*Promises and Realities:*
# The Biological Control of Turfgrass Diseases

Eric B. Nelson, Ph.D.
Cornell University

The management of turfgrass diseases has become one of the more challenging and const-intensive aspects of turfgrass maintenance and culture. More money per acre is spent annually for disease control in turfgrasses than on any other commodity.

Increasing concern has arisen about fungicide dependency of turfgrasses and the environmental consequences of repeated and sometimes unnecessary fungicide application. This has prompted regulatory agencies, fungicide manufacturers, university researchers, and golf course superintendents to examine the potential for other strategies in disease management.

One of the more exciting alternative strategies being explored is the use of biological controls. This is the practice of deploying microorganisms individually or in mixtures to either reduce the activities of pathogens or enhance the tolerance of plants to disease.

This approach to disease control has been used successfully on an experimental as well as commercial basis for the control of plant pathogens on several crop plant species. It has only recently begun to find its place in commercial turfgrass management.

Major developments in the biological control of turfgrass diseases have occurred only in the last five to 10 years. Although this approach to disease control promises to reduce or eliminate the need for fungicide applications, there are a number of limitations to the use of biological controls for the management of turfgrass diseases on high-maintenance turfgrass.

In this article the latest finding in this rapidly developing field will be explored. Biological control research and biological approaches to disease control will be discussed. In addition, some of the limiting factors to the use and management of living organisms as biological control agents for turfgrass diseases will be presented.

**What Is Biological Control And How Does It Work?**

Most turfgrass managers are familiar with the negative aspects of soil microorganisms because many are pathogenic and can damage a turfgrass stand. However, in addition to these turfgrass pathogens, the soil harbors a variety of microorganisms that do not damage plants but actually improve plant health.

These soil bacteria and fungi are responsible for increasing the availability of plant nutrients, forming symbiotic associations with turfgrass roots, and producing substances stimulatory to plants growth. They also protect plants against infection from pathogenic fungi.

The practice of biological control attempts to take advantage of all of the above mentioned microbial attributes in order to minimize damage from plant pathogens. Biological control may be achieved either through the application of introduced disease-suppressive microbes or though the manipulation of native microbes present in soils and on plant parts.

For example, cultural management techniques such as core aeration, vericutting or the application of lime may reduce disease development by altering the soil and thatch microbial communities within which pathogens must function. In such cases cultural practices may indirectly affect disease severity by changing the environment to favor disease-suppressive microorganisms to the detriment of the pathogen population. Similarly, the application of composts or other well-decomposed sources of organic matter to turf provides substrates on which disease-suppressive soil microorganisms can grow. At the same time this introduces populations of microorganisms that may reduce disease severity by interfering with the activities of pathogenic fungi.

With either approach, the goal is to reduce or eliminate damage from pathogens either by reducing pathogen inoculum in soil, protecting plant surfaces from infection or by inducing natural defense mechanisms within the plant.

Biological control of turfgrass pathogens may occur through the microbial destruction of pathogen spores or the prevention of spore formation. In either case, biological control processes serve as a means of reducing pathogen inoculum in soil.

In addition, antibiotic-producing microorganisms may displace pathogens in decaying plant residues such as thatch and also reduce their populations in soil. Many non-pathogenic soil microorganisms are able to effectively colonize above-ground as well as below-ground plant parts. In so doing, they protect these tissues from becoming infected by pathogens.

Some root- and crown-colonizing soil microorganisms also can induce natural defense mechanisms in plants, rendering them more tolerant to disease. Some soil bacteria can also compete more effectively than pathogens for essential nutrients and other growth factors, thereby reducing pathogen spore germination, growth and plant infection.

Microbes that suppress turfgrass pathogens can be found in a variety of sites. They are particularly abundant in turfgrass soils and thatch as well as in decaying organic substrates such as composts. In established turf, a greater percentage of disease-suppressive bacteria is associated with thatch than with the roots or foliage. Additionally, those microbes associated with thatch are generally more suppressive than those recovered from other turfgrass tissues.

