

Chapter 1: Introduction to Soil Management in Berry Production – *Dr. Harold van Es, Cornell University*

What is soil?

The Soil Science Society of America defines soil as, “the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural

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medium for the growth of land plants.” For commercial berry growers, soil is the growth medium that supports production of their crops. The types of soils available, their physical, chemical, and biological characteristics, their past, present, and future management all contribute to their suitability and sustainability for berry crop production. (Page 9 photo: *planting beds ready for plastic-laying*, photo courtesy H. van Es)

Why do I need to manage soil health and when?

The most opportune time for soil health improvement is prior to planting. Thus it is neither efficient nor expedient to randomly select a site and establish berry plants without first assessing the suitability of the soil for berry crop production. Careful consideration of the available soils and their characteristics should be made in light of berry crop requirements. Once a suitable site with an appropriate soil is selected, additional soil management practices may be called for to further improve soil health prior to planting.

Site selection is **critical** to successful berry crop management; if a grower starts out with an inherently low quality soil it is often extremely difficult if not impossible to overcome soil constraints that limit yield and productivity of the berry

For example, subsoil properties are not regularly assessed, but are important for perennial crops such as berries. Soil health improvements that may need to be implemented prior to planting might include such things as drain tile installation, subsoil fertility amendment, pH correction, deep ripping to break up compaction or fragipan layers, cover cropping for the same and/or to increase soil organic matter content, reduce soil pathogens, compost addition to boost organic matter content and/or increase soil biological activity. Slope and aspect are important considerations for site selection for high value, long-lived perennials; slope for water runoff and air drainage and aspect for best growth. Nearness and/or availability of irrigation are also important.

Soil health management does not end once the plants are in the ground. Post-establishment soil and nutrient management is also critical to successful berry crop production: periodic soil testing in conjunction with foliar analysis to monitor plant nutrient status, continuing pH monitoring and/or adjustment, addition of amendments such as fertilizers and/or compost side dressings to maintain fertility, establishment of row middle cover crops, etc.

What are the benefits of soil health management?

Soil health management can provide multiple short-term and long term benefits for commercial berry growers:

- Maximizes yield potential in terms of quantity and quality of fruit produced
- Improves and maintains plant health
- Extends the life of the planting
- Reduces inputs and corresponding management costs
- Facilitates sound environmental stewardship

Soil health concepts

Soil health is the capacity of the soil to function. The function in the case of berry crops is sustaining plant health and facilitating good yields.

All soils are not created equal

Overall quality of a particular soil is a result of both its inherent and dynamic qualities. *Inherent soil quality* results from natural soil forming processes and long-term geologic, biotic, climatic and topographic factors.

Physical characteristics contributing to inherent soil quality include soil type, soil texture (sand/silt/clay content), stoniness, internal drainage (may be modified), soil depth, presence of barriers such as fragipan, clay layer or tillage pan (may sometimes be modified), and slope.

Chemical characteristics that play a role in inherent soil quality are pH, P, K, Ca, Mg, Fe, Al, Mn, Zn, B and Na content (these may be modified by use/management practices) and salt accumulation (this varies by location across the US.)

Finally, a biological characteristic contributing to inherent soil quality is organic matter content; organic matter serves as part of the nutrient exchange complex, increases the moisture holding capacity of the soil, provides compounds that help maintain soil structure and supports biological activity (organic matter content may be modified over the long-term).

Information on inherent soil quality may be obtained from soil survey reports and includes things such as basic soil properties and suitability for use. Information on inherent soil quality may also be obtained from on-line tools such as Web Soil Survey (<http://websoilsurvey.nrcs.usda.gov/app/>). More information on how to use this tool is provided in Appendix A.

Dynamic soil quality results from changes due to human use (management) either in a positive or negative sense. Evaluation of dynamic soil quality, as portrayed by a Cornell soil health test, provides more detailed information than inherent soil quality characteristics alone. The Cornell soil health test consists of standard soil nutrient analysis enhanced with 4 biological and 4 physical indicators. The test uses chemical analysis results in conjunction with these indicators to identify soil constraints, allowing growers to initiate management actions to overcome them prior to planting.

Characteristics of healthy soils

What are the characteristics of a healthy soil? Sufficient soil depth for plant root development is important; a soil depth of 8 inches or greater is preferred in the case of berry crops. A healthy soil should have good tilth, water storage and drainage. It should have sufficient *but not excessive* nutrients and be free of chemicals harmful to plants such as heavy metals, herbicide residues or other contaminants.

