AN INDEPENDENT NEWSLETTER FOR TURFGRASS MANAGERS

Turf Grass TRENDS

[Vol 3 Iss.1]
Issue 13

January 1994

Biological controls

Promising new tools for disease management

by Dr. Eric B. Nelson

DISEASE MANAGEMENT represents a significant challenge for turfgrass managers. The task is made particularly demanding by the perennial nature of turfgrass plantings, as well as that of the disease-causing organisms. Most, if not all, fungal pathogens of turfgrass are always present in turfgrass plantings.

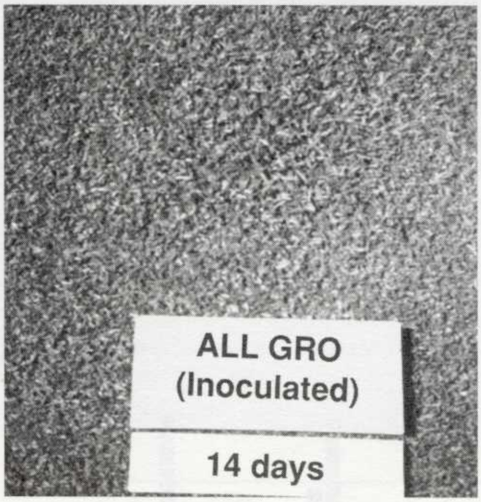
As a result, the principal factors determining the incidence and severity of turfgrass diseases are environmental factors and plant stresses that influence not only the activity of pathogens, but the susceptibility of the plants. This is particularly true for some root pathogens that reside inside turfgrass plants year round. In many cases, these factors cannot be manipulated adequately to minimize losses from fungal diseases. So, to control fungal root diseases, turfgrass managers rely largely on fungicide applications.

Most of the materials currently used for turfgrass disease control are broad-spectrum systemic fungicides. Problems have arisen from the repeated and prolonged use of these chemicals:

- THE DEVELOPMENT of fungicide-resistant pathogen populations,
- DELETERIOUS EFFECTS on non-target organisms, particularly those involved in carbon and nitrogen cycling,
- ENHANCEMENT of non-target diseases,
- AND THE SELECTION OF FUNGICIDE-degrading microorganisms.

In an effort to reduce this fungicide dependency and to minimize the undesirable biological and environmental effects of excessive fungicide use, alternative management practices are being explored.

–continued on page 2



▲ Within two weeks the untreated part of a putting green innoculated with Pythium root rot fungi begins showing severe damage. Less damage is apparent in areas treated with All Gro, a commercial brewery waste compost (similar results obtained with Endicott sewage sludge compost).

Photo provided by Mary Thurn, Cornell University

" The principal factors determining the incidence and severity of turfgrass diseases are environmental factors and plant stresses that influence not only the activity of pathogens, but the susceptibility of the plants."

IN THIS ISSUE

IN-DEPTH ARTICLES

DEPARTMENTS

INTERACTIONS

Biological controls *continued from page 1*

One of the more exciting alternative management strategies being developed is the use of antagonistic microorganisms (also called 'antagonists') to reduce either 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 a commercial basis for the control of plant pathogens on several crop plant species and has recently seen applications in the turfgrass industry.

Biocontrol approaches

MOST TURFGRASS MANAGERS are familiar with the negative aspects of soil microorganisms, since some are pathogenic and can damage a turfgrass stand. However, in addition to pathogens, the soil harbors a variety of non-pathogenic microorganisms that actually improve plant health. These soil bacteria and fungi are responsible for

- INCREASING THE AVAILABILITY of plant nutrients,
- FORMING SYMBIOTIC ASSOCIATIONS with turfgrass roots,
- PRODUCING SUBSTANCES STIMULATORY to plant growth,
- AND PROTECTING PLANTS against infection from pathogenic fungi.

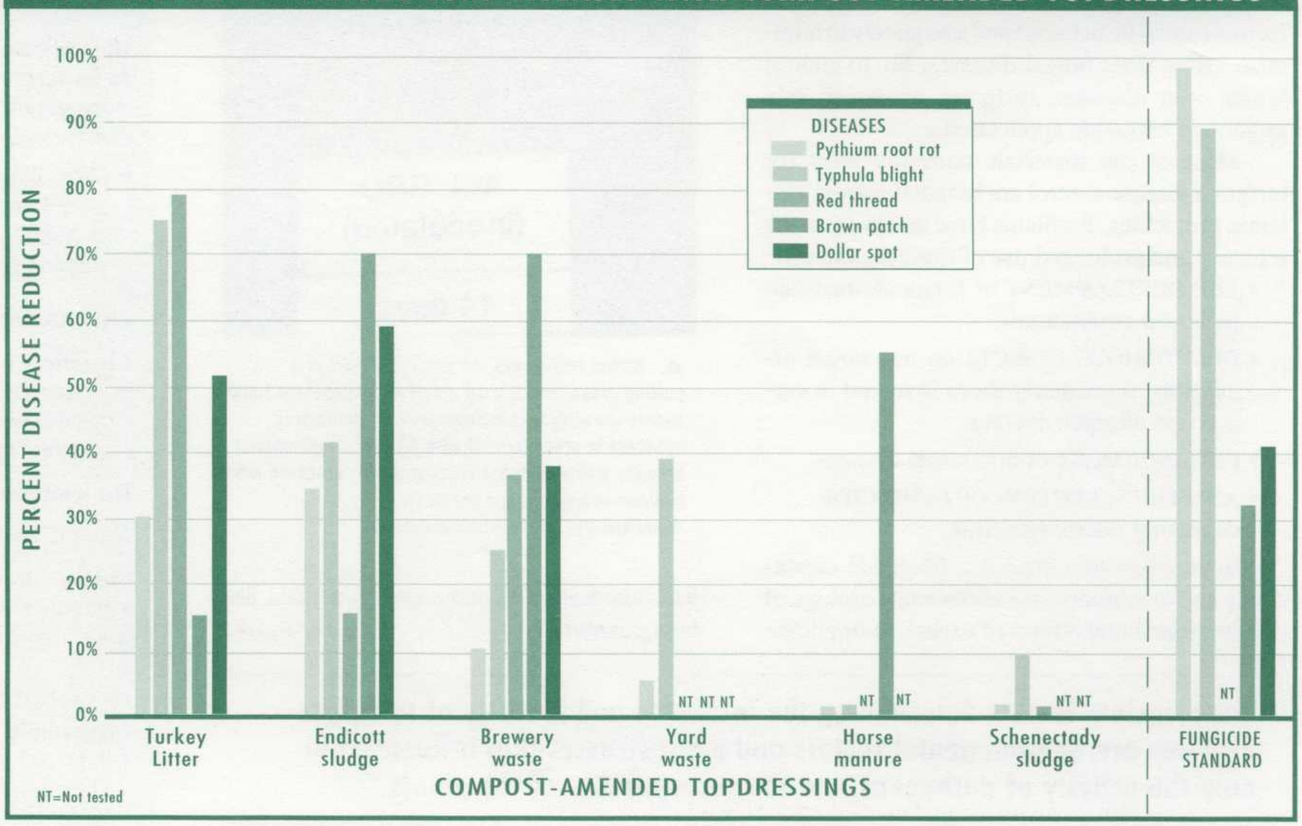
To minimize damage from plant pathogens, biological control attempts to take advantage of all the above-mentioned microbial attributes. For example, the application of composts, or other sources of organic matter, to turf may introduce large populations of antagonistic microorganisms that may reduce disease by interfering with the activities of pathogenic fungi. Similarly, cultural management techniques (such as core aeration, fertilization, or the application of pH-altering materials such as 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 antagonistic microbial communities to the detriment of pathogen populations.

