A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TurfGrass TRENDS

Volume 5, Issue 5

May 1996

IN THIS ISSUE

Multiple Considerations in Turfgrass and Landscape Pest Management

by Michael G. Villani
Cornell University

Lawns in the United States occupy an area estimated at between 25 million and 30 million acres (10.1 million and 12.2 million hectares), 50,000 sq. miles, or roughly the size of the five New England states. Approximately 50% of these properties receive pesticide applications by homeowners who the last time such data were gathered were estimated to be spending over $688 million on pesticides and fertilizers (Lawn Care Industry, 1985). Pesticides are also applied to approximately 10-20% of residential properties by the professional lawn care industry. Golf courses, athletic fields and parks planted to turfgrass are becoming an increasingly important part of American recreational activities.

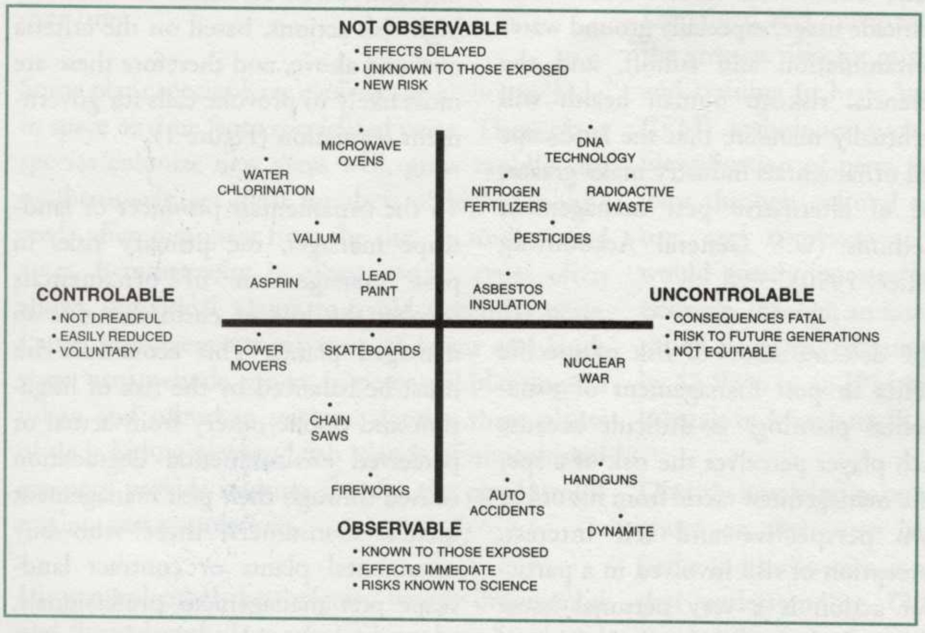

Figure 1 — **Adapted from Morgan 1993**

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TurfGrass TRENDS
1775 T Street NW
Washington, DC 20009-7124
Phone: 202-483-TURF
Fax: 202-483-5797

76517.2451 @ CompuServe.com

Abstracts: 800-466-8443 TGIF

Reprint Permission: 202-483-TURF

TurfGrass TRENDS is published monthly. ISSN 1076-7207. The annual subscription price is $180.00.

Golf courses are the most intensive users of turf pesticides on a per acre basis. Golf course superintendents are highly trained turfgrass managers, but rely heavily on pesticides to insure high quality playing surfaces. Between professional turfgrass management and homeowner lawn care, turf maintenance has become a $25,000,000,000 industry in the United States (Gibb & Buhler 1995).

Assessing the risks

Historically, insecticides, fungicides and herbicides have been the major control tactic used against insect, pathogen and weed pests of ornamental plantings. However, because many of the plants attacked by these pests are grown in urban or suburban areas (golf courses, parks, home lawns and gardens, landscaping around commercial buildings), the potential for human exposure to pesticides directly through application or indirectly through environmental contamination is considerable. Growing concerns about the hazards of urban pesticide usage, especially ground water contamination and runoff, and the potential risk to human health will eventually mandate that the landscape and ornamentals industry make greater use of alternative pest management methods (U.S General Accounting Office, 1990).

