SUSTAINABLE FOOD GARDENING: NURTURE AND PROTECT THE SOIL
by Master Gardener Karen Guma

It can be very hard to know when your soil practices are helping. One gardener will say, "I always add *x, y,* and *z* to my soil and my plants are beautiful." And indeed, you can see that the plants are healthy. But there are several things you don't know. Were the soil additives necessary or would the plants have been healthy without them? Was one of the additives crucial and the others neutral or even harmful? What effect do the additives have on the water table and the environment? What effect do the additives have on the longer-term health of the soil? Is the soil improving or deteriorating over time?

There are several ways that soil can be healthy or unhealthy, and there are even different ideas of what constitutes "good soil." When gardeners talk about good garden soil, most of the time they mean the type of soil that is good for cultivating vegetables or exotic ornamentals. But the quality of the soil is also relative to the plants you intend to put in it.

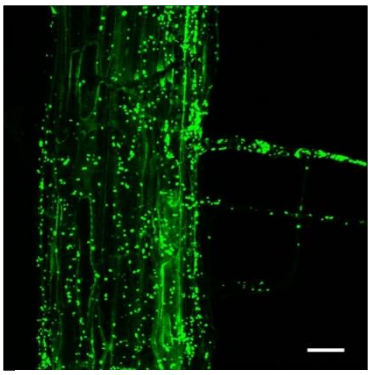
Some dimensions of soil health include the structure, the organic content, the health and variety of soil microorganisms, the nutrients present and whether or not they are available to the plants, the acid-alkaline balance, the drainage, the effect of plant roots on their environment and the variety and diversity of the plant-soil ecosystem, which affects its resilience.

Every soil has some advantages and disadvantages. Soils are broadly classified into sand, silt and clay. Sand has the coarsest, largest particles and the smallest surface area. Clay is the most dense and has the largest surface area. Silt generally is sedimentary deposits and is in between. Most soils are not one or the other, but a mixture of all three. The more sandy the soil, the more quickly water drains through and the poorer the nutrients. The higher the clay content, the more nutrients adhere to the soil particles but the poorer the drainage.

Hyphal extensions to roots (Guillaume Becard, University of Toulouse)

One way to improve the structure of all types of soil is to add organic content. The aim is to create a crumbly structure, like good baked goods: not too hard to penetrate but not falling through your fingers either. The particles adhere to each other in aggregate form (the crumbs). If you look at a soil aggregate under an electron microscope, you would see mineral particles held together by thin fungal strands (hyphae) and slimy material left by living organisms. There would be a hole or two in the middle containing air, and water would be adhering to the surface of the particles. There also would be lots of bacteria, and perhaps

some protozoa, microarthopods and nematodes. The crumbly structure is essential for storing water, air and nutrients.



Bacteria in root (MPI for Plant Breeding Research)

Normally, that is if you haven't killed it, soil is teeming with life. The vast majority of the organisms are too small to see, but these are the most important, especially the bacteria and the fungi. They are essential for breaking down the dead and decaying matter on which your plants rely for photosynthesis. And the plants take an active role in attracting the kind of microbial life they need to thrive—as much as 20% of what they produce gets exuded through the roots to draw beneficial organisms.

In nature, plants germinate, grow and eventually die, returning everything they have used in their lifetimes to the soil, where the living organisms break it down and nurture the new generation of plants. In gardens, however, we take fruits, flowers, stems and roots out for our own use, and the system is no longer self-sustaining. Even weeding withdraws energy and nutrients from the soil without returning anything. So to keep our soils healthy, we need to put something back in. Compost and mulch replace the organic matter we have taken out.

The earlier prescription for healthy soil was to rototill it, fertilize it and water it, and if the plants don't grow well, fertilize and water some more. Our understanding of soil science was based on chemistry and physics, not biology. As we have learned more about the life of the soil, especially the microscopic life, we have begun to see the essential importance of living organisms in nurturing soil and plants, and the interdependence of all the living things in the plant-soil ecosystem. Before, we thought that if the plant needs nitrogen or phosphorus, just add them in the pure chemical form and the plant will utilize them just as it would if it had obtained the nutrients from the soil.

