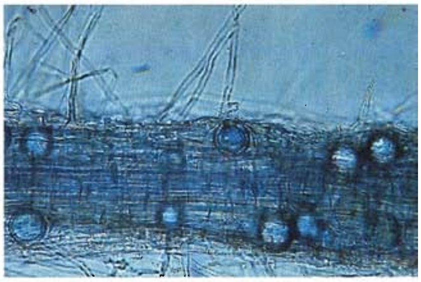
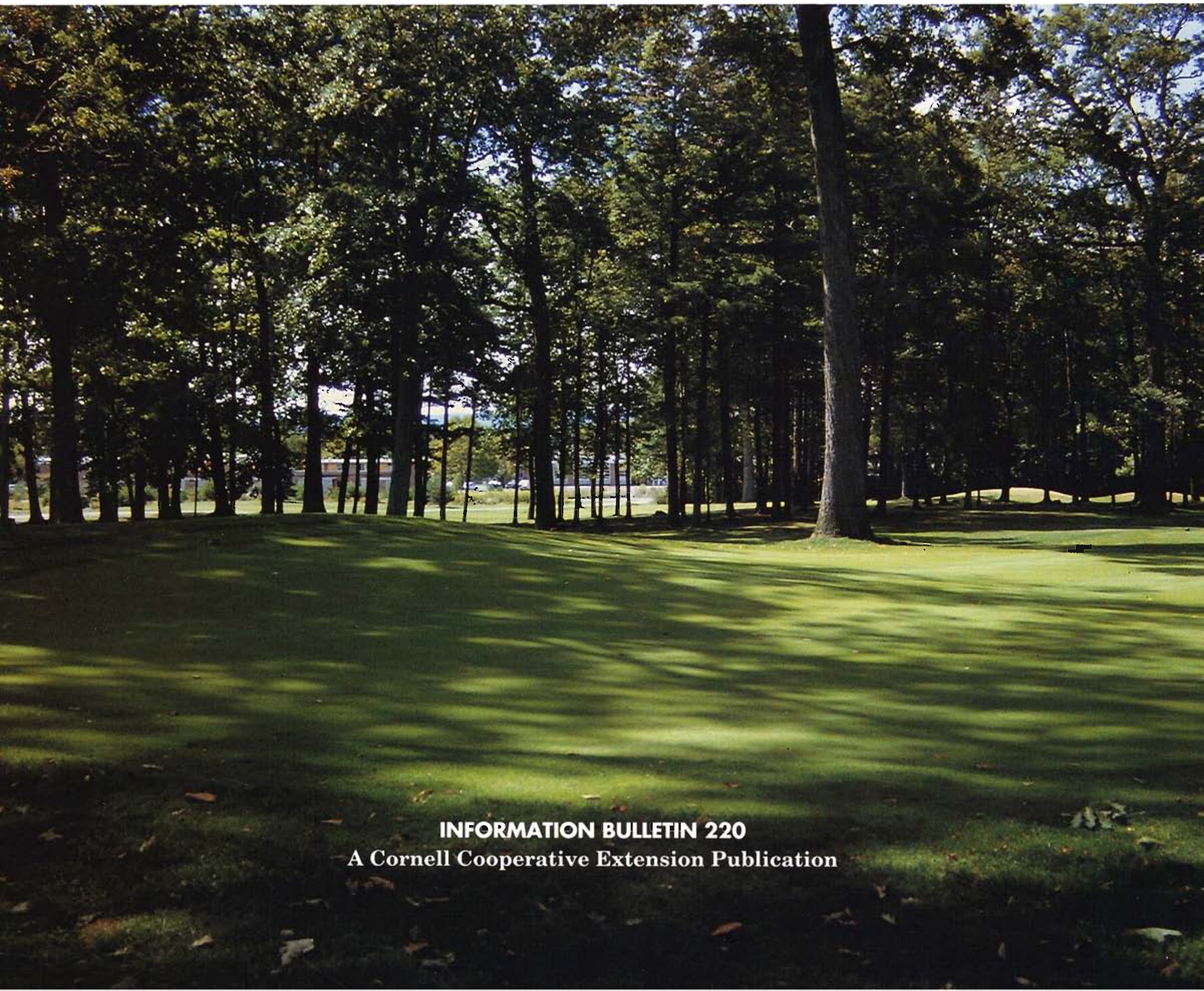
Biological Control of Turfgrass Diseases

Eric B. Nelson





INFORMATION BULLETIN 220

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Cover: the eighteenth green of the Cornell University golf course. Top, left to right: perennial ryegrass plants infected with *Laetisaria fuciformis,* the cause of red thread disease; patches of pink snow mold caused by *Microdochium nivale* on a golf course putting green; oospores of *Pythium graminicola,* the cause of pythium root rot, in a creeping bentgrass root.

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Biological Control Products

In the United States, the development of a microbial fungicide is estimated to take approximately two to three years at a cost of less than $500,000, while the development of a new chemical fungicide takes approximately ten to fifteen years at a cost exceeding $80 million. The estimated cost of applying Dagger G, a recently developed microbial fungicide, is $9.50 per acre. When these figures are used as a general standard with which to base future product economics, microbial fungicides seem to be economically attractive if they are used by a large portion of the turfgrass industry.

