ENVIRONMENTAL EDUCATION IN THE COMMUNITY GARDEN

LESSON 2

HEALTHY SOIL IS ALIVE

By actively supporting a vibrant ecosystem of microorganisms in the soil, organic gardeners can increase plant health and resistance to pests and disease. Chemical fertilizers destroy the balance of beneficial organisms in the soil and make the plants dependent on continued reapplication of fertilizers. Simply applying organic fertilizer, however, does not always give your garden plants sustained access to the nutrients they actually need. Applying compost, mulch, and actively aerated compost teas transform your soil into an ecosystem that helps plants get the nutrients they need without as much dependence on added fertilizers.

This lesson introduces gardeners to the soil food web and highlights the cycling of nutrients between soil organisms and plants. Encourage your gardeners to respect the balance of soil biology as the best defense against pests and disease. The beneficial organisms in the soil are crucial to the decomposition of organic matter, nutrient availability, creation of soil structure, and capacity for stable water retention. Double digging and soil disturbances destroy the structures and nutrient processing systems that support the life of the organisms and your plants.

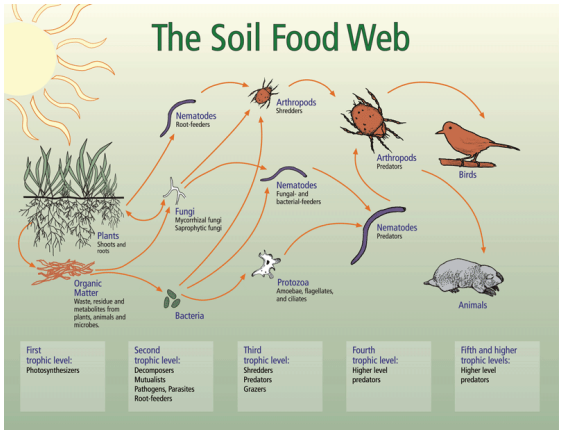

Image source: USDA NRCS, www.nrcs.usda.gov

A teaspoon of healthy soil can contain more microorganisms than there are people in the world! These organisms make up only one half of one percent of the total soil mass, but are the true workhorses of the garden. In addition to the visible earthworms we all hope to have in our garden, the invisible organisms in healthy soil are busily working in symbiotic relationships with roots to make sure that plants get the nutrients they need in usable forms. Countless numbers of yeast, bacteria, archaea, fungi, algae, protozoa, and nematodes process nutrients in the soil and support the life cycle of larger arthropods (spiders, mites, flies, beetles), earthworms, and gastropods (slugs and snails).

In order to thrive, these organisms need organic material to eat and shred. They do best in minimally disturbed soil as they develop a balanced ecosystem. Rotating crops and planting diverse varieties of plants in each garden plot ensures that different plants feed microorganisms a range of nutrients excreted from their roots (exudates). A symbiotic relationship develops between soil life and plant life that enhances the growth and health of all beneficial participants in the soil food web. This ecosystem helps to edge out opportunities for pathogens and pests to take root.

WHAT ORGANISMS LIVE IN HEALTHY SOIL?

BACTERIA

Bacteria form the base of the soil's network of beneficial microorganisms. There can be 100 million to 1 billion bacteria in a single teaspoon of healthy soil. Vegetables and annuals generally thrive in bacterially dominated soil because of their ability to convert nitrogen into these plants' preferred available forms.

Single cell bacteria eat root exudates and the cells sloughed off root tips. They use enzymes to break the chemical bonds of organic matter into simple sugars, amino acids, and fatty acids. Bacteria ingest nitrogen while decomposing plant and animal materials and lock that nitrogen, carbon compounds, and other nutrients into their cell walls. The nutrients release into the soil when bacteria die and decay or are eaten by other organisms and excreted. Different forms of bacteria are essential to the nitrification process or "fixing" of nitrogen from different sources of organic matter and air. The fixing process transforms nitrogen and carbon that would otherwise be unavailable to the plant into energy the plant roots can use.

Aerobic bacteria create enzymes that give good garden soil its earthy, fresh aroma. Smelly soil usually indicates the presence of anaerobic bacteria and pathogens that kill off the beneficial aerobic bacteria.