Many disease-suppressive microbes prefer to live in decaying organic matter, which they use as a food source and protective habitat. Therefore, some level of organic matter is usually necessary to promote effective biological control of turfgrass diseases. Diversity of disease-suppressive microbes is quite low in putting greens that are low in organic matter. As a result, natural biological processes do not operate optimally in them. This is one reason that some diseases, particularly root diseases, can be so damaging on high sand-content greens.

In order for biological control strategies to work effectively, disease-suppressive microbes (or biological control agents) must be compatible with other turfgrass management inputs. In particular, biological control agents, whether they are native or introduced, must be tolerant of fungicides, insecticides, herbicides and fertilizers currently used in management programs. Their activities also must not be discouraged by cultural practices sued in turfgrass maintenance.

Just as pathogens are influenced by environmental conditions, so too are biological control agents. Therefore, biological control strategies must be employed primarily to control the pathogen, but maintain the associated suppressive microflora at the same time.

The most effective disease suppression can be obtained from introduced microorganisms whose biology and ecology in turfgrass ecosystems are understood. Biological control agents differ fundamentally from chemical fungicides in that they must grow and proliferate to be effective. Therefore, effective disease-suppressive microbes must be able to establish and survive in turfgrass ecosystems and remain active in controlling pathogens during periods favorable for plant infection.

The two factors most important in determining how well these microbes establish and grow are 1) the environmental conditions, particularly temperature, organic matter content and pH, and 2) their ability to compete with the existing soil- and plant-associated microorganisms. Just as some microorganisms inhibit pathogens, these disease-suppressive microbes can be inhibited by other microorganisms as well.

**Biological Control Strategies With Disease-Suppressive Microbes**

Although few in-depth studies on the biological control of turfgrass diseases have been conducted, promising results have been obtained using individual as well as complex mixtures of microorganisms (Table 1).

The use of individual fungi and bacteria as biological control agents has been studied most thoroughly. In these studies, disease-suppressive microbes are typically applied either in the form of an infested topdressing mix, alginate pellets, a granular prill or liquid drenches.

Results with individual microbes tested in laboratory, greenhouse and growth chamber experiments have been spectacular. For example, fungi and bacteria suppressive to take-all patch caused by *Gaeumannomyces graminis* var. *avenae* have been isolated from soils and used in topdressing preparations to provide 100 percent control of take-all patch in greenhouse experiments.

Similarly, bacteria recovered from turfgrass thatch and soil can provide up to 100 percent control of Pythium blight of creeping bentgrass caused by *Pythium aphanidermatum* in laboratory and growth chamber experiments.

Populations of *Enterobacter cloacae*, applied as a drench, are as effective as metalaxyl (Subdue) in suppressing Pythium blight. Application of topdressing preparations of the fungus *Fusarium heterosporum* to creeping bentgrass grown in the greenhouse provided more than 90 percent control of dollar spot.

Promising field results also have been obtained in a few studies. Monthly applications of topdressings prepared from cornmeal-sand mixtures inoculated with strains of the bacterium *E. cloacae* provide up to 63 percent disease control and were as effective as iprodione (Chipco 26019) or propiconazole (Banner) in reducing dollar spot severity on golf course putting greens. Disease suppression lasted up to two months after applications. Strains of *E. cloacae* have also provided nearly complete control of Pythium root rot on golf course putting greens.

In another study, field plots treated with the fungus *F. heterosporum* remained up to 97 percent dollar-spot-free. Only 16 percent of the plot area remained free of dollar spot on untreated plots.

Similar results have been obtained using individual microorganisms for brown patch control and for dollar spot control on bermudagrass.

In studies by Dr. Lee Burpee and his colleagues at the University of Guelph, topdressing preparations of the fungus *Typhula phacorrhiza* applied to creeping bentgrass turf effectively suppressed Typhula blight caused by *Typhula incarnate* and *T. ishikariensis*. The level of control provided by this low-temperature fungus in March was inversely proportional to the concentration of inoculum of *T. phacorrhiza* applied to turf in November. Application of this biocontrol agent provided control of Typhula blight equal to that achieved with the fungicide PCNB.