Biological control may be achieved either through the application of introduced microbes or through the manipulation of native microbes, present either on plant parts or in soils, that "naturally" suppress diseases. In either case, the goal is to reduce or eliminate pathogen activities by

- REDUCING PATHOGEN inoculum in soil,
- PROTECTING PLANT SURFACES from infection,
- OR TRIGGERING NATURAL DEFENSE mechanisms within the plants.

Biological control of pathogen inoculum is achieved by the microbial destruction of pathogen propagules and the prevention of inoculum formation—through the action of mycoparasites (fungi that are parasitic on other fungi). In addition, antibiotic-producing microbes may displace pathogens in decaying plant residues, such as thatch, and reduce their populations in soil. Some non-pathogenic soil

SUPPRESSION OF VARIOUS TURF DISEASES WITH COMPOST-AMENDED TOPDRESSINGS



microorganisms are able to effectively colonize above-ground, as well as below-ground, plant parts and, in so doing, protect these tissues from infection by pathogens. It is also apparent that some biological control agents can induce natural defense mechanisms in plants. This phenomenon is called "cross protection" or "induced resistance."

The number and variety of potential antagonists is large and diverse. More commonly studied biological control agents include fungi in the genera: *Fusarium, Gliocladium, Laetisaria, Penicillium, Sporidesmium, Talaromyces, Trichoderma,* and *Verticillium* and bacteria in the genera: *Bacillus, Enterobacter, Erwinia,* and *Pseudomonas.*

Research has shown that these microorganisms can interfere with pathogen populations in a number of ways. Mycoparasites such as *Trichoderma* and *Sporidesmium* may parasitize pathogen propagules and mycelium. Other antagonists—particularly *Pseudomonas, Bacillus, Enterobacter, Erwinia* and *Gliocladium*—produce antibiotics that inhibit pathogen growth. Some strains of *Pseudomonas* and *Enterobacter* species are efficient competitors for essential nutrients and other growth factors, thereby reducing the amount of materials available for pathogen germination, growth, and plant infection.

Antagonists of 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. Studies have shown that a greater percentage of antagonists of some pathogens are associated with thatch more commonly than with the underlying soil, both in low and in high maintenance sites. Also, these "thatch microbes" are generally more effective in suppressing diseases such as Pythium blight. In tests with various groups of soil bacteria, members of certain, less common groups showed significantly more biocontrol potential than other more abundant populations of bacteria.

To predictably and successfully manipulate biological control agents, turf managers must understand the biology and ecology of these micro-organisms in turfgrass ecosystems. (Unfortunately, we lack much of that knowledge.) The reason why this understanding is essential is simple: biocontrol agents differ fundamentally from chemical fungicides in that they must grow and proliferate to be effective. Therefore, effective antagonists must be able to become established in turfgrass plantings and remain suppressive to pathogens during periods favorable for plant infection.

The two factors most important in determining an-

–continued on page 4

KNOWN MICROBIAL ANTAGONISTS OF TURFGRASS PATHOGENS

DISEASE (PATHOGEN)	ANTAGONISTS	LOCATION*
BROWN PATCH *Rhizoctonia solani*	*Rhizoctonia spp.*	Ontario Canada
	Laetisaria spp.	North Carolina
	Compost microbes	New York, Maryland
DOLLAR SPOT *Sclerotinia homoeocarpa*	*Enterobacter cloacae*	New York
	Fusarium heterosporum	Ontario Canada
	Gliocladium virens	South Carolina
	Compost microbes	New York
NECROTIC RING SPOT *Leptosphaeria korrae*	Native soil microbes	Michigan
PYTHIUM BLIGHT *Pythium aphanidermatum*	*Pseudomonas spp.*	Illinois, Ohio
	Trichoderma spp.	Ohio
	Trichoderma hamatum	Colorado
	Enterobacter cloacae	New York
	Various bacteria	New York, Pennsylvania
	Compost microbes	Pennsylvania
PYTHIUM ROOT ROT *Pythium graminicola*	*Enterobacter cloacae*	New York
	Compost microbes	New York
RED THREAD *Laetisaria fuciformis*	Compost microbes	New York
SOUTHERN BLIGHT *Sclerotium rolfsii*	*Trichoderma harzianum*	North Carolina
SUMMER PATCH *Magnaporthe poae*	various bacteria	New Jersey
TAKE-ALL PATCH *Gaeumannomyces graminis var. avenae*	*Pseudomonas spp.*	Colorado, France
	Gaeumannomyces spp.	Australia
	Phialophora radicicola	Australia
	Microbial mixtures	Australia
TYPHULA BLIGHT *Typhula spp.*	*Typhula phacorrhiza*	Ontario Canada
	Trichoderma spp.	Massachusetts
Compost microbes	New York	

* The location indicates where experiments, demonstrating the effectiveness of the biocontrol agents on the indicated diseases, were conducted.

Studies have shown that a greater percentage of antagonists of some pathogens are associated with thatch more commonly than with the underlying soil, both in low and in high maintenance sites.

Biological controls continued from page 3

tagonist establishment and growth are:

- THE ENVIRONMENTAL CONDITIONS (particularly temperature, moisture, nutrients, and pH)
- AND THEIR ABILITY TO COMPETE with the existing soil and plant micro-organisms.

Just as some organisms are antagonists of pathogens, antagonists have their own antagonists as well.

Biocontrol agents also must be compatible with other management inputs. In particular, biological control agents must be tolerant of fungicides, insecticides, herbicides and fertilizers currently in use. Their activities must also not be discouraged by cultural practices used 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 pathogens, but at the same time, maintain the associated antagonistic microbial communities. Organisms isolated from many different environments might be suitable biocontrol agents, but composts are perhaps the best sources of complex mixtures of antagonistic microorganisms. Incorporation of organic matter into turfgrass soils is one of the better ways of maintaining antagonistic microbial communities.

Disease suppression with composts

A NUMBER OF DIFFERENT APPLICATION strategies have been tested with composts used for the purpose of disease control. These have included the use of composts as:

- TOPDRESSING AMENDMENTS,
- TURF COVERS,
- ROOT ZONE MIX AMENDMENTS,
- TEAS PREPARED BY EXTRACTING THE COMPOST with water for various periods of time. Another approach that has as yet to be tested is the use of composts as seed coating or pelleting material.

Perhaps the most exciting results have been obtained when composts have been used as a topdressing amendment. For example, monthly applications of topdressings composed of as little as 10 lbs of suppressive compost/ 1000 ft^2 have been shown to be effective in suppressing diseases such as dollar spot, brown patch, Pythium root rot, Typhula blight, pink snow mold, and red thread. Reductions in severity of Pythium blight, summer patch and necrotic ring spot have also been observed in sites receiving periodic compost applications.

Root zone amendments of various composts (20% compost: 80% sand; v:v) have produced excellent control of *Pythium graminicola*-incited root rot on creeping bentgrass putting greens. This technique involves incor-

–continued on page 7

Process is the key to disease-suppressive composts

COMPOSTING CAN BE DEFINED as the "biological decomposition of organic constituents in wastes under controlled conditions". Since composting relies exclusively on microorganisms to decompose the organic matter, the process has biological as well as physical limitations. During composting, the environmental parameters (i.e. moisture, temperature, aeration) must be stringently controlled. This is necessary to maintain adequate rates of decomposition and to avoid the production of decomposition by-products that may be harmful to plant growth.

