ADVANCED SOIL TESTING

Recent public attention on local, healthy food has focused on the means of its production, namely the “health” and “quality” of the soil in which our food is grown. Unfortunately, neither soil “health” nor “quality” is defined legally. Studies from geology to culinary arts to agronomy, as well as popular opinion may regard these important concepts quite differently. One common popular definition for healthy food, for example, is that it is free of heavy metals like lead and arsenic, pathogenic microbes, or other soil contaminants often associated with urban areas or industrial agriculture.

What is meant by healthy food or high quality soil has been at the heart of recent discussion across the globe about whether that food production relies on a conventional (aka modern, green revolution, industrial) means of adding a given limiting or missing nutrient to the soil to maintain soil fertility and plant fertility in the form of readily soluble, synthetic or “bagged” fertilizer. Sustainable and regenerative approaches, in contrast, rely on biological activity to recycle nutrients from the living soil to plants. Soil fertility is renewed through methods such as conservation agriculture (a system of no-till, cover crops, and diverse rotations), French Biointensive gardening, permaculture or other regenerative agricultural method that grows organic matter, thus supplying fertility to plants.

Regenerative agricultural advocates argue that the responsible gardener will instead focus on returning organic matter and increasing biological activity as an indicator of healthy living soil over the long term.

Academic programs like WSU’s Center for Sustaining Agriculture and Natural Resources study soil fertility and health in regenerative agriculture which is regarded as a consequence of recycling organic matter back into soil and increasing its percentage through the method of food production selected. A regenerative soil practitioner equates soil fertility, health, and quality primarily with the percent organic matter (one of the tests in the suite of Nutrient Soil Tests), measured over the long-term, to arrive at a beneficial agricultural method that increases this critical number. This is what is meant when one refers to regenerative agriculture “growing” soil.

Mineral soil can take thousands of years to form on the landscape from bedrock or other parent material. On a human timeframe, this irreplaceable resource on which we depend is virtually non-renewable. However, the addition of organic matter to a soil can dramatically improve its physical, chemical and biological behavior. Adding organic matter to the soil’s surface triggers biological and chemical processes that cause the soil profile to grow downward, to deepen, and relatively quickly in human terms rather than in a geological time frame. Ensuring adequate levels of organic matter with sufficient carbon to feed in your soil provides a base for the living microbes that dwell within.
These microbes (fungi, bacteria, nematodes) help bind the soil by means of biochemical “glues”, which heightens better soil water management and prevents surface erosion. Larger soil creatures eat the smaller microbes and this is referred to as the soil food web. Regenerative agriculture practitioners are digging some older DIY Soil Tests out of the archives (e.g., Soil Texture, Munsell, Worm Count) as well as some new ones (e.g., Rainfall Simulation, the % Organic Matter from the suite of Nutrient Soil Tests) to assess soil health. Solvita and other more experimental Soil Biology Tests may also help the gardener better understand the health of their soil.

The Nature and Property of Soils by Nyle C. Brady and Ray. R. Weil is enjoying its 15th edition as of 2018. A passage in this long-standing agronomy textbook can be used to bolster arguments for either conventional agriculture or for regenerative agriculture. Brady and Weil state:

“A common myth about fertilizers suggests that inorganic fertilizers applied to soil directly feed the plant and that therefore the biological cycling of nutrients, are of little consequence where inorganic fertilizers are used. The reality is that nutrients added by normal applications of fertilizers, whether organic or inorganic, are incorporated into the complex soil nutrient cycles, and that little (from 10% to 60%) of the fertilizer nutrient actually winds up in the plant being fertilized during the year of application.”

People concerned the environmental impacts of conventional agriculture see the above passage as a dire warning that 40 to 90% of fertilizer applied does not benefit the plant and instead erodes off or contaminates the groundwater.

Practitioners of conventional agriculture often go on to emphasize the remainder of Brady and Weil’s passage. “Even when the application of fertilizer greatly increases both plant growth and nutrient uptake, the fertilizer stimulates increased cycling of the nutrients, and the nutrient ions taken up by the plant come largely from various pools in the soil and not directly from the fertilizer. For example, some of the added N may go to satisfy the needs of microorganisms, preventing them from competing with plants for other pools of N. This knowledge has been obtained by careful analysis of dozens of nutrient studies that used fertilizer with isotopically tagged nutrients.” This more complete passage aptly captures the reason behind for the emphasis on readily available nutrients in standard Nutrient Soil Tests. One might regard a Nutrient Soil Test as a short-term snapshot of soil fertility at given instant of time or season of the year.