Evidence from studies conducted with *T. phacorrhiza* suggests that the fungus survives and reproduces in turfgrass thatch and soil and suppresses Typhula blight up to 16 months after two annual applications of infested grain. This type of residual disease suppression is a significant advantage that biocontrol agents may have other chemical agents.

Although research on the use of individual microbes for the biological control of turfgrass diseases is still very much in the developmental stages, it is providing the groundwork for development of these microorganisms into microbial fungicides.

It is encouraging that a number of chemical pesticide companies are now funding biological control research and are actively engaged in the development of microbial fungicides. Research efforts aimed at the discovery and development of specific biological control agents for turfgrass diseases will continue to grow for some time.

The future use of microbial fungicides will come only from a better understanding of the ways of disease-suppressive microbes function and how they interact with other turfgrass management inputs. Recent development in molecular biology have tremendously increased researchers' abilities to answer some of these questions. This is one of the principal reasons that biological control with preparation of individual microorganisms has become a more viable option for turfgrass management than it was in the past.

Although there are no microbial fungicides registered in the United States for the control of turfgrass diseases, a number of products registered for other crops have paved the way for their development it is likely that in the next five to 10 years, biological fungicides for turfgrass disease control will become available.

**The Use Of Composts As Biological Controls**

Whereas individual organisms isolated from any different environments can be suitable for use as biological control agents, composts are perhaps the best sources of disease-suppressive microbes. This is due, in part, to the way in which composts are produced.

Composting relied exclusively on microorganisms to decompose organic matter. During various phases of decomposition, the assemblage of microorganisms present in the compost changes. Each microbial community makes an important contribution to the nature of the composted material.

During the composting process, temperatures rise rapidly as a result of the metabolic activities of the decomposing organisms. This effectively eliminates any pathogens, weed seeds, insect pests and even disease-suppressive microbes from the compost.

As food sources for the decomposing microbes are exhausted, temperatures fall and decomposition rates decrease. Then the compost is recolonized by a variety of microorganism, many of which are disease-suppressive. In general, the longer the composting and stabilization period, the higher the level of disease-suppressive microbes.

In a sense, composting serves to fortify the organic matter with high populations of disease-suppressive microbes. Unfortunately, because the nature of the recolonizing microbial populations is left to chance and determined largely by the microorganisms present at the composting site, there is no reliable way to predict the disease-suppressive properties of compost.

Composts are currently available – in many cases at no charge – and they can be applied as a topdressing without the need for elaborate and expensive equipment. Golf greens and tees are topdressed several times a season with a mixture of sand and peat or soil. Although peat has been the standard organic matter used in green construction mixes and topdressing mixes, government regulations are now restricting much of the peat harvesting in the United States and Canada. This makes the search for alternative sources of organic matter more imperative.

Most sources of sphagnum peat used in green construction topdressing mixes have a little or no disease-suppressive properties. Therefore it would be desirable to replace the peat with composted manures, sludges or food and agricultural wastes that are readily available and inherently disease-suppressive. They also should possess many of the physical and water-holding properties that have made peat a preferred organic amendment.

Applications of composted materials can be quite effective in controlling turfgrass diseases. Monthly applications of topdressing composed of as little as 10 pounds of suppressive compost/1.00 $ft^2$ have been effective in suppressing diseases such as dollar spot, brown parch. Pythium root rot, Typhula blight and red thread (Table 2). Reductions in severity of Pythium blight, summer patch and necrotic ring spot have also been observed on sites receiving periodic applications of composts.

