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Of Gardens, Microorganisms, and Long Island Sound

Judy Preston

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How Healthy Soil Can Make An Environmental Difference

By Judy Preston

I am an avid gardener, to be sure, and have always "understood" the value of healthy garden soil. From an early age I liked the feel and smell of soil, and fancied myself a careful alchemist of potting soil mixes for my houseplants. But it wasn't until I became a master gardener, composter, organic land care practitioner, and started to read about the soil food web that the complexities of soil – and the services that soil microbes provide – began to take on new meaning.

It takes me a lot longer to garden than most people I know, mostly because I often find incredible things happening in my backyard that encourage me to drop everything and go inside for my camera. This is what, in part, started me down the path of investigating the world of soil organisms. I happened to turn over a large rounded stone in my garden to find a mesmerizing world of organisms that had, just moments earlier, been going about their business before being exposed to the sunlit world, and me.

Among the scramble of golden ants desperately seeking to relocate their nest, there were the familiar "pill bugs" and, yes, the gardeners' dreaded white grubs hunched in their excavated chambers. But there were also tiny, hair-sized white worms – nematodes – soil critters at the visible end of the mysterious, and otherwise invisible underworld of soil microbes.

Soil microbes, as it turns out, have everything to do with the productivity of garden plants, as well as the fate of soil additives --_nutrients and chemicals that may begin their journey when added to soil, but can eventually end up in coastal waters – such as Long Island Sound, where the consequences can be disastrous for marine life.

But to get from soil to sea, we need to follow those nematodes into the hidden recesses of my backyard garden soil.

One teaspoon of good garden soil is said to contain in the order of a billion invisible bacteria, several yards of equally invisible fungi, several thousand single-celled protozoa, and a few dozen of my barely visible nematodes. As it turns out, biological diversity is not just a good idea for above ground nature; the soil ecosystem thrives when it is well populated with a multitude of species.

At the most invisible spectrum of the soil animal community is the bacteria and fungi – names that we most readily associate with germs, moldy bread and that insidious black mildew that inhabits bathtub grout over time. Despite the bad rap, of the over 100,000 species of fungi and up to a million species of bacteria that scientists know about in the soil ecosystem, there are many that display clever adaptations and provide invaluable ecosystem services.

One critical skill of these invisible organisms is the ability to break down organic material – leaves, twigs, insect parts – the debris of the forest – into the nutrients that plants need to grow. Fungi, for example, plays a major role in the formation of humus, the dark,

D LONG ISLAND SOUND

This colorful mushroom is the reproductive "flower" - and only visible part - of a vast network of underground fungal strands. Photo by Judy Preston.

(Top) Forest litter generates rich soil with the help of microorganisms

(Bottom) Coral fungi (*Claveria*) are one of the many interesting representatives of a fascinating, and diverse soil fungi world.

organic material in healthy soil that helps it retain moisture and nutrients. The tough raw materials that make plant stems stiff and produce protective tree bark – lignins, cellulose, and even insect skeletons that are made of chitin – are the very things that microscopic fungi and bacteria are specialized to decompose. Consider the state we'd be in if these invisible workhorses were not available to process all the leaves and trees that fall to the ground every year.

Fungi and bacteria eat raw organic matter, using this to build their own bodies and reproduce, and in the process, convert this material into plant-available nutrients. Fungi and bacteria, then, are moving about the soil filled with what plants need to grow; they are, in essence, tiny fertilizer bags. More importantly, these diminutive animals are preventing these essential nutrients from leaving the soil ecosystem.

Soil fungi grow primarily from tiny spores into threadlike bodies that are capable of moving through soil and leaf litter with amazing speed. Masses of individual threads may twist together to form light, visible strands called mycelia that can move great distances through the soil, securing resources. So resourceful are these organisms that at least one has captured the attention of scientists and fungi enthusiasts for the shear magnitude of the area it covers, some 2,384 acres of soil in Oregon – it is the record holder for the title of the world's largest known organism.

