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Beyond Bacteria: The Importance of Fungi, Protozoa, and Nematodes in Soil Microbiology

Discussions about microbial life in soil often focus on bacteria and to a lesser degree actinomycetes (a specialized group of anaerobic bacteria). This is partially due to the population of bacteria and actinomycetes found in the soil often being larger than all other microbial life combined, and secondarily because of the broader knowledge of beneficial bacteria that can be added to cropping systems. Often left out of the discussion are other microorganisms such as fungi, protozoa, and nematodes, which all have critical roles in soil health. While the fungi, protozoa, and nematodes found in an acre furrow slice (6 in. depth X 1 acre) are dwarfed in population by bacteria and actinomycetes, they contribute more microbial biomass to the soil than the larger population (Table 1). While soil applied agricultural products that add fungi, protozoa, and nematodes are rare, it is important to understand the importance of these microbial species in plant nutrition and soil health.

Table 1: Relative number and biomass of microbial species in the soil[1].

Microorganisms	Relative Number/g of Soil	Biomass (lbs/ac) (6 in.)
Bacteria	100 million - 1 billion	350 - 4,450
Actinomycetes	10 million - 100 million	350 - 4,450
Fungi	10,000 - 1 million	9 - 13,300
Protozoa	1,000 - 10,000	varies
Nematodes	10 - 1,000	minor

Fungi

Many fungi have a role in the conversion of carbon from residue sources higher in lignin and cellulose (e.g., high C:N ratio plant materials such as wood, corn stalks etc.), which are tougher and take more time to be broken down in the soil compared to leaves or annual crop roots. Fungi are often more efficient in the decomposition of plant residues and release less carbon dioxide into the atmosphere than bacteria. Fungi convert 40 - 55% of the carbon consumed to more stable forms of organic matter, while the carbon conversion rate for bacteria is 15 - 20%[1]. Life cycles are typically longer than bacteria, but fungi are typically not as hardy. After a tillage event, or after a period of the soil being frozen, it takes fungi more time to repopulate back to critical mass. Beyond decomposition of carbon sources in soil, many genera of fungi also serve roles in plant health acting as probiotics in the soil or aiding in crop nutrient availability. One example is that several fungi excrete the enzyme phytase, which enables the release of soil organic phosphorus into a plant available form.

Mycorrhizal Fungi

Plants form symbiotic relationships with certain fungi in which both organisms benefit. Mycorrhizal fungi deserve special note because they form mutually beneficial relationships with plant roots. These fungi serve a unique purpose specific to the rhizosphere, or area immediately around the root, by providing greater access to water and nutrients (particularly nitrogen, phosphorus, zinc, manganese, and copper)

- Fungi are more efficient than bacteria in converting carbon to organic matter.
- Mycorrhizal hyphae are smaller than plant roots but can account for 176 miles of length in 1 ounce of soil.
- Nematodes account for 8 - 19% of nitrogen mineralization annually.

for plants. The hyphae, or branches of the fungi, form extensions of root systems and increase the root surface area for water and nutrient absorption from soil[2]. In some instances, mycorrhizal fungi may be responsible for up to 50% of total nutrient uptake (e.g., zinc) in crops[3]. The network of hyphae can account for up to 75% of the total soil microbial biomass and can have a total length of 176 miles per ounce of soil in ag ecosystems[4].

Mycorrhizae are classified into two types: endomycorrhiza which produce hyphae inside the roots, and ectomycorrhiza which produce hyphae outside the roots[2]. Endomycorrhiza fungi have hyphae that help plants exchange water and nutrients, and are found with most crops grown in North America. Additional benefits of mycorrhizal fungi include increased pathogen resistance, increased salinity stress tolerance, higher yield through increased flowering, and improved soil structure.

Soil pH and Fungi

The effect of soil pH goes beyond affecting plant roots and nutrient availability. Soil pH also influences many different aspects of soil microbiology including the balance of beneficial bacteria, pathogens, and fungi. The optimal pH range for bacteria is somewhat narrow, being between 6.0 and 7.0. Other microbial life such as fungi can tolerate a slightly wider pH range and maintain their functionality. This means that even small changes in soil pH outside of what is considered optimal for row crop production can have an impact on microbial populations.

As soil acidity increases and soil pH drops below 6, the size of the rhizosphere and the mycorrhizosphere begin to decrease (Figure 1). With a decrease in the size of the rhizosphere, plants have less surface area for water and nutrient uptake. The decrease in the rhizosphere surface area also allows for more soil fungus, both beneficial and non-beneficial types, as well as pathogens to occupy the area near plant roots that the mycorrhiza would have been in.

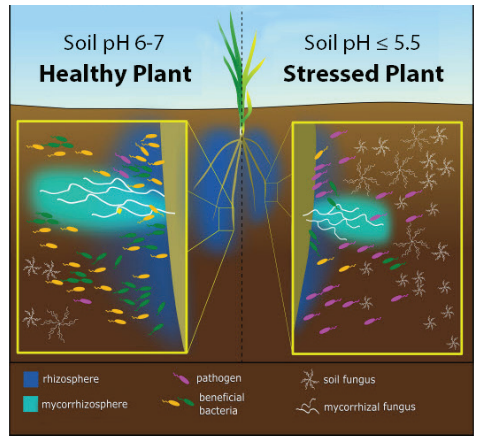

Figure 1: Soil pH effect on microbiology composition and size of the rhizosphere. Adapted from Reference 4.

Protozoa

One of the roles that protozoa fulfill in the soil system is to regulate microbial populations by feeding on bacteria and other microbes. When bacterial populations increase rapidly, protozoa can simultaneously increase populations to match the need of the soil system, with some species reproducing 3-4 times per day[1]. While this might sound detrimental to microbiological life found in soil, protozoa are beneficial because they keep bacteria from overpopulating and depleting plant available nutrients. The bacteria and other microbes consumed by protozoa are high in nitrogen, and when consumed, release ammonium (NH_4^+) into the soil which is plant available.

Nematodes

Even though there are groups of nematodes, such as Soybean Cyst or Lance nematodes, that can be harmful to plant growth, most soil nematode species are beneficial for plant growth and soil health. Some nematodes help regulate bacterial and fungal populations in a matter similar to protozoa. Other nematode groups consume soil organisms that can cause diseases. In farming systems where manure is applied to soil, bacterivorous nematodes contribute to nitrogen mineralization indirectly by grazing on decomposer microbes, excreting ammonium, and immobilizing nitrogen[5]. Predatory nematodes which feed on bacterivorous nematodes serve to regulate the rate of nitrogen mineralization in the soil. Depending on the farming systems, nematodes are estimated to contribute between 8-19% of nitrogen mineralization each year[5].

Conclusion

Although the roles of fungi, protozoa, and nematodes are less well known than bacteria, these microorganisms have a critical role in nutrient cycling, plant nutrition, and plant health. Beyond decomposition, many fungi excrete the enzyme phytase, which enables the release of organic phosphorus. Protozoa and nematodes recycle nitrogen as well as help control the rate of mineralization of organic matter. All classes of soil microorganisms perform many other functions in agriculture aside from nutrient cycling and biomass decomposition, such as suppressing pathogens or working as probiotics in the soil. Soil amendments for pH and Integrated Pest Management (IPM) practices can have major impacts on total counts and population shifts of soil microbiology, which can in turn have an impact on plant health, soil health, and crop nutrition.

References:

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