BLUE-GREEN ALGAE AND BLACK LAYER

Continuing research at Iowa State University suggests the causes of black layer on golf greens. Only when the causes are determined can appropriate remedies be determined.

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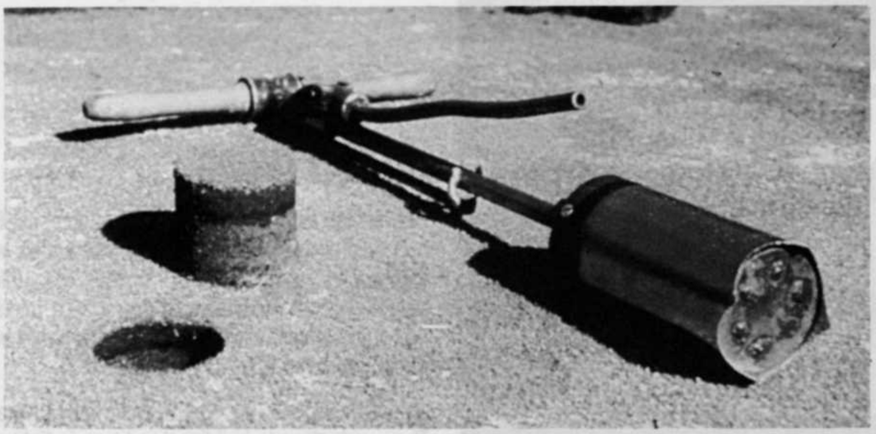

Photo 1: Black layer usually occurs about one-half to three inches below the green's surface.

A gradual increase in the construction and use of high-sand content golf greens in the last 20 years has brought into focus the need for research on microbiological ecosystems that develop in these greens.

Many high-sand content greens develop problems shortly after new construction or renovation of greens. Problems range from increased activity of non-pathogenic micro-organisms and soil-borne pathogens, unpleasant odors, and impaired drainage. Many of these problems, or combinations, result in poor growth or loss of turf.

One problem that is of special interest to golf course superintendents in the U.S., Canada and Australia is a condition called "black layer." Although the expression adequately describes the condition's appearance, it provides little insight into its causes.

Researchers and superintendents have proposed many theories on black layer's causes. Theories range from types of chemicals applied to greens, to nutritional and/or chemical imbalances in the sand greens, to biotic factors such as algae and bacteria. The ideas differ, but most seem to agree that the disorder is related to water problems and to anaerobic conditions.

In this respect, black layer might better be described as anaerobic decline of creeping bentgrass, as has been suggested by Houston Couch, Ph.D.

There seem to be two primary types of black layer development, surface and subsurface layering. Surface black layering develops at the surface of the green and extends downward, forming a layer one to three inches thick. Subsurface black layering generally occurs about one-half to three inches below the green's surface. The layer may range from one-quarter inch to more than one-inch thick (Photo 1).

The mix between the surface of the green and the top of the subsurface layer may appear normal in color, or may show a slight darkening.

Subsurface black layering may be more complex on old soil-type greens where sand top dressing has been initiated. In most instances where black layer occurs under these conditions, the layer is where sand and soil meet. If alternating applications of sand and other top dressing mixes have been applied to the green, the black layers may occur as a series of thin bands (one-quarter inch thick or thinner). Although black layer develops most aggressively in high-sand content greens, it can occur in greens with a relatively high soil content. The black layer in high-soil content greens is generally thin and at the surface, often directly under a thin thatch layer.

Black layer shows a number of variations on high-sand content greens. The layer may involve an entire green, but more often it develops in portions of the green. Low areas of a green, or shaded areas with poor air movement, may show the most successful development and the more severe damage. But the disorder is by no means restricted to such areas. The layer itself (especially subsurface) may be discontinuous, or be composed of unconnected circular-to-oblong globules of black layer material.