The determination of risk of specific tactics in pest management of ornamental plantings is difficult because each player perceives the risk of a specific management tactic from his or her own perspective and self interest. Perception of risk involved in a particular action is a very personal issue. Although the actual danger or 'risk' of an activity such as being struck by lightning, drowning while surfing, or being poisoned by an insecticide on a golf course may be analytically determined (the probability of an action occurring in chances per million) (see Kenna, USGA Grounds Record, July/August 1995), the public may not define risk solely as the number of deaths or injuries per unit time (according to M. Granger Morgan 1993). For example, the actual risk of any individual being killed in a nuclear war is extremely small, but this is clearly a risk few are willing to take. Instead, the risks associated with some action are ranked by the public based on a number of quite reasonable criteria, only one of which is the probability of being harmed by that action. These additional risk factors include: how well the action being considered is understood; how equitably the danger is distributed; how well individuals can control their exposure; and whether risk is assumed voluntarily. Morgan suggests that the public perceives the development of DNA technology, the use of pesticides, and the application of nitrogen based fertilizers as relatively high risk actions, based on the criteria outlined above, and therefore these are most likely to provoke calls for government regulation (Figure 1).

To the ornamentals producer or landscape manager, the primary risks in pest management of ornamentals involve the loss of customers due to damaged plants. This economic risk must be balanced by the risk of litigation and public outcry from actual or perceived environmental degradation caused through their pest management tactics. Consumers, those who buy ornamental plants or contract landscape pest management professionals, must weigh the risk of plant loss on the one hand with the exposure to potentially harmful pest control products on the other. They must also consider the impact of the use of specific management tactics on their neighbors and the reaction of their neighbors to those decisions. Finally, public administrators, guided by public opinion, must weigh the associated risks to the public at large. The public is passively exposed to pest management tactics, yet receive little direct benefits for assuming those risks.

Where do all the pests come from?

Over time, plants have evolved a wide array of biochemical, mechanical and ecological traits that help protect them against injury from pests. However, traditional ornamental breeding programs have generally focused on enhancing agronomic characteristics such as growth patterns, flowering, or tolerance of environmental stresses such as drought. As a result, plant characteristics that contributed to resistance against pests have been lost or diluted over time through benign neglect. We have stripped the natural armor off ornamental plantings, making them vulnerable to attacks by insects, plant pathogens and weeds. In many cases, the addition of pesticides into horticultural systems represents our feeble attempt to replace the protection factors we have inadvertently bred out of our ornamentals over time.

Some plant species have evolved the ability to 'hide' in space or time from specialized pests. These plant species colonize new areas well, grow rapidly and unobtrusively, set great numbers of highly mobile seeds, then disappear from the site. In undisturbed areas, heterogeneity in plant species types often allows individual plants to avoid potential pests. Large, homogeneous expanses of lawns and landscape ornamentals, grown in perennial plantings in urban and suburban settings, deprive these plants of their hiding places. Lush islands of unprotected greenery provide inviting sites for the rapid proliferation pest populations.

Large numbers of the turfgrass, woody ornamental and floricultural plant species have been imported from other lands. Many of the insects, weeds and pathogens that are important pests of ornamentals were carried over with these exotic plants, often without their associated predators, parasites and pathogens. Freed from their natural control agents, these pests soon spread unchecked, causing extreme feeding damage to plants. Over time, endemic beneficial organisms often reduce pest populations, but in other situations, researchers must travel to the home of the pests to find and import specific predators, parasites or pathogens to control these introduced pests.

Integrated Pest Management

What is IPM?

IPM is an approach that utilizes all suitable technologies in a compatible manner to maintain pest densities below levels causing unacceptable damage. Pest management strategies will differ depending upon the value of planting, the degree of damage deemed acceptable by growers or consumers, and the conditions under which the ornamentals are grown.

Educating the public

Untrained and unregulated consumers pose one of the greatest risks for misuse of pesticides. Awareness and training in basic Integrated Pest Management (IPM) techniques such as detection and proper identification of pests, minimization of pest problems through cultural means, optimized pesticide use, and employment of chemical alternatives would greatly increase consumer awareness. As an example, through an intensive and appropriate education program, consumer awareness was increased by 45-83% in an IPM program on landscape ornamentals in Maryland (Raupp et al. 1989).

