The Microbiology of Turfgrass Soils

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Most turfgrass managers do not have a strong understanding of turfgrass soils, particularly the biological aspects. Certainly most know that living things, such as worms and insects can reside in soil, but they're not sure where in the soil they live or what they live on. In fact, it might be safe to assume that most turfgrass managers consider soil to be a mysterious world below the turfgrass canopy. Rarely do turfgrass managers consider soil as something that should be managed as prudently as the turf itself. It is becoming clear, however, that the management of the soil, in particular its biological components, is perhaps as important as the management of the plant for the long-term productivity and health of a turfgrass stand.

Most soils below turfgrass stands contain a vast array of living organisms, ranging from the larger macroscopic earthworms and insects, to the microscopic invertebrates, bacteria, fungi, actinomycetes, nematodes, algae, and protozoa. The types, numbers, and activities of these organisms directly and indirectly impact on turfgrass health. Most turfgrass managers are familiar with the harmful effects that some microorganisms have on turfgrass health. For example, these damaging microorganisms include fungal, bacterial, and nematode pathogens of turfgrass plants, cyanobacteria—a form of blue-green algae that causes black layer, and green algae that cause surface crusting and plant damage. There are other groups of microorganisms that are indirectly harmful to turfgrass plants. These include pesticide-degrading non-pathogenic and pesticide-resistant pathogenic microorganisms. In nearly all cases, turfgrass managers have developed elaborate management techniques to avoid some of the detrimental effects caused by the activities of these organisms. Despite the presence of harmful microorganisms in turfgrass soils, most soils contain large populations of beneficial microorganisms. These offer the most promise for enhancing turfgrass health and maintaining long-term productive turfgrass stands (Table 1).

Bacteria

Of the microorganisms in soil, bacteria are found in the greatest abundance and are perhaps the most diverse in their morphology and activities. Many different populations of bacteria with a wide array of activities can be found in most turfgrass soils; many carrying out processes important to plant health (Table 2). However, the exact bacterial composition of each soil may vary depending on the soil type, prevailing environmental conditions, and management practices.

Bacteria are small, rod-shaped organisms that reproduce prolifically by simple cell division, producing massive amounts of cells in a short period of time. Under favorable conditions, bacteria may divide every 20 minutes, so that conceivably, one bacterium could give rise to one million bacteria in 10 hours! Although the total numbers of cells can be great, the size of each individual cell is quite small, usually not more than one or two microns (0.00004 inches) in length.

During the explosive growth of bacteria, a diverse array of food sources must be available to support such a high rate of metabolic activity. During the transformation of food sources, a number of metabolic by-products are also produced. As a result, great chemical changes may occur in the soil as a result of the proliferation of

Table 1. Important beneficial microorganisms found in turfgrass soils.

Microbial Group	Major Benefit to Turfgrasses
Nutrient-cycling microorganisms	Making nutrients available to plants Decomposition of organic matter
Thatch-degrading microorganisms	Thatch maintenance
Nitrogen-fixing microorganisms	Improvement in turfgrass nutrition
Endophytes	Pest resistance Stress tolerance
Mycorrhizal fungi	Improved phosphorus nutrition
Plant growth promoting rhizobacteria	Improved root and shoot development Disease tolerance Protection from pests
Biological control organisms	Protection from pests

bacteria in the environment. It is this latter attribute that makes bacteria such significant microorganisms in the turfgrass environment.

Bacteria require water in order to grow and reproduce. Their survival is limited if water availability diminishes. Although, most bacteria in turfgrass ecosystems are extremely good saprophytes (i.e. they prefer to live on decaying organic matter), some are endophytic (i.e. they live inside healthy plants, usually in roots). In both cases, they are usually good competitors with plant pathogens which results in reduced damage from plant pathogenic fungi.

Of particular importance to turfgrass health are the bacteria that play a role in nutrient transformations in soil, particularly those involved in nitrogen cycling. Numerous bacteria within the genera *Azotobacter*, *Azospirillum*, *Enterobacter*, and *Klebsiella* are efficient free-living nitrogen-fixing bacteria. That is, they take nitrogen from the atmosphere and convert it to a form that the plant can use. Although they contribute significantly to the nitrogen nutrition of such grass species as *Poa pratensis* (Kentucky bluegrass), the magnitude of their contribution to the nitro-

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Despite the presence of harmful microorganisms in turfgrass soils, most soils contain large populations of beneficial microorganisms.

Table 2. Predominant bacteria and their known activities in turfgrass soils.