Where Can You Get Soil Testing Done?

Regardless of what type of soil testing (biology, environment, nutrient), if you opt to patronize any commercial laboratory, we highly recommend selection of an accredited, local laboratory. Certification programs are typically run by independent, third parties who regularly test laboratory equipment, processes, and for operator error. Certification is the means by which a commercial laboratory assures the client that their results are replicable, precise, and accurate. As an example, many agricultural Soil Nutrient Test laboratories are accredited through the North American Proficiency Testing Program (NAPT), a program of the Soil Science Society of America. Regardless of certification agency, any certification should be current. Review laboratory certifications before selecting laboratories for any commercial tests. Laboratories that are not accredited may not produce worthwhile results.

How to Collect a Soil Sample

Most commercial labs will give instructions for how to collect & process samples for your soil tests.
Most Nutrient Soil Labs will provide an auger for customers to use while taking samples from the surface down further than just a few inches. They provide this instrument because it is hard to get a core sample using a shovel.

The following tips will help in collecting a good soil sample:

- Remove all mulch before taking a sample otherwise, this results in the test overstating the percentage of organic matter (%OM).
- Soils tests in perennial beds and orchards should include soil from greater depths than soil areas planted to annuals. This is because organic matter levels are typically higher in perennial beds and orchards than in tilled annual beds.
- Galvanized buckets, shovels, and trowels will result in inaccurate results for Nutrient Soil Test.
- Medical gloves should be worn while taking the samples so that oils, lotions, and pollutants on the sampler’s hands do not contaminate the soil being tested. Since micronutrients are present in small amounts expressed in parts per million it does not take much to throw off the sample results.

Why Are There Different Soil Tests and Do Their Goals Differ?

If your goal is to grow healthy food, which types of soil tests will meet your gardening needs depends largely on your where you fall regarding the end points of a spectrum of agricultural food production. For a conventional gardener, responsible gardening is all about good water and nutrient management. At the other end of the spectrum are scientists and public examining whether long-term sustainability should factor into our food production and agricultural methodology.

There are many different reasons for soil testing, a wide variety of soil testing laboratory types, multiple methods to test your soil, and an often even more confusing array of outcomes. Having your samples tested at a local lab, rather than a more distant one, assures you of obtaining interpretations that are the most useful to you or for comparing to your neighbor’s or someone nearby gardening the same way. This advice is critical with Soil Nutrient Tests, but may also be of assistance when interpreting the results of other soil tests.

Typical Soil Tests

*Easy DIY Soil Tests* will satisfy many gardeners and they will not opt for further testing by a commercial laboratory. Easy DIY Soil Tests are also invaluable tools for understanding the typical parameters of your soil and to determine its baseline, so that one may better understand any changes over time. Other tests such as Munsell Color (to assess adequacy of organic matter) and Worm Count are rarely performed by commercial laboratories, and thus typically only available to the do it yourself gardener.

Spokane County Master Gardeners would like to add a caveat for dedicated Easy DIY Soil Tests users. Some DIY tests, including pH, while considered sufficiently accurate for developing a baseline, are not accurate enough for management decisions such as the application of soil amendments and fertilizer. For example, it would be appropriate to test the soil of your home garden to determine if the pH is suitable for growing tomatoes. However, if your intent is to apply calcium to a lawn or lower the pH of the soil for growing blueberries, we highly recommend that you have your soil tested at a commercial laboratory.
Nutrient Soil Testing was originally developed and commercialized to identify limiting nutrient elements and calculate the quantity of this element a gardener or farmer would need to add to restore soil fertility.