The cause-and-effect relationship between black layer and dead turf seems to be very complex. Perhaps one of the least-noted facts about black layer is that not all black-layered greens result in dead turf. It is not uncommon to find healthy turf on high-sand content greens with a distinct subsurface layer. Such greens may not have optimum infiltration or drainage, but the turf can be maintained.

When turf is lost in association with black layer, it dies in a relatively nondescript pattern. The grass can die rapidly by turning a straw to reddish-straw color; or occasionally, the afflicted areas may become chlorotic prior to dying and becoming straw-colored.

A variety of odors is emitted from black-layered greens with dying turf. The odors are not associated with healthy turf on greens with or without black layering. They have been de-

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scribed as "earthy," "swampy," "rotten-egg like," "sulfurish," or "outhouse-like." The latter three seem related to possible evolution of sulfur-containing gases or aromatics. Whether the constituents of any of these odor-producing substances are toxic to the turf is unknown.

There may be some evidence, however, that some subsurface black layers may contain substances directly toxic to roots. The turf can be lifted directly off some black-layered greens; the roots either stop growing or are killed when they come into contact with the layer.

Some superintendents have observed that if aerifier cores from some black-layered greens are left on tbe surface of the green, they will kill the leaves they touch. These observations certainly suggest a high level of toxicity associated with the black layer.

It also has been observed on some black-layered greens that coring which penetrates through the layer may temporarily stimulate the turf near the hole and disrupt the layer. This may be due to temporary improvement of an anaerobic condition and/or removal of toxic substances.

Aeration seems very important; the layer's color often fades when exposed to air and in some instances during winter dormancy. These observations suggest an anaerobic condition.

Knowledge of how to control loss of turf on black-layered greens is, unfortunately, scarce. Reducing irrigation to a minimum and increasing aerification seems to have the greatest effect on slowing black-layer development, but these operations are unlikely to end the problem. Using wetting agents and fungicides with algicidal properties also may help. To date, however, I have not seen black layer eliminated by any chemical or cultural means; but many creative superintendents have learned to manage the problem somewhat.

It also seems that the problem may decrease in severity with time, irrespective of cultural and chemical practices. Once established, however, it seems to always be active at some level.

Our prospects for effective control of this problem seem to rest squarely on the ability of the research community and superintendents to exchange information and to work together to find the problem's causes.

Biotic connection

Black layer was first brought to my attention in 1978, on the Iowa State University golf course.

The black-layer condition initially was viewed as a curiosity and was thought to be peculiar to specific problems on that course. It also was thought to be associated with the green's physical components. From 1978 to 1984, however, the number of black layer samples received in my laboratory increased dramatically, and were being received from midwestern, eastern and south central states, and Canada. It soon became apparent that no physical, chemical or cultural factor was common to the various samples received. Many superintendents, however, complained of poor water infiltration and/or drainage of greens.

During 1985's growing season, all black layer samples were carefully examined for the types and prevalence of microorganisms associated with the disorder. This involved isolation of organisms in leaf and root tissues, in the top one-eighth inch of the sand mix, in the subsurface sand not involved in the black layer, and in the black layer. Some common denominators evolved from these efforts.

Perhaps of greatest interest is that the black layer is essentially devoid of aerobic microbes. However, mixed cultures of anaerobic bacteria (bacteria that can survive on extremely low levels of oxygen) have been isolated regularly from black layers. Species of pythium and another unidentified fungus also are found in some black layers, and like the bacteria present, can survive on low levels of oxygen. Blue-green algal species of the genus nostoc and other unidentified species also are common on black-layered greens.

