Sulfur, Organic Matter And The Black Layer

Research made possible by GCSAA's S&R Fund provides some key observations in response to a complex puzzle.

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Golf course superintendents have reported black layer in a variety of soils nationwide. Black layer is most common in hot, wet weather and is especially visible in sand greens with highly active root systems. Black layer is not, however, limited to sand greens or wet weather and may appear in dry weather when heavy irrigation is used. Frequently associated with black layer is a decline in turfgrass quality. The decline first appears as a bronzing or thinning of the turf resulting in sporadic turf loss but may eventually result in total turf loss.

Attempts to control black layer have involved Pythium fungicides, wetting agents, core aerifying, spiking, slicing, phosphate application, anti-microbial agents, aldicides and even total renovation. All remedies thus far have met with limited success in terms of effort and money. The question then
remains, “What can be done about black layer?”

Before you fully understand how to cope with black layer, you must first understand its nature. This article will attempt to shed some insight on the cause of black layer and possible management strategies.

**Black Layer Formation**

Black layer is an accumulation or deposition of metallic sulfides. These compounds precipitate from soil solution in pore space and deposit on soil particles. The sulfides are generated from dissimilatory sulfate or sulfur reduction. This is a process where anaerobic bacteria, which are active only in the absence of oxygen, metabolize carbon using sulfur compounds as electron acceptors. These bacteria are known as sulfate or sulfur reducers. Sulfur-reducing bacteria are poisoned by even traces of oxygen because of a lack of a critical enzyme.

In aerobic respiration, organisms, including humans, use oxygen as an electron acceptor and give off carbon dioxide and water. This also could be called oxygen reduction. Reduction means gain of electrons. The water given off is formed from reduction of oxygen by electrons from food burned for energy according to this reaction:

$$4H + O_2 \rightarrow 2H_2O$$

where 4H represents four electrons from food.

This is a very simplistic model, but it illustrates the point. In soils, food for bacteria is organic matter. Instead of passing electrons to oxygen when food is consumed and burned for energy, sulfate or sulfur reducers pass their electrons to sulfur compounds when oxygen is absent:

$$2H + S \rightarrow H_2S$$

The end product is hydrogen sulfide ($H_2S$). Hydrogen sulfide is a respiratory toxin and is more poisonous than hydrogen cyanide.

The turf decline is also probably related to hydrogen sulfide occurrence. Hydrogen sulfide is extremely reactive with soil metals (i.e., iron, etc.) forming insoluble, black metal sulfide precipitates. A precipitate is a substance separated from solution by chemical or physical means. These precipitates constitute the black color in black layer. If sulfides did not precipitate with metals and become inert, more turf would probably be lost to decline because of greater occurrence of free, gaseous hydrogen sulfide. (In fact, in past times Asian rice farmers would routinely add iron-rich red soil to rice paddies to precipitate hydrogen sulfide and prevent rice straighthead disease — a sulfide poisoning.)

Sulfur or sulfate reduction occurs only when systems are at least partially devoid of oxygen. Other factors in black layer development include soil sulfur type and concentration and organic matter concentration. It is appropriate here to discuss each factor briefly.

**How Anaerobiosis Occurs**

Absence of oxygen is termed anaerobiosis and is necessary for sulfide to form. This is because oxygen has a greater affinity for electrons than does sulfur or sulfate. Sulfide is formed only when sulfur compounds attract these electrons. Soils may become anaerobic in several ways, the most obvious of which is for soils to become waterlogged. This may occur when heavy

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times more organic matter, is needed to produce sulfide from sulfate in an amount equivalent to that produced by mineral sulfur. Electrons come from organic matter. The distinction between sulfur types and sulfide yield was evidenced in our research as indicated in Table 1.

When Lake Michigan dune sand was treated with 1 pound of sulfur per 1,000 square feet from either sodium sulfate or from flowable elemental sulfur and then water-logged for 21 days with tap water, more sulfide was detected in experimental units treated with elemental flowable sulfur than in units treated with sulfate sulfur. In our study, the amount of organic matter in that soil was initially constant and became limiting as the study progressed. In theory, if you added four times more organic matter to the soil amended with sulfate sulfur you would produce sulfide in an amount comparable to that found in the sulfur-treated soil.