Nutrient Soil Tests can be valuable tools for learning which nutrients may already be naturally abundant, thus application of more would be bad for the environment. A Nutrient Soil Test will help flag excessive and potentially toxic levels of macro- or micro-nutrients, which may have built up in the soil through over-application of fertilizer. In Spokane County, for example, phosphorus (P) is naturally abundant within our soil. Addition of more of this chemical element in fertilizer will cause algal blooms in our waterways, waterway eutrophication (a reduction in dissolved oxygen in water), fish die offs, and other environmental ills. Over-application of fertilizer does not just apply to conventional gardeners. Organic gardeners may also be at risk of adding too much phosphorus (P) or other elements in the form of manure or other sole source soil amendments such as rock phosphate.

Regular Nutrient Soil Testing allows conventional gardeners to take a snapshot of their soil’s baseline data, compare this to typical NRCS Soil Survey data, monitor changes in the soil chemistry, and make informed decisions that will assure plant vitality yet avoid environmental downsides such as soil erosion. The challenge is adding sufficient fertilizer to the soil for uptake by plants yet not too much so that excess will be leached as a pollutant into the aquifer or run off the soil surface in the form of erosion.

Unfortunately, a homeowner or gardener may mistakenly believe that a balanced fertilizer (e.g., 10-10-10) is best; therefore, is at risk of over-applying nutrients which are already abundant naturally. Over-application of fertilizer may cause salts in the soil to rise into toxic levels. The average person may not be aware that rainfall or other precipitation will erode excess fertilizer with the soil in the form of surface runoff or cause it to infiltrate into and contaminate our groundwater and aquifers.

Environmental Soil Testing can help determine whether your garden soil has toxins or contaminants that may affect healthiness of food grown in that soil. Commercial availability of environmental soil tests grew out of the environmental movement, so much of the technical terminology and standards are based on a geology or Earth Science perspective.

Typical patrons of Environmental Soil Test laboratories are often compost businesses, large agricultural producers, and government agencies. Based upon a Spokane County Master Gardener pilot, your soil testing experience may not be as seamless\(^1\) as it is at Nutrient Soil Labs. Background research on your site to identify potential contaminants and diligent follow-up during testing may be of help producing best results.

Soil Test Results

Even within a given testing category (environmental, biology, nutrient), there are multiple methods to test for concentrations of the very same chemical element. For example, testing for phosphate (P), one of the major plant nutrients; the second element seen on fertilizer labels can either be a qualitative (non-numerical) test such as the Eidt (1972) field based phosphate test or by using the more qualitative Mehlich-II acid extractant

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\(^1\) By seamless, Master Gardeners means both that Environmental Testing Labs may be unused to addressing the concerns of home gardeners and that the scientific research and interpretation may not yet be adequate. Soil may not be a regularly tested item for a given lab (as opposed to water, compost, plant samples, etc.). Complete panels testing for any possible heavy metal, toxin, or other contaminant panels are currently prohibitively costly. Is there one or two heavy metals or soil contaminants that would serve as a reliable, cheap screening indicator? More study is recommended.
and colorimetric methods. Various chemicals, combinations of chemicals, or processes may be employed to assess phosphate tightly held in the soil (i.e., total phosphate) or for merely the water soluble fraction easily available to plants in the time span of a given season. Labs in different regions may prefer different methods to test for a given element. For example, labs may test for phosphorus (P) using Olsen, Bray P1, or Bray P2 methods, producing results not readily comparable between laboratories or tests.

Thus, the outcome of testing for a given nutrient like phosphorus can be confusing. Different methodologies, however, do not mean results are any less valid. Your goals must guide your selection of the tests. An agriculture farmer or deep mulch gardener, for example, may prefer to explore total amounts of phosphate in the soil as well as presence of fungal hyphae capable of recycling that phosphate tightly held in the rock or mineral portion of the soil and make it available to fertilize food or lawn. Someone relying on bagged fertilizer may instead require the concentration of phosphate readily available for plant uptake. Regardless of whether testing for total or readily available amounts of a given nutrient, your best bet for consistent results is to do tests at the same season over time, for example, scheduling testing during the fall. Consistent scheduling of soil tests to achieve more consistent results is the most critical with Soil Nutrient Tests, as these tests are typically predicated on assessing concentrations of water soluble nutrients, which will vary seasonally.