Bacterial Genus	Predominant Activities
Arthrobacter	Degradation of pesticides Decomposition of organic matter
Azospirillum	Nitrogen-fixation
Azotobacter	Nitrogen-fixation
Bacillus and insects	Biological control of diseases Decomposition of organic matter Degradation of pesticides Denitrification Phosphate solubilization Conversion of ferric to ferrous iron Release of native soil potassium Manganese oxidation
Desulfovibrio	Conversion of sulfates to sulfides
Enterobacter	Nitrogen-fixation Biological control of diseases
Flavobacterium	Decomposition of organic matter Phosphate solubilization Pesticide degradation Biological control of diseases
Klebsiella	Nitrogen-fixation Conversion of ferric to ferrous iron Manganese oxidation Pesticide degradation
Nitrosomonas	Oxidation of ammonia to nitrite (nitrification)
Nitrobacter	Oxidation of nitrite to nitrate (nitrification)
Pseudomonas	Decomposition of organic matter Biological control of diseases Plant growth promotion Some species can be pathogenic to turfgrasses Denitrification Phosphate solubilization Conversion of ferric to ferrous iron Release of native soil potassium Manganese oxidation Pesticide degradation
Thiobacillus	Conversion of inorganic sulfur and iron compounds to sulfates and ferric forms of iron Denitrification
Xanthomonas	Biological control of weeds Some species are pathogenic to turfgrasses Decomposition of organic matter

Great chemical changes may occur in the soil as a result of the proliferation of bacteria, making them such significant microorganisms in the turfgrass environment.

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One of the more pivotal groups of bacteria that impact on turfgrass health are those involved in the biological control of turfgrass pathogens.

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Many of the antibiotic compounds produced by actinomycetes also affect the growth and development of pathogenic fungi allowing the organisms to participate in the biological control of turfgrass diseases.

gen nutrition of turfgrass plants in the field is unknown. Undoubtedly these organisms have the potential to contribute substantially to the nitrogen economy of a turfgrass planting if they were managed in an effective way.

Of equal importance to the nitrogen-fixing bacteria are the those involved in organic matter degradation. These organisms play a key role in maintaining the delicate balance between thatch accumulation and thatch degradation. These organisms can be managed to some degree. In fact, there are a number of commercial preparations of thatch-degrading microorganisms as well as preparations of the enzymes that they produce. Some of these have been used successfully in a thatch maintenance program whereas other fail miserably.

One of the more pivotal groups of bacteria that impact on turfgrass health are those involved in the biological control of turfgrass pathogens. These bacteria can be found in all types of turfgrass soils, from low maintenance to high-maintenance areas. Their effects may sometimes go largely unnoticed. However, they can have huge impacts on disease development. In some cases, high populations of these bacteria are responsible for the development of what we call suppressive soils. These are soils where conditions are ideal for disease development and the pathogens are present, but no disease develops because of the activities of these biological control bacteria. Since all of these bacteria prefer to live on dead and decaying plant tissue, large amounts of organic matter, either in the form of topdressings or direct soil amendments, are usually very beneficial in promoting the activities of these bacteria.

Fungi

The fungi are best known for their disease-causing activities on turfgrasses since nearly all of the economically-important turfgrass diseases are caused by fungi. However, pathogenic fungi represent only a small proportion of the total communities of fungi in soil. The vast majority of fungi found in turfgrass soils are beneficial to plant health. Some of the major genera of fungi present in turfgrass soils include *Penicillium, Aspergillus, Trichoderma, Gliocladium, Fusarium, Mucor,* and *Mortierella.*

Fungi obtain their energy for growth through the decomposition of organic matter. It is not surprising, therefore, that organic matter decomposition is one of their predominant activities in turfgrass ecosystems. Generally, fungi are more prevalent than bacteria in soils of pH lower than about 5.5 whereas bacteria tend to predominate in higher pH soils. Since fungicides are the primary pest control chemical used on golf course turf, soils at these sites can vary dramatically in the composition of fungal communities, depending on the type, rate, and frequency of fungicides used. Mycorrhizal fungi are another beneficial group of fungi that form unique symbiotic associations with plant roots called *mycorrhizae*. In mycorrhizal relationships, the fungus benefits from the carbon provided by the plant while the plant benefits from the increased phosphorus nutrition and water movement to the roots. Both bentgrasses and bluegrasses have been reported to be mycorrhizal, although little information is available on the beneficial or detrimental properties of mycorrhizae in these grasses. As with other fungi, mycorrhizal fungi are sensitive to a number of fungicides commonly used in turfgrass management.