Directly involving consumers in practical IPM programs on their own lawn, and at local schools, parks and businesses, is an excellent way to provide that understanding. One public group that has expressed a strong interest in alternative to turfgrass pesticides is local school districts. In New York State, extensive educational efforts since the mid 1980's have trained golf course personnel in the use of IPM techniques. In addition, intensive State-sponsored pilot programs have demonstrated the feasibility of applying these techniques, resulting in pesticide reductions of up to 65%. Currently, over 25 golf courses are involved in these programs in three focal areas of the state.

Although landscape management professionals have more training in pest control than the average homeowner, pesticide use would be reduced if an intensified IPM training program were developed for this audience. The problem is exacerbated by the fact that many lawn care companies have traditionally based fees on pre-scheduled pesticide applications. As public environmental concerns increase, and pollution regulations grow, those companies adopting an IPM approach will survive and prosper. IPM-specialized professionals who detect and identify pest problems, rather than simply apply pesticides, can greatly expand the market for alternative landscape management.

Current industry sentiments are reflected by local landscape companies whose interest precipitated research on sampling for grubs in New York lawns. These companies felt that consumer pressure warranted development of appropriate IPM techniques, and that these techniques made commercial sense.

What are the essentials of an IPM Program?

(adapted from Ferrentino et al., 1993)

A. Scouting

"Scouting" is the process of systematically looking at plant health and monitoring for pests and their symptoms. Turf scouting provides important pest information, which can be used to determine the need for pest control actions. As a result, pesticides are used only when necessary to preserve quality, at the optimal time in the pest life cycle, and can be optimally selected based on site specific knowledge. Scouting information is even more essential when using alternatives to chemical pesticides, such as cultural and biological controls. Residential scouting procedures can be readily adapted from existing procedures for golf course turf in New York State, and from scouting programs in other states. A well integrated, grower supported scouting program for pests of poinsettias in greenhouses has been developed and implemented through the efforts of the New York IPM Ornamentals Program. This program couples scouting of poinsettias for arthropods (whiteflies, mealybugs, fungus gnats, spider mites), diseases (powdery mildew, pythium, phytophora, rhizoctonia, botrytis, scab,) and weeds with recommendations for appropriate control measures should pest populations rise above economic injury levels.

B. Pest identification

Accurate identification and knowledge of insect, mite, disease and weed pests enables the grower to select an appropriate, pest-specific management strategy. It is important to know the major pests that are likely to appear, where to look for them, and how to identify them. With IPM it is necessary to understand the biology of a pest and its interaction with other organisms and the environment. Identification can be accomplished by a professional scout, by the grower or consumer, by county extension personnel, or in difficult cases by public or private diagnostic laboratories.

C. Records keeping

Brief, concise and accurate information recorded on a data sheet is the best tool available to make a diagnosis or decision. IPM programs rely on records to make field recommendations. When program evaluations and future plans are developed, field records and data analysis are priceless.

D. Appropriate intervention technology

There are many possible pest management tactics that may be appropriate for controlling the pest complex in ornamental plantings. Pest management technologies must be developed that improve individual management tactics and optimize the integration of various techniques. Although some control technologies fit more comfortably into an integrated management program than do others, there are no technologies that must be dismissed out of hand as incompatible with an IPM philosophy.

Ornamental pest management tactics

Host plant resistance

Resistance of plants to pests is the property that enables a plant to avoid, tolerate, or recover from injury by pest populations that would cause greater damage to other plants of the same species under similar environmental conditions. There has been considerable progress in the identification of ornamental cultivars that show increased tolerance to insect feeding damage and decreased susceptibility to plant diseases. In most of these instances, this increased level of pest tolerance has not been the focus of a directed breeding program, but was instead a fortunate by-product of the breeding of agronomically important traits. Traditional and molecular ornamental breeding programs are now focusing on pest-related issues, a primary objective in cultivar improvement. Advances in genetic engineering make the insertion of Bt and protease inhibitor genes into ornamental cultivars for insect control technically feasible.

Complex plantings

The trend towards large monoculture systems with low intra-cultivar genetic variability has been cited as a cause for rapid build up of large pest populations. Complex landscapes, where many types of plants are grown on the same piece of land, has been suggested as a tactic to lessen plant injury. Mixtures of ornamental plants in landscapes and mixtures of grass varieties on lawns, each with its own level of tolerance and susceptibility to pest problems, will often reduce overall pest impact in an area.