Our research also supports the idea that sulfur concentration and organic matter concentration affect sulfide yield (Figures 2 and 3). In Figure 2, when Lake Michigan dune sands were treated with elemental sulfur at rates of 0, 1.5 or 3.0 pounds per 1,000 square feet, and sodium lactate (i.e., organic matter) at 0, 112 or 1,120 ppm, and were then water-logged for 21 days, sulfide yield increased with sulfur and lactate rates. Sulfide yield in response to sulfur concentration depended on lactate concentration and vice versa.

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In Figure 3, when Lake Michigan dune sands were treated with sulfur at rates 0, 1, 2, or 3 pounds per 1,000 square feet and amended with organic matter as creeping bentgrass root tissue and then waterlogged for 21 days, again more sulfides were produced at higher sulfur rates where root tissue was added.

Black Layer Management

Sulfides in black layer are best controlled or managed when approached from several directions. Control the amount of sulfur applied supplementarily. Pay attention to the sulfur contents of fertilizers, fungicides and other pesticides. Some of these products contain greater than 10 percent sulfur by weight.

If you must use sulfur as a nutrient, use sulfate. Mineral sulfur will increase the sulfide formation potential. Limit the amount of sulfur applied for pH control. Lowering soil pH using sulfur will remove valuable soil oxygen and provide sulfur necessary for sulfide formation. If soil pH is high it is better to add nutrients such as iron than to stimulate sulfide production by adding sulfur.

Control the addition of organic nitrogen if black layer is a problem. Organic fertilizers need oxygen to release available N and will help to make conditions conducive to sulfide production. These types of fertilizers also provide an abundance of organic matter and thus a source of reducing electrons. Use instead a fertilizer that is nitrate-based, such as ammonium nitrate or calcium nitrate. Research at Michigan State suggests that addition of nitrate to soil systems will prevent sulfide from forming or lessen its intensity (Figure 4). This is because, like oxygen, nitrate has a greater affinity for electrons than does sulfur or sulfate. If nitrate is present, electrons will be attracted to it exclusively over sulfur or sulfate. When nitrate is depleted electrons flow to sulfur.

It is interesting to note that theoretically, if sulfides accumulate in turf soils, nitrogen as ammonia may be present, but nitrate is depleted and is not available to the turf plants. If sulfides tend to accumulate in greens, care must be taken to spoonfeed nutrients to the afflicted turf so that nutrients are not wasted and plant uptake of nutrients is maximized. Fertility in managing black layer is very important.

Control the amount of water added to greens as far as possible. Light, frequent syringings during hot, humid weather are superior to deep, infrequent waterings. Extreme care must be used during irrigations so that the root zone is not saturated. As stated earlier, golf greens are built to retain water in the event of drying conditions. Excess water is one of the fastest ways to attain oxygen deficiency in soils, the main prerequisite for sulfide formation.

The common denominator in these suggestions for black-layer control is that each involves an aspect of prevention rather than a cure. Once sulfides have formed in soils, they are difficult, if not impossible, to get rid of until sufficient oxygen becomes available. Core aerification is a convenient method for enhancing oxygen entrance into soil, as it is drying the soil and adding nitrate N. When sulfides are present, however, any oxygen diffusing into soil is quickly scavenged in an attempt to oxidize sulfides back to sulfate. This not only utilizes oxygen otherwise available for plant and micro-organism respiration, but creates temporary excesses of sulfuric acid in the process.

Summary

In summary, black layer is an accumulation of sulfides in soil. Sulfur, organic matter and soil aeration status are important determinants in sulfide formation and intensity. As sulfur and organic matter contents of a soil increase and oxygen content decreases, the potential for sulfide formation increases. Avoiding the use of elemental sulfur will help prevent sulfide formation. If avoiding sulfur is not possible, then care must be taken to restrict use of organic fertilizers and to promote soil aeration. This can be accomplished by being judicious with irrigation, using aerification and maintaining adequate nitrate levels in soil.

If sulfides begin to accumulate in your soil, dry it out as much as is possible. Syringing in this instance is mandatory. Core aeration with hollow tines will help, but do not topdress or refill the holes. Spoonfeed the turf nutrients, including P and K. A check on drainage may also be wise. If turf loss begins to occur, steer traffic away from the afflicted site.

If possible, allow the height of cut to be raised, thus increasing rooting potential. Apply light rates of calcium nitrate or potassium nitrate in solution to the area. This will help to alleviate further sulfide production by promoting aeration. Maintain an adequate fungicide schedule to help prevent additional stresses on the turf.