Subsurface Algae in Turfgrass Soils: Both Friend and Foe

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Even though many algae, including the cyanobacteria and green algae, require light for photosynthesis and growth, many of the terrestrial algae found in turfgrass soils can also be heterotrophic. This means that, in addition to photosynthesis, they can also get energy from the decomposition of other organic compounds. As a result, they are able to survive deep within the soil where no light can penetrate. However, growth rates and activities are greatly reduced as compared with those in the light and it is believed that algae found below the first few inches of soil are simply passive survivors and not contributing to the metabolic activities in the soil.

Conditions Favoring Algae

Algae have been found in soils at populations ranging from about 10,000 cells per gram of soil (typical of most soils) to nearly 100,000,000 cells per gram of soil in an undisturbed grassland. More common populations on golf course turf are in the range of 30,000 to 60,000 cells per gram of soil. These populations represent some of the higher populations of terrestrial algae found on earth. The vast majority of this population occurs in the top inch of soil. Even though both aquatic and terrestrial algal species are widely distributed on golf course turf, there is a high degree site specificity of specific genera and species. Those occurring in soils are generally not the same as those occurring in ponds and streams.

The major abiotic factors affecting the distribution of algae in turfgrass soils is solar radiation, moisture, temperature, nutrients, and pH. Things such as organic matter content and soil texture are less important. Generally, the higher the soil moisture, soil temperature, and sunlight penetration to the soil surface, the greater the population and activities of algae. Increased levels of both organic and inorganic nutrients also enhance the growth and activity of terrestrial algae.

Soil pH also affects the activities of certain types of algae. For example, cyanobacteria thrive best in alkaline soils (pH 7.0 and above) whereas green algae do best in more acidic soils (pH 5.5 and below).

On golf course putting greens, moisture and nutrients are frequently not limiting. In fact, in many cases, moisture levels can be excessive, creating anaerobic conditions that favor the growth of some cyanobacterial species. On these types of sites, temperature appears to be the overriding factor influencing algal growth and activity. Generally the warmer the soil, the greater the growth of algae. Surprisingly, however, many of the same algae that are active at high temperatures can be

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somewhat active even in frozen soils. Many of these species are extremely resistant to freezing temperatures and in some areas, problems with algae are more commonly seen in mild wet winters than in the summer.

The turfgrass species can also affect the type of algae found in a given soil. For example, in a Mississippi State study in 1991, it was found that species of *Oscillatoria* were the predominant algae in bermudagrass greens whereas species of *Anacystis* were the dominant algae in bentgrass greens. This distribution can vary too according to the time of year and geographical location.

Pesticides are another factor affecting the distribution and activity of soil algae. In general, most herbicides, fungicides, and soil fumigants are toxic to algae whereas insecticides generally are not. Nearly all of our knowledge about pesticide toxicity to algae comes from either laboratory culture studies or from a limited number of field studies on agricultural crops. Much remains to be learned about the impact of turf management chemicals on soil algae.

Algae's Roles in Soil Health

Subsurface algae play important roles in the formation and maintenance of a healthy soil. For example, algal growth is an important means by which organic carbon and nitrogen are added to the soil. Many species of cyanobacteria not only fix carbon in CO_2 through photosynthesis, but they can also fix atmospheric nitrogen. Both of these processes also play an important role in humus formation.

In natural soils, algae produce considerable amounts of polysaccharide that helps to aggregate soil colloids and improve soil structure while at the same time improving water infiltration and percolation.

Subsurface soil algae are also known to associate with plant roots, producing hormones that stimulate root growth and enhance the activities of other beneficial root-associated microorganisms. In fact, in many of the rice growing regions of the world, some cyanobacterial species are inoculated into soils to enhance rice yields by as much as 36%! However, the growth stimulating effect of cyanobacteria in turfgrass soils has not yet been documented.

Soil algae also commonly interact with other microorganisms in soil. Many soil algae excrete a variety of antimicrobial compounds that affect the activities of other microorganisms, including plant pathogens. In this case, a species of Nostoc was used for the biological control of a seedling disease of millet. Upon the death of nearly all algae, they serve as an important food source for many important bacteria and fungi in soils. While living, soil algae serve as food sources for protozoa, earthworms, nematodes, and microarthropods.

A number of associations of algae with other microorganisms in soil can result in enhanced algal growth resulting in detrimental effects on turfgrass growth and quality. This is particularly the case with a problem known as black layer discussed below.

Algae-Related Turf Problems

Despite the beneficial properties of soil algae, occasionally, the excessive growth (or blooms) of algae can create problems in the management of turfgrasses. Of the problems associated with algae on golf course turf, surface slimes and black layer are perhaps the most troublesome. Usually the presence of these problems in turfgrasses indicates that some environmental parameter (usually moisture, temperature, or fertility) are somehow out of balance. In Dr. Elliot's article, the problems associated with surface algae are reviewed. Here, I will focus on problems associated with algae beneath the soil surface.