According to Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers, PNW64 --- WSU, OSU, UI:

“Soil laboratories run soil analyses that estimate the availability of nutrients to plants. Laboratory fertilizer recommendations are based on decades of field studies that match a certain laboratory result with actual plant uptake of nutrients. If a soil analysis indicates there is an insufficient amount of a nutrient in the soil, then the laboratory will recommend adding fertilizer that will raise the soil concentration of this nutrient. Basing soil recommendations on nutrient availability in the soil is known as the sufficiency level of available nutrients (SLAN) concept (Kopittke and Menzies 2007).”

Despite the soil testing methodology preferred by any given lab, the hope is that the interpretation and recommendation within a given region will produce comparable guidance. Labs that give Nutrient Soil Tests recommendations usually follow a cook book formula taking the critical concentration number (usually expressed in ppm) below which an addition of a specific nutrient will most likely increase production/yield. Practitioners of regenerative agriculture may get more usage out the readily available fractions of nutrients from their test results (ppm of P or % O.M.) from Nutrient Soil Tests than in their interpretation and recommendations.

Spokane County Master Gardeners would like to include a warning about the challenges of getting an accurate measurement of nitrogen in a conventional Nutrient Soil Test. Regenerative practitioners rarely seek to test for the biological active and rapid cycling element of nitrogen. One of the reasons labs sometimes recommend adding too much nitrogen is because there is a natural loss of nitrogen when the soil is disturbed while taking the sample. In addition, if the sample is not kept cold, or the sample is not tested immediately, the test will understate the nitrogen content.

Over-application of nitrogen fertilizer on landscapes and farms has resulted in runoff that pollutes our waterways and creates dead zones in our oceans. Although Spokane County’s watersheds drain toward the Pacific Ocean, it is worth mentioning that the polluted dead zone in the Gulf of Mexico, comprised of the nitrogen rich runoff from Midwest farms, measured 8,776 square miles in 2017. If your goal is the application of fertilizer in accordance to recommendations from a Nutrient Soil Test, how you collect and submit your soil sample for the nitrogen (N) test is critical. This is a literally a “garbage in: garbage out” caveat.
For the best results and least damage to our waterways and environment, **pay close attention** to all your selected commercial laboratory recommendations for gathering and submitting uncontaminated, fresh, and the most accurate samples for any Nutrient Soil Test, Environmental Soil Test, Biology Soil Test, or another specialized test.

Regardless of where one falls out on the spectrum from regenerative to conventional agriculture, better understanding the seasonal fluctuation of nutrient availability in your soil is useful. However, despite certification and cook-book approach, a given laboratory’s experience enters the equation. The volume of laboratory tests, use of local calibrations, and locally developed skills may factor into the most skilled interpretations and recommendations relevant in each area.

**Soil Test Terminology**

The technical terminology and standards for Nutrient Soil Tests (rising in commercial availability after World War II) and Easy DIY Soil Tests (often early 19th century Agronomy teaching tools) arose from the study of Agriculture. In contrast, much of the technical terminology and standards for Biology Tests, whether simple home tests or commercial lab tests, arises from Biology, Ecology, or other Natural Resource fields. No wonder the same word can mean many different things!

**Specialized Soil Testing**

We would be remiss if we failed to discuss specialized soil testing and various reasons for pursuing such tests. Often specialized soil testing is undertaken to better understand an anomaly seen in the results of a previous soil test, to answer a specific academic research or policy question, or is a common practice or experimental endeavor in a certain scientific discipline or profession. We would also be remiss if we did not discuss soil testing caveats and best practices.

Surprised by a recurring oddity on your [nutrient] soils tests that no agronomy professional seems to be able to explain? New to carbon farming and interested in tracking your soil carbon sequestration effectiveness as you improve your living soil? Trying to determine whether a specific soil management practice will lower levels in your garden of toxic contaminants or fecal coliform? Researching the pH of pine needle compost? Have you thought of a new method for integrating biochar? Attempting to measure the weight and contribution of a specific microbial denizen of your living soil? Want to know explore just how fungal hyphae multiply the root zone of wheat or raspberries?