Since the 1920s when interest in the biological control of plant diseases first arose, only five commercial biological controls targeted for plant diseases have been marketed in the United States. Four of those—Quantum-4000 (Gustafson Chemical Company, Dallas, Tex.), a preparation of the bacterium *Bacillus subtilis,* Dagger G (Ecogen, Inc., Langehorne, Pa.), a preparation of the bacterium *Pseudomonas fluorescens,* Binab-T (United States distributor unknown), a preparation of the fungus *Trichoderma harzianum,* and most recently, a preparation of the fungus *Gliocladium virens* (unknown trade name but marketed by W. R. Grace)—are targeted for fungal pathogens. The fifth, Galltrol-A (AgBioChem, Inc., Orinda, Calif.), a preparation of the bacterium *Agrobacterium radiobacter,* is effective against one specific bacterial disease.

Only a few commercial products are available in Europe and the Middle East. Unfortunately, none of these materials are labeled for turf disease control at this time.

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More than $55 million is spent annually in the United States on turfgrass fungicides. This constitutes more than 13 percent of the total U.S. fungicide market. Coupled with the fact that most turfgrass is grown in areas of high population density—lawns, golf courses, parks, and school grounds—this high level of fungicide use greatly increases the risk of human exposure to potentially harmful pesticides.

In urban areas, golf course turfgrasses receive the greatest amount of synthetic pesticides. Nationwide, more than $41 million is spent annually for disease control on golf course turf. In New York State alone, more than 800 golf courses have a total fungicide budget of more than $6.4 million. As the popularity of the game grows, the golfing public is placing unprecedented demands on existing facilities to provide high-quality playing surfaces. This has forced many golf course superintendents to adopt preventative pest control programs based on frequent applications of broad-spectrum, persistent pesticides.

On home lawns, more responsibility for pest control is being assumed by homeowners than by certified pesticide applicators affiliated with lawn care services. Because homeowners lack training in the proper handling, use, and disposal of pesticides, there is a risk of unnecessary human exposure. From a 1987 study, it was estimated that in a typical suburban neighborhood more than 8,000 homeowners could be exposed to lawn pesticides in a season. As pesticide use increases, this estimate will likely rise.

Most fungicides being used for turfgrass disease control are broad-spectrum and environmentally persistent systemic fungicides. Many problems have arisen from their excessive and prolonged use, including the development of fungicide-resistant pathogens; the suppression of nontarget organisms, particularly those involved in carbon and nitrogen cycling; the enhancement of nontarget diseases; and the selection of fungicide-degrading microorganisms. Particular concerns are the contamination of soil and water and the undue exposure of turfgrass managers and the public.

In an effort to reduce fungicide use and prevent the undesirable biological and environmental effects of excessive fungicide use, alternative pest management practices are being explored. Among the most attractive strategies is biological control using microbial-based fungicides. This approach has been experimentally and commercially successful on several crop plant species. Currently, several biological products are commercially available, and many others are likely to become available in the future. This bulletin summarizes our current knowledge of biological control and its application to managing turfgrass diseases.

Approaches to Biological Control

Most turfgrass managers are familiar with the negative effects of soil microorganisms, many of which are pathogenic and can damage turfgrass. In addition to pathogens, however, the soil harbors a variety of nonpathogenic soil microorganisms that improve plant health. Soil bacteria and fungi can increase the availability of plant nutrients in soil, form symbiotic associations with turfgrass roots, produce substances that stimulate plant growth, and protect plants against infection from pathogenic fungi. The practice of biological control takes advantage of all these microbial attributes to minimize damage from plant pathogens.

Organisms that interfere with the activities of plant pathogens are called antagonists. Biological control can be achieved either by introducing antagonists or by manipulating antagonists already present in the soil and on plant parts. The goal in either case is to reduce or eliminate pathogen activities by reducing pathogen inoculum in soil, protecting plant surfaces from infection, or inducing natural defense mechanisms in the plant.

For example, the application of composts or other well-decomposed organic matter to turf introduces large populations of antagonistic microorganisms that interfere with the activities of pathogenic fungi. Cultural management techniques can reduce disease development by altering the microbial communities of soil and thatch, in which pathogens must function. This can indirectly reduce disease severity by changing the environment to favor the antagonistic microflora but not the pathogen population.

Biological control of inoculum can result from the destruction of pathogen propagules by microbes or the prevention of inoculum formation by mycoparasites (i.e., fungi that are parasites of other fungi). In addition, antibiotic-producing antagonists can displace pathogens in decaying plant residues such as thatch and reduce their populations in soil.

Many nonpathogenic soil microorganisms can effectively colonize aboveground as well as belowground plant parts and protect those tissues from infection. It is also apparent that some antagonists can induce natural defense mechanisms in plants—a phenomenon referred to as cross-protection or induced resistance.

Some commonly studied antagonists are fungi in the genera *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. Antagonists such as *Trichoderma* and *Sporidesmium* may parasitize pathogen propagules and hyphae and function as mycoparasites. Other antagonists, particularly *Pseudomonas, Bacillus, Erwinia,* and *Gliocladium,* produce antibiotics that inhibit pathogen growth and development. Some species of *Pseudomonas* and *Enterobacter* outcompete pathogens for essential nutrients and other growth factors, reducing their germination, growth, and pathogenicity.

Antagonists of turfgrass pathogens can be found in nearly every soil and in association with all plant species. They are particularly abundant in turfgrass soils and thatch as well as in decaying organic substrates (table 1).