Inhibition of Turfgrass Root Growth - Little attention has been given to algae as potential inhibitors of turfgrass root growth and incitants of turfgrass decline. Even though algae are not typically infectious pathogens, a number of cyanobacteria species have been shown to inhibit root growth of a number of crop plants by producing antibiotic substances that also inhibit bacterial growth. It is well known in the floriculture industry that algal proliferation (usually cyanobac-

Management Strategies for Control of Black Layer in Putting Greens

Control Approach	*Treatment*
Suppress Cyanobacterial Blooms	Apply any of the following: Chlorothalonil Mancozeb Quaternery Ammonium Salts (Algaen-X)
Maintain High Redox Potentials	Fertilize with NO_3 fertilizers (frequent applications at light rates) Reduce irrigation so soil surface can dry Improve air flow to reduce relative humidity and promote drying
Minimize Free Sulfur	Avoid the application of elemental sulfur and sulfur-containing fertilizers

teria) on subirrigation mats and on roots of potted plants in greenhouses can lead to reductions in plant growth and quality. Similarly, it is very common in the diagnosis of turfgrass problems to observe a number of different filamentous and unicellular algal species associated with the roots of turfgrasses in a state of decline. In the absence of recognizable pathogenic agents, algae are sometimes the only biotic agent associated with such general decline symptoms. This luxuriant algal growth is usually absent from healthy turf roots. Despite this apparent association, we currently do not know whether algae do indeed directly lead to declines in turfgrass health. This is another area of important research that will shed new light on the ecology of algae in turfgrass soils.

Black Layer - Black layer has been the most notable problem caused by subsurface algae in golf course turf. This is a problem primarily limited to golf course putting green constructed with a high sand content root zone mix. On the surface, turf takes on a bronze color before gradually thinning. Removing a cup-cutter plug generally reveals a prominent black layering approximately 1 to 4 inches below the soil surface. This layer often contain small black globular bodies that can be seen easily with a hand lens. The most notable characteristic is the noxious sewage odor associated with the black layer. This odor is due to reduced forms of sulfur such as hydrogen sulfide gas (H_2S) that is formed under anaerobic conditions as a by-product of the action of sulfur-reducing bacteria. This gas can further react with metal elements like iron to form black globules of iron sulfide which gives the layer a black color.

The black layer represents a zone where roots cannot penetrate and water movement is restricted. The lack of drainage through this layer gives rise to a perched waterlogged zone creating anaerobic conditions at that site. How then does this plugging occur? Black layered greens often show varying levels of cyanobacterial infestations, usually by species of *Nostoc* and *Oscillatoria*. These species are known to produce copious amounts of mucilages and organic matter, particularly in the calcareous sands commonly used in greens construction. Mucilage production is also enhanced in the presence of elemental sulfur, chelated iron, lime, and gypsum. These mucilages can bind together the sand particles and fill the pore spaces creating this impermeable layer where water and organic substances can accumulate. The resulting anaerobic conditions can then favor the activities of the sulfate-reducing bacteria and the generation of hydrogen sulfide.

It is believed that the hydrogen sulfide directly inhibits root growth since it is a well known inhibitor of root respiration in higher plants. Furthermore, research has shown that exposure of creeping bentgrass turf to 1000 ppm H2S resulted in death of the entire plant in as little as 7 days. The actual black layer, which is composed of metal sulfides, is not toxic and the presence of the layer should be an indication that anaerobic conditions are present in the root zone and that a turfgrass toxin is present.

Control of Black Layer

The predisposing factor for black layer formation is the growth of cyanobacteria in the root zone profile. Without this growth, the general plugging of the profile does not occur, the anaerobic conditions to not arise and H_2S is not formed. Therefore, controlling black layer formation can be approached from several different angles (Table 2). First, minimize surface growths of cyanobacteria on the putting green surface. This can be accomplished through the application of a number of different materials listed in Table 2. Research has shown correlations between surface proliferation of cyanobacteria and black layer formation. Second, maintain high redox potentials. In other words, maintain high oxygen levels in the root zone. This can be accomplished primarily through water and fertility management. Finally, avoid the use of sulfur-containing fertilizers. Under anaerobic conditions, H_2S is formed from the action of sulfur-reducing bacteria only in the presence of sulfur-containing compounds.

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Glossary

Anaerobic - growing or living in the absence of oxygen.

Aquatic - growing or living in water.

Chlorophyll - the green photosynthetic pigment in plants that converts light energy and carbon dioxide into carbon for the plant.

Heterotrophic - requiring complex carbon and nitrogen compounds for growth and activity.

Microarthropods - a group of microscopic insects.

Mucilage - slimy, gelatinous substances composed of polysaccharides and proteins.

Protists - a group of relatively primitive organisms classified within the Protoctista.

Protozoa - microscopic single-celled non-photosynthesizing Protists.

Redox Potential - the measure of the oxidative potential of a soil; redox potentials increase as oxygen levels increase; at high redox potentials, a greater amount of oxidation can occur.

Terrestrial - growing or living in the soil.