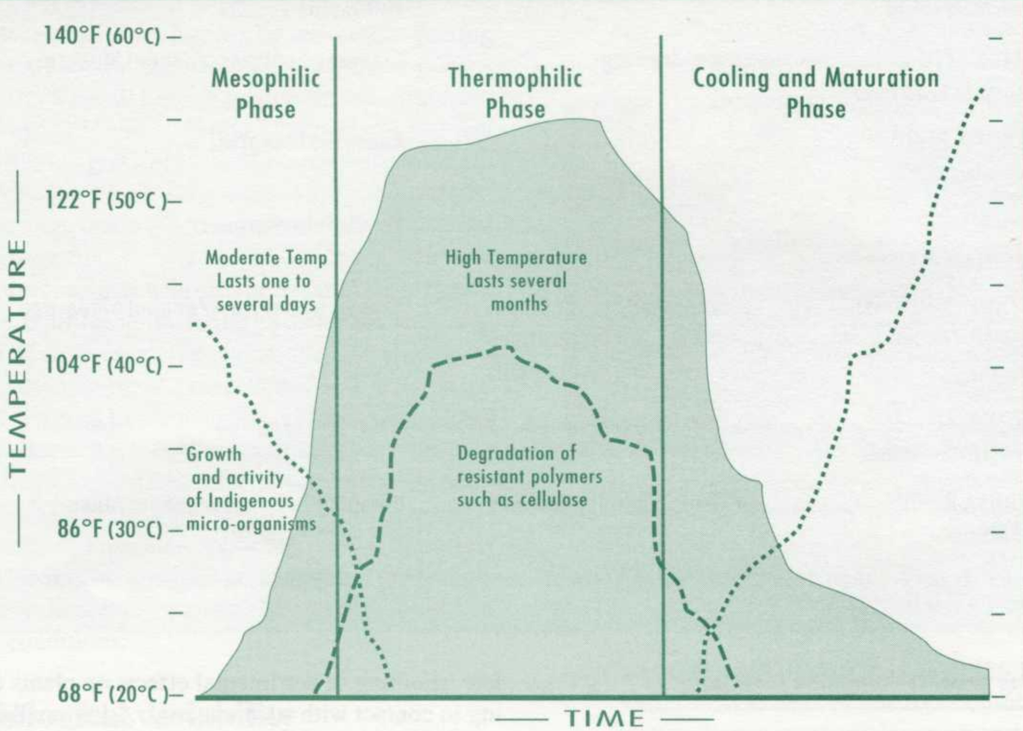
Compost "pile" design, construction, and maintenance play vital roles in the successful outcome of the process. For example:

- TO MAINTAIN PROPER TEMPERATURES, the composting mass must be large enough to be self-insulating, but not so large that compaction results in reduced air exchange.
- TO SUPPORT MICROBIAL ACTIVITY, the composting mass must be moist enough, but not excessively moist, so that the air exchange is limited.
- TO PROVIDE PROPER INSULATION, the particle size of the material must be small enough, but not too small—again to control air exchange.

When environmental and physical conditions are optimized, composting should proceed through three distinct phases (See the diagram of the composting process). The first stage of composting can last one or more days, depending on the type of starting materials used. During this phase, the temperature of the internal portions of the composting mass rise, as a result of the growth and activity of the indigenous mesophilic microorganisms associated with the starting organic material. During this self-heating phase, most of the soluble, readily degradable materials are broken down by these naturally-occurring microorganisms, precluding the

The activity ranges of the microbes involved in composting are relatively narrow in terms of temperature, so increases in temperature above 135°F (57°C) can limit decomposition.

TEMPERATURE PHASES OF COMPOST PRODUCTION



When environmental and physical conditions are optimized, composting should proceed through three distinct phases

▲ **THE COMPOSTING PROCESS**

Temperature plays a critical role in composting:

- DURING PHASE I, initial heating takes place and readily soluble components of the compost heap are degraded.
- DURING PHASE II, cellulose and hemicellulose are degraded under high temperature (thermophilic) conditions. This is accompanied by the release of water, carbon dioxide, ammonia and heat.
- FINALLY, DURING PHASE III, curing and stabilization are accompanied by a drop in temperatures and increased humification of the material. Low temperature (mesophilic) microorganisms, including populations of microbial antagonists, recolonize the compost heap during this final cooling and maturation phase.

need for additional inoculum. At this stage of composting, populations of microorganisms increase in magnitude and activity.

The entire process is characterized by successions of both mesophilic (moderate-temperature) and thermophilic (high-temperature) microorganisms during various phases of organic matter decomposition. Each microbial community makes an important contribution to the nature of the final compost. Failure to maintain environmental conditions favorable for adequate microbial activity can jeopardize the quality of the final product.

As temperatures increase above 100°F (33°C), the mesophilic populations are replaced by thermophilic populations capable of degrading most resistant polymers, such as cellulose and hemicellulose. During this second stage of decomposition, microbial diversity decreases until only a few species of the bacterial genus, *Bacillus,* are active in decomposition processes. –continued on page 6

TURFGRASS DISEASES FOR WHICH COMPOSTS HAVE BEEN SUPPRESSIVE

DISEASE (PATHOGEN)	MODE OF APPLICATION	TURFGRASSES
■ BROWN PATCH *Rhizoctonia solani*	topdressings	Creeping bentgrass/annual bluegrass; Tall fescue
■ DOLLAR SPOT *Sclerotinia homoeocarpa*	topdressings	Creeping bentgrass/annual bluegrass
■ NECROTIC RINGSPOT *Leptosphaeria korrae*	topdressings	Kentucky bluegrass
■ PYTHIUM BLIGHT *Pythium aphanidermatum*	topdressings	Perennial ryegrass
■ PYTHIUM ROOT ROT *Pythium graminicola*	topdressings[a] and heavy fall applications[b] root-zone amendments[c]	Creeping bentgrass/annual bluegrass
■ RED THREAD *Laetisaria fuciformis*	topdressings	Perennial ryegrass
■ TYPHULA BLIGHT *Typhula spp.*	heavy fall applications	Creeping bentgrass/annual bluegrass

[a] Applied at the rate of ~10 lbs/1000 ft2; [b] Applied at the rate of ~200 lbs/1000 ft2; [c] Incorporated into sand at the rate of 20% compost, 80% sand (v,v)

***Composting process** continued from page 5*

The thermophilic phase may last several months, depending on the cellulose content of the material and the temperatures maintained during this period. Generally, the higher the cellulose content, the longer the thermophilic phase. Temperatures required for thermophilic decomposition range from 95–160°F (35–71°C). However, the highest rate of microbial activity and decomposition occurs at the lower end of the thermophilic range at temperatures of 95–135°F (35–57°C).

The activity ranges of the microbes involved in composting are relatively narrow in terms of temperature, so increases in temperature above 135°F (57°C) can limit decomposition. To overcome these constraints, most composts need to be aerated—either through repeated pile inversions or through forced air ventilation. Prior to placing in windrows, many composts are started in aerated vessel systems where temperatures can be precisely regulated and uniform decomposition can be established.

Since composting consumes much oxygen, aeration serves to keep the composting mass aerobic. Lack of oxygen can make composts anaerobic, and a number of toxic microbial metabolites can accumulate, resulting in detrimental effects on plants coming in contact with such material. Additionally, uncontrolled anaerobic composts produce undesirable odors. Most composts produced in a proper aerobic environment should have little or no odor associated with the decomposing mass. Aeration also serves as a means of drying the material making it more suitable for handling and transport.

As the cellulose and hemicellulose components are exhausted, the compost enters a curing or maturation phase where temperatures decline, decomposition rates decrease, and the thermophilic microbial populations are again replaced by mesophilic populations. In general, the longer the maturation period, the more diverse the colonizing mesophilic microbial community.

It is this re-colonizing mesophilic microbial community that is most important in suppressing turfgrass diseases, since large proportions of the re-colonizing microbes are antagonists that render the compost disease-suppressive. Unfortunately, there is no reliable way to predict the disease-suppressive properties of composts, since the numbers and types of re-colonizing microbes are left to chance and determined largely by the types of microbes present at the composting site. ■

Biocontrols *continued from page 4*

porating the composts in the soil during construction of the greens.

Perhaps the most important benefit of compost use on established turfgrasses is its impact on root-rotting pathogens in the soil. Populations of soil-borne Pythium species are generally not suppressed following traditional chemical fungicide applications, but can be reduced on putting greens receiving continuous compost applications—in the absence of any chemical fungicide applications. Additionally, heavy applications of certain composts (~200 lbs/ 1000 ft^2) to putting greens in late fall can be effective, not only in suppressing winter diseases such as Typhula blight, but in protecting putting surfaces from winter ice and freezing damage.