Cultural practices

Factors such as plant species, fertilization application rate and timing, mowing height, and irrigation can greatly affect pest population numbers.Temperature, relative humidity, irrigation and light may be manipulated to provide conditions unfavorable to plant disease. Conversely, improper environmental management may exacerbate disease problems. Environmental factors that give a competitive advantage to desirable plants over undesirable species will decrease weed problems. Additionally, healthy ornamentals and turfgrass should be more tolerant of moderate levels of insect feeding injury than those stressed by insufficient nutrients and water.

The time of planting or harvesting of a horticultural crop to avoid specific pest problems is well understood by growers and landscape managers. Plants taken from greenhouses in early spring, before the flight of Oriental beetle females, will prevent infestation of these plants by beetle grubs and avoid the need to treat the crop before shipment. Starting a new lawn in the fall rather than in the spring will greatly reduce possibility of weed infestations, because most annual weed seeds germinate in early spring.

Protection, encouragement and introduction of natural enemies

A large number of turfgrass, woody ornamentals and floriculture plantings have been imported from other lands. Many of the insects and weeds and some of the pathogens that are important pests of ornamentals were carried here with these exotic plants. Freed from their natural control agents these pests soon spread unchecked, causing extreme feeding damage to plants. Over time, endemic beneficial organisms often reduce pest populations, but in other situations, researchers must travel to the homes of the pests to find and import specific predators, parasites or pathogens to control the introduced pest. Japanese beetles colonizing a new territory will typically follow a pattern of several years of population build-up, followed by a reduction to levels commonly found in established areas. This suggests that natural biotic factors are reducing and stabilizing the population. Due to the constraints governing the use of naturally occurring biological control agents, considerable efforts have been directed to the introduction of predators and parasites isolated in geographic regions from which the exotic pest species originated.

Microbial pathogens, plant pathogen antagonists, and entomogenous nematodes

Insect pathogens that have been observed in nature to decimate pest populations can be encouraged through proper manipulation of the environment or through inundative release of laboratory-reared infective stages. Augmenting the natural levels of the Milky disease pathogen (Bacillus popilliae) to control Japanese beetle, first attempted by White and Dutky in the 1930's, continues to be an effective long term management option in many regions. Epizootics caused by endemic fungal and bacterial pathogens have also been reported for many other insect pest species. Entomogenous nematodes are potentially useful in the management of a wide number of ornamental insect pests. The most promising use of entomogenous nematodes is against soil insects; in the soil, nematodes are protected from desiccation, ultraviolet radiation and temperature extremes. Increased knowledge concerning nematode biology and mass-rearing techniques for entomogenous nematodes has led to increased research in recent years.

Biological control of root pathogens may be achieved through the addition of 'antagonist' microorganisms found in composts or through the manipulation of antagonists already present in soils and on plant parts. The goal in either case is to reduce or eliminate pathogen activity by parasitizing pathogen proprogules and mycelium (Trichoderma), producing antibiotics inhibitory to pathogen growth and development (Pseudomonas), or out-competing plant pathogens for growing space on roots, or for nutrients (Enterobacter) (Smiley et al. 1992).

Exclusion

Physical barriers to pests are a "low-tech" but effective weapon in reducing pest problems. Proper screening of greenhouses can greatly reduce insect pests, while weeds are often a problem in turfgrass, where disease, arthropods or construction has opened an area for weed establishment. Mulches and geotextiles are established tools for excluding weeds and soil insects from ornamental plantings.

Trapping and monitoring

Chemical attractants or arrestants may lure insects from their hosts, thereby lowering the number of insects feeding on plants. These chemicals, alone or in traps, may be used in conjunction with insecticides as baits to attract feeding stages, thereby increasing the effectiveness of the insecticides and potentially lowering the application rates.

Pheromones, black lights, food lures and trap crops may also be used to reduce or to monitor adult populations. Special circumstances may improve the efficacy of trapping strategies. For example, pheromone trapping may be effective against the Oriental beetle because the majority of males emerge before females and may be trapped without female competition. A major effort has been instituted to develop chemicals attractive to adult scarab beetles and black cutworms as tools for monitoring pest populations.

