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Soil Organisms: Don't Garden Without Them

Most gardeners realize the importance of amending our naturally sandy soils with organic matter, but it is much more than just the organic matter. Organic matter in the soil is needed to maintain high populations of soil organisms. The soil organisms all relate to one another based on their location within the soil food web. The food web converts energy and nutrients from organisms on one level to organisms on another level. The lower level organisms are a food source for higher level organisms. Check out the following information on the organisms that live in healthy soils:

- Soil microbes consume organic matter, minerals, nutrients and each other. The minerals, nutrients, and water that are stored in their bodies are released for the plants to use when they die. So, when microbes feed on other microbes, or simply just die, they can actually fix chemical deficiencies in the soil[1].
- The main **organisms** found in the soil include:
    - Primary producers on the first, or lowest, level of the food web. They are photosynthesizers and include plants, mosses, algae, lichens, and photosynthetic bacteria.
    - Primary consumers, which feed on the primary producers or their residues, make up the second level of the soil food web and include herbivores (e.g. nematodes, insects, slugs, and mice) which feed on living plants. The other members of this level include detrivores (e.g. bacteria and fungi) that feed on dead plant tissue.
    - The secondary consumers are the next level up and include bacteria, fungi, centipedes, mites and spiders which feed on the primary consumers.
    - The tertiary consumers are the highest level of consumers and include the beetles, earthworms, ants, moles, and even birds.
    - Fungi (including the symbiotic mycorrhizal types)
        - Most fungi, such as mushrooms and molds, are multi-cellular and produce long strands called hyphae.
        - Fungi are important because they help with nutrient cycling, the decomposition of organic residue, creation of organic matter, improvement of the soil structure, and the suppression of disease.
        - Fungi can be grouped into one of following three groups: decomposers, mutualists, and pathogens.
        - Mycorrhizae fungi, which fall in the mutualist category, help supply plants with H_2O during droughts as well as nutrients such as phosphorus. Mycorrhizae fungi are both the highway (they move nutrients to the plants from areas of the soil that the plant roots can't reach) and internet of the soil (they help plants communicate to one another through them.)[2]
        - Mycorrhizae fungi are particularly important in marginal soils and in coarsely-

rooted tree crops like citrus and avocado. Mycorrhizal fungi can increase the absorbing surface of roots, thereby facilitating the uptake of essential nutrients and can function as "biological fertilizers" by reducing fertilizer requirements for certain crops. Here is a list of crops on which VA Mycorrhizal fungi have been found:

Avocado	Citrus	Sand Pine
Bahiagrass	Corn	Strawberry
Bean	Grape	Tomato
Carrot	Lettuce	Watermelon
Celery	Papaya	Peach
Chrysanthemum		

- Fungi dominate soils in the forests. They are the first microbes to move in when a tree dies. They have the ability to break down lignin.
- Wood chip mulches are great for areas where soil is predominately fungi.

o Bacteria
- After fungi break down lignin, bacteria move in to break down the remaining organic matter. Herbaceous plants can be broken down easily by bacteria.
- Prairies, grasslands, and other places that are predominately grasses, have soils with larger populations of bacteria.
- Grass clippings, dead leaves, pine needles, and straw are just a few examples of good mulches over soils that have high bacteria populations.
- There are free-living nitrogen-fixing bacteria that are "associative diazotrophs". Associative meaning, like mycorrhizal fungi, they require the presence of a living plant for their carbon. Diazotroph meaning the nitrogen that they fix occurs as di-nitrogen (N_2). These bacteria live in the rhizosphere or are linked via the mycorrhizal highway.[2]

o Protozoa
- These single-celled, mobile organisms play an important role in regulating bacteria populations in the soil and for nutrient cycling.
- Protozoa are larger than bacteria and more abundant in the soil.
- Their populations can reach 1 million per teaspoon in fertile soil.
- Feeding on bacteria and other protozoa often results in the release of nitrogen in a form that can be used by plants.
- The highest protozoa activity will be found in the rhizosphere near the plant roots.
- Soil moisture will influence the size and type of protozoa found in the soil as well as their movement and feeding.

o Nematodes
- The majority of nematodes that live in the soil are microscopic, non-segmented worms.
- Many feed on fungi, algae, bacteria, or are predators of microscopic animals.