One of the more practical uses of composts in turfgrass applications is in the preparation of compost teas. The preparation of these extracts consists of soaking compost in water at ratios of 1 part compost to 3–10 parts water. Extracts are allowed to incubate at ambient temperatures from 1 to 14 days, at which time the mixture is filtered—to remove large particulates prior to spraying with standard pesticide application equipment.

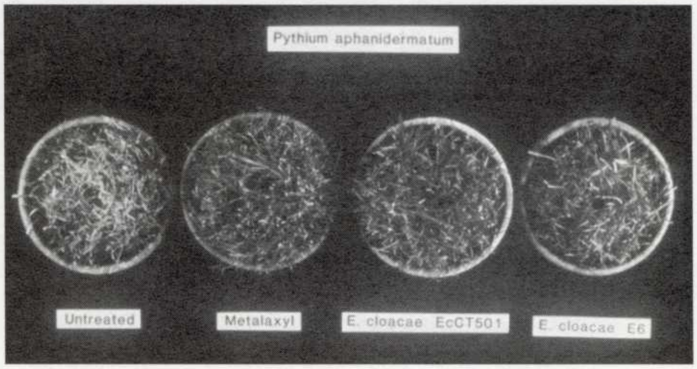
This method of disease control has proven extremely effective in laboratory experiments for control of Pythium species, but little is known about the activity of extracts under field conditions.

Microbiological variability in composts

COMPOSTS PREPARED from different starting materials, as well as those at different stages of decomposition, vary in the level of disease-suppression and in the spectrum of diseases that are controlled. 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 the expression of disease-suppressive properties in most composts, the specific nature of disease suppressiveness is, in general, unknown.

The microbiology of disease-suppressive composts has not been extensively studied, but a limited number of studies have shed light on several important microbes in suppressive composts:

- FUNGAL AND BACTERIAL ANTAGONISTS suppressive to a number of plant pathogens have been recovered from hardwood bark and sewage sludge composts.
- RELATIONSHIPS BETWEEN microbial activity and Pythium suppression in bark composts have also been described. The levels of microbial activity have been used as a means of predicting Pythium suppression in composts.
- THE MOST IMPORTANT FUNGI in bark composts for the suppression of *R. solani,* the cause of brown patch were found to be *Trichoderma hamatum, T. harzianum* and *Gliocladium virens*.
- A NUMBER OF BACTERIAL SPECIES effective against *R. solani* and *Pythium spp.* have been discovered *(see photo below)*. Bacterial strains such as *Enterobacter cloacae, Flavobacterium balustinum, Xanthomonas maltophila* and various *Pseudomonas spp.* are more effective when combined with other fungal antagonists.



▲ This greenhouse test compared an untreated sample on the left, one using Metalaxyl (a chemical fungicide) and two strains of *E. cloacae* bacteria. The strain EcCT501 produced disease suppression comparable to the fungicide. In this test, all of the samples were inoculated with *Pythium aphanidermatum*.

- VARIOUS *PSEUDOMONAS* SPECIES from composts were found to be effective root colonists and antagonists of such root-rotting pathogens as *Pythium ultimum*.
- IN SOME SEWAGE SLUDGE COMPOSTS, strains of *Bacillus subtilis* have been shown to be effective in inducing suppression to a number of soilborne plant pathogens.

Although a wide variety of microbial antagonists can be found in composts, the predominant species, and their relative contributions to disease suppression, remain unknown. However, those microorganisms that are rapid and aggressive colonizers of organic matter or plant roots and crowns, are more likely to contribute the most to disease suppression in composts.

Predictable suppression is needed

TURFGRASS MANAGERS ARE ACCEPTING the use of composts 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 compost-based organic fertilizers are commercially available. Research has shown that the use of composts and organic fertilizers for turfgrass disease control is economically

–continued on page 8

Biocontrols continued from page 7

and technologically practical and, in some instances, can provide control equivalent to that currently attained with fungicides.

One of the principal problems 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 depends upon the ability of producers to provide material with predictable levels of disease control. Gross variations cannot be tolerated.

Unfortunately, with our current level of understanding, it is not possible to predict the suppressive properties of certain composts without actually testing them in field situations. A number of tests have been developed to determine compost maturity and degree of stabilization for the purpose of reducing the variability in physical and chemical properties. However, none have been designed to directly assess microbiological aspects of maturity and disease suppressiveness.

In order to develop more effective biological control strategies with compost-based materials, several aspects of the turfgrass ecology of key compost-inhabiting antagonists will need to be understood. For example, the ability of antagonists to establish and survive in turfgrass ecosystems is necessary for biological control to occur. The interactions of antagonists with other soil organisms and the soil and plant factors affecting optimum biological control activity will be important in developing strategies with compost-based materials. In addition, these organisms may serve as indicators of how long to compost a material before it can be certified as disease-suppressive. Research aimed at understanding the fate of antagonistic organisms in soils and on plants following compost applications will aid in understanding why composts fail at certain times and in certain locations, but not at others. Such research should also help to predict the compatibility of composts and their resident antagonists with pesticides and other cultural practices now in use.

To make composts more predictably disease-suppressive, it may be possible to introduce antagonistic organisms, with known control properties, into composts at key stages in the curing process. This strategy has been used successfully to produce composts more predictably disease-suppressive and more highly suppressive to a number of plant pathogens. This approach should enable compost producers to ultimately produce predictably suppressive biological control materials.

Over the past five years, a large number of composts have become available for turfgrass applications. Some are properly composted and formulated and of high quality. Others are not. In the past, quality control was of less concern—when composts were used primarily as fertilizers. However, for disease management, quality control is important. When improperly composted, some organic materials can be extremely phytotoxic. Other improperly composted materials can even accentuate the development of some diseases.

Unlike traditional synthetic chemical fungicides, more careful consideration must be made of various aspects of the storage and application of microbial inoculants.

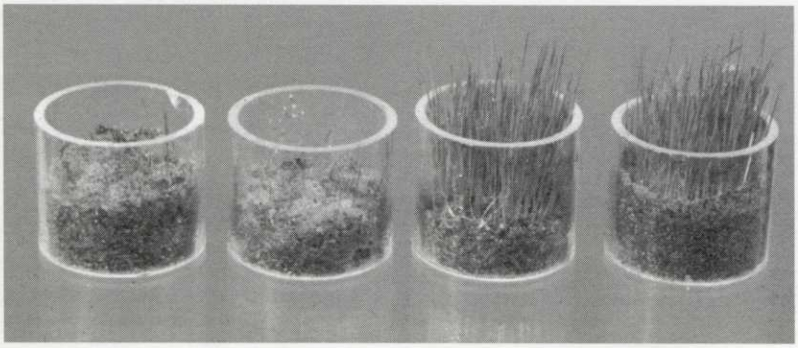
Use of microbial inoculants

MICROBIAL INOCULANTS ARE PREPARATIONS of living microorganisms that inhibit plant pathogens. In their development and use, beneficial microorganisms are isolated from the environment (usually from soils or plant tissues), and their populations are artificially increased. In some instances, they may be culturally or genetically improved in the laboratory. Then they are introduced back into the environment as an inoculant.

Unlike traditional synthetic chemical fungicides, more careful consideration must be made of various aspects of the storage and application of microbial inoculants. Of particular importance is the shelf life of microbial inoculants, since the organisms may not remain viable for extended periods of time. One also needs to consider that, for any microbial-based inoculant to be effective, the organism(s) must become established in turfgrass plantings and must remain active throughout the period when disease pressure is greatest. Additionally, the organisms in these products must be compatible with other agrichemicals in use. For example, whereas bacterial preparations should generally be tolerant of most chemical fungicides, fungal preparations may or may not be as suitable as bacterial preparations—depending on the characteristics of the species of fungus used.