Pesticides

The use of pesticides is often the corner stone of pest management programs. Historically, pesticides were often considered the first line of defense against plant pests. Concerns about the hazards of urban pesticide usage have mandated that the landscape and ornamentals industry make greater use of alternative pest management methods. However, the prudent use of effective pesticides, often as the tactic of last resort, is the safety net of control that permits the practice of the more benign tactics of an integrated pest management program.

Effective long-term control of insects was achieved with organochlorine insecticides. Less effective control has been achieved with the organophosphate and carbamate insecticides that replaced them. Many factors, including soil pH, organic matter, moisture, thatch and microbial degradation of insecticides influence the efficacy of currently registered insecticides. Resistance to organophosphate insecticides and miticides has been documented in many instances.

Weeds can be removed from the environment only through physical removal (often reasonable if small areas are affected) or through the application of pre or post emergence herbicides. Such factors as the herbicides' impact on target weed species, secondary weed species present and non-target plant and animal species present are of primary concern. Product residual, leaching characteristics and costs will also determine the proper herbicide to be used. Pesticides that control plant diseases include fungicides, nematicides and fumigants. Fungicides are formulated to kill certain groups of plant pathogens, or temporarily render them incapable of growth. Nematicides generally kill plant parasitic nematodes, plus some insects and other soil fauna; and fumigants are highly toxic gases that kill all living entities, including weed seeds, insects and nematodes (Smiley et al 1992).

Quarantines

Exotic pests that are potentially damaging or difficult to control are often best managed by reducing the chance of their introduction into uninfested areas. Quarantine efforts may be based on predicted spread of the pest into new areas. This is derived from a knowledge of the physiological ecology of the pest, including overwintering requirements and host range and movement behavior.

Dr. Michael G. Villani is an Associate Professor of Soil Insect Ecology in the Department of Entomology at NYSAES/Cornell University. He has degrees from the State University of New York at Stony Brook and–in entomology–from North Carolina State University. Dr. Villani, who is active in both research and extension work, concentrates on the interrelationships between soil insects, their host plants, and the soil environment. His most recent contribution to *TurfGrass TRENDS* appeared in the September 1995 issue.

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The First Registered Biological Control Product for Turf Disease: Bio-Trek 22G

by G. E. Harman and C-T Lo
Cornell University

Diseases of golf green turfgrasses cause unsightly spots and discolorations that are undesirable and unacceptable to golf course managers and the golfing public. The development of highly effective turfgrass fungicides has revolutionized disease management of turf, especially on golf courses. However, high levels of fungicides are required. Fungicide usage on golf courses, and greens especially, is probably the most intense large-scale application per unit area in the US. Fungicide sales are about $400 million annually in the United States, and about $100 million is spent on turf applications, with 90% of this used on golf courses.

There are disadvantages to this heavy use. The most obvious of these is the frequent exposure of workers and users of managed turf areas to fungicides. In addition, there is the possibility for contamination of soil and water in and around golf courses and other areas of managed turf. This possibility of contamination is a matter of concern because much of the treated turf is in urban areas with high adjacent human populations. Wildlife may also be affected by contamination of soil or water.

In addition, a large and diverse population of soil microorganisms is important to plant health. Typically, populations of fungi and bacteria (including actinomycetes) predominate in soils. Generally, the greater the diversity and activity of these soil microorganisms, the greater the overall health and fertility of the soil. However, repeated fungicide applications can severely impair microbial diversity and activity in soils of golf courses and other intensively managed turf areas. In our preliminary studies, we found one area of golf course turf in which no fungi could be detected in soil or roots. This is very unusual, and aside from golf turf ecosystems we know of no other situation where such a drastic reduction in fungal populations has occurred. Specific undesirable consequences of this alteration of soil microflora are as follows:

- It is not uncommon (nearly 100 examples can be documented) to see increases in certain diseases following fungicide application for control of other disease This increase is due primarily to detrimental effects on nontarget organisms.

- In soils where fungicides have not been applied at high rates, the diverse microbial communities present frequently provide a substantial measure of biological control. The increase in disease noted in the preceding paragraph probably is due to destruction of nontarget beneficial microorganisms.

