Soil Biology

The Soil Biology Primer

Chapter 3: BACTERIA

By Elaine R. Ingham

THE LIVING SOIL: BACTERIA

Bacteria are tiny, one-celled organisms – generally 4/100,000 of an inch wide (1 µm) and somewhat longer in length. What bacteria lack in size, they make up in numbers. A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria. That is as much mass as two cows per acre.

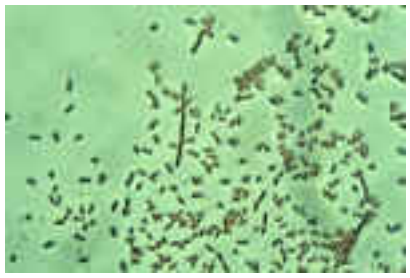

Figure 1: A ton of microscopic bacteria may be active in each acre of soil.
***Credit**: Michael T. Holmes, Oregon State University, Corvallis.*

Figure 2: Bacteria dot the surface of strands of fungal hyphae.
***Credit:** R. Campbell. In R. Campbell. 1985.* Plant Microbiology*. Edward Arnold; London. P. 149. Reprinted with the permission of Cambridge University Press.*

Bacteria fall into four functional groups. Most are decomposers that consume simple carbon compounds, such as root exudates and fresh plant litter. By this process, bacteria convert energy in soil organic matter into forms useful to the rest of the organisms in the soil food web. A number of decomposers can break down pesticides and pollutants in soil. Decomposers are especially important in immobilizing, or retaining, nutrients in their cells, thus preventing the loss of nutrients, such as nitrogen, from the rooting zone.

A second group of bacteria are the *mutualists* that form partnerships with plants. The most well-known of these are the nitrogen-fixing bacteria. The third group of bacteria is the *pathogens*. Bacterial pathogens include *Xymomonas* and *Erwinia* species, and species of *Agrobacterium* that cause gall formation in plants. A fourth group, called *lithotrophs* or *chemoautotrophs*, obtains its energy from compounds of nitrogen, sulfur, iron or hydrogen instead of from carbon compounds. Some of these species are important to nitrogen cycling and degradation of pollutants.

WHAT DO BACTERIA DO?

Bacteria from all four groups perform important services related to water dynamics, nutrient cycling, and disease suppression. Some bacteria affect water movement by producing substances that help bind soil particles into small aggregates (those with diameters of 1/10,000-1/100 of an inch or 2-200µm). Stable aggregates improve water infiltration and the soil's water-holding ability. In a diverse bacterial community, many organisms will compete with disease-causing organisms in roots and on aboveground surfaces of plants.

A FEW IMPORTANT BACTERIA

Nitrogen-fixing bacteria form symbiotic associations with the roots of legumes like clover and lupine, and trees such as alder and locust. Visible nodules are created where bacteria infect a growing root hair (Figure 4). The plant supplies simple carbon compounds to the bacteria, and the bacteria convert nitrogen (N2) from air into a form the plant host can use. When leaves or roots from the host plant decompose, soil nitrogen increases in the surrounding area.

Nitrifying bacteria change ammonium (NH4+) to nitrite (NO2-) then to nitrate (NO3-) – a preferred form of nitrogen for grasses and most row crops. Nitrate is leached more easily from the soil, so some farmers use nitrification inhibitors to reduce the activity of one type of nitrifying bacteria. Nitrifying bacteria are suppressed in forest soils, so that most of the nitrogen remains as ammonium.

Denitrifying bacteria convert nitrate to nitrogen (N2) or nitrous oxide (N2O) gas. Denitrifiers are anaerobic, meaning they are active where oxygen is absent, such as in saturated soils or inside soil aggregates.

Actinomycetes are a large group of bacteria that grow as hyphae like fungi (Figure 3). They are responsible for the characteristically "earthy" smell of freshly turned, healthy soil. Actinomycetes decompose a wide array of substrates, but are especially important in degrading recalcitrant (hard-to-decompose) compounds, such as chitin and cellulose, and are active at high pH levels. Fungi are more important in degrading these compounds at low pH. A number of antibiotics are produced by actinomycetes such as Streptomyces.

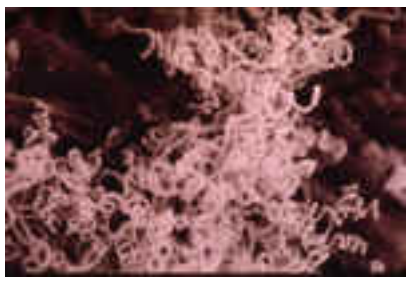

Figure 3: Actinomycetes, such as this Streptomyces, give soil its "earthy" smell.
Credit: *No. 14 from* Soil Microbiology and Biochemistry Slide Set*. 1976. J.P. Martin, et al., eds. SSSA, Madison, WI*

Figure 4: Nodules formed where Rhizobium bacteria infected soybean roots.
Credit: *Stephen Temple, New Mexico State University*

WHERE ARE BACTERIA?

Various species of bacteria thrive on different food sources and in different microenvironments. In general, bacteria are more competitive when labile (easy-to-metabolize) substrates are present. This includes fresh, young plant residue and the compounds found near living roots. Bacteria are especially concentrated in the rhizosphere, the narrow region next to and in the root. There is evidence that plants produce certain types of root exudates to encourage the growth of protective bacteria.

Bacteria alter the soil environment to the extent that the soil environment will favor certain plant communities over others. Before plants can become established on fresh sediments, the bacterial community must establish first, starting with photosynthetic bacteria. These fix atmospheric nitrogen and carbon, produce organic matter, and immobilize enough nitrogen and other nutrients to initiate nitrogen cycling processes in the young soil. Then, early successional plant species can grow. As the plant community is established, different types of organic matter enter the soil and change the type of food available to bacteria. In turn, the altered bacterial community changes soil structure and the environment for plants. Some researchers think it may be possible to control the plant species in a place by managing the soil bacteria community.

BUG BIOGRAPHY: Bacteria That Promote Plant Growth

By Ann Kennedy, USDA Agricultural Research Service, Pullman, WA

Certain strains of the soil bacteria Pseudomonas fluorescens have anti-fungal activity that inhibits some plant pathogens. P. fluorescens and other Pseudomonas and Xanthomonas species can increase plant growth in several ways. They may produce a compound that inhibits the growth of pathogens or reduces invasion of the plant by a pathogen. They may also produce compounds (growth factors) that directly increase plant growth.

These plant growth-enhancing bacteria occur naturally in soils, but not always in high enough numbers to have a dramatic effect. In the future, farmers may be able to inoculate seeds with anti-fungal bacteria, such as P. fluorescens, to ensure that the bacteria reduce pathogens around the seed and root of the crop.