Liebig's Law of the Minimum states yield is proportional to the amount of the most limiting nutrient, whichever nutrient that may be. We now know this law should be applied in a broader context where the limiting factor may be soil chemistry and/or a physical or biological factor.

The most important part of the whole puzzle in terms of soil testing and soil fertility for any berry crop is getting soil pH to the right level for optimum crop performance ***before planting, and keeping it there.***

Healthy soils should have low populations of plant disease and parasitic organisms such as fungi, bacteria, nematodes, springtails, and so on. Conversely, a healthy soil should contain high populations of beneficial organisms like mycorrhizae and earthworms.

Finally, healthy soils should exhibit resistance to being degraded and along with that – resiliency or the ability to recover quickly from adverse events such as flooding, drought, hurricanes, etc.

Understanding the three soil health processes

Think of soil health then in terms of the three major realms that impact it: the physical, the chemical, and the biological. These three realms intercept and interact (Figure 1); thus it is important to view each of these more as processes than characteristics. If any process is compromised, the others are also affected. A healthy soil is balanced in this respect and therefore provides for better growing conditions, crop resiliency and reduced inputs.

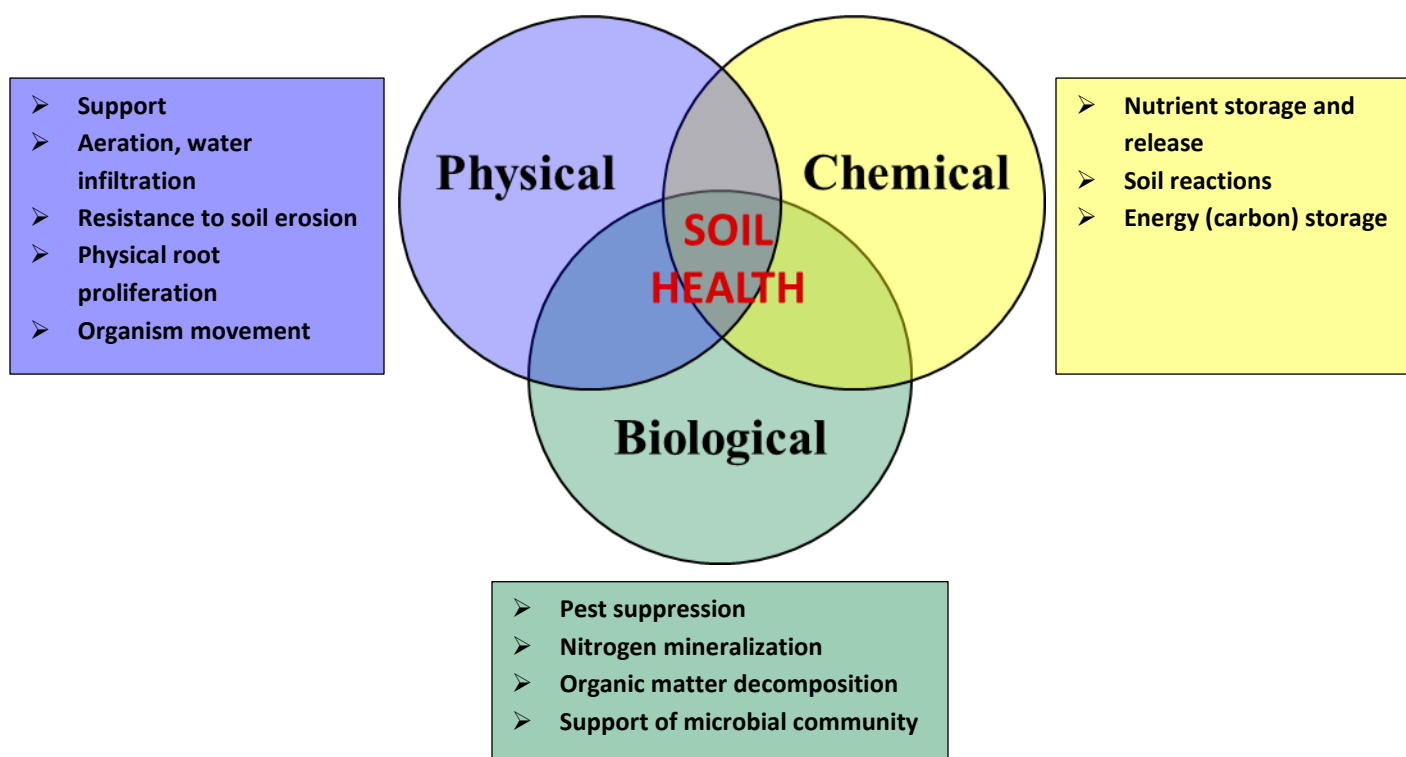


Figure 1: Soil health – an expression of the interactions between chemical, physical and biological processes in soil

