BLACK LAYER RESEARCH UPDATE 1989

Lee Berndt, Joe Vargas, Jr., and Brad Melvin
Department of Botany and Plant Pathology
and the Pesticide Research Center, MSU

Metal sulfides exist in turfgrass black layer. Sulfides are biologically produced in a bacterial respiratory process called dissimilatory sulfate (or sulfur) reduction. Reduction in this sense means gain of electrons. Reduction of sulfur compounds results in production of hydrogen sulfide, a gaseous compound more toxic than hydrogen cyanide and especially reactive with metals. Hydrogen sulfide is thought to be involved in the decline of turfgrass quality which frequently accompanies black layer. When a reaction between hydrogen sulfide and metals such as iron or copper occurs, dark colored metallic sulfide precipitates form provided pH is not too low. A precipitate is a compound separated from solution physically or chemically. Sulfide precipitates then deposit on soil particles and organic matter giving the black color to black layer. Our research involves various aspects of sulfate or sulfur reduction.

Research in 1988 suggested that sulfur (S) concentration and organic matter (OM) concentration affected sulfide production in water-logged sand. When replicates of washed Lake Michigan dune sand were amended with elemental S at rates of 0, 1.5, and 3.0 # S/M, and water-logged with lactate solution (i.e., OM) at 0, 112, or 1120 ppm for 21 days, sulfide concentration increased as rate of S and OM increased. Sulfide production in response to sulfur rate depended on OM concentration and vice versa. Metal sulfide concentration was greater than free hydrogen sulfide concentration under all experimental conditions, but as S and OM rates increased so did occurrence of hydrogen sulfide. Very little sulfide of any type was detected where S had not been added to sand. Soil pH and redox potenital were also lowered as S and OM increased. The pH decline was attributed to the acidifying effects of S, but pH usually increases when redox potential decreases. When redox potential is low "anaerobiosis" is initiated. Anaerobiosis is a term to indicate oxygen deficiency which is a necessary prerequisite to black layer formation. A major contributor to anaerobiosis in soil is waterlogging. Oxygen diffusion into water-logged soils can be 10,000 times less than into non-saturated soils. Sulfur also helps to produce anaerobiosis when added to soil by binding available oxygen for conversion to sulfate (i.e., oxidation). Sulfides, like sulfur, also oxidize to sulfate by binding available oxygen. In fact, sulfides are routinely used to take oxygen out of (i.e., reduce) microbial cultures when raising anaerobic bacteria. Organic matter also encourages soil anaerobiosis by increasing microbial growth and therefore consumption of oxygen.

Research also suggested that hydrogen sulfide occurrence could contribute to the turfgrass quality decline which may accompany black layer. Washed Penncross creeping bentgrass sod was transplanted and allowed to root in 4 inch diameter PVC cores with a glass bead soil matrix, then was water-logged by continuously circulating a 1500 ppm hydrogen sulfide solution through the core. Turf in the cores receiving sulfide appeared stunted and lost green color after only 3 days. Core respiration and carbon dioxide uptake was also less than in a check core which was treated identically except that it received no sulfide. It was assumed that the sulfide interferred with plant photosynthesis, and plant and micro-organism respiration since hydrogen sulfide is a known respiratory toxin which inhibits aerobic electron transport.

Field research at the Hancock Turfgrass Research Center in 1988 suggested that black layer in a Penncross creeping bentgrass golf green contained metal sulfides. Turf was treated with mineral S at rates of 0, 1, or 5# S/M, then water-logged daily by irrigating for 1 hour. Black layer became visually more intense where S had been added and more metal sulfides accumulated as S rates increased. Sulfide accumulation declined with soil depth and was postulated to be related to turf rooting activity. Root measurements were not done in 1988 but will be in 1989 since visual observations suggest rooting activity to decrease with soil depth.

There are several things one can do to prevent black layer formation, and prevention is the best control. Control the amount of irrigation applied to your turf. As a turf manager you may not be able to control torrential rains which last for lengthy periods but you can manipulate your irrigation system. Golf greens are built to drain readily but they are also built to retain water as drying conditions develop. Thus, control of soil moisture is mandatory in preventing black layer. Control the amount of supplemental sulfur applied to your turf. Sulfur is applied to lower soil pH to make certain nutrients more available. Why risk black layering by adding large amounts of elemental sufur when addition of nutrients such as iron or phosphorus, which are less available at high pH, is so easy with modern nutrient solutions and spray rigs? Many fertilizers and pesticides also contain up to 10% S by weight. For this reason and with the amount of sulfur in the atmosphere from car exhaust it is very rare today to find cases of true sulfur deficiency in turfgrass. If sulfur is truly deficient use small amounts of sulfate to correct the deficiency in place of elemental sulfur. Black layer potential is less with sulfate because only 2 electrons are needed to reduce 1 mole of S to sulfide while 8 electrons are needed to reduce 1 mole sulfate to sulfide. Thus, for the amount of organic matter present in the soil, 4 times more black layer can be produced from mineral sulfur than can be produced from an equivalent amount of sulfate. Nitrogen carriers without sulfur recommended for general fertility are ammonium nitrate, calcium nitrate, or potassium nitrate. Research has also suggested that addition of nitrates will prevent sulfate reduction from occurring. This is because nitrate acts like oxygen in soil when oxygen is absent.

If black layering has already become a problem do not add sulfur or organic fertilizers to the soil. These compounds are already in a highly reduced state and need oxygen to oxidize and become plant available. Just as elemental sulfur can become an oxygen "sink" by conversion (oxidation) to sulfate, organic nitrogen can become an oxygen "sink" by its conversion (oxidation) to nitrate. Add compounds such as calcium nitrate as an N source. Calcium nitrate is a powerful "oxidizing agent" and will also help to neutralize acidity created by oxidation of black layer sulfides. Add other nutrients such as P and K which are stimulatory to rooting. Fertility is very important in managing black layer and rooting potential is paramount. Lastly, core aerification with hollow tines may help. Leave core holes open and remove plugs from the greens surface. This will encourage oxygen diffusion into the soil profile and help to increase surface drainage.

In conclusion, black layering is a problem which can lead to many headaches. The layer is biologically produced by the bacterial reduction of sulfur compounds to sulfide. Black layer can be prevented by limiting the addition of sulfur and organic matter, and by keeping the nitrate levels up in your system. Prevention also centers on encouraging oxygen diffusion into your soil by restricting irrigation practices. Once black layer occurs do what you can to get oxygen or oxygen like compounds (i.e., nitrate) into your soil. Spoonfeed nutrients, reduce irrigation input and use common sense in all management practices. If black layer has already developed don't add sulfur or organic sources of N! Good luck!