Table 1. Recovery of microbial antagonists suppressive to pythium blight from soils, composts, and thatch

Source	No. Effective Antagonists/ No. Strains Tested	Percentage
I. Low maintenance (parks, cemeteries, selected home lawns)		
Thatch	31/57	54.4
Soil	5/22	22.7
Total	36/79	45.6
II. High maintenance (golf courses)		
Thatch	15/41	36.6
Soil	35/80	43.8
Total	50/121	41.3
III. Nonturf sources (field soils, composts)		
Soil	3/14	21.4
Composts	10/15	66.7

Lesser-maintained turfgrass areas may support more abundant populations of antagonists than highly managed turf. This is because the methods by which highly managed turf (i.e., on golf course putting greens) is produced discourage the development of diverse and potentially suppressive microflora. For example, newly constructed greens lack available organic matter capable of supporting high populations of antagonists, and the continued use of broad-spectrum, persistent pesticides suppresses not only the pathogenic organisms but the beneficial ones. As populations of natural antagonists are reduced, pathogenic microorganisms more readily become established on susceptible plant tissues. This is one reason turfgrass diseases are often so devastating and difficult to control. It also may explain the resurgence of previously unimportant or unrecognized turf diseases.

To manipulate biological control agents predictably and successfully, an understanding of their biology and ecology in turfgrass ecosystems is needed. Biological control agents differ fundamentally from chemical fungicides in that they must grow and proliferate to be effective. Therefore, organisms must be able to establish and survive in turfgrass ecosystems and remain active against their target pathogens during periods favorable for plant infection. It also is important that biological control agents be compatible with the fungicides, insecticides, and herbicides being used in a management program.

Three factors are important in determining how well antagonists will establish and grow:

1. the level of available organic matter in soil
2. the environmental conditions, particularly temperature, moisture, nutrients, and pH
3. their ability to compete with existing soil and plant microflora

Because both pathogens and antagonists are influenced by environmental conditions, turfgrass managers must learn how to control the pathogen and, at the same time, maintain associated antagonists. And just as some organisms are antagonists of pathogens, antagonists have their own antagonists.

Few in-depth studies on the biological control of turfgrass diseases have been conducted. Promising results for managing fungal diseases of golf course turf, however, have been obtained using complex mixtures of microorganisms, such as those found in composts and soils, as well as individual antagonists (table 2). Although individual antagonists isolated from many different environments are suitable biological control agents, composts are some of the best sources of complex mixtures of antagonistic microorganisms.

Use of Compost-based Organic Fertilizers

To reestablish the microbiological balance of soils on which intensively managed turfgrasses have been grown, sufficient organic matter must be introduced into the soil-plant system to support microbial growth and activity. The best sources of both organic matter and populations of antagonistic microorganisms are composted materials. Fortunately, composts are readily available, in many cases at no charge, and they can be applied as a topdressing without elaborate and expensive equipment.

Golf course greens and tees are top-dressed several times a season with a mixture of sand and some type of organic matter, usually peat, or with soil. Peat, however, has no disease-suppressive properties. Replacing peat with composted manure, sludge, or agricultural waste—all readily available and naturally disease suppressive—should be easy. Any of these materials can be applied with a drop spreader or simply by hand, so additional practices are not introduced into an existing turfgrass management program.

Composting Process

Composting is the "biological decomposition of organic constituents in wastes under controlled conditions" (Golueke 1972). Composting relies exclusively on microorganisms to decompose organic matter, so the process has biological as well as physical limitations. The environmental parameters—moisture, temperature, and aeration—must be stringently controlled, making the process of composting different from the rotting or putrefaction that occurs in landfills and manure piles.

Composting involves the actions of both mesophilic (moderate temperature) and thermophilic (high temperature) microorganisms during various phases of organic matter decomposition. Each contributes to the nature of the composted material. Failure to maintain environmental conditions favorable for adequate microbial activity could jeopardize the quality of the final product.

Table 2. Known biological controls of turfgrass disease

Disease (Pathogen)	Antagonists	Location
Brown patch (*Rhizoctonia solani*)	*Rhizoctonia* spp. *Laetisaria* spp. Complex mixtures	Ontario, Canada North Carolina New York Maryland
Dollar spot (*Sclerotinia homoeocarpa*)	*Enterobacter* spp. *Fusarium* spp. *Gliocladium* spp. Complex mixtures	New York Ontario, Canada South Carolina New York
Gray snow mold (*Typhula* spp.)	*Typhula* spp. *Trichoderma* spp. Complex mixtures	Ontario, Canada Massachusetts New York
Pythium blight (*Pythium aphanidermatum*)	*Enterobacter* spp. *Pseudomonas* spp.	New York Ohio Illinois
	Various bacteria	New York
	Complex mixtures	New York
	Trichoderma spp.	Ohio
Pythium root rot (*Pythium graminicola*)	Complex mixtures	New York
Red thread (*Laetisaria fuciformis*)	Complex mixtures	New York
Southern blight (*Sclerotium rolfsii*)	*Trichoderma* spp.	North Carolina
Take-all patch (*Gaeumannomyces graminis* var. *avenae*)	*Pseudomonas* spp. *Gaeumannomyces* spp. *Phialophora* spp. Complex mixtures	Colorado Australia

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. The composting mass must be moist enough to support microbial activity, but not so moist that air exchange is limited. The particle size of the material must be small enough to provide proper insulation, but not so small that air exchange is decreased.

With optimal environmental and physical conditions, composting proceeds through three distinct phases (fig. 1). During the initial phase, which lasts one to several days depending on the type of starting material, the internal temperature of the composting mass rises as a result of the growth and activity of the indigenous mesophilic microflora. Most of the soluble, readily degradable materials are broken down by the naturally occurring microorganisms, precluding the need for additional inoculum. At this stage, populations of microorganisms increase in size, activity, and composition.