The search for candidate strains of bacterial and fungal antagonists has been promising based on laboratory, greenhouse, and field tests, with many being effective against a wide range of turfgrass pathogens (see "Known Microbial Antagonists of Turfgrass Pathogens" table on page 3). Many of these antagonists, when applied at the proper time and manner, can establish high population levels in bentgrass putting greens and can be as effective as some of the newest chemical fungicides. The antagonist, *Enterobacter cloacae* is able to establish high populations in creeping bentgrass/annual bluegrass turf; levels between 100 million and 1 billion cells per gram of thatch. Although populations decline steadily through the season, nearly 1 million per gram remain after 13 weeks, and the following season, only about 1000 cells per gram can be recovered.

Through the past couple of decades, it has become apparent that the use of microbial inoculants is not without problems. This is primarily due to the lack of knowledge about how to adequately produce, formulate and handle living organisms. However, through continued evaluation in agronomic and horticultural systems, it has become evident that microbial inoculants may have an important place in commercial plant production and realistically offer important disease-control alternatives in plant health management. They can provide levels of disease control that, in many cases, facilitate reduced applications of fungicides and, in a few cases, may eliminate the need for fungicides altogether. In addition, microbial inoculants are a potentially important tool in managing fungicide resistance among pathogen populations. Furthermore, the success of sustainable plant production is largely dependent upon the integration of biological and other non- chemical means of control into disease management strategies. Recent developments in Integrated Pest Management (IPM) are a direct result of growing awareness of the importance of biological controls in holistic approaches to plant health management.



▲ This test of the suppressive effect of a particular group of microbial antagonists called Actinomycetes on *Pythium graminicola* showed dramatic results. The absence of the Actinomycetes resulted in total seeding failure, on the left. Their presence lead to successful establishment on the right. Photo by Christine Stockwell, Cornell University

Although the biological control of turfgrass diseases is still in the early development stages, long-term, the future of microbial inoculants for turf disease control is extremely bright. It is encouraging that a number of chemical pesticide companies are now funding biological control research and have made commitments to the development of microbial inoculants.

The future use of antagonists as microbial inoculants will come only from a better understanding of how antagonists function and how they interact with other turfgrass management inputs. Recent developments in molecular biology have tremendously increased our ability to answer some of these questions. These advances have been one of the principal reasons that biological control of fungal plant pathogens has become a more viable option for turfgrass disease management than it was just a few years ago.

The future of turfgrass biocontrols

BIOLOGICAL CONTROL OF TURFGRASS DISEASES is still in the developmental stage. Although there are a number of biological control products available for disease control on other commodities, none are currently available specifically for turfgrass disease control. Despite the past lack of emphasis on biological control research, the last five to 10 years have seen tremendous advances in our efforts to understand and develop biological control strategies for turfgrass diseases.

As the need to reduce fungicide dependency, and to provide more rigorous environmental stewardship become more critical, the greater the need will be to develop safe, effective and more environmentally sound control strategies.

The potential of composts to suppress turfgrass diseases is clear. At present, applications of these materials provide excellent alternatives to the use of fungicides on turf and may, in the long term, provide the only means of reducing soil populations of pathogens in turfgrass plantings. As we learn more about composting and the benefits of composted materials to plant health, there will be a greater demand from turfgrass managers for high quality disease-suppressive composts. Composted products for use on turfgrass are becoming increasingly available. In general, compost producers are committed to providing the highest quality materials at an equivalent cost of disease control far below that of traditional fungicides. In addition to providing effective disease control, the use of composts will help ease the burden on our nation's landfills and foster a commitment from turfgrass managers to sound environmental stewardship.

Because microbial inoculants used for disease control 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 federal and state regulatory agencies. Although it is encouraging that more biological control products are becoming available, time will tell whether the beneficial properties of such materials can augment or replace traditional fungicides. It is critical that some of the initial biological control products consistently perform comparable to conventional fungicides if they are to find their way into the marketplace and gain widespread acceptance. As our search for more effective antagonists of turfgrass pathogens expands, suitable bacterial and fungal antagonists will provide a pool from which organisms can be developed into microbial inoculants. Biological control is on the verge of a new era of discovery and commercialization. The benefits of biological controls, once realized, may change the way in which disease control is approached. ■

What will biologicals do for turfgrass management?

by Christopher Sann

BIOLOGICAL CONTROL PRODUCTS are not new to the plant management business. For over thirty years, turf managers have used milky spore disease to control grubs. Several companies have made advances recently in the use of parasitic nematodes as an effective alternative to chemical controls for grubs, molecrickets, and billbugs. Most recently, several organic based fertilizers and compost amendments have become available that have shown varying degrees of pathogen suppression in the field.

In agriculture and horticulture, a series of microbial insecticides based on the "BT" bacteria, *Bacillus thuringiensis,* are used for the control of a ever widening group of insect pests. Although not microbial based, naturally rendered soap or fatty-acid based insecticides have become popular in the ornamental plants industry.

Additionally, in agriculture, inoculants are added to silage, to augment the fermentation process. Several broadleaf "bio-herbicides" are also in use. One called "Devine" is based on *Phytophthora spp.* It has been successfully used for control of weeds in citrus groves. Another is called "Collego", based on *Colletotricum spp.,* for control of Northern Joint Vetch in rice and soybean fields.

A variety of bio-news is on the way

AS MORE RESOURCES are directed at increasing our knowledge about the turfgrass micro-environment, many new approaches to the science of turfgrass management will develop. Not only will new products and procedures be identified, but this increase in knowledge will help fine tune the use of existing control products through better timing of applications at reduced rates.

Future bio-products probably will be separated into several types:

- EXISTING MATERIALS THAT CONTROL or suppress pests and pathogens;
- FORMULATED "SPECIES SPECIFIC" microbial fungicides, insecticides, or herbicides— designed to control certain pathogens, insects or weeds;
- BIO-ENGINEERED TRANSGENIC TURFGRASS species that exhibit some of the genetic traits from microbes that are involved in pest control;
- AND BIO-ENGINEERED or naturally selected, endophytic fungi-enhanced turfgrasses that exhibit disease suppression, similar to those that now show insect resistance.

As more resources are directed at increasing our knowledge about the turfgrass micro-environment, many new approaches to the science of turfgrass management will develop.

Of the four types listed above, the hunt for naturally occurring suppressive materials is ongoing, and provides the greatest possibility for immediate applications of biologically suppressive products. This process requires the identification of possible suppressive microbes or organic materials, the collection of microbes or matertials, and a thorough sorting-out process to confirm their suppressive nature. Once they have been identified as suppressive, they must be analyzed to see if they can be formulated or processed into a form that the turfgrass manager can use without too much disruption to existing techniques.

Several of these suppressive products are being marketed as organic based fertilizers - Sustane (5-2-4), Ringer "Compost Plus", Ringer "Lawn Restore", and Ringer "Greens Restore". These and similar products have been tested at Cornell University and Michigan State University. They were found to provide varying levels of suppression to certain pathogens.

At Cornell, three organic fertilizers were included in a field test for the control of dollar spot, brown patch, red thread and gray snow mold *(see Tables 1 and 2: Brown Patch and Red Thread on page 11).*

Michigan State University researchers evaluated various combinations of commercially available organic fertilizers, wetting agents, synthetic fertilizers, and fungicides applied at different rates—for suppression of the pathogens that cause summer patch and necrotic ring spot *(see Tables 3 and 4: Summer Patch and Necrotic Ring Spot on page 11).*

The mechanism by which these materials work vary from product to product and in many cases have yet to be thoroughly understood. In the case of Sustane, applications of the product after it had been sterilized to kill any microbial antagonists present, produced the same results as applications of unsterilized Sustane. This result indicated that the factor that is effective in Sustane is likely of a chemical nature, rather than biological.