- Heavy fungicide use encourages the development of resistant populations of plant pathogens. There are numerous reports on the development of pathogen populations that are resistant to chemical fungicides, including cases where resistance was observed on golf courses. This would be expected given the heavy fungicide applications made to greens.

The development of Bio-Trek 22G

Clearly, alternatives to chemical pesticides are needed for turf disease management and other applications. The authors, in conjunction with Dr. E. B. Nelson, have been developing biological alternatives to chemical pesticides for turf disease management for several years, especially beneficial fungi in the genus Trichoderma. These fungi are present in nearly all soils and no doubt contribute to a lessening of disease where they occur. However, their numbers and physiological types are normally insufficient to give high levels of disease control.

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How can proper fungicide and fertility programs manage thatch accumulation?

Read about the accumulation of thatch as an inevitable fact of growing particular turfgrass species. However, thatch accumulation can be readily managed if proper care is exercised in fungicide and fertility programs. New biological approaches may offer exciting solutions.

What is the best way to handle root diseases such as summer patch, Pythium root rot and necrotic ringspot?

Learn about the importance of roots to turf quality and stress tolerance; energy partitioning in grass plants, factors governing root growth, like nitrogen fertility, light supply, shoot disease stress, drought effects. Management strategies to promote root growth are yours to make. We'll tell you about species and cultivar selection, mowing height, fertility and stress management, pest control, soil or root zone characteristics, biostimulants. We'll address the difference in root growth between warm-season and cool-season grasses.

To what extent can biological control of foliar diseases help you reduce dependency on fungicides?

Biological control is an exciting new area of turfgrass disease management offering an opportunity to reduce dependency on fungicides. New information and products are being developed that will revolutionize turfgrass disease control in the coming decades.

Do you fully understand the impacts of algae and other biotic problems?

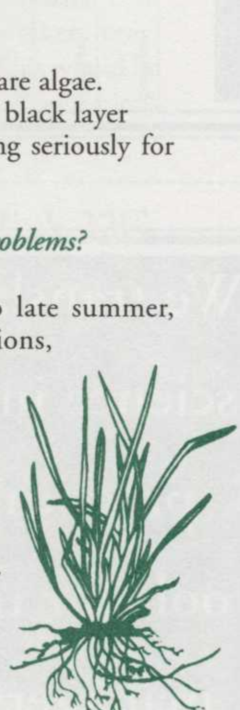
Among the more common yet least understood biotic problems affecting golf course turf are algae. A nuisance most times of the year, algae causes problems ranging from surface crusting to black layer to suspected turfgrass decline. The management of these pests is something worth taking seriously for optimum turfgrass health.

How can you diagnose Anthracnose and other major diseases before they become serious problems?

Once thought to be a problem of bluegrasses under warm temperatures of mid to late summer, Anthracnose has now become a major disease of golf course turf under cool wet conditions, affecting bentgrasses as often as other turfgrasses. Serious losses occured because of this disease last summer. Anthracnose is a particular problem because of the difficulty in diagnosis.

How can you maximize yellow nutsedge control while minimizing turf injury?

Begin treatments when weeds are young. Avoid applications during hot, dry weather. Calibrate the sprayer. Overdosing will decrease effectiveness. Due to long-term tuber viability, it may take five years or more to get this weed under control. Keep after it!



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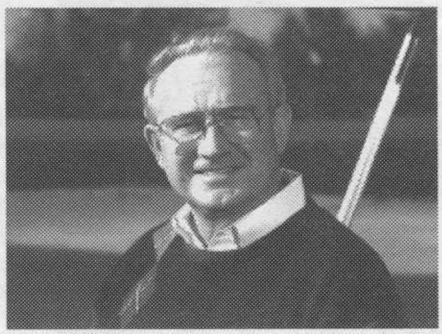

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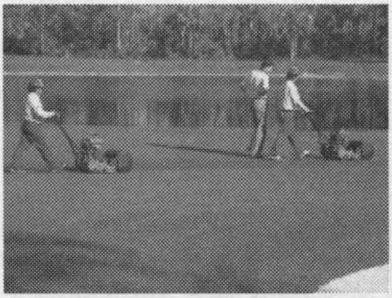
Golf Course Employee Training Topics



S-101A Greens Mowing Tips and Orientation

Covers basic greens mowing operations for both tri-plex and walk-behind greens mowers, from pre-start checks through clean-up. Explains how and why each procedure and step is performed on the green.