Over past decades, chemical aspects of soil were, in general, perhaps overemphasized; not to a fault necessarily, as good testing procedures and crop recommendations were the outcome of these investigations. But at the same time, not nearly as much attention was paid to the physical and biological aspects of soil. Research is ongoing in the physical and biological realms today, providing a more complete snapshot of soil health and as a result, more comprehensive short-term and long-term management strategies for soil health improvement.

The chemical processes

The chemical processes in soil provide essential nutrients for plants. pH is a **critical** component of the chemical process as it affects nutrient availability. Any changes in pH must be addressed, before the planting is established; failure to adjust pH to optimal levels for the crop will seriously impact plant establishment as well as future crop

production. pH adjustment is more difficult after a perennial crop is established and may reduce the success of the planting.

The chemical process also includes both macronutrients (nutrients needed in larger quantities (such as N, P and K) secondary nutrients like Ca, Mg and S and micronutrients required in smaller quantities (such as B and Zn); specific recommendations have been developed for correcting deficiencies of these nutrients essential for berry crop production.

The physical processes

The physical processes of soil may be limited by inherent or dynamic qualities; some of these may be remediated; others may not.

Poor internal drainage is often due to local hydrology and impeding soil layers (fragipans) resulting in poor aeration which reduces root growth and function and may support disease development. Poor internal drainage may also be a result of past management practices such as compaction, intensive tillage, etc. Poor internal drainage is frequently identifiable from a soil survey; however, on-site excavations are recommended to evaluate the extent of the condition. Internal drainage issues may be remediated through installation of subsurface drain lines and use of raised beds to reduce susceptibility to imperfect drainage (aerobic vs. anaerobic conditions).

Poor water availability is mostly a function of soil texture, organic matter content and rooting depth. Compaction reduces root proliferation and water access by plants. Often this condition may be improved through deep ripping and/or compost additions. Where coarse soils with good drainage are present in humid climates mild water stress readily occurs; in dry years drip irrigation is almost always required.

Soil aggregates (crumbs) come in various sizes (0.002 to 2 mm in diameter) and are composed of soil particles (sand, silt and clay) held together by moist clay, organic matter, organic compounds produced by bacteria and fungi, and fungal hyphae (threads).

Well aggregated soils consist of about 50% soil aggregates and 50% soil pores. These soils typically have a range of pore sizes; the pores are important for drainage, aeration, and rooting. Small pores are important to long-term moisture retention. Intermediate pores are needed for water retention and biological function. Large pores occur between medium size aggregates and facilitate drainage; they are most often lost with compaction.

Good soil structure is important to plant growth and development. Roots need soil pores > 0.2 mm in diameter or larger to move through soil and strength <300 psi to penetrate, porous loose fitting crumbs and blocks as is found with a well –aggregated (naturally softer) soil.

Compacted soil structure is characterized by a surface crust, tightly packed crumbs, large blocks with few cracks, and subsoil compaction. Compacted soils are subject to extended periods of saturation, standing water; compacted plow layers (big clods), are more disease prone, limit rooting; and experience problems with infiltration and erosion.

Plow layer compaction may have one or more causes including loss of organic matter (and thereby aggregate stability) from intensive tillage, lack of organic matter additions, traffic on wet soil, lack of controlled traffic, and/or soil settling from heavy rain.

Subsoil compaction, unlike plow layer compaction, evidenced by big clods, is very invisible and more difficult to address. Causes of subsoil compaction include heavy traffic on wet soils (i.e. manure spreaders), use of equipment with poor weight distribution (with more modern equipment there is less of this problem), and a long history of plowing, especially wheel in open furrow plowing.

