Understanding Microbes Helps Explain Nutrient Cycling

By Dan Lloyd, Doug Soldat and Teri Balser

As urban areas continue to expand into the rural landscape, agricultural land is converted to turfgrass cover in the form of golf courses, parks, athletic fields and lawns. With urbanization expected to increase 79 percent in the United States over the next 25 years (Alig et al, 2004), turfgrass ecosystems inherit an even more prominent role in urban nutrient cycling, water management and carbon interactions.

Previous research has examined nutrient use and carbon sequestration by turfgrass and other natural and agricultural ecosystems. However, little is known about the tiny creatures that orchestrate these processes: soil microorganisms. The study of soil microorganisms is difficult on a number of levels. First, we can't see them, so they are out of sight and out of mind. Second, most methods for studying these critters are rife with difficulties. Third, while we can identify thousands of different species, we only really know what a small percentage of them are doing in the soil. In short, we have a lot left to learn. By understanding what microbes are doing and under what conditions they dominate, we can learn more about how to improve nutrient and organic matter cycling in turfgrass areas.

Soil microorganisms have an enormous influence on plant-soil interactions crucial for maintaining healthy turfgrass. Perhaps the most important of these interactions is the cycling of nutrients, especially nitrogen. As much as half of applied nitrogen fertilizer can be consumed by the microbial community within three days. This immobilized nitrogen is only temporarily unavailable to the plant and is re-released, or mineralized, over time depending on climate and soil properties along with the demographic and activity of the microbial pool. Substantial amounts of both soluble and slow-release nitrogen fertilizer sources undergo several transformations between ammonium, nitrate and organic nitrogen before finally being absorbed by the plant. Soil microorganisms are the behind-the-scenes facilitators of nitrogen immobilization, mineralization and transformations in the soil.

Organic matter accumulation is another turf-management issue of particular concern to golf course managers because of its significance on playing conditions. Once again, the rate of organic matter degradation and accumulation is dependent on the population and activity of the soil microbial community. With such important roles in these fundamental processes in turf management, an increased understanding of this active and complex population could enable turf managers to use these soil microbes to their advantage. Understanding and potentially manipulating this community could have significant implications on turf-management strategies.

Studying soil microorganisms is notoriously difficult, and there are several different methods that can be used, each with their own inadequacies. The method we used to study the multitude of microorganisms in the soil was to identify them by their unique fatty acids (PLFA-FAME analysis) and then lump the individual species into broadly defined groups. We can then study how the groups dominate in different environments. To obtain a representative sample, we collected soil samples from 42 turfgrass sites in southern Wisconsin. We then analyzed the soil to see the relative distribution of the various functional groups and then compared the functional groups to the soil properties. The groupings, or functional groups, of microorganisms are listed here:

- Gram positive bacteria (GPB) have a rigid cell wall and are tolerant of stressful conditions. These bacteria are usually dominant in extreme environments, and can form spores and remain in a dormant condition until favorable growing conditions return.
- Gram negative bacteria (GNB) have weak cell walls and require a "biofilm" to survive. These bacteria are important for all aspects of the nitrogen cycle (immobilizing,

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mineralizing, nitrifying and denitrifying). These bacteria are usually dominant in agricultural ecosystems and prairies.

- Saprophytic fungi (SF) are important for breaking down plant material and other organic matter. These fungi typically dominate forest and other ecosystems that produce large amounts of relatively recalcitrant materials.
- Arbuscular mycorrhizal fungi (AMF) form symbiotic relationships with plants and trade water and nutrients (especially phosphorus) for carbon-containing compounds made by the host plant.
- Total biomass is the sum of all these functional groups plus all the additional microorganisms that did not fit into one of the above functional group categories. Very little is known about the function of these uncategorized species.

The turfgrass sites were found to be bacterially dominated and particularly abundant in gram positive bacteria — the stress tolerators. This result confirmed what Karp and Nelson (2004) found for soil (push-up) putting greens. The relative dominance of gram positive bacteria is somewhat unique to turfgrass. Typically, this level of community dominance by gram positive bacteria is found in extreme climates. Previous research on the microbial diversity of prairies found that arbuscular mycorrhizal fungi dominate prairies followed by gram negative bacteria.

The turfgrass soils tested had a wide range in physical and chemical properties. Bulk density ranged from 0.7 grams per cubic centimeter. (g/cm3) to 1.4 g/cm3, organic matter from 2 percent to 18 percent, and there was a great diversity of soil texture as shown by the large ranges in sand and clay content of the soils. Regression analysis was performed to see how the microbial functional groups were affected by soil properties. Soil texture, organic matter, bulk density and soil pH had very little effect on the individual functional groups and the total microbial biomass.

However, of the functional groups, saprophytic fungi were most sensitive to changes in soil properties and were found to increase in abundance as organic matter increased, and decrease in abundance as clay content increased. The gram positive bacteria also increased in abundance with increasing organic matter, although the relationship between these two variables was fairly weak. While no strong linear correlations were found among functional groups and soil properties, a statistical technique known as principle component analysis discovered some significant interactions between the microbial community and soil properties. Principle component analysis can be thought of as a diversity index, which determines a unique fingerprint for each microbial community. In short, the results from this analysis confirm that microbial communities are indeed influenced by the properties of their soil habitats, although the differences do not break down as simply as the above mentioned functional groups.

The results of this research serve somewhat as a census of the microbial community in turfgrass systems, defining the species demographic and the corresponding labor force of the population as well as the influence of soil properties.

While this research does not directly suggest how these population dynamics can improve turf quality, it provides a starting point to move that direction.

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