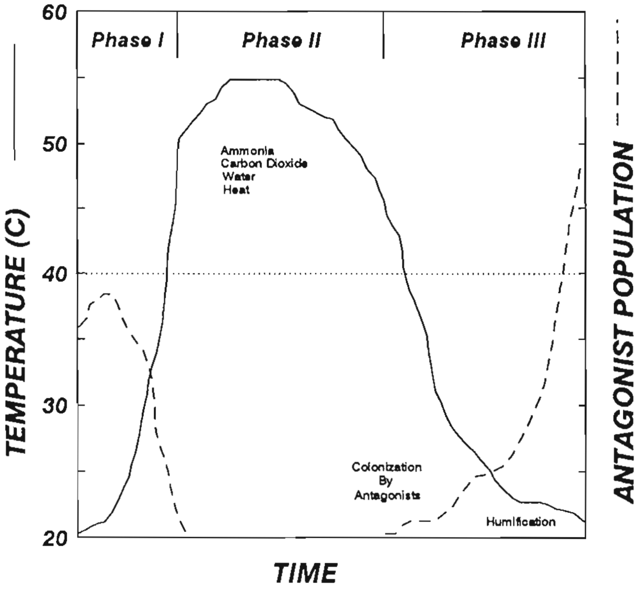

Fig. 1. Schematic diagram of the composting process. During phase I, initial heating takes place and readily soluble components are degraded. During phase II, cellulose and hemicellulose are degraded under thermophilic (high temperature) conditions. This is accompanied by the release of water, carbon dioxide, ammonia, and heat. During phase III, curing and stabilization are accompanied by a drop in temperature and recolonization of the compost by mesophilic microorganisms. Included in these microbial communities are populations of antagonists.

As temperatures increase above 105°F (40°C), the mesophilic populations are replaced by thermophilic populations, which can degrade resistant polymers such as cellulose and hemicellulose. The thermophilic phase may last several months, depending on the cellulose content of the material and the temperature maintained. Generally, the higher the cellulose content, the longer the thermophilic phase.

Temperatures required for thermophilic decomposition range from 95°F to 165°F (35°C to 74°C). The highest rate of microbial activity and decomposition, however, occurs at temperatures of 95°F to 130°F (35°C to 55°C). Temperatures above 130°F (55°C) can be self-limiting to decomposition. Therefore, most composts need to be aerated by either repeated pile inversions or forced air ventilation. Many composts today are produced in aerated vessel systems where temperatures can be precisely regulated.

The composting process consumes much oxygen. Aeration, either with repeated pile inversions or with forced air, keeps the composting mass aerobic (with oxygen) instead of anaerobic (without oxygen). In anaerobic composts, toxic microbial metabolites can accumulate, which damage plants. In addition, undesirable odors are produced. Composts that are aerated have little or no odor.

As the cellulose and hemicellulose components are depleted, the compost enters a curing or stabilization phase, in which temperatures begin to decline, decomposition rates decrease, and the thermophilic microbial populations are replaced again by mesophilic populations. In general, the longer the curing period, the more diverse the colonizing mesophilic microflora.

Many of the mesophilic microflora that recolonize the compost at this stage are microbial antagonists, which render the compost disease suppressive. Unfortunately, there is no way to predict the disease-suppressive properties of composts because the types of antagonists are determined largely by the microflora present at the composting site.

Disease Suppression with Composts

Research results indicate that topdressing applications of compost-based organic fertilizers can suppress turfgrass diseases. For example, monthly applications of top-dressings composed of as little as 10 lbs/1,000 sq ft of suppressive compost effectively suppressed dollar spot (fig. 2), brown patch, gray snow mold, and red thread (table 3). Reductions in the severity and

Fig. 2. Biological suppression of dollar spot on a creeping bentgrass/annual bluegrass putting green 32 days after application of selected composts and organic fertilizers: **A,** the plot on the left was untreated while the one on the right was treated with approximately 10 lbs/1,000 sq ft of an organic fertilizer. **B,** the plot on the bottom was untreated while the one on the top was treated with a poultry litter/cow manure compost mixture at the rate of approximately 10 lbs/1,000 sq ft.

incidence of pythium blight, pythium root rot, and necrotic ringspot have also been observed in sites receiving continuous applications of composts.

Additionally, heavy applications of composts (approximately 200 lbs/1,000 sq ft) to putting greens in late fall are effective not only in suppressing winter diseases such as gray snow mold but in protecting putting surfaces from winter ice and freezing damage. Of particular benefit is the season-long effect of late-fall compost applications on root-rotting soil pathogens. Populations of soilborne *Pythium* species are generally not suppressed following traditional chemical fungicide applications but are substantially reduced during the season following heavy, late-fall applications of some composts (fig. 3).

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 they control. These variations result from differences in the mechanisms of disease suppression and from the microbial variability among different composts. Similarly, differences in disease suppression may also result from the microbial variability in organic matter at different stages of decomposition. Although microbial activity is known to be necessary for disease suppression in composts, the specific nature of this property is generally unknown.

The use of disease-suppressive topdressings is now widely accepted by turfgrass managers as an acceptable strategy for managing some turfgrass diseases. In some cases, the use of suppressive topdressings has resulted in reductions in fungicide use. Many composted materials and organic fertilizers can be purchased in garden centers. Others are available from municipal waste treatment facilities. Research has shown that the use of composts and organic fertilizers for turfgrass disease control is economically and technologically practical and that they can control diseases as effectively as fungicides (table 4).

Disease Control with Suppressive Soils

Most soils vary in their ability to support plant disease development. Those soils in which a pathogen cannot establish, persist, or cause disease despite the presence of an adequate population are called suppressive soils. As in composts, the microbial activity in these soils is responsible, in most cases, for their disease-suppressive properties. Many of the microorganisms responsible for making soils disease suppressive are in the genera of bacteria and fungi previously listed.