An enormous spectrum of soil testing methods and laboratories are utilized by a wide diversity of professionals such agronomists researching compost, foresters studying carbon sequestration in Christmas tree plantations, epidemiologists worried about pathogens encysted in soil, forensic scientists employing ground penetrating radar to locate unmarked human burials, archeologists evaluating vertical soil profiles to find spikes of organic matter or phosphorus that indicate former human occupation surfaces, and geologists remediating levels of toxic metals to reclaim mine sites and brown field. It is possible that your topic has already been well-researched. Professionals in each discipline may even be approaching scientific consensus of recommended types of testing that will address the question you have in mind. Of course, science is a process and consensus may change with new research and understanding.
However, data may be relatively scarce on your topic even in obscure professional journals. In this eventuality, the type of specialized soil tests recommended, the methodologies selected, or the laboratory utilized will typically depend on the professional discipline or researcher with whom you chance to consult. If you are pursuing specialized soil testing for any reason, we highly recommend that you do not limit your quest to any one individual or technique or laboratory, thus falling into the what more experienced professionals often refer to as the “black box trap.” Fascination with a particular testing method (the black-box trap) may actually divert you from answering your original question, side-track your efforts for an unconscionable length of time, and could potentially cost a lot of money for very limited results. In other words, keep your goal firmly in mind rather than a given method for testing.

Instead, first discuss your overarching goals with several professionals, preferably from diverse academic disciplines, for the best overall perspective on your question. Seek out professionals or researchers with excellent credentials for best results. Do your homework and prepare yourself by amassing and citing multiple professional papers from well-respected, peer reviewed scientific journals in the various professional disciplines (e.g., agronomy, forestry, medicine, geology, archeology, biology) most relevant to your topic. Your discussions with different professionals from different disciplines should guide you towards the optimum way(s) to address your question. For the most replicable, accurate, precise, and regionally comparable results, prioritize credentialed scientific professionals and accredited, local laboratories.

Likely, if you have encountered a puzzling phenomenon demanding an answer only available from Advanced Soil Testing, other people have probably been curious about the same thing and learning more. Science is a process. Good agricultural management that takes care of our healthy soil, to assure good health now and in the future, is even more of a trial and error process. Who knows? The answer you are seeking might be just the one that will change farming methods, scientific knowledge and policy across the nation and our world.

To Learn More About Soil and Soil Testing:

**Soil Health, Soil Quality, Soil Food Web, Biology of Soil and Role of Organic Matter:**

- Center for Sustaining Agriculture and Natural Resources (2014) Building Soils For Better Crops Conference, [http://chanr.wsu.edu/program-areas/bioag/bioag-conferences-proceedings/soils/](http://chanr.wsu.edu/program-areas/bioag/bioag-conferences-proceedings/soils/)


**History and Sustainability of Agriculture:**

• David R. Montgomery (2017) *Growing a Revolution: Bringing Our Soil Back to Life*,

• David R. Montgomery (2012) *Dirt: The Erosion of Civilizations*,

• Garcia, Deborah Koon (2012) *Symphony of*. This documentary features WSU Professor John Reganold, UW Professor David R. Montgomery, and many others. WSU Master Gardeners of Spokane County showed this film extensively during the 2015 International Year of Soils public outreach, with the premier introduced by WSU Professor Lynn Carpenter-Boggs.


• Articles in the Master Gardener’s Lowdown newsletter highlighting our 2018 “Strive For Five % Organic Matter” public outreach may also be of interest.

**Soil Fertility, General Agronomy, and Green Revolution:**


• Washington State University-Oregon Sate University-Idaho State University (Date?) *Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farms*, A Pacific Northwest Extension Publication, PNW646
http://cru.cahe.wsu.edu/CEPublications/PNW646/PNW646.pdf Although the authors assume that Nutrient Soil Test is your only goal, this is an essential publication is soil fertility and soil nutrient testing if that is the case.

- Oregon State University (date?) “Should I Worry About Heavy Metals in My Garden?”
  http://extension.oregonstate.edu/emerging-issues/should-i-worry-about-heavy-metals-my-garden-soil This excellent publication warns about particular environments where heavy metals are likely, links one to publications which compare normal and anomalous results, and provides interpretation and mitigation recommendations.

**Heavy Metals, Pathogens, and Other Contaminants in Soil:**


**Soil Health in Urban Areas**


**Soil Sampling and Testing (Primarily Directed At Users of Nutrient Soil Tests):**

C225 - Advanced Soil Testing