Applying green mulches such as grass clippings, straw, hay, alfalfa meal, and fresh plant clippings can encourage beneficial bacteria, as long it is not too thick or wet. The mulch layer should be less than 2 inches and leave space around the stem of plants so that adequate air can reach the soil. Gardeners can also apply bacterially dominated compost to inoculate the soil below or brew their own actively aerated compost tea as a soil drench and foliar spray (see instructions in Lesson Plan 2). Wait until after a good rainfall or a few days before eating from the garden after applying foliar compost tea.

FUNGI

Fungi use acidic digestive substances similar to human digestive juices to decay organic material. Through osmosis and active transport, fungi pull nutrients into their cell walls while leaving behind enzymes that continue to break down the soil even as the fungus moves on to new areas in the soil.

Important mycorrhizae fungi form on 90% of plant species and extend the reach of plant roots by relaying nutrients to the plant in exchange for carbon. Fungi are crucial to the process of transferring phosphorous, copper, calcium, magnesium, zinc and iron.

Like bacteria, fungi also serve as living packets of nutrients in the soil that are released when the fungi decay or are eaten and excreted by other organisms. Beneficial fungi work with bacteria to prevent pathogenic and parasitic fungal cousins from invading the plants. Some fungi even produce toxins that kill aphids, improve seed germination, or boost a plant's resistance to disease.

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EECapacity Growing capacity among *all* environmental educators.
Cornell University Founded A.D. 1865
CIVIL ECOLOGY LAB
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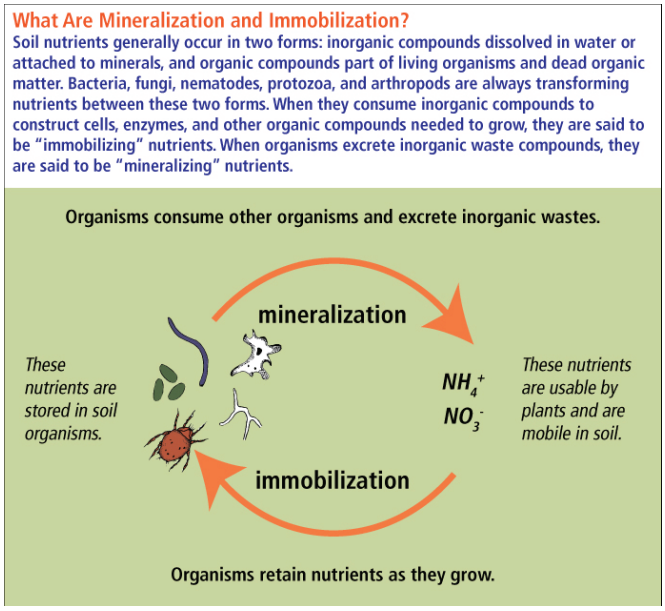
LESSON 2

WHAT ORGANISMS LIVE IN HEALTHY SOIL? (CONT.)



How microorganisms cycle mineralize nutrients.
Source: http://www.nrcs.usda.gov

EARTHWORMS

Worms are visible in the soil and do some of the most important work in the food soil web. They love to eat bacteria, as well as fungi, nemotodes, protozoa, and the orgranic material that microorganisms also eat.

Earthworms shred blocks of organic material, aerate the soil as they wiggle through, secrete substances that aid soil aggredates and build soil structure, and facilitate the distribution of microorganisms and nutrients in the soil.

ARTHROPODS

Arthropods such as flies, beetles, centipedes, and spiders participate in the soil food web by shredding up organic matter on the soil surface and making it easier for fungi and bacteria to eat.

GASTROPODS

Gastropods (snails and slugs) are usually thought of as terrible garden pests. They can devour plants overnight when out of balance with other organisms in the soil; however, they usually only spend 5 to 10% of their time eating plants. They also shred organic material for bacteria and fungi, and improve soil structure by creating underground paths for air, water, and roots.

ALGAE

Algae are photoantropic, meaning that they are able to take energy directly from the sun and produce their own food. Diatomaceous earth, often used in garden to deter soft-bodied pests, is actually made from the silica skeletons of diatom algae. When present in the soil, algae excrete substances that bind and aggregate soil to build structure and form passageways for airflow and drainage in compact clay soil.