Some of the better-known fungi used in turfgrass management are endophytes. Fungal endophytes are typically found in the seeds and leaf sheaths of nearly all turfgrass species. Most commonly, however, the endophytes of perennial ryegrass, tall fescue, hard fescue, chewings fescue, and creeping red fescue have been exploited. Useful endophytes have not been found in creeping bentgrass and Kentucky bluegrass.

Actinomycetes

One of the least known and least understood groups of soil microorganisms are the actinomycetes. These microbes are classified more closely with the bacteria, but they grow more like a fungus. Although their populations in some soils can be quite high, their growth rates are much slower than the other microorganisms in soil.

Actinomycetes are typically more abundant in dryer soils high in organic matter or in high temperature soils. As a group, they are not tolerant of low soil pH (i.e. less than 5.0). They prefer to grow at temperatures ranging from 80 to 100 degrees. Some of the major genera of soil actinomycetes include *Streptomyces, Nocardia, Micromonospora,* and *Actinoplanes*.

These organisms are best known for their abilities to produce a number of industrially and medically-important compounds. Many of the clinically-important antibiotics used in human and animal medicine come from soil actinomycetes. Many of the antibiotic compounds produced by actinomycetes also affect the growth and development of pathogenic fungi allowing the organisms to participate in the biological control of some turfgrass diseases.

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Algae

Algae can be found in essentially all soils worldwide. Although in most turfgrass soils, the algae are a minor microbial component, their presence, under certain conditions, can create difficult management problems. Unlike the previously-mentioned groups of microorganisms, algae are capable of photosynthesis, allowing them to synthesize their own carbon compounds. Since algae require light, their presence in turfgrass plantings is often observed on the soil surface in sparsely seeded areas and in excessively close-cut turf such as on putting greens.

The types of problems caused by algae in turfgrasses include 1) the formation of surface crusts, 2) the production of copious slime, and 3) the formation of 'black layer'. The soil algae responsible for these problems can be classified into the green algae and the cyanobacteria (formerly referred to as blue-green algae). The genera of green algae recovered from turfgrasses include *Cosmarium, Coccomyxa, Cylindrocystis, Dactylothece, Mesotaenium, Klebsormidium,* and *Ourococcus*. All but the latter two are capable of producing surface crusts and slime. The two most abundant genera of cyanobacteria in turfgrasses include *Nostoc* and *Oscillatoria*. The latter genus has been implicated as the primary cause of slime formation on golf greens. The cyanobacteria are also known for their abilities to fix atmospheric nitrogen, which, in some instances, may actually contribute to the nitrogen nutrition of the turfgrass plant.

Algae are strictly dependent on adequate soil moisture for activity. Algal problems occur whenever the soil remains wet for prolonged periods of time and where the soil surface is exposed or the turfgrass stand is thin and weak. Although fertility has no clear relationship to algal activity, the use of acidifying fertilizers such as ammonium sulfate can enhance algal colonization.

Managing Microbial Resources

It is apparent that the soil contains an extremely rich wealth of microbial resources in addition to the harmful microorganisms with which we are familiar. Microbial communities in turfgrass soils influence all of the important processes related to plant nutrition and the general maintenance of plant health. Furthermore, soil microbial communities provide a genetic resource of potentially useful products and processes that can be exploited for the management of turfgrasses. The challenge to turfgrass managers is to become an expert, not only in the management of what everyone can see aboveground, but to master the management of soil microorganisms to achieve the maximum, sustainable means of turfgrass health and maintenance.

ERIC B. NELSON
DEPT. OF PLANT PATHOLOGY

Microbial communities in turfgrass soils influence all of the important processes related to plant nutrition and the general maintenance of plant health. Furthermore, soil microbial communities provide a genetic resource of potentially useful products and processes that can be exploited for the management of turfgrasses.

Compost

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or sports field. Therefore, thorough testing of mix ratios by a competent lab will be necessary.

While the benefits of using compost are well documented, use only *thoroughly* composted materials from known sources. Make an effort to find a source with a good track record for successful plantings. It will be time well spent.

MARY THURN
DEPT. OF FLORICULTURE AND ORNAMENTAL HORTICULTURE

Table 1. Guidelines for identifying high-quality compost.

Physical Properties		Chemical Properties	
Color:	Brown to black	Organic Matter:	25 to 80 percent
Odor:	Earthy or mouldy	pH:	5.5-7.5
Moisture:	15-25%	Ash:	20-65%
Water-Holding Capacity:	150-200%	Nitrogen:	0.4-3.5%
Bulk Density:	0.2-0.6 g/cc	Phosphorus:	0.2-1.5%
		Potassium:	0.4-1.5%
		C:N Ratio:	25-30:1
		CEC:	50-150 meq/100 g