Soil Biology

The Soil Biology Primer

Chapter 4: SOIL FUNGI

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THE LIVING SOIL: FUNGI

Fungi are microscopic cells that usually grow as long threads or strands called hyphae, which push their way between soil particles, roots, and rocks. Hyphae are usually only several thousandths of an inch (a few micrometers) in diameter. A single hyphae can span in length from a few cells to many yards. A few fungi, such as yeast, are single cells.

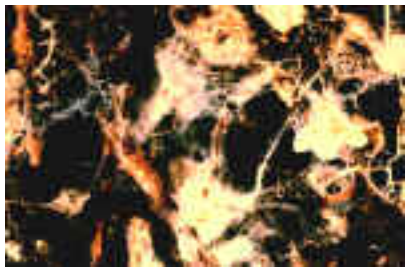
Hyphae sometimes group into masses called mycelium or thick, cord-like "rhizomorphs" that look like roots. Fungal fruiting structures (mushrooms) are made of hyphal strands, spores, and some special structures like gills on which spores form. (See figure) A single individual fungus can include many fruiting bodies scattered across an area as large as a baseball diamond.

Fungi perform important services related to water dynamics, nutrient cycling, and disease suppression. Along with bacteria, fungi are important as decomposers in the soil food web. They convert hard-to-digest organic material into forms that other organisms can use. Fungal hyphae physically bind soil particles together, creating stable aggregates that help increase water infiltration and soil water holding capacity.

Soil fungi can be grouped into three general functional groups based on how they get their energy. *Decomposers* – saprophytic fungi – convert dead organic material into fungal biomass, carbon dioxide (CO_2), and small molecules, such as organic acids. These fungi generally use complex substrates, such as the cellulose and lignin, in wood, and are essential in decomposing the carbon ring structures in some pollutants. A few fungi are called "sugar fungi" because they use the same simple substrates as do many bacteria. Like bacteria, fungi are important for immobilizing, or retaining, nutrients in the soil. In addition, many of the secondary metabolites of fungi are organic acids, so they help increase the accumulation of humic-acid rich organic matter that is resistant to degradation and may stay in the soil for hundreds of years.

Mutualists – the mycorrhizal fungi – colonize plant roots. In exchange for carbon from the plant, mycorrhizal fungi help solubolize phosphorus and bring soil nutrients (phosphorus, nitrogen, micronutrients, and perhaps water) to the plant. One major group of mycorrhizae, the *ectomycorrhizae* (Figure 3), grow on the surface layers of the roots and are commonly associated with trees. The second major group of mycorrhizae are the *endomycorrhizae* that grow within the root cells and are commonly associated with grasses, row crops, vegetables, and shrubs. Arbuscular mycorrhizal (AM) fungi (Figure 4) are a type of endomycorrhizal fungi. Ericoid mycorrhizal fungi can by either ecto- or endomycorrhizal.

The third group of fungi, *pathogens* or *parasites*, cause reduced production or death when they colonize roots and other organisms. Root-pathogenic fungi, such as *Verticillium*, *Pythium*, and *Rhizoctonia*, cause major economic losses in agriculture each year. Many fungi help control diseases. For example, nematode-trapping fungi that parasitize disease-causing nematodes, and fungi that feed on insects may be useful as biocontrol agents.



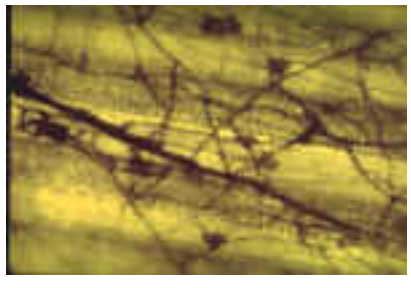


Figure 1: Many plants depend on fungi to help extract nutrients from the soil. Tree roots (brown) are connected to the symbiotic mycorrhizal structure (bright white) and fungal hyphae (thin white strands) radiating into the soil.
Credit: *Randy Molina, Oregon State University, Corvallis*

Figure 2: Fungus beginning to decompose leaf veins in grass clippings.
Credit: *No. 48 from Soil Microbiology and Biochemistry Slide Set. 1976. J.P. Martin, et al., eds. SSSA, Madison WI.*

Figure 3: Ectomycorrhizae are important for nutrient absorption by tree and grape roots. The fungus does not actually invade root cells but forms a sheath that penetrates between plant cells. The sheath in this photo is white, but they may be black, orange, pink, or yellow.
Credit: *USDA, Forest Service, PNW Research Station, Corvallis, Oregon*

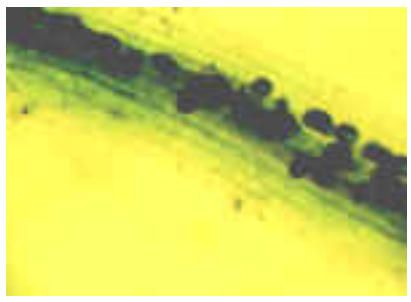


Figure 4: The dark, round masses inside the cells of this clover root are vesicules for the arbuscular mycorrhizal fungus (AM).
Credit: *Elaine R. Ingham*

WHERE ARE FUNGI?

Saprophytic fungi are commonly active around woody plant residue. Fungal hyphae have advantages over bacteria in some soil environments. Under dry conditions, fungi can bridge gaps between pockets of moisture and continue to survive and grow, even when soil moisture is too low for most bacteria to be active. Fungi are able to use nitrogen up from the soil, allowing them to decompose surface residue which is often low in nitrogen.

Fungi are aerobic organisms. Soil which becomes anaerobic for significant periods generally loses its fungal component. Anaerobic conditions often occur in waterlogged soil and in compacted soils.

Fungi are especially extensive in forested lands. Forests have been observed to increase in productivity as fungal biomass increases.

Figure 5: In arid rangeland systems, such as southwestern deserts, fungi pipe scarce water and nutrients to plants.
Credit: *Jerry Barrow, USDA-ARS Jornada Experimental Range, Las Cruces, NM.*

Figure 6: Mushrooms, common in forest systems, are the fruiting bodies made by a group of fungi called basidiomycetes. Mushrooms are "the tip of the iceberg" of an extensive network of underground hyphae.
Credit: *Ann Lewandowski, NRCS Soil Quality Institute*

MYCORRHIZAL FUNGI IN AGRICULTURE

Mycorrhiza is a symbiotic association between fungi and plant roots and is unlike either fungi or roots alone. Most trees and agricultural crops depend on or benefit substantially from mycorrhizae. The exceptions are many members of the Cruciferae family (e.g., broccoli, mustard), and the Chenopodiaceae family (e.g. lambsquarters, spinach, beets), which do not form mycorrhizal associations. The level of dependency on mycorrhizae varies greatly among varieties of some crops, including wheat and corn.

Land management practices affect the formation of mycorrhizae. The number of mycorrhizal fungi in soil will decline in fallowed fields or in those planted to crops that do not form mycorrhizae. Frequent tillage may reduce mycorrhizal associations, and broad spectrum fungicides are toxic to mycorrhizal fungi. Very high levels of nitrogen or phosphorus

fertilizer may reduce inoculation of roots. Some inoculums of mycorrhizal fungi are commercially available and can be added to the soil at planting time.

Figure 7: Mycorrhizal fungi link root cells to soil particles. In this photo, sand grains are bound to a root by hyphae from endophytes (fungi similar to mycorrhizae), and by polysaccharides secreted by the plant and the fungi.
Credit: *Jerry Barrow, USDA-ARS Jornada Experimental Range, Las Cruces, NM.*