Identifying compaction layers - Penetrometers, shovels, and trenches for root observations are good diagnostic methods to identify and locate compaction layers. Measuring penetration resistance with a simple tool called a penetrometer is one way to begin to locate and assess compaction layers. Penetrometers are relatively inexpensive, around \$200. Often, extension offices or soil and water conservation offices have penetrometers growers may borrow to use for this purpose.

Mediating compaction layers – Mitigation of deep (subsoil) compaction requires deep tillage, and/or deep-rooted cover crops. For shallow compaction layers a different strategy is in order.

The biological processes

Understanding soil biology is very much at forefront of our science today. Soil represents a complex environment with highly variable conditions. Most biological activity occurs near the surface of the soil where most of the organic matter is located. There are 3 general types of organic matter found in soil: Living, dead, and very dead. All 3 play important roles in helping produce high yields of healthy crops. Adding organic matter to soil results in many benefits (see Chapter 9 for more detail).

Living organic matter is comprised of those soil organisms that play important roles in making nutrients available, suppressing disease, producing plant growth promoting hormones, creating humus, aggregating soils. These might include such things as bacteria, fungi, nematodes, earthworms, mites, springtails, collembolans, moles, and many other types of organisms. These organisms often interact in very, very complex ways. They use resources in soil in various ways, decomposing organic matter, cycling nutrients, influencing plants and other biota, and responding to their chemical and physical environment: i.e. in compacted soil we find less numbers of soil organisms along with less diversity of organisms present.

How Do Management Practices Affect Soil Life?

- ❖ **Intensive tillage** reduces mycorrhizal colonization and diversity of soil organisms
- ❖ **Organic matter application** increases diversity, density & activity of fast growing microorganisms
- ❖ **Fertilizer application** proliferates the growth of fast growing microorganisms and reduces nitrogen fixation, and mycorrhizal colonization
- ❖ **Irrigation/drainage** benefits either anaerobic or aerobic soil organisms depending on whether either is adequate or inadequate.

Examples of Soil Process Interactions

(*chemical, physical, biological*)

- ❖ **Hard soil** reduces **rooting**
- ❖ **Compacted soil** suppresses **beneficial biological processes**
- ❖ **Compaction** increases **root diseases** and **denitrification losses**
- ❖ **Organic matter decomposition** increases **aggregation**
- ❖ **Prolific rooting** decreases **compaction**
- ❖ **Poor drainage** reduces **rooting** and **aerobic biological processes**
- ❖ **High sodium content** reduces **aggregate stability, drainage, aeration, and rooting**
- ❖ **Tillage** increases **bacteria** and decreases **fungi**

Soil organisms may also manipulate the chemical and physical environment of the soil in a beneficial way. Examples of these soil organisms include plant roots, organic matter decomposers and mycorrhizae.

Mycorrhizae are non-pathogenic fungi that live in a symbiotic relationship with roots of higher plants, enhancing nutrient uptake by the plant (P, N, K, micronutrients), especially P. They also assist in soil aggregation, provide a form of defense against pathogens, protect plants against metal phytotoxicity, and enhance plant fitness (pollen quality, plant-pollinator interaction). They are especially beneficial in undisturbed soils.

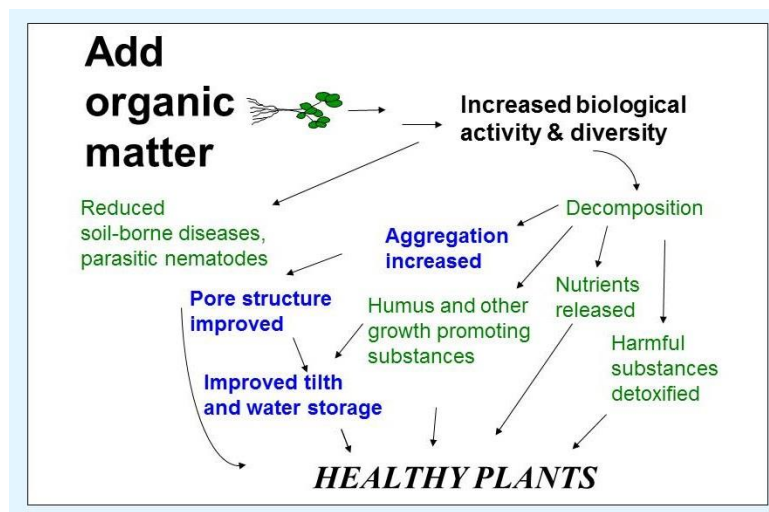
Suppressive soils are described as those that for various reasons suppress soil-borne pathogens such as *Pythium*, *Phytophthora*, *Rhizoctonia*, etc. This may be due to the presence of organisms with suppressive ability: (direct suppression or out-competing through larger population numbers) including *Pseudomonas aureofaciens*, *Bacillus subtilis*, *Trichoderma*, *Paxillus involutus*, etc.