But it doesn't work that way. True, once inside the plant, the chemical will be processed in the same way, whether it comes from the soil or from artificial fertilizer. The effects on the soil, however, are quite different. Nitrogen, for example, one of the key ingredients of growing plants, can be very volatile. You can add it to the soil, but once added, it easily washes away in the rain or volatilizes into the air. Our over-fertilized soils are one reason our waterways are becoming polluted, because nitrogen that is useful in the soil becomes deadly in a waterway, nurturing algae that absorb all the oxygen and leave aquatic life to die. Phosphorus, on the other hand, binds quickly to other elements in the soil within minutes of adding it, thus becoming unavailable to the plants. An oversupply of it is also an environmental hazard. In a natural system, the mycorrhizal fungi (fungi in a symbiotic relationship with plant roots) break down phosphorus from its compounds and supply it to the plants in a form they can absorb. Put the artificial stuff in the soil instead and the plants will bypass the mycorrhizal network, which will eventually die off. Once it is gone, the plants are exposed to pathogens they otherwise wouldn't be, and lose their access to water that fungal hyphae can reach, but roots can't (hyphae are much, much smaller than plant roots). This also means that once you start adding artificial fertilizer, you have to keep adding fertilizer, and more and more of it to get the same effect—like an addiction.

Mycorrhizal extensions to roots

Tillage is an ancient practice still in widespread use, but it harms the soil. It is only since we have discovered the teeming microbial life of the soil that we have started to realize how much harm we have done. Tilling breaks up the fungal hyphae in the soil, besides taking the roots out of the ground. Without roots, their symbiont, the mycorrhizae, have nothing on which to live. Tilling also exposes the ground to erosion, runoff and temperature extremes. It releases carbon into the air, which binds with oxygen to form carbon dioxide, a greenhouse gas. About a third of the greenhouse gases produced worldwide come from our land use practices. In addition, if the soil is always tilled to the same depth, a layer of hardpan forms just beneath that depth, impeding proper drainage. You don't see bare soil anywhere in nature, and you shouldn't see it in your garden.

So what's the alternative? Cover crops, groundcover plants, mulch, sheet mulching, intercropping with compatible plants, planting very densely—any of these is an improvement over bare soil. Compost and mulch are best added in the fall and winter, the rainy season in California, so that they will percolate into the ground slowly and naturally. Cover crops can serve dual purposes: replenishing the nitrogen or retaining last season's nitrogen while attracting pollinators. Deep-rooted cover crops can be used to break up dense, hard-packed soil. In the event you are starting a garden from scratch in compacted soil, you may find it necessary to break it up initially. The best ways to break up soil are the slow ways: sheet mulching, compost layered on top and cover crops. But if there is no time to wait, limit the tilling to the initial breakup. A broadfork or similar needle-like tools can be used to plant seeds while causing minimal disturbance. Running machinery over soil or stepping on it is enough to harm the life within and make soil harder to work. What you want is a light fluffy soil texture with a high organic content—a living soil.

Soil in containers or raised beds, especially if the soil is brought in, is cut off from the soil ecosystem, and, so will need a lot more inputs—water, fertilizer and compost—than natural soil. If you have to add fertilizer, use natural slow-release organic fertilizers with N-P-K (Nitrogen, Phosphorus and Potassium) numbers no higher than 10. Most artificial fertilizers are also salts, and as such they suck the liquids out of living organisms.