        - Some nematodes are parasitic to animals or plants.
        - Nematodes help with nutrient cycling in the soil, can be a food source, and can suppress plant diseases when they feed on harmful fungi or bacteria.
- The main **macro-organisms** of the soil include:
    - Arthropods
        - These are animals with exoskeletons such as insects, crustaceans, and arachnids.
        - Arthropods physically shred the organic materials in the soil, stimulate microbial activity, and help in nutrient cycling.
        - The function they perform determines which category they fall into. Shredders of dead plant material include millipedes and termites. Herbivores such as mole crickets feed on plant roots. Both the shredders and herbivores can become pests if their populations get too large. Centipedes and spiders are predators and can help control the populations of the other arthropods. Some arthropods even eat soil bacteria and fungi.
    - Earthworms
        - "Earthworms are the intestine of the soil." - Aristotle
        - Earthworm castings are known to suppress certain diseases of grass. Castings and grass clippings composted together have been used on golf courses for new plantings of turf and bare spots. Castings can also improve soil structure by enhancing soil aggregation.
        - Earthworms are an indicator of a healthy soil.
        - In Florida's naturally sandy soil earthworm activity is usually low due to the lack of organic matter.
    - Crustaceans
        - Pillbugs or rolly-pollies, are amazing! They have a special fluid filled pouch that they tote their eggs in called a marsupium, they don't urinate, they eat their own poop to retrieve the essential element copper, sick pillbugs turn bright blue (due to a virus), their blood is blue (which is why they need copper), and they breathe through gills so they need a moist environment.[4]

What harms Soil Microbe Populations?

- Bare soil is horrible because those areas are food deserts for the soil microbes and when the soil microbes die the formation of soil aggregation stops[2]. A thick layer of mulch is better than bare ground but a diverse plant population is best!
  There are some exceptions to the bare soil rule for some of our pollinators. One is if you are butterfly gardening then it is fine to maintain a small area of bare soil so that the butterflies can obtain water and minerals when "puddling". The second exception is for our native ground dwelling solitary bees.
- Pesticides can also be called biocides and their use can destroy the crucial bridge between plants and microbes[2].

The health of the soil has a direct correlation to the health of the plants growing in it. So, sick plants are a sign, and the result of, poor soil because without organic matter the soil microbes can't live. When the soil microbes aren't present, then many of the plant nutrients won't be made available for the plants to absorb. Between 85-90% of the nutrients that plants require for healthy growth are acquired through the carbon exchange of root exudates for the microbes. The root exudates provide food for the microbes and in return, the plants are able to obtain minerals and other trace elements, such as copper and zinc, which would normally be unavailable. Healthy soil is alive with billions of microbes per gram (4.2 grams/tsp) and over 4 billion in just one teaspoon of soil. That type of soil would be considered biologically active and would allow for a conversion from chemical gardening to biological gardening.

"We've been schooled in the notion that plants are takers, removing nutrients from the soil and leaving it poorer. But when plants are allowed to work with their partners in the soil, they are givers. They feed carbon exudates to the community of bacteria and fungi to keep them humming with life and pulling mineral nutrients from the bedrock as well as from particles of sand, silt, and clay because they "know" that they will profit from the gift. A major player in the plant-microbe bridge is having a healthy population of predators like protozoa and nematodes which feed on the bacteria and fungi-thereby making their nutrients available to the plants. There's always enough, unless humans or some other factor messes up the system."[1]

Dr. David Johnson, molecular biologist with New Mexico State University, discovered that the ratio of fungi to bacteria in the soil is a more important factor for plant health than the amount of available nitrogen or phosphorus.[2] A healthy soil food web allows the soil organisms to manage the soil by adjusting the pH, digest organic carbon, regulate calcium and phosphorus, capture and release nitrogen, store water, etc. Healthy soils also produce their own organic matter which results in a rich soil that is dark brown to black because of the carbon, which is in a solid state, in the form of humus. This is why the saying, "feed the soil not the plants," is so true!

Suggested Reading

1. The Soil Will Save Us by Kristin Ohlson
2. SOS: Save Our Soils by Dr. Christine Jones in the March 2015 issue of ACRES U.S.A. You can also check out her website http://amazingcarbon.com/
3. UF/IFAS Fruit Crops Fact Sheet: Mycorrhizal Fungi FC-70 by James Ferguson
4. 10 Fascinating Facts About Pillbugs http://www.insects.about.com/
5. http://www.bbc.com/earth/story/2014111-plants-have-a-hidden-internet
6. Weedless Gardening by Lee Reich
7. Teaming with Microbes by Jeff Lowenfels & Wayne Lewis

8. The Soil and Health by Sir Albert Howard
9. How Plants Repel Insects – an Observation of Monarchs, Brix and Nutrient Dense Plants www.permaculturenews.org/2013/05/29/how-plants-repel-insects-an-observation-of-monarchs-brix-and-nutrient-dense-plants/
10. Impacts of Fertilizers on Insect Pests http://www.sare.org/
11. Soils and Fertilizers for Master Gardeners: Organisms in the Soil by Amy L. Shober https://edis.ifas.ufl.edu/pdffiles/MG/MG45200.pdf