Very slow release synthetic fertilizers, such as IBDU, and other organic based fertilizers are probably effective because they reduce the expression of symptoms—by avoiding fertilizer stress during periods of high environmental stress. And products like Aqua Gro L probably work by reducing excess root zone moisture and thereby disrupting the reproductive cycle of the pathogens.

HOW EFFECTIVE ARE BIOCONTROLS AT DISEASE SUPPRESSION?

TABLE 1

BROWN PATCH FIELD STUDY

TREATMENT	% DISEASED
Banner (fungicide)	8%
Sustane	18%
Ringer "Compost Plus"	18%
Ringer "Greens Restore"	24%
End. sludge compost	42%
End. leaf compost	44%
Peat moss	50%
Brewery compost	54%
Cow manure compost	54%
Mushroom compost	54%
Balt. sludge compost	60%
Schen. sludge compost	66%
Moody cow compost	72%
CONTROL	**72%**

TABLE 2

RED THREAD FIELD STUDY

TREATMENT	% DISEASED
Sustane (fungicide)	10%
Ringer "Compost Plus"	20%
Balt. sludge compost	23%
Brewery compost	30%
Peat moss	37%
End. sludge compost	40%
Cow manure compost	43%
Ringer "Greens Restore"	43%
CONTROL	**47%**
End. leaf compost	53%
Moody cow compost	53%
Mushroom compost	53%
Schen. sludge compost	57%

Source for Tables 1 and 2: Field studies by Dr. Eric B. Nelson (Cornell University, 1989).

TABLE 3

SUMMER PATCH FIELD STUDY

TREATMENT.	% DISEASED
Ringer "Turf Restore" + Bayleton (.5N/m, 2 oz. May)	1.00%
Sustane + Aqua Gro L (.5N/m, 8 oz/m)	1.00%
Biogroundskeeper + G.P. 27-2-3 (2 oz/m, .5N/m)	1.67%
Turf "Restore" + Rubigan (.5N/m, 2 oz. May)	1.67%
Rubigan + NPK 10-3-4 (2 oz. M, J, J & .5N/m)	2.33%
Biogroundskeeper + Rubigan (2 oz./m, 2 oz. May)	3.00%
Sustane (.5N/m)	3.33%
Biogroundskeeper + Bayleton (2 oz./m, 2 oz. May)	3.67%
Turf Restore (.5N/m)	4.00%
IBDU 18-3-24 (.5N/m)	5.00%
Biogroundskeeper (2 oz/m)	8.00%
Aqua Gro L (8 oz/m)	11.33%
CONTROL	**18.33%**
Urea (.5N/m)	20.00%

▲ These four tables of results compare use of a chemical fungicide and use of a variety of potential biocontrol materials with an untreated control plot.

TABLE 4

NECROTIC RING SPOT FIELD STUDY

TREATMENTS	% DISEASED
Ringer "Lawn Restore" (1#N/m)	10%
IBDU 18-3-24 (1#N/m)	10%
Sustane (1#N/m)	11.7%
Sustane + Aqua Gro L (1#N/m, 8 oz./m)	13.3%
Urea (1#N/m)	23.3%
Aqua Gro L (8 oz./m)	41.7%
Biogroundskeeper (./m)	50.0%
CONTROL	**61.7%**

Source for Tables 3 and 4: Summer Patch and Necrotic Ring Spot field studies by Vargas, Melvin, Berndt, Detweiler, Golembiewski, Slater (Michigan State University, 1989).

Other potential products, especially from compost sources, are being evaluated for incorporation at turf sites, either by top dressing in mixtures with sand or by incorporation at the initial construction phase as an organic matter source. Work at Cornell by Dr. Nelson has demonstrated that when suppressive materials are incorporated into putting greens, by either of these means, they have shown significant control of Pythium Root Rot— a very difficult to control disease of the northern tier of states.

Dr. Nelson also has looked at aqueous extracts or teas of these same materials. The tea is produced by soaking a quantity of the suppressive material in water, draining the water off and filtering out larger organic particles. A spray is then produced by mixing the concentrated tea with a larger amount of water. The resulting spray mixtures have proven to be pathogen suppressive, but they usually are only half as effective as the solid material and on occasion is totally ineffective. These drawbacks have to be successfully addressed, before suppressive teas become viable alternatives to solid applications—or occasionally even chemical fungicides.

Nematode-based soil insecticides have come of age

RECENTLY, FOUR COMPANIES have released three nematode-based soil insecticides, "Exhibit" by Ciba-Geigy, "Biosafe" by Ortho and SDS Biotech, and "Vecter" by Biosys. These products target

–continued on page 12

What will biologicals do continued from page 11

caterpillars, billbugs, leatherjackets, mole crickets, and white grubs. The latest research data has shown that nematode-based insecticides offer efficacy of control that rivals traditional chemical controls. Several well-know turfgrass entomologists now endorse the concept of nematode based insecticides.

In 51 trials of three species of parasitic nematodes species versus two chemical controls for white grubs, the average percent control reached 73% +/- 8.7% for the nematodes versus 83% +/- 7.9% for the chemical controls.

In 24 trials of two parasitic nematodes versus two chemical controls for Tawny mole crickets, the average percent control for the nematodes was 63.4% +/- 13.9% and 70.8% +/- 8.3% for the chemical controls.

In 25 trials for Black cutworm control two parasitic nematodes averaged 86.1% control +/- 8.6% versus 99.1% +/- 5.3% for the single chemical control. And 14 trials for billbug control yielded 77.2% control +/- 7.6% for the average of two parasitic nematodes and 83.6% +/- 5.9% for the one chemical control.

The care and handling of nematode-based insecticides will require some changes in approach and timing. There are considerable differences in the storage, mixing, and use of these materials compared to chemical controls. Manufacturers recognize this potential barrier to the widespread use of these alternative pesticides, and are making a concerted effort to close that gap.

Microbial fungicides may be available within 10 years

MICROBIAL FUNGICIDES MAY OFFER an effective alternative to fungicides sometime in the near future. Microbial fungicides will be mixed and sprayed in a manner similar to existing chemical fungicides; they will offer efficacy that rivals existing fungicides with a duration of control that matches current controls. Depending on the biology of the selected antagonist, they may offer long-term control.

Research at Cornell has indicated that several antagonist microbes offer control of disease expression that rivals current chemical fungicides, when they are applied at the optimum time and in the best manner. In field trials for dollar spot, when rated thirty days after two successive applications, a bacterium, *Enterobacter cloacae*, showed disease control that was 60% and 59% as successful at controlling as a labeled fungicide. Applications of *Typhula phacorrhiza* provided 74% control of gray snow mold, caused by *Typhula incarnata* and *T. ishakariensis*. Also, isolates of binucleate *Rhizoctonia spp.* and *Laetisaria arvalis* produced up to 90% control of brown patch.

Once an individual or group of antagonist species have been identified as suppressive, checked for mechanism of action, tested for efficacy and duration of control, monitored for consistency of control under varying microenvironments and checked for cost and difficulty of production, they can be formulated into an appropriate delivery system and sent to the EPA for approval. As they become available these microbial fungicides may be packaged in several different ways. They could be

- AVAILABLE IN EITHER A FREEZE DRIED FORM (a technique that was successfully developed at the University of Idaho) or as granular organic materials colonized by the appropriate micro-organisms,
- AVAILABLE AS STARTER CULTURES that are mixed with water and require incubation for a period of time following a specific procedure,
- OVERNIGHT EXPRESS MAIL ready to be mixed by the user just before their scheduled application.

Most single species microbial fungicides, herbicides, and insecticides will be narrowly focused. With some exceptions, like *Enterobacter cloacae,* which has provided effective control of multiple pathogens, many microbial antagonists suppress only one or two closely related pathogens. Where possible, mixtures of antagonists may be able to broaden the spectrum of control, but that will only happen where the antagonists are compatible.