Some suppressive soils have been used to control turfgrass diseases in the same way composts and organic fertilizers have been used. In greenhouse experiments, a topdressing application of as little as

Table 3. Turfgrass diseases for which composts have been suppressive

Disease (Pathogen)	Mode of Application	Turfgrasses
Gray snow mold (*Typhula* spp.)	heavy fall applications topdressings	creeping bentgrass/annual bluegrass
Pythium blight (*Pythium aphanidermatum*)	topdressings	perennial ryegrass
Dollar spot (*Lanzia*, *Moellerodiscus* spp.)	topdressings	creeping bentgrass/annual bluegrass
Brown patch (*Rhizoctonia solani*)	topdressings	creeping bentgrass/annual bluegrass
Red thread (*Laetisaria fuciformis*)	topdressings	perennial ryegrass
Summer patch (*Magneporthe poae*)	topdressings	Kentucky bluegrass annual bluegrass
Necrotic ringspot (*Leptosphaeria korrae*)	topdressings	Kentucky bluegrass
Pythium root rot (*Pythium graminicola*)	heavy fall applications topdressings	creeping bentgrass/annual bluegrass

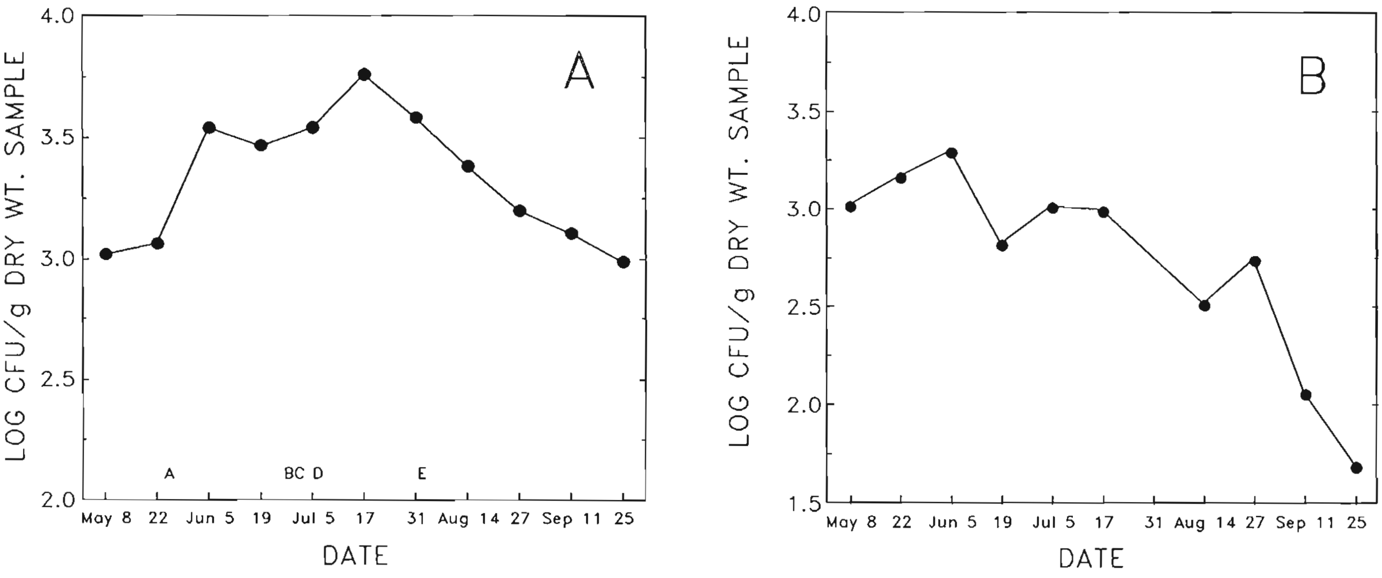

Fig. 3. Populations of soilborne *Pythium* spp. in a creeping bentgrass/annual bluegrass putting green: **A,** populations of *P. graminicola/P. torulosum* in a green receiving standard management inputs. The letters A, B, C, D, and E indicate various pesticide applications: A = propamocarb, 3 oz/1,000 sq ft; B = fosetyl A1, 4 oz/1,000 sq ft; C = propiconazole, 2 oz/1,000 sq ft; D = isophenphos, 3 oz/1,000 sq ft; and E = chlorothalonil, 6 oz/1,000 sq ft. **B,** populations of *P. graminicola/P. torulosum* in a green receiving no pesticide applications. The green received compost applications during the previous two years.

Table 4. Biological suppression of dollar spot, brown patch, red thread, and gray snow mold with compost-amended topdressings

Treatments	Dollar Spot Spots/Plot	Brown Patch % Plot Area Diseased	Red Thread % Plot Area Diseased	Gray Snow Mold % Plot Area Diseased
Untreated	19.8	72	47	33
Banner (fungicide check)	0.6*	8*	–	28
Ringer "Compost Plus"	5.2*	18*	20	55
Ringer "Greens Restore"	6.8*	24*	43	45
Sustane (poultry litter compost)	13.8	18*	10*	28
Endicott Sludge Compost	13.0	42*	40	10*
IPS Cow Manure Compost	16.9	54	43	23
Baltimore Sludge Compost	17.3	60	23	–
Peat	17.4	50	37	–
AB Brewery Compost	17.8	54	30	10*
Endicott Leaf Compost	18.0	44*	53	–
MH Manure Compost	20.2	72	53	15*
Autoclaved cornmeal sand	21.0	–	–	–
Schenectady Sludge Compost	21.4	66	57	–
Spent Mushroom Compost	21.8	54	53	–

* Numbers are significantly (p=0.05) different from the untreated check.