Rich soil is usually, but not always, the best soil for your plants. Ecology gives us the concept of "natural succession." Nature is not static, so "natural succession" is a bit of an abstraction, but it goes like this. First comes bare soil (from fire, flood, a tree falling in the forest, a volcanic island rising out of the sea). The soil is first colonized by annuals and grasses. As they grow, they shade the ground, and as they die, they enrich the soil. Perennials are better adapted to the new conditions, so they take over. They in turn change the conditions, and shrubs grow, shading the ground even more and making it hard for annuals and grasses to grow. In one type of succession, the climax plant community is a hardwood forest. Your area may never have been forested, but here is what you need to know. The soil changes along with the vegetation. As natural succession proceeds, the soil becomes more acidic (*i.e*., it has lower pH numbers). The amount of bacteria stays roughly the same, but the amount of fungi greatly increases. Earthworms become scarcer as the soil becomes acidic.

Vegetables are on the annuals end of the spectrum. They favor a bacterially dominated soil. Ornamentals favor the kind of soil they had in their original plant community. Desert plants (like succulents) favor a more alkaline soil. Forest understory plants (*e.g*., blueberries, azaleas) favor a more acidic soil with a higher fungal content. Native plants may grow quite well in rich soil, but so will their competitors. You can tinker with the bacterial-fungal balance of your soil by altering your compost. In your compost pile, you are attempting to balance nitrogen-rich materials with carbon-rich materials. These are often referred to, in a simplifying shorthand, as “green” and “brown” layers, but it is really the nitrogen-carbon balance that you are after (*i.e.*, some “green” materials, like coffee grounds, are actually brown, but they are lumped under “green” because they are nitrogen-rich). For a more in-depth look at compost, see the Sonoma County Master Gardeners’ composting page. Generally, you balance the amount of the green layer with the amount of the brown layer, but a little more green and you tip the balance toward bacteria, a little more brown and you tip the balance toward fungi. For a list of common "green" and "brown" materials for your compost pile, see "Composting is Good for Your Garden and the Environment."

Few gardeners will find it necessary to alter the pH balance of their soil, just as few will find it necessary to add some of the micronutrients that are essential for plant life (*e.g.,* molybdenum, boron). Most soils will be sufficient in those regards. But the most common soil additives are lime (for soil that is too acidic), sulfur (for soil that is too alkaline) and gypsum (for compacted soil—gypsum will not alter the pH). These kind of additives are best used only when the need is indicated by a soil test. A word on soil tests: the best and most reliable way to use them is to test over time, from the same locations in the garden, and using the same lab). Soil tests are not reliable when it comes to nitrogen content, due to the volatile nature of nitrogen. Their best use is to show the way in which your soil has changed over the years.

Some have heard of the cat-ion or an-ion exchange ratio of soil. A high exchange ratio indicates that the nutrients in the soil are more available to the plants. The main reason gardeners need to know about it at all is to know that adding one plant nutrient may make another nutrient less available. You are better off nurturing the microorganisms of your soil and letting them figure out what your plants need.

The best way to cultivate the life of your soil is by composting, mulching, making sure the water drainage fits the type of plants and continuously covering the ground. Instead of raking up and disposing of leaves in the fall, put them through a mulcher attachment to cut them into smaller pieces and put them back where you found them. Harmful practices include tilling, compaction and using chemical herbicides, fungicides and pesticides. Most of the microorganisms in your soil are beneficial, just as most insects are beneficial and

most of the microorganisms in your body are beneficial. Problems arise when the natural balance is thrown out of whack. The soil has processes akin to your immune system, and it will protect your plants naturally if it is nurtured.

Soil also will sequester carbon and protect the planet. Fossil fuel use is the main cause of climate change, but land exposure and soil degradation add significantly to it. Changing our soil practices not only has the potential to save us work and improve our plants, it is one thing that actually reverses the process of greenhouse gas production and puts the carbon back in the soil where it belongs. Humble gardeners can make the world a better place.

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Fungi in the author's compost.

To learn more about nurturing and protecting the soil, please refer to the appended "Sources and Resources for Soil."

This is one of a series of articles about Sustainable Food Gardening.

SUSTAINABLE FOOD GARDENING: NURTURE AND PROTECT THE SOIL
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