Concurrent applications of broad-spectrum chemical fungicides may not be compatible with the use of microbial fungicides, as they could inadvertently target the antagonist microbes as well as the target pathogens. Also, chemical fungicides might stimulate microbes that are antagonistic to the applied antagonists—rendering the microbial fungicides ineffective.

Transgenic turfgrasses may be closer than you think

TRANSGENIC PLANTS MAY HAVE specific genes (from antagonist microbes) spliced into their DNA, to endow them with the desired characteristic of the antagonist. Such plants are already in the testing stage. Several species of agricultural plants, including cotton, have had controlling genes from the BT bacteria spliced into their DNA. The plant then produces the BT's natural insecticides. New transgenic agricultural plants should be available in a few years.

In addition to being pathogen resistant, bio-engineered turfgrasses could include spliced genes from antagonist microbes and other sources that produce

- INCREASED INSECT RESISTANCE
- RESISTANCE TO WEED INFESTATIONS
- IMPROVED UTILIZATION OF NUTRIENTS AND WATER
- IMPROVED HEAT AND DROUGHT RESISTANCE
- REDUCED VERTICAL LEAF GROWTH
- INCREASED ROOTING and root mass regeneration
- INCREASED SEED PRODUCTION

• AND ANY NUMBER of additional desirable traits.

Transgenic plants have "the greatest chance at improving turfgrass management of all the biologically based solutions," according to Dr. Nelson. The sad news is that these benefits for the turfgrass industry are probably at least ten years away.

Up to now, the association of endophytic fungi and turfgrass species has meant increased resistance to some insects. These naturally selected endophyte infected plants live a symbiotic life style: the fungus receives the benefit of living between the cells of the plants, and the turfgrass gets the benefits of improved pest resistance that the waste products of the fungus provide.

There are hundreds of species of endophytic fungi, and probably dozens of varieties that can provide other benefits. Research at Rutgers University recently established a link between high endophyte levels in some varieties of fine fescues and considerable dollar spot resistance. Carefully selecting "wild" types that exhibit disease suppression from endophytic fungi is probably the quickest way to produce edophitically enhanced resistance to disease.

Dr. Lea Brillman, the plant breeder at Seed Research, Inc., in Corvalis, Oregon (a major producer of high endophyte turfgrass seed) says that Seed Research had only moderate success in isolating other promising endophyte strains from multiple sources and introducing them into commercially desirable turfgrasses with low endophyte levels. Because the company has had greater success by cross-breeding varieties with desirable high endophyte levels , Dr. Brillman says that, for now, they would concentrate on identifying desirable "wild types" for their sources of new endophytic species.

Bio-engineering has the potential to produce desirable traits that do not occur naturally in a single variety of turfgrass, but for now traditional hybridization is the road being followed.

Some biological controls are currently available for plant managers, but over the next twenty years a whole range of new products, supplies, and procedures will enable tomorrow's turfgrass manager to get pinpoint, long-term control of turf problems that are hard to control today. ■

Massachusetts charters a different course on recertification

AS OF JANUARY 1, Massachusetts will substantially broaden the number and types of activities that qualify as pesticide recertification training, according to Mark Buffone of the Massachusetts Department of Food and Agriculture Pesticide Bureau.

To reduce the paperwork burden of approval required under its current system and to provide a set of guidelines that event producers can follow, Massachusetts will replace the existing system of credits assigned to a course with a new concept of contact hours—50 minutes of continuous exposure to educationally designed lectures, short courses, study courses, correspondence school, degree and non degree academic courses in the biological sciences, or self study materials.

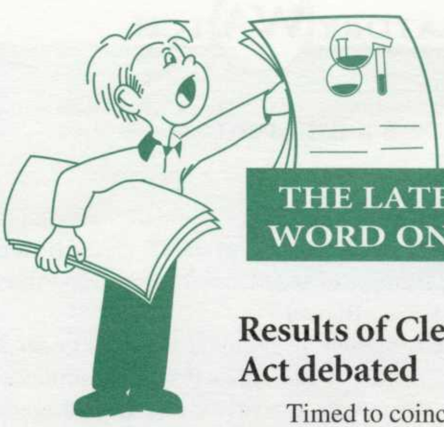
The concept is designed to give the producers of materials and events with a guideline for evaluating the content of their productions and assigning it a value. The participant at an event will be given a certificate to keep and turn into the Bureau. The certificate would be good unless otherwise notified. The Bureau will randomly audit the productions, and provide their producers with comments on its appropriateness.

Mr. Buffone also noted that the first criteria that will be used when evaluating a program is how the material relates to pesticide use. The primary charge of his department is to regulate the use of pesticides. Programs or materials about alternate management strategies and biocontrols will be considered appropriate if the information presented is related to the use and regulation of pesticides.

Other regulatory changes effective this January also include:

- AN EXPANSION OF THE NUMBER of individuals required to be licensed or certified to include all public and private employees who use pesticides as part of their duties.
- ALL APPLICATOR AND CERTIFICATION EXAMS will be closed book exams.
- WITH THE EXCEPTION of dealer certification exams, all certification tests will be of two parts, a core exam and a specialty exam.
- CERTIFICATION CANDIDATES must have a minimum of two years related work experience.
- CERTIFICATION CANDIDATES must be at least 18 years old.
- A CANDIDATE WHO FAILS an exam may apply at the next available test date. After two failures, a candidate must wait three months before another re-examination.
- PESTICIDE DEALERS MUST GET THE SIGNATURE of an agent of a certified applicator and the signature of the certified applicator when that agent seeks to purchase restricted use pesticides for the certified applicator. ■

***TGT's view:** The expansion of the number of people that require some sort of training to handle or apply pesticides to include anyone who has to use pesticides on the job is the logical extension of this sort of regulation. The expansion of the number and types of recertification avenues is a excellent idea, and is long overdue. This greatly increases the turfgrass managers flexibility in dealing with his and his employees certification requirements.–CS*



THE LATEST WORD ON . . .

Results of Clean Water Act debated

Timed to coincide with lobbying efforts related to debate on the re-authorization of the Clean Water Act, the Natural Resources Defense Council has released a book entitled, "The Clean Water Act: Twenty Years Later." The book notes that industrial pollution has been reduced substantially since the act was passed, but says that many problems remain. The new report already has drawn fire from various groups, including the Delaware Rural Water Association which criticized it for sensationalism and using "smoke-and-mirror statistical methods."

Landscaping has average home improvement value

A *Home Mechanix* magazine survey of the costs and values of various home improvements put landscaping "about in the middle of the pack for professionally done work", noting that homeowners who sell their renovated properties should be able to make back more than half of what they invested in labor and plant materials. The landscaping included planting 21 trees and shrubs, 1,000 $ft.^2$ of grass seed, and installing a walkway with lighting.

The total cost given was $2,890 for professional work and $1,442 for do-it-yourself. In high cost regions of the country, the landscaping ranked #7 for professionally done work and #10 for do it yourself—out of 12 possible projects, which included everything from major kitchen remodeling to replacing the windows.

The report also pointed out that landscaping should fit the general pattern of the neighborhood, and noted that "nicely landscaped houses move faster in any housing market."

Endophytes don't aid drought tolerance

High endophyte levels in tall fescue varieties do not appear to enhance drought survivability, according to researchers at Texas A&M and North Carolina State Universities. In the testing three varieties of tall fescue, with and without high endophyte levels, were subjected to drought stress. In all measures of the effects— number of tillers, tiller survival, overall plant survival and recoverability, and net plant dry weight—there was no appreciable difference between the high and low endophyte samples.

COMING ATTRACTIONS

FEBRUARY ISSUE

Future directions and soil microbes

Dr. Eric Nelson and Christopher Sann explore emerging new technologies and practices that will make dramatic changes in 21st century turf management.

In it we provide:

- OVERVIEWS OF KEY SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENTS,
- FUTURE DIRECTIONS IN ENVIRONMENTAL REGULATIONS,
- IMPACTS ON FIELD PRACTICES AND OFFICE PROCEDURES.