PROTOZOA

Protozoa also ingest bacteria, fungi, and algae and release their nutrients to the plants in available forms. Their waste provides 80% of the nitrogen a plant needs and delivers it around their roots. Other organisms such as worms, some nematodes, and arthropods eat protozoa.

NEMATODES

Nematodes also mineralize the nutrients locked in bacteria and fungi, and release even more available nitrogen than protozoa. These blind microbes have specialized mouthparts that eat as they move through the soil. These microscopic worms need porous soils to move freely and even carry living bacteria with them as they move. Almost all nematodes are non-pathogenic and are important predators of pest such as flea beetles, fungus gnats, grubs and other soil-born pests.

SLIME MOLDS

Slime molds envelope and digest bacteria, fungi, spores and small protozoa as part of the nutrient cycling process that prevents leaching. In turn, insect larva, worms, and beetles eat them.

Native earthworm.
Image Credit: Bigstock, Earth worm 1662502

ENVIRONMENTAL EDUCATION IN THE COMMUNITY GARDEN

LESSON PLAN 2

BREWING MICROBIOLOGY

OBJECTIVE:

Show gardeners how to build an inexpensive and easy system for brewing actively aerated compost tea (AACT) as an effective way to increase biological activity in the soil.

MATERIALS NEEDED:

- One 5-gallon bucket
- Five gallons of de-chlorinated water (or tap water left to sit for 12 to 24 hours)
- One aquarium air pump
- Three to four ft. of appropriate aquarium tubing
- One to two air stones (depending on air pump)
- One aquarium water heater capable of keeping the 5-gallon bucket between 65 and 78 degrees Fahrenheit.
- Duct tape
- Two to three cups earthworm castings
- One old stocking or nylon knee-high
- Two tablespoons unsulphured molasses

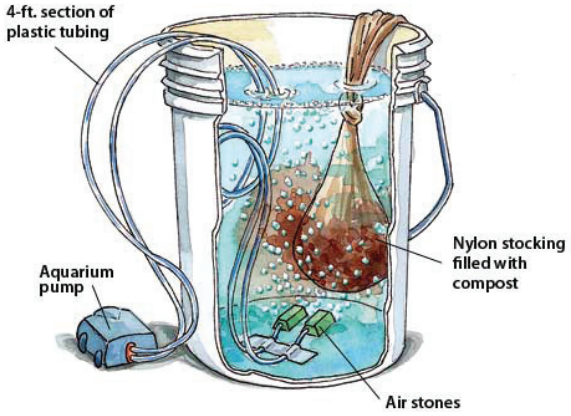


Diagram of a set-up for brewing AACT.
Image source: jardinclassicgardens.com

ACTIVITIES:

1. Discuss reasons why the aerator pump is essential to encouraging aerobic bacteria to reproduce in the compost tea, as well as the need to keep the bacteria happy at a steady warm temperature.

2. Assemble air stone on water pump tubing. Use duct tape attached tubing to the bottom of the 5 gallon bucket so that the air reaches all the way to the bottom of the water.

3. Install the water heater into bucket and plug in with air pump to begin adding air and warmth to the water.

4. Fill the stocking with one to two handfuls of earthworm castings or other well-rotted (non-smelly) compost. Tie end of stocking with a knot and place into the bucket.

5. Stir bucket and check temperature after a half hour to be sure that air is flowing and the temperature is around 70F. Provided there is enough porosity in the stocking, the water should begin to turn brownish black as you stir.

6. Add 2 T of unsulphured molasses to feed the bacteria and stir again.

7. Instruct gardeners to let the compost tea brew for 24 to 48 hours. They can then apply the tea as a soil and foliar feed to garden plants. Unlike chemical fertilizers, they do not need to worry about applying too much of the AACT. The resulting compost tea will be teeming with the beneficial bacteria, fungi, nematodes, and protozoa needed to improve life in the soil.

RESOURCES:

Lowenfels, Jeff and Wayne Lewis. *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web.* Timber Press, Portland and London, 2010.
www.nrcs.usda.gov
www.soilfoodweb.com

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