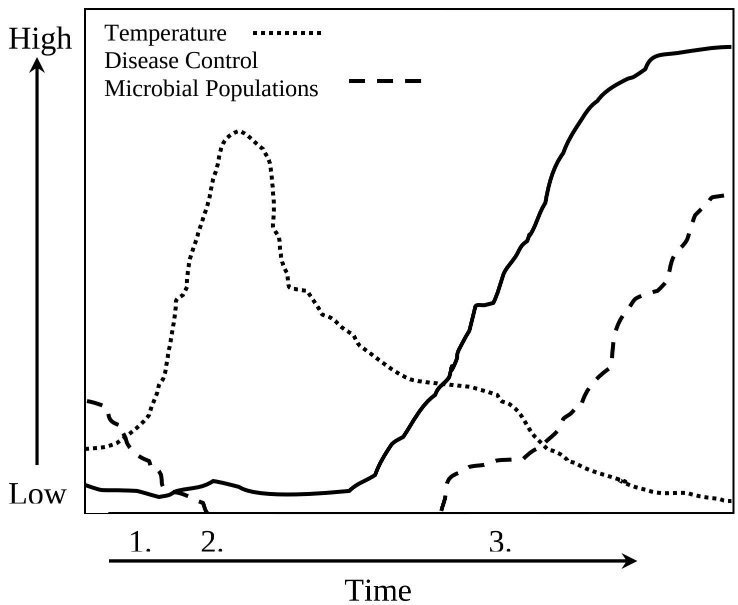
Of particular benefit is the impact of prolonged compost applications on rootrotting pathogens in soil. Populations of soilborne *Pythium* species in golf putting greens are generally not reduced or eliminated after traditional chemical fungicide applications have been made, but they can be reduced on putting greens receiving continuous compost applications in the absence of any chemical fungicide applications. Additionally, heavy applications of composts (approximately 200 lbs./ 1,000 $ft^2$) to putting greens in late fall as effective in suppressing winter diseases such as Typhula blight. They also increase soil microbial populations that may provide some level of disease control throughout the following season.

Composts prepared from different starting materials as well as those at different stages of decomposition vary in levels of disease-suppression and in the spectrum of diseases they control (Table 2). This is primarily a result of the microbial variability among different composts and among the different qualities of organic matter present in any one compost at various stages of decomposition.

Although microbial activity is necessary for disease-suppressive properties to be expressed in most composts, the microbiology of disease-suppressive composts has not been studied extensively. Fungi and bacteria suppressive to *Rhizoctonia solani* (cause of Pythium root rot and Pythium blight) have been recovered from various types of composts.

Microorganisms suppressive to other turfgrass pathogens have been studied in less detail. Although a wide variety of disease-suppressive microbes can be found in composted substrates, the predominant species and their relative contributions to disease suppression remain unknown. However, those microorganisms that are rapid and aggressive colonizers or organic matter are more likely to contribute the most to disease suppression in composts.

Changes During Composting




The use of topdressing amended with disease-suppressive composts or organic fertilizers is being accepted by turfgrass managers as an attractive disease control alternative. In the few cases that have been examined, substantial reductions in fungicide use have accompanied the adoption of these strategies. Many composted materials and other organic fertilizers are available commercially in bulk quantities or in 40- to 50-pound bags.

The use of composts and organic fertilizers for turfgrass disease control is economically and technologically practical. In some instance they can provide levels of control as good as that attained with fungicides. One of the principal problems associated with the use of composts for disease control is that a given compost may not be predictably suppressive from year to year, batch to batch and from one site to the next. turfgrass managers and compost producers agree that the future success of these materials in commercial turfgrass management depends upon the abilities of producers to provide composts with predictable levels of disease control.

Gross variations in disease-suppressive qualities of composts cannot be tolerated because end users need to be assured that every batch of compost used specifically for disease control will work every time. Unfortunately, the suppressive activity of certain composts cannot be predicted unless they are tested in field situations.

Despite the fact that microbial activity is required for the expression of disease-suppressive properties in most composts used in turfgrass applications, little is known about the specific microorganisms that are involved in imparting disease-suppressive properties. Much remains to be discovered about the unique microbiological aspects of composting and compost-amended soils.

Identification of specific disease-suppressive microorganisms in composts will be a key factor in understanding how composts suppress diseases. This knowledge has proved to be important in developing hardwood bark composts for use in the production of container-grown ornamentals.

Several aspects of the ecology of key compost-inhabiting microorganisms in turfgrasses will be important in developing more effective biological control strategies with compost-based organic fertilizers. For example, effective disease suppressive microbes must be able to establish and survive in turfgrass ecosystems for biological control to occur. The interaction of these microbes with other soil microorganisms and the various soil and plant factors affecting optimum biological control activity will be important in developing control strategies with compost-based materials. In addition, these organisms may serve as indicators of the length of time needed to compost a material before it can be certified as disease-suppressive.