5 mm of a suppressive soil completely controlled take-all patch (*Gaeumannomyces graminis* var. *avenae*) on creeping bentgrass turf. Although disease suppression is a result of the complex microflora present, bacteria in the genus *Pseudomonas* and fungi in the genus *Phialophora* isolated from that soil are particularly effective in suppressing take-all patch.

Need for Predictably Suppressive Composts

Turfgrass managers and compost producers agree that the future success of suppressive composts in commercial turfgrass management depends on the ability of producers to provide material with predictable levels of disease control. Gross variations from year to year and batch to batch in various locations will not be tolerated by end users, who need assurance that composts used specifically for disease control will work every time in every location. Unfortunately, we do not yet know how to predict the suppressive activity of certain composts from year to year and batch to batch without testing them in field situations.

Although we know microbial activity is necessary for disease suppression in most composts, we don't know what specific microorganisms are involved. The identification in composts of specific organisms with biological control activity is a key to understanding how composts suppress diseases. This knowledge has been important, for example, in developing hardwood bark composts for the production of container-grown ornamentals.

Several aspects of the ecology of compost-inhabiting antagonists in turfgrasses will be important in developing more effective biological control strategies with compost-based organic fertilizers. For example, antagonists must be able to establish and survive in turfgrass ecosystems for biological control to occur. The interactions of antagonists with other soil organisms and with the soil and plant factors that affect biological control will also be important. In addition, antagonists may serve as indicators to determine how long a material should be composted before it can suppress disease.

Research aimed at understanding the fate of antagonists in soils and on plants following compost applications will help us understand why composts fail at certain times and in certain locations but not in others. Such research should also help us predict the compatibility of composts and their antagonists with other pesticides and cultural practices commonly used in turf management.

As a means of making composts more predictably disease suppressive, it may be possible to introduce antagonistic organisms with known biological control properties into composting materials at key stages in the curing process. This would enable compost producers to certify that their product will suppress the appropriate target diseases.

In the past few years, many composts and organic fertilizers have become available. Although some are properly composted and formulated and of high quality, others are not. In the past, quality control was of little concern when composts were used primarily as fertilizers. For disease management, however, quality control is extremely important. Organic materials that are improperly composted can be extremely phytotoxic, and some can even enhance the development of diseases. These facts, in conjunction with recent reports of control failures of some apparently suppressive composts, point out the importance of understanding the microbiology of disease-suppressive composts.

Use of Microbial Fungicides

Microbial fungicides are preparations of living microorganisms that inhibit fungal plant pathogens by acting as competitors for nutrients, as fungal parasites, or as producers of fungicidal compounds such as antibiotics. Some microorganisms alter the plant so that it is less susceptible to infection.

Just as some soil microorganisms produce medically important antibiotics, so do similar soil microorganisms produce antibiotics that are effective in treating plant infections.

In the development and use of microbial fungicides, we try to take advantage of the beneficial microorganisms commonly found in nature. We isolate them from the environment, usually from soil or plant tissue, increase their populations artificially, improve their activity culturally or genetically in the laboratory, and then put them back into the environment as a pesticide.

Careful consideration must be given to the storage and application of microbial fungicides. The shelf life of microbial fungicides is a particular concern because the organisms may not remain viable for extended periods. In addition, for microbial fungicides to be effective, the organisms present must be able to establish and remain active throughout the period when disease pressure is greatest. The organisms also must be compatible with other agrichemicals being used. For example, bacterial preparations will generally be tolerant of most chemical fungicides used in management programs, but fungal preparations may not.

In the past couple of decades, it has become apparent that the use of microbial fungicides has limitations, primarily because we are trying to manipulate living organisms instead of synthetic chemicals. Through their continued evaluation in agronomic and horticultural systems, however, it has become evident that microbial fungicides have a very important place in commercial plant production and offer important alternatives for plant health management.

Biofungicides can provide levels of disease control that, in many cases, facilitate reduced applications of chemical fungicides and, in a few cases, eliminate the need for fungicide applications altogether. They also are a potentially important tool in managing fungicide resistance among pathogen populations, a problem with many of the newer systemic fungicides on the market today.

The success of sustainable plant production depends largely on the integration of biological and other nonchemical controls into disease management strategies. Recent developments in integrated pest management (IPM) are a direct result of the awareness of the importance of biological controls in holistic approaches to plant health management.

Development and Use of Microbial Fungicides in the United States.

A commercial microbial fungicide must have the following attributes if it is to succeed in the marketplace:

1. It must perform consistently with superior levels of disease control.
2. Its suppressive effect must be persistent.
3. It must be safe for humans to handle and apply.
4. It must have a reasonable shelf life.
5. It must be acceptable to environmentalists and regulatory agencies.
6. It must be easy and cheap to produce.
7. It should be able to be applied with existing technology and equipment.

Turfgrass production and maintenance in the United States can provide a market of sufficient size to justify the development of microbial fungicides for turf. Although research conducted in both the public and the private sectors will eventually provide us with the information needed to develop effective microbial fungicides for turf, regulatory constraints, as in the past, may impede development, particularly of those preparations based on nonindigenous microorganisms.

Interest in the biological control of plant diseases first arose in the 1920s. Only in the last few years, however, have traditional chemical pesticide producers become interested in developing microbial fungicides for turf. Similarly, more research at various universities around the country is now being directed toward the discovery and use of microbial antagonists for turfgrass disease control.