Plus Dr. Eric Nelson provides a guided tour of the unseen microscopic life in the soil, which plays a variety of important roles in the health of turfgrass plantings.

Previous studies have shown that high endophyte levels do provide increased leaf and root insect resistence, enhanced growth characteristics, some enhanced disease resistance, and improved persistence under high heat conditions.

TGT's view: *Drought stress has such a negative effect on all plant systems. Apparently, the plants and their symbiotic partners, the endophytic fungi, are both dramatically affected.–CS*

Nitrogen volatilization studied

Researchers at the University of Iowa are looking at ways of reducing the volatilization of nitrogen from surface applied urea. Under greenhouse conditions, the loss of nitrogen due to volatization can be as high as 50% after only one week. The researchers focused Urease, a naturally occurring soil enzyme that breaks down urea into CO^2 and ammonia gas—the natural process that makes the fertilizer plant available. When a urease inhibitor was introduced, the nitrogen loss fell to as little as 20% under the same conditions. However, when this promising development was put out in field trials to confirm the green house results, the researchers found no difference in the amount of nitrogen lost—with or without the urease inhibitor.

TGT's view: *Despite the failure of the field test to confirm the results obtained in the greenhouse, this area of research may prove successful in slowing down the actual soil release characteristics of urea, the most common of all turf fertilizers. Polymer and sulfur coatings moderate which urea perticles are available to be released, but they do not control the actual release characteristics once the process* has begun. – CS ■

INTERACTIONS
COMMENTS & OBSERVATIONS

Curing disease is one thing, but changing hearts and minds is another

by Chris Sann

WILL EXPERIENCED turfgrass managers examine the "brave new world" of biologically based products, and say, "sorry, but I will stick with what has worked for me in the past." Obviously, such a reaction would be as narrow-minded as the school of thought that says turfgrass management is a major creator of environmental mayhem. Use of chemicals isn't an automatic foul, and using new biocontrols won't be the end of the world as we know it.

Man has used microbes since he baked the first loaf of bread and brewed the first beer to wash it down. Today microbes help fight diseases in people, animals, and plants. They digest toxic pollutants, and produce food and beverages. Any feeling that the "brave new world" of biocontrols is either brave or new is just wrong.

In fact, there is a lot of interest in biocontrols among turf professionals, but there are a lot of uncertainties—about what microbial biocontrols are, how they work, how well they work, their costs, how they are used, and—for some people—a big question about why they are needed in the first place. All of these concerns need to be answered.

As Dr. Nelson points out, we are years away from many of the answers. At this point, however, we can answer one of the basic questions: Are biocontrols just an environmental version of political correctness? The answer is—no, they are not. They are real new tools designed to reduce real problems, some of which are of our own making. They undoubtedly will lead to new problems of their own.

Even a good new tool takes getting used to, but many professional turfgrass managers are already well along in the process. We are comfortable with, and have confidence in, chemical controls, which gave us greater effectiveness and more precision than traditional materials and methods, but we also know that the replacement of "tried and true" with "new and improved" is neverending. What throws a lot of us off is that the improvements somewhow aren't what we expected, and our skills and fortunes tend to become tied to particular stops along the way.

Modern science is leading us to deeper levels of understanding and ever more refined levels of precision—deep enough for us to see that biological and chemical controls aren't opposites. In fact, they aren't just related: they're family. Future practice is not likely to be based on an inaccurate and unrealistic either/or decision. If we do our jobs right, it will reflect the benefits of our ceaseless search for all kinds of new and improved disease controls. ■

TERMS TO KNOW

aerobic/anaerobic . . . With and without oxygen

binucleate . . . Cells with two nuclei. [OKAY?]

biological suppression . . . Preventing or reducing disease activity using microbial antagonsists.

cross protection or induced resistance . . . Use of a biocontrol agent that enhances the development of natural defenses against pathogens.

humification . . . The formation of humus or humic acid in soils or composts..

inoculants . . . Micro-organisms that are introduced into soils or onto plants for a variety of purposes.

mesophilic . . . Moderate-temperature conditions

microbiological . . . Of or pertaining to living organismd that can only be seen with a microscope.

milky spore disease . . . A bacterial inoculant used to control grub species. This bio-insecticide has been used for over 30 years.

mycoparasites . . . Fungi that are parasitic on other fungi.

pathogen inoculum . . . The mass of infectious fungi present at a site.

pathogen propagules . . . Bodies or forms of disease-causing fungi that allow the fungus to survive and to form new plant infections.

particulates . . . Small pieces of material.

phytotoxic . . . Poisonous to plants.

selection . . . The evolutionary process by which individual members of a species develop one ore more characteristics that help the species to adapt to changing conditions.

soilborne . . . Of or residing in the soil. Usually used in reference to micro-organisms.

suppressiveness . . . The characteristic of minimizing disease activity or reducing the amount of pathogen inoculum.

thermophilic . . . High temperature conditions

v:v . . . Volume to volume. ■

ASK THE EXPERT

Have a question on any aspect of turf management? Send it to:

Ask the Expert–Turf Grass Trends
1775 T St. NW, Washington, DC 20009
or send your message via
Fax: (202) 483-5797
CompuServe: 76517,2451
Internet: 76517.2451@COMPUSERVE.COM

For subscriptions, call 202-328-0888 or mail in today.

Yes, SEND ONE YEAR'S SUBSCRIPTION TO *TURF GRASS TRENDS*—12 REGULAR ISSUES. I MAY CANCEL WITHIN 30 DAYS AND RECEIVE A FULL REFUND.

NAME ______________________________

TITLE ______________________________

COMPANY ______________________________

ADDRESS ______________________________

CITY ______________ STATE ______ ZIP ________

BUSINESS PHONE (______) ______________

(MAKE CORRECTIONS TO LABEL HERE.
ALLOW 4–6 WEEKS FOR DELIVERY.)

PLEASE AFFIX YOUR BUSINESS CARD HERE

Number of subscriptions:

1 YR. (12 ISSUES) OF TGT .... $ 120.00

ADD'L SUBSCRIPTIONS ___ X $100 EA. . $ ______

AMOUNT ENCLOSED .... $ ______

Method of payment:

☐ CHECK ENCLOSED (PAYABLE TO **TURF GRASS TRENDS**)

☐ PURCHASE ORDER ENCLOSED

☐ BILL ME

Yes, I WOULD LIKE *TURF GRASS TRENDS* TO REFLECT MY COMPANY'S NEEDS.

(PLEASE TAKE A FEW MINUTES TO GIVE US INFORMATION ON YOUR BUSINESS, CONCERNS, AND SPECIAL INTERESTS.)

WHAT CURRENT TREAND IN THE TURF MANAGEMENT INDUSTRY ARE YOU MOST ENTHUSIASTIC ABOUT?

WHAT CURRENT TREND IN THE TURF MANAGEMENT INDUSTRY ARE YOU MOST CONCERNED ABOUT?

OTHER SUBJECTS OF SPECIAL INTEREST TO ME ARE:

I ALSO READ (LIST OF OTHER PUBLICATIONS):

MAILING ADDRESS: TURF GRASS TRENDS, 1775 T ST. NW, WASHINGTON, DC 20009

Turf Grass TRENDS

Turf Grass Trends is published monthly.
1775 T St. NW. Washington, DC 20009
(202) 328-0888 Fax: (202) 483-5797
CompuServe: 76517,2451
Internet: 76517.2451@COMPUSERVE.COM

Subscriptions are $120 per year for a single subscription and $100 per year for multiple subscriptions. *Turf Grass Trends* accepts no advertisements. Not responsible for unsolicited manuscripts.

Turf Grass Trends
1775 T St. NW
Washington, DC 20009

DEC 30 1993

BULK RATE
US POSTAGE
PAID
WILMINGTON, DE
PERMIT NO. 324