Research aimed at understanding the fate of disease-suppressive microbes in soil and on plants following compost applications will aid in the understanding of the reasons composts fail at certain times and in certain locations but no in others. Such research also should help predict the compatibility of composts and their resident biological control agents with other pesticides and cultural practices commonly used in turf management.

Table 2.
Biological Suppression of Various Turfgrass Diseases
With Compost-Amended Topdressings [a]

| Topdressing Amendment | % Disease Control: Dollar Spot | Brown Patch | Red Thread | Typhula Blight | Pythium Root Rot |
|---|---|---|---|---|---|
| None | -- | -- | -- | -- | -- |
| Greens Restore [b] | 65.7* | 66.7* | 8.5 | 0.0 | 47.4 |
| Sustane | 30.3 | 75.0* | 78.7* | 15.2 | 52.6* |
| Sludge Compost A | 34.3 | 41.7* | 14.9 | 69.7* | 57.9* |
| Brewery Compost | 10.1 | 25.0 | 36.2 | 69.7* | 36.8 |
| Leaf Compost | 4.5 | 38.9 | 0.0 | -- | -- |
| Horse Manure Compost | 0.0 | 0.0 | 0.0 | 54.5* | -- |
| Sludge Compost B | 0.0 | 8.3 | 0.0 | -- | -- |
| Fungicide Standard [c] | 97.0* | 88.9* | -- | 33.3 | 42.1 |

[a] Determined 30, 13, 27 and 19 days post-application for Dollar Spot, Brown Patch, Red Thread and Pythium Root Rot, respectively. Gray snow mold evaluated in the spring (April), 6 months after the last fall applications.
[b] Greens restore is an uncomposted organic fertilizer composed of plant and animals meals.
[c] Fungicide standard for all diseases except Pythium root rot consisted of Banner applied at the rate of 4 oz./1,000 $ft^2$. For pythium root rot, Subdue was applied at the rate of 2 oz./1,000 $ft^2$.
*Numbers followed by an (*) indicate statistically significant levels of disease control as compared with untreated plots.*

**Promises For The Future**

Biological control of turfgrass disease is still very much in the developmental stages. Although there are a number of biological control products available for disease control on other commodities, none are available specifically for turfgrass. Despite the lack of emphasis on biological control research in the past, recent years have seen tremendous advances in efforts to understand and develop strategies for the biological control of turfgrass diseases. As it becomes more critical to reduce fungicide dependency and practice sound environmental stewardship, the need for safe, effective and environmentally sound alternative control strategies will become even greater.

The potential for composts to suppress turfgrass diseases is clear. At present, applications of these types of materials provide the best alternative to the use of fungicides on turf and may, in the long term, provide the only means of eradicating pathogens from turfgrass soils.

As we learn more about composting and the benefits of composted materials to plant health, there will undoubtedly be a greater demand from turfgrass managers for high-quality, disease suppressive composts. Composted products for use in turfgrass applications are rapidly becoming available.

Because microbial fungicides are relatively new to the marketplace, it is not yet clear, particularly in the United States, whether they will compete well with chemical fungicides and be acceptable to environmentalists and regulatory agencies.  Although it is encouraging that more and more biological control products are becoming available, time will tell whether the beneficial properties of biological controls turn out be effective enough to either augment or replace traditional fungicides.

It is critical that some of the initial biological control products perform consistently as well as or better than conventional fungicides if microbial fungicides are to rapidly find their way into the marketplace and gain widespread acceptance.  Performance of individual microorganisms in research trials certainly suggest that the efficacy of disease suppressive microbes can rival the control provided by fungicides, plus provide the added advantage of residual control, which may last weeks, months, or perhaps even years.

The future of biological control of turfgrass diseases is bright.  As the search for more effective disease-suppressive microbes expands, suitable bacterial and fungal strains will provide a pool from which these organisms can be developed into microbial fungicides.

Biological control is on the verge of a new era of discovery and commercialization.  One must believe that the benefits of biological controls, once realized will ultimately change the way in which disease control is approached.