As our knowledge of the types, nature, and ecology of microbial antagonists active against turfgrass pathogens increases, it is likely that microbial turfgrass fungicides will soon be available on a commercial scale (see insert).

For the most up-to-date information on specific products, consult your local Cornell Cooperative Extension association.

Microbial Fungicides for Turf

Although the biological control of turfgrass diseases is still in the development stages, research on the use of microbial fungicides for turf disease control has been promising. Results of laboratory and greenhouse studies have shown that antagonists can suppress pythium blight caused by *Pythium aphanidermatum* (figs. 4 and 5), brown patch caused by *Rhizoctonia solani,* and take-all patch caused by *Gaeumannomyces graminis* var. *avenae.*

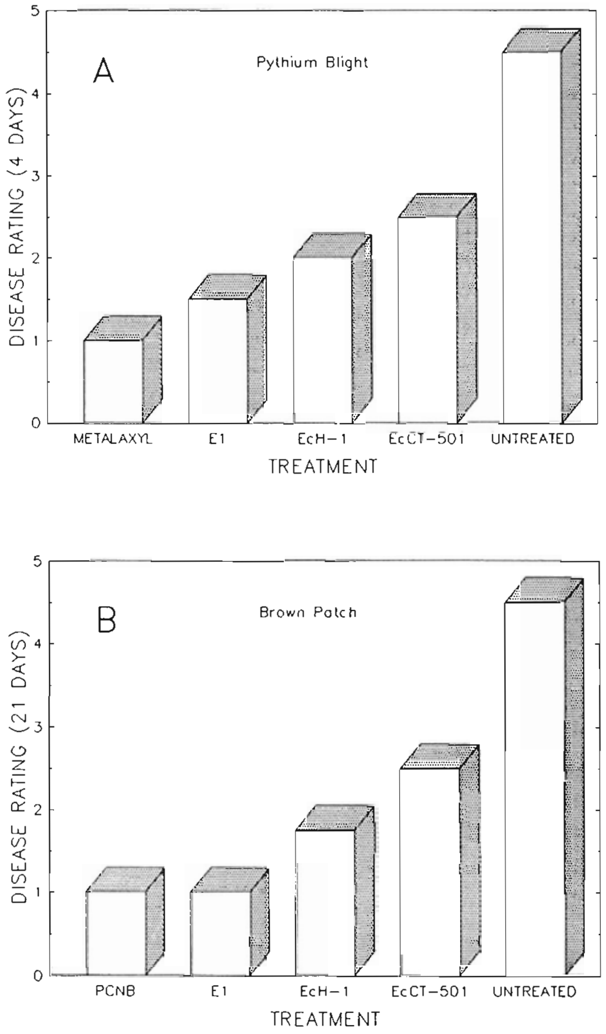

Fig. 4. Effect of various strains of the bacterium *Enterobacter cloacae* and fungicides on the suppression of pythium blight (A) and brown patch (B) on creeping bentgrass (Penncross) under controlled environmental conditions. Disease severity was rated on a scale of 1 to 5 where 1 = no foliar blight and 5 = 100% foliar blight.

Table 5. Comparison of biological and chemical suppression of dollar spot on creeping bentgrass with *Enterobacter cloacae* (EcCT-501) and the fungicide propiconazole

Treatment	Rating 1[1]		Rating 2[1]	
	Spots per Plot	% Control	Spots per Plot	% Control
Untreated	3.4 a	0.0	19.8 a	0.0
Propiconazole[2]	1.4 c	58.8	0.6 b	97.0
E. cloacae (EcCT-501)[3]	2.2 b	35.3	8.6 b	56.5
Autoclaved cornmeal (Carrier)[4]	3.6 a	0.0	21.0 a	0.0

Numbers followed by the same letter are not significantly different (*p*=0.05).

[1] Rating 1 (June 26, 1989) 30 days after the first application. Rating 2 (July 19, 1989) 23 days after the second application.
[2] Propiconazole (Banner) applied at the rate of 174 mg a.i./sq m (4 oz/1,000 sq ft) as a fungicide check
[3] Cornmeal-sand preparations of EcCT-501 applied at monthly intervals. Recoverable populations at the time of application were approximately 10^9 cells/g dry wt. thatch.
[4] Cornmeal-sand mixture consisted of 70% fine sand and 30% cornmeal (v/v) and was used as a carrier for *E. cloacae*.

Fig. 5. Laboratory screening of bacterial strains for the biological control of pythium blight. Each row of four wells was inoculated with a different bacterial strain. Rows of healthy grass indicate effective biological control.

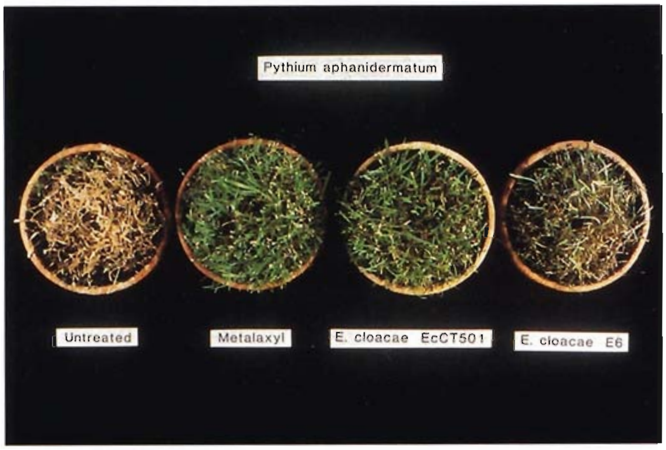

Fig. 6. Suppression of pythium blight on creeping bentgrass (Penncross) by *Enterobacter cloacae* and the fungicide Subdue under growth chamber conditions

In field studies, applying preparations of *Typhula phacorrhiza* to creeping bentgrass swards provided up to 74 percent control of gray snow mold caused by *Typhula incarnata* and *T. ishikariensis*. Similarly, isolates of binucleate *Rhizoctonia* spp. and *Laetisaria arvalis* provided up to 90 percent control of brown patch on creeping bentgrass putting greens. Isolates of *Gliocladium virens* suppressed dollar spot on bermudagrass. Strains of the bacterium *Enterobacter cloacae* were effective in suppressing dollar spot activity in the field (table 5) as well as pythium blight (*P. aphanidermatum*) (figs. 4 and 6) and brown patch in greenhouse trials.