Plants are so taken with the resourcefulness of fungi, that a large percentage of them have developed a quid pro quo with certain fungi

continued on page 22

OF GARDENS, MICROORGANISMS, AND LONG ISLAND SOUND

How Healthy Soil Can Make An Environmental Difference

continued from page 21

species. In exchange for the high-energy sugars that plants harness directly from the sun through photosynthesis, these fungi (who cannot photosynthesize) provide water, phosphorus and other essential nutrients that plant roots might not otherwise be able to reach. These fungi, known as mycorrhizae (*fungus root*) interface with plants at the very tips of their roots, in a narrow, watery realm known as the rhizosphere: the plant exchanging the sun's energy for the resources that the fungi can access far beyond the root zone. By this happy association, it is believed that mycorrhizal fungi increase the effective surface area of tree roots many fold.

No other organism has more members in the soil community than bacteria: one solitary bacterium can produce billions of offspring in a single day. These single-celled organisms are second only to fungi as decomposers of organic matter. Unlike fungi, bacteria are dependent upon water in the soil; like many microbes they live and travel in the ultra thin coating of water that adheres to soil particles. Because of their association with water, soil bacteria produce a thin slime that sticks to things – soil particles, organic debris, even the backs of nematodes, which bacteria conveniently hitch a ride on to improve their mobility. Like the threadlike strands, or hyphae, of fungi, bacterial slime helps hold particles of soil together, stabilizing and ultimately adding structure to the soil.

Perhaps the most recognizable soil bacteria, despite its invisibility, is *Actinomycetes*, which produces chemicals that vaporize into the "earthy" aroma of soil – a smell that is much coveted by gardeners, and many others emerging from a long, tough winter.

And finally we get to our just-barely-visible garden soil nematode, who, along with the microscopic soil protozoa – single-celled organisms such as amoebas, are the major consumers of bacteria and fungi in the soil panoply. By consuming the "fertilizer bags", nematodes and protozoa make essential plant nutrients -- such as nitrogen -- available through their waste products. These are the fertilizer spreaders, the soil organisms that share the hard work of the decomposers – the fungi and bacteria, with the plants.

Nematodes are effective predators; their worm-like body is outfitted with specialized mouthparts that reflect any number of strategies to secure their prey. Some nematodes have teeth, others employ retractable, spear-like mouthparts used to puncture and drain their hapless victims. Lest it appear that the decomposers are entirely defenseless, several species of fungi actually prey on nematodes. At least one fungi species uses a chemical to attract the nematode and employs a strangling ring that rapidly contracts to ensnare the nematode.

Understanding the pathways of nutrients in healthy soil becomes particularly relevant when we realize how chemically based fertilizers and soil additives short circuit the process. Inorganic nitrogen-based fertilizers are readily available, inexpensive, and work fast. But because the main ingredients of these plant foods are nitrogen-based inorganic salts, frequent use of them makes the soil ultimately toxic to soil microorganisms. The loss of a diverse soil ecosystem shortchanges plants by making them dependent on external (and petroleum-based) sources of nutrients; they no longer have access to a steady food supply that is the by-product of biological processes in the soil.

What's more, the salts in inorganic nitrogen-based fertilizers are vulnerable to leaching from the soil once there are no organisms to ingest them, and therein lies the ultimate issue of pollution to nearby waterways. Excess nitrogen fertilizer leaches through soil, and runs off our landscaped surfaces until it reaches its ultimate destination: the ocean. Too much nitrogen in the marine ecosystem fuels hypoxia, the biological equivalent of asphyxiation to organisms that live on the ocean floor.

The bacteria, fungi, protozoa and nematodes – and all the other myriad soil organisms – have evolved a time-honored way of partnering with plants to maintain a healthy soil ecosystem. Organic material is broken down and recycled by a complex soil food web, providing a steady supply of nutrients and compounds to the plants that ultimately provide the source of organic material that keeps the system cycling.

Understanding the significance of my backyard nematodes, and what I hope are all the other countless soil microorganisms that are flourishing there, helps me appreciate the fantastic intricacies of nature. It also stresses the value of working with long-standing and proven systems that have had the benefit of time to iron out the details.

If every coastal resident added organic matter (in the form of compost), and, only when needed, used slow-release organic fertilizer on their lawn and garden, a significant difference could be made in the effort to stem the tide of excess nitrogen entering Long Island Sound. And consider the billions of microorganisms that would sleep better at night, too.

Judy Preston is Connecticut's Outreach Coordinator for the EPA Long Island Sound Study, via Connecticut Sea Grant.