CHALKBOARD

TIPS FROM THE PROS

Thoughts on the Black Layer

By Lee Berndt and Joe Vargas

As with other poorly understood phenomena, a great deal of controversy exists regarding the black layer. Hypotheses have arisen suggesting that the occurrence of black layer and its turfgrass decline may be directly related to root-infecting fungi, algae, excess water, improper construction, poor management, topdressing or sulfur.

Root-infecting fungi probably have little to do with the actual black layer development. These organisms (i.e., Pythium spp.) may, however, invade root tissue secondarily in response to stress related to black layer development, and further contribute to the decline. If these organisms were solely responsible, the decline would be easily controlled with the excellent fungicides currently available.

Algae, topdressing, improper contruction, and sometimes poor management come into play by effecting conditions of soil anaerobiosis (lack of available oxygen). Algae, for instance, can be very prolific in soil systems. When conditions become favorable for algal growth, soil oxygen may become limiting due to algal consumption and surface crusting, which restricts diffusion.

The muco-polysaccharidic slime manufactured by algae may also physically plug soil pores, thus reducing oxygen diffusion. If topdressing contains an appreciable amount of silt or clay, or is of dissimilar particle size compared to the base mix, repeated use might contribute to soil layering, possibly restricting oxygen diffusion and water drainage by creating perched water tables.

However, it is our contention that black layer (or the black coloration of the soil profile) results directly from anaerobic dissimilatory sulfate reduction. This is the biological reduction of sulfate (oxidized sulfur) to sulfide (reduced sulfur) mediated by a select group of anaerobic bacteria (i.e., *Desulfovibrio).*

Biologically produced hydrogen sulfide subsequently reacts with soil metals, such as iron, to produce metallic sulfide particles which deposit within the soil pore space. These particles are black compounds that generally lose their color upon exposure to atmospheric oxygen.

Where the coloration occurs depends on subsurface water movement, sulfate/organic matter distribution and dynamic oxygen gradients affecting microbial activity. It is possible in some instances that algae or topdressing may play a role in the sulfate-reducton process by creating the necessary anaerobic condition and contributing organic matter for the anaerobic bacteria. However, many black layers have been observed where no visible evidence of algal growth exists.

Research at Michigan State University supports the sulfate-reduction hypothesis. When washed dune sands receiving either one or five pounds of sulfur per 1,000 square feet were inoculated with lactate-enriched, mixed cultures of sulfate reducers and were subjected to waterlogging (i.e., anaerobiosis), *a black layer was formed.*

When these same soils *did not* receive sulfur applications, but were subjected to identical inoculations and water conditions, the black layer *did not* develop. Also, when a creeping bentgrass golf green composed of similar sand soils was subjected to extensive waterlogging, a black layer was formed.

Both layers were shown by inorganic spot analysis to be composed of reduced iron and sulfur compounds. Thus, it appears that the presence of sulfur (from whatever source), metals, anaerobiosis and soil bacteria are necessary for black layer formation.

As far as sulfur is concerned, there is usually a considerable input to most highly maintained turfgrass soils, even though most soil sulfur is considered to be tied up in organic matter. Sulfur may accumulate in soils through the application of elemental sulfur, fertilizers, iron sulfate, irrigation water, acid rain, thiol-based fungicides and pesticides, micronutrient solutions, organic matter containing sulfur amino acids, and direct adsorption of gaseous sulfur dioxide.

In fact, it is estimated that in cities such as Gary, IN it is not unusual to have greater than 50# sulfur per 1,000 square feet per year deposited from rainfall alone. Thus we believe that the anaerobic chemistry of such sulfur compounds (originating from whatever source) is related to black layer development.

The appearance of the black layer itself may not initially be detrimental to turfgrass growth, but is an *indication* of "reducing" soil conditions, which may eventually lead to turf thinning and loss. The decline of turfgrass is probably due to the lack of available oxygen, and the accumulation of toxic anaerobic metabolites such as hydrogen sulfide, methyl mercaptans, volatile fatty acids, alcohols and ethylene which naturally occur with anaerobiosis.

However, if lengthy anaerobic conditions remain, as when spring and fall rains occur, metallic sulfides may accumulate in pore spaces and eventually produce a layer or profile with a gluelike consistency. The metallic sulfide particles in the gluelike layer may then actually help maintain the anaerobic conditions by chemically attracting and binding diffusing oxygen.

When diffusing oxygen is scavenged in this way, it becomes unavailable for respiration, and the detrimental effects produced by lack of oxygen and accumulation of toxic soil compounds can be extended. Sulfur will not initially induce anaerobic conditions in soil. However, if sulfur is present in sufficient quantities and is allowed to reduce, the resulting compound(s) will make diffusing oxygen less available. In fact, reduced sulfur compounds are routinely used as "reducing agents" to chemically scavenge oxygen in anaerobic microbiological media, as microbiologists know.

In summary, dissimilatory sulfate reduction plays a key role in anaerobic black layer formation and the associated turfgrass decline, regardless of whether the sulfur originated in organic matter, acid rain, irrigation water, or from supplemental input. Reduced sulfur compounds such as ferrous sulfide (FeS) impart the characteristic black color commonly associated with many black layers. This has been experimentally shown in our laboratory.

These reduced sulfur compounds also bind diffusing oxygen, making it less available to the turf plant. Thus, if you have experienced problems with black layer in your soil, additional sulfur will only aggravate the situation if conditions for black layer again become favorable.

The key ingredients for black layer development include anaerobic conditions, the presence of sulfur compounds and soil metals (from whatever source), organic matter and sulfate-reducing bacteria. Reduced sulfur compounds, such as hydrogen sulfide and methyl mercaptans, in association with naturally occurring anaerobic metabolites such as ethylene, fatty acids and carbon dioxide, impart the characteristic foul odor associated with the layer and are thought to be responsible for the observed turfgrass decline.

Thus it is clear that the anaerobic biochemistry of black layer (and its related anaerobic metabolites) should receive the brunt of research attention, since giving the golfer or sports turf user a playable surface with acceptable aesthetics is the name of the turf-management game.

Editor's Note: The authors are researchers at Michigan State University, East Lansing, MI.