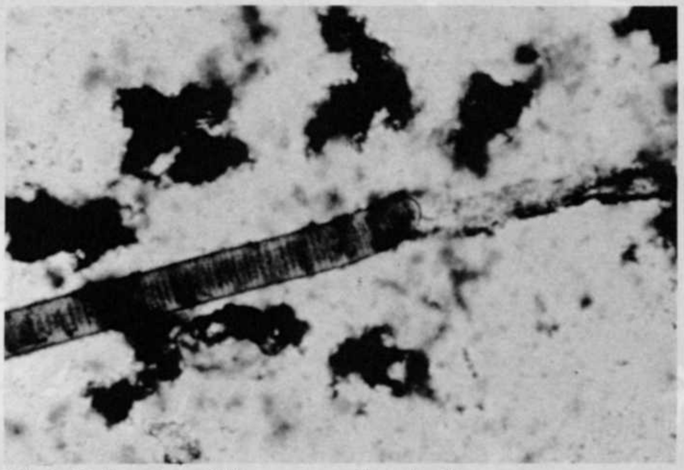

Photo 2: Species of blue-green algae in the genus *oscillatoria* glide on extracellular mucilage produced by the algal organism.

Why are blue-green algae of interest in black layer development? Blue-green algae are among the oldest plant forms on Earth and are found in soil world-wide. They have been shown to be an important factor in soil formation. Many species have natural habitats characterized by wet, light, sandy soils; characteristics typical of high-sand content greens.

The algae probably exploit the porous nature of sand mixes that permit greater light penetration than finer-textured soils. Light conditions for the algae also are improved by close mowing, a common practice on greens. The combination of light penetration, abundant water, relatively high levels of nitrogen and other usable elements, and perhaps reduced competition from other microbes in sand mixes help the algal organisms flourish.

It also is possible that today's highly specialized pesticides may inadvertently promote algal growth. General biocides (mercury and arsenic) once commonly used may have contained algal growth more than many of the less toxic and more biodegradeable compounds of today.

Once the blue-green algae are established on a green, the prerequisites for black-layer formation may be set into motion. Species of oscillatoria and nostoc are filamentous blue-green algae; that is, they are worm-like filaments and are mobile. Their movement is facilitated, in part, by producing an extracellular mucilage upon which they glide over the surface of the sand (Photo 2).

Mucilage probably protects the algae from desiccation and also functions as an adhesive, holding the algae to sand particles and binding particles together. These materials are hydrophilic, quite stable, and adhere strongly to the sand particles.

It is believed that the extracellular mucilage, in combination with organic matter produced by the death of algal organisms, gradually fills and plugs the pores between sand particles at the green's surface. The initial effect of this process, prior to any black-layer formation, may be a slow

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ing of water infiltration and drainage due to a biologically induced perched water table at the green's surface.

Surface or subsurface black layer formation may be started at this point.

If growth of the blue-green algae is excessive, the green's surface may be tightly sealed and accumulation of mucilage, dead algae, and infestation of these products by other microbes (bacteria and fungi) may result in surface black layering. If the algae proliferation is slower, the mucilage and other organic products of dead algae may move more slowly into the sand mix's profile and eventually form a barrier below the surface. This barrier of mucilage and other organic substances from the algae may then serve as substrate for anaerobic bacteria and some fungal species.

It is not entirely clear what contributes to the black layer's color, but some of the color is probably due to deteriorating organic matter (perhaps algae and organic substances, and tissues from grass roots). Also, the mucilage supports bacterial and fungal growth and probably promotes mineralization of the organic matter in the layer. This activity would further contribute to the layer's color and may be further influenced by fertilizers and iron and sulfur amendments. Iron and sulfur can be metabolized by algae and bacteria, often in different ways, depending on the presence or absence of oxygen.

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The black layer problem seems to be the result of an abnormal opportunistic microbiological ecosystem. The system's components (blue-green algae, bacteria, and perhaps some fungi) are set into motion by the physical characteristics of high-sand content greens and the cultural regimes required to maintain them.

The superintendent may have little control over the development of black layer. He is often locked into the requirements of the sand green cultural regime and can make only minor changes in his operation. If enough components of the ecosystem emerge on the green, black layer will form. The concept of an abnormal microbiological ecosystem forms the basis for research being conducted at Iowa State University on the black layer problem. **LM**