, although they will thrive at anywhere from 5.5 to 7.5 if soil life is healthy and balanced. Strawberries, brambles and potato do well at pH 5.5 to 6.0; and blueberries at about 5.0.

A good soil test should include a measurement of total soil organic matter (SOM), usually given in percent. This is a *rough* index of the vigor of the soil life and organic matter cycle. Generally, good SOM levels for tilled fields in Virginia and neighboring states are 1.5 to 3% for sandy soils, 2.5 to 5% for loams, and 4 to 6% for heavy, clayey soils. These figures are for "wet chemistry" methods for total SOM. Some labs estimate

SOM as “loss on ignition,” which includes fresh residues as well as digested soil organic matter; this figure is not as good an indicator of soil life, and is *on average* about 1.5 times as high as the wet chemistry SOM.

Researchers at University of Maryland have developed an even better index of the health of soil life, the *active soil organic carbon*. They are now developing a low-cost kit for conducting active organic C tests in the field.

The warmer the climate, the lower the SOM, even if soil life is healthy and active. So don't let those northern gardeners give you an “organic matter inferiority complex!” If your soil is dark brown, crumbly and well drained, and plants are thriving, the soil probably has a healthy organic matter cycle. It is actually possible to have too much SOM. At 7 to 10%, it may tie up micronutrients, leach nitrate to the groundwater, or contain so much available P and K that plant nutrition is unbalanced.

Some labs also report *cation exchange capacity* (CEC). This is an estimate of the soil's ability to hold positively charged (*cation*) nutrients in plant-available form, especially K, Ca, Mg and Na. The soil's CEC resides in its clay and humus content; thus rich, clay-loam soils will have a high CEC, and dry sandy soils will have a low CEC. Building soil organic matter will gradually enhance CEC. Some farm consultants and soil test labs pay attention to the *relative* amounts of Ca, K and Mg held on a soil's CEC (base saturation ratio), and seek to adjust the cation balance. On most soils in the southeastern US, plants and soil life thrive over a fairly wide range of cation ratios. On most agricultural soils, Ca base saturation generally runs 50-75%, Mg 10-25% and K 3-8%. A Ca:Mg base saturation ratio *less* than 2 or *more* than 10, or a K base saturation that approaches or exceeds Mg, may indicate a yield-limiting imbalance.

How to Avoid Pitfalls in Reading Soil Tests

Some soil labs do more accurate work than others; some provide vital data (e.g. SOM) that others do not; and a few offer recommendations for organic or sustainable production systems. Different labs use different procedures, so that lab A may report 100 ppm P for a given soil, and lab B only 40 ppm. Each lab also develops its own ranges for deficient, optimal or excessive levels based on experience with its particular methodology. Find a lab whose philosophy and methodology you like, and whose accuracy you trust, and stick with it.

Because soil is a dynamic, living system, its pH and the levels of some nutrients can vary significantly during the course of one season. Retest your soil every two to three years - *at the same time of year and using the same lab* - and notice the trends. Are SOM, pH and nutrient levels approaching the optimum range? Are “low”

nutrient levels coming up, and “excessive” nutrient levels coming down?

Note that soil test reports do not always correspond exactly with what the crop “sees.” On healthy, biologically active soil, crops may obtain sufficient P, K and other nutrients even if the soil test shows somewhat low levels. Highly beneficial mycorrhizal fungi and other friendly micro-organisms often help crops obtain nutrients from insoluble sources that don't show up on a soil test. On the other hand, depleted soil life, soil compaction, poor drainage or drought can lead to crop deficiencies in nutrients that appear sufficient on the soil test. In the latter case, correcting these conditions is much more effective than adding more nutrients. It is often valuable to conduct a crop foliar nutrient analysis to determine what the crop actually “sees” in the way of nutrients. *Be sure to follow laboratory instructions precisely in collecting foliar samples, as this is essential to correct interpretation of results.*

Some soil labs are prepared mainly to give recommendations for chemical fertilizers, and will often recommend more N, P, K and lime than is actually needed, even on highly fertile soils. When this happens, you can learn how to convert their recommendations to organic inputs, or to make your own recommendations. Or, you could switch to an organic- or sustainable-oriented soil testing lab.