Additionally, our research has shown that individual microorganisms, when applied at the proper time and in an appropriate manner, can establish large populations in bentgrass putting greens (fig. 7) and can be as effective as chemical fungicides in controlling turfgrass diseases.

Recent developments in molecular biology have tremendously increased our ability to gain a better understanding of how antagonists function and how they interact with other turfgrass management strategies. As a result, we have learned how we can manipulate antagonists to perform certain tasks. For example, we now have the potential to introduce and establish antagonists on specific plant parts or in specific ecosystems. We also have the techniques to identify the genes conferring biological control activity and the ability to understand the interaction of introduced antagonists with the environment.

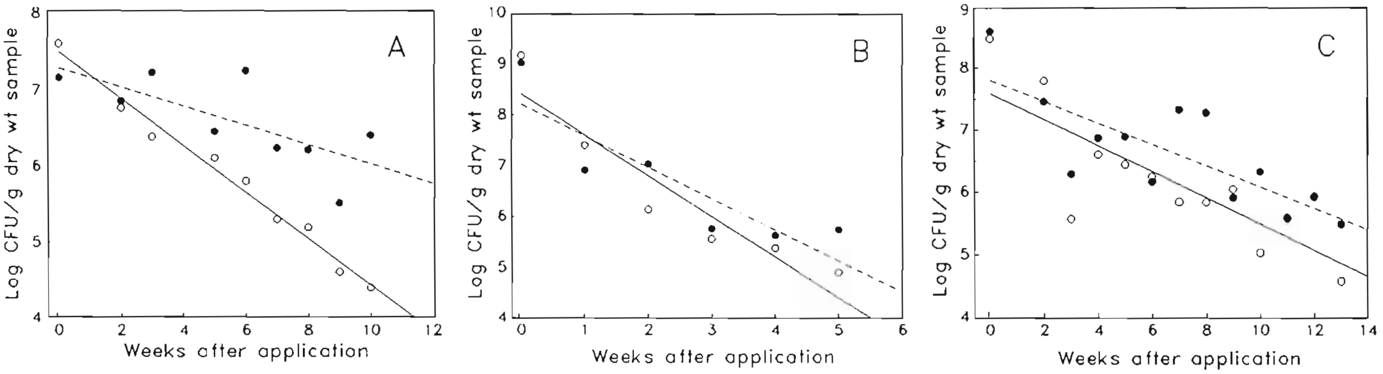

Fig. 7. Population dynamics of introduced strains of *Enterobacter cloacae* in a creeping bentgrass/annual bluegrass putting green: **A,** spring application (1988) of strains E6-R8 (-●-) and E1-R6 (—○—); **B,** fall application (1988) of E6-R8 and E1-R6; **C,** spring application (1989) of strains EcCT-501-R3 (-●-) and EcH-1-R8 (—○—).

Undoubtedly, advances in the molecular biology of microbial antagonists have made the biological control of fungal plant pathogens more a reality today than it was just a few years ago. Future developments in the use of microbial fungicides for turf depend on similar gains in our understanding of the biology of antagonists.

Future Perspectives

More emphasis than ever before is being placed on environmental protection, and people are expressing increased concern about unnecessary exposure to pesticides and other environmental pollutants. In response, pressure is being placed on state and federal agencies to institute legislation to help regulate the indiscriminate use of pesticides. At the same time, alternative disease control strategies are in much greater demand to reduce or eliminate the need for environmentally hazardous pesticides.

Golf course superintendents, lawn care companies, landscapers, sod producers, and even homeowners are being asked to use pesticides more judiciously than in the past. There could therefore be no better time than the present to encourage the development of biological controls for turfgrass diseases.

The potential of composts to suppress turfgrass diseases is clear. At present, applications of these materials are the best alternatives to the use of fungicides on turfgrass sites, and perhaps in the long term, they provide the only means of eradicating pathogens from turfgrass plantings. As we learn more about composting and the benefits of composted materials on plant health, there will undoubtedly be a greater demand from turfgrass managers for high-quality composts.

Composted products for use in turfgrass applications are becoming available at an ever-increasing rate. Compost producers are committed to providing the highest quality materials to turfgrass managers at a cost far below that of traditional fungicides. In addition to providing effective disease control, the use of composts will ease the burden on our nation's landfills and foster a commitment to sound environmental stewardship.

Because microbial pesticides are relatively new to the marketplace, it is not yet clear, particularly in the United States, how well they will compete with chemical fungicides and whether they will 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 they will be effective enough to either replace or augment traditional fungicides. If microbial fungicides are to find their way into the marketplace and gain widespread acceptance, it is critical that the initial products consistently perform as well as or better than conventional fungicides.

Biological control is at the verge of a new era of discovery and commercialization. We believe that the benefits of biological controls, once realized, will overcome the impediments to their development and that biological controls will ultimately change the way turfgrass disease control is approached.

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