Another living component of soil is plant roots- the below ground portion of plants, which are typically very beneficial to the soil.

Dead organic matter is composed of recently dead soil organisms and crop residues that provide food (energy and nutrients) for soil organisms to live and function. Dead organic matter is also called “active” or “particulate” organic matter. This is the other essential partner in mineralizing nutrients for plants, aggregating soils, and forming humus.

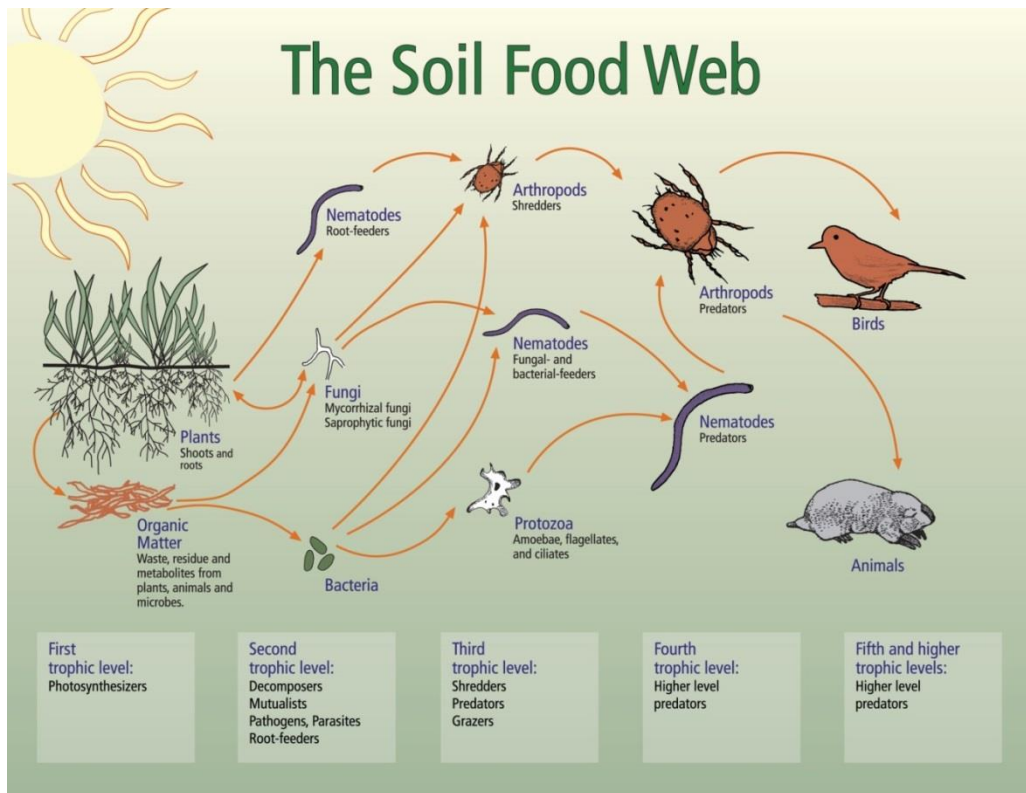
Very dead organic matter is not a biologically active fraction; rather it consists of well-decomposed organic materials, also called humus. Humus supports the chemical activities of soil; it contains very high amounts of negative charges that hold nutrients and cations in the soil. Humus also has high water-holding capacity, and stores carbon.

Adding organic matter results in many benefits.