Amendments for Specific Nutrient Problems

Acidity (pH below 6.0): Use *agricultural limestone* or marine deposits such as Aragonite or marl to raise pH. Never use hydrated or quick lime, as these are very harsh on soil life and hazardous to handle. If the soil is rated L or M in calcium, but H or VH in magnesium, use *high calcium lime*. If magnesium is also L or M, use *dolomitic limestone*. Use 1,000-3,000lb/acre (23-45 lb/1,000 sq. ft) for moderate acidity on loamy to clayey soils. Very sandy soils should be limed *lightly*, 500-1,000 lb/acre, and only if pH drops to 5.5. Retest soil one to two years later to see if more lime is needed.

Alkalinity (pH 7.5 or above; rare in eastern US): Use acidic organic mulch (tree leaves, pine straw, chipped brush), avoid liming. For strong alkalinity or for acid-loving fruits, use *elemental sulfur* at 200 - 500 lb/acre (5-11 lb/1,000 sq ft).

Low organic matter: Use generous amounts of compost (5 to 20 tons/acre, or 250 to 900 lb/1,000 sq. ft) the first couple of years. Grow vigorous cover crops and use organic mulch. You may need an organic N-P-K fertilizer to obtain satisfactory crop yields at first. Grow a legume green manure or apply *composted* manure to provide N. Foliar-feed with fish emulsion or fish-seaweed fertilizers. Reduce tillage if practical to allow SOM to accumulate.

Phosphorus: If P is low, supplement with colloidal phosphate or rock phosphate at 500 to 1,000 lb/acre (12

to 23 lb/ 1,000 sq. ft), then apply some high quality compost and grow legume or buckwheat cover crops to unlock the P. NOTE: avoid liming at same time as rock phosphate is applied, since mild acidity (pH about 6.0) promotes P availability, while alkaline Ca ties it up.

Optimal available P (P1 or "weak Bray") is about 20 to 40 ppm. If available P soars above 100 ppm, it can tie up micronutrients, and suppress the highly beneficial mycorrhizae on which many crop varieties depend for optimal vigor and stress tolerance. Where P is very high, cut back on manure and manure-based compost, which are rich in P.

Potassium: If K is low, it can often be supplemented with manure compost and/or hay mulch, both of which are rich in K. Potassium sulfate, greensand and sul-po-mag are three mineral amendments that can add K if the soil is very low in this nutrient. If K gets very high (over 350 ppm or over 8% base saturation) it can make the soil sticky, upset plant nutrition or reduce vegetable quality. Cut back on the use of hay mulch and manure compost until K is reduced.

NOTE: if both P and K are sky-high but SOM is low, the land probably has a history of intensive chemical fertilizer use. Grow cover crop mixtures that include legumes to replenish N and SOM without aggravating P and K excesses.

Calcium: If Ca is low but pH is optimal or high, use gypsum at 300 to 500 lb/acre (7-11 lb/1,000 sq ft) once or twice a year until soil tests indicate that Ca levels are medium to high.

Magnesium: if Mg is low but pH is optimal or high, use sul-po-mag or Epsom salts at 200 to 300 lb/acre (5-7 lb/1,000 sq ft), and retest soil in a year to see if more is needed.

Sulfur: If soil test indicates low S, do a crop foliar test to check for S deficiency. If needed, use gypsum at 500 lb/acre, or sul-po-mag at 200-400 lb/acre to add S.

Micronutrients: A low level of boron (B) should be corrected with about 5 to 10 lb borax per acre (2-4 ounces/1,000 sq ft) - *no more*, as some crops are sensitive to too much B. For other micronutrients, moderately low levels can usually be amended with good compost, seaweed meal or rock powders such as granite dust (check label for micronutrient content). A critically low micronutrient (VL on soil test, or diagnosed crop deficiency) can be supplemented in sulfate or chelate form.

Resources

Seven Springs Farm carries a variety of natural fertilizers, soil amendments, high-calcium lime, and compost-based potting mixes. Call 540-651-3228, or visit the web site at www.7springsfarm.com.

Building Soils for Better Crops, 2nd ed. Fred Magdoff & Harold van Es, 1999. This is an excellent

manual of sustainable soil management, written in user-friendly language, and covering all aspects of sustainable management of nutrients and SOM, soil conservation and proper tillage. Available from Sustainable Agriculture Publications, Hills Bldg, Rm. 10, U. Vermont, Burlington, VT 05405-0082, for \$19.95 + 3.95 shipping.

Appropriate Technology Transfer for Rural Areas (ATTRA) is a national sustainable agriculture information service that provides bulletins on a wide variety of topics, including sustainable soil management, organic fertilizers, soil conservation, and a listing of alternative soil testing labs. Visit www.attra.ncat.org, or call toll-free 1-800-346-9140.

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