Feeding the soil vs. feeding the plants – a different paradigm

Natural soil ecosystems evolved with little disturbance as forest or grassland. Nutrients were recycled through organic materials such as leaves and animal droppings. Decomposing materials “fed the soil” nutrients and carbon and stimulated diverse biological activity. This mineralized (inorganic) nutrients and then “fed the plants” (plants only take up basic mineral nutrients)



A Soil Food Web Glossary	
Arthropods	Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, arachnids (spiders), and others.
Bacteria	Microscopic, single-celled organisms that are mostly non-photosynthetic. They include the photosynthetic cyanobacteria (formerly called blue-green algae) and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).
Fungi	Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi, such as yeast, are single-celled. Saprophytic fungi: Fungi that decompose dead organic matter. Mycorrhizal fungi: Fungi that form associations with plant roots. These fungi get energy from the plant and help supply nutrients to the plant.
Grazers	Organisms, such as protozoa, nematodes, and microarthropods, that feed on bacteria and fungi.
Microbes	An imprecise term referring to any microscopic organism. Generally, "microbes" includes bacteria, fungi, and sometimes protozoa.
Mutualists	Two organisms living in an association that is beneficial to both, such as the association of roots with mycorrhizal fungi or with nitrogen-fixing bacteria.
Nematodes	Tiny, usually microscopic, unsegmented worms. Most live free in the soil. Some are parasites of animals or plants.
Protozoa	Tiny, single-celled animals, including amoebas, ciliates, and flagellates.
Trophic levels	Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking about the food web. In reality, some organisms eat members of several trophic levels.

Figure 2. Soil food web – a bottom up effect where the abundance of a resource affects the abundance of its consumers.

Source: Soil Biology Primer <http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/> [August 7, 2013].

In modern agriculture, with the onset of the use of fertilizer and soil disturbance through tillage – we have accelerated organic matter mineralization. Use of chemical fertilizer had led to feeding plant directly with mineral nutrients; with this practice we have essentially stopped feeding soil organisms.

Summary

For perennial crops such as berries, the most opportune time for soil health improvement is prior to planting.

Additional Resources

1. Magdoff, F. and van Es, H. 2009. "How good are your soils?" Chapter 22 in *Building Soils for Better Crops: Sustainable Soil Management*, 3rd edition. Sustainable Agriculture Research and Education (SARE) program handbook series no. 10. 294 pp. <http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition>
2. *Soil Biology Primer* http://soils.usda.gov/sqi/concepts/soil_biology/biology.html
3. *Cornell Soil Health Manual* <http://soilhealth.cals.cornell.edu/extension/manual.htm>
4. *Soil Quality for Environmental Health* web site <http://www.soilquality.org/home.html>
5. *Soil Quality/Soil Health – USDA NRCS* web site <http://soils.usda.gov/sqi/>
6. *Managing Cover Crops Profitably*, 3rd edition <http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition>
7. *Cornell Cover Crops Decision Tool* <http://covercrops.cals.cornell.edu/decision-tool.php>
8. *Midwest Cover Crop Council Cover Crop Decision Tool* <http://mcccddev.anr.msu.edu/>

Chapter 2: Soil Testing for Berries– Ms. Janet Fallon, DairyOne

What does a soil test measure?

A soil test is a process using chemical analyses to assess current nutrient levels in soil. Elements (phosphorus, potassium, calcium, magnesium, sodium, sulfur, manganese, iron, copper, aluminum and zinc) are chemically removed from the soil and measured for their "plant available" content within the sample. A soil test also measures soil pH, humic matter and exchangeable acidity. These analyses indicate whether lime or sulfur are needed to change the pH, and, if so, how much to apply. Components of soil testing include field sampling, extraction and chemical analysis, interpreting analytical results and making a fertilizer recommendation based on those results.

Why do I need to soil test and when?

As indicated in chapter 1, soil health management does not end once the plants are in the ground. Post-establishment soil and nutrient management is also important to successful berry crop production.

This includes periodic soil testing (every three years or so) in conjunction with foliar analysis to monitor plant nutrient status, pH monitoring and/or adjustment as needed to maintain nutrient availability for good plant nutrition, and addition of amendments such as fertilizers and/or compost side dressings to maintain fertility.

What are the benefits of soil testing? Think of soil testing as a crop management tool to be used both preplant and post-plant to optimize crop yield and quality. Much like the hand lens you may use to scout for diseases and insect pests, a soil test can provide an early warning that potential problems may be looming on the horizon. It also provides advisement on how to address potential issues once they have been identified, such as soil pH

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4. *Soil Quality for Environmental Health* web site <http://www.soilquality.org/home.html>
5. *Soil Quality/Soil Health – USDA NRCS* web site <http://soils.usda.gov/sqi/>
6. *Managing Cover Crops Profitably*, 3rd edition <http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition>
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