Includes: One 35-min. video tape, half tri-plex, half walk-behind
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines

S-102A The Knowledgeable Operator 1

Familiarizes employees with basic operation and safety procedures of ride-on maintenance equipment, including how to identify common malfunctions, what to do when they occur, and how to report them.

Includes: One 30-minute video tape
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines

S-108A The Knowledgeable Operator 2

Introduces employees to the basics of hand-held equipment, such as blowers, edgers, hedge clippers, string trimmers, brush cutters and "Flymo's". Beginning with pre-start inspections and fueling, through operation and safety basics.

Includes: One 30-minute video tape
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines

S-109A Crew Etiquette

Designed to promote a positive work ethic and a team atmosphere, this program details the basics of courtesy and toward golfers and co-workers in various situations.

Includes: One 22-minute video tape
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines

Golf Course Employee Training Topics

S-110A Safety Basics on the Golf Course

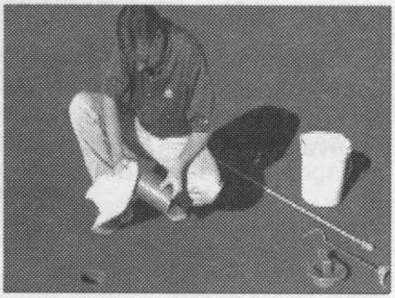
This program promotes taking personal responsibility for one's own safety, using a series of examples from the maintenance facility, on the course, with power equipment, and in the natural world.

Includes: One 26-minute video tape
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines

S-111A Basic Maintenance Procedures 1

Cup cutting, bunker maintenance and ball mark repair are the focus of this workshop. Covers in detail the how's and why's of these basic maintenance functions, appropriately for new and experienced crew members.

Includes: One 31-min. video tape, including mechanical and hand raking
18 employee training handbooks
18 employee tests, sign-off sheets
Instructor guidelines



S-115A This is a Golf Course (an introduction)

Introduces new employees to basic golf course terminology and how maintenance responsibilities on the course relate to the golfers game. Stresses responsibility and respect. Provides basic foundation upon which you can build formal training.

Includes: One 27-minute video tape
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Instructor guidelines

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Management Training Topics

S-106A Turf Restoration and Renovation

Innovative young superintendent, Paul B. Latshaw, shares an aggressive turf restoration program to quickly return damaged turf to top playing condition, even after severe winter kill or other disaster.

Includes: One 30-minute video tape
5 Workbooks

S-107A Training the Trainer

Gerry Sweda, noted golf industry training expert, shares tips for making the most of training, from selecting who should do the training, where and when, to follow-up and evaluation, plus how to build pride in a job well done.

Includes: One 40-minute video tape
10 Workbooks
20 Training worksheets

S-113A Environmental Stewardship

Project leaders from throughout the Pebble Beach Company discuss the evolution of a wide variety of environmental projects, from native plant seed collection to composting. Learn how these projects can be scaled to any size operation, and how they're ultimately good for business.

Includes: One 55-minute video tape
Fact sheet: How golf courses are good for the environment
Training materials: How to write a press release

S-116A Bringing Out the Best in the People You Manage

Noted GCSAA trainer, Gerry Sweda, shares secrets and practical tips for motivating employees to care as much about the quality of their work as you do.

Includes: One 48-minute video tape
5 Workbooks

Topics of Interest to Pro Shop *and* Maintenance

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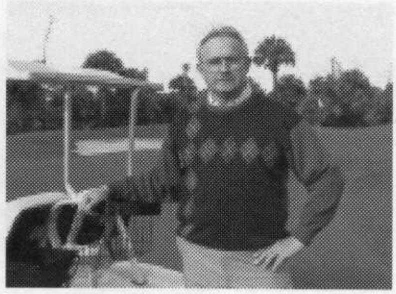

S-103A Golf Car Safety

Directed to golfers, this program also offers valuable tips for maintenance personnel, covering basic do's and don'ts of safe golf car operation, potential risks, and basic courtesy issues.

Incl:
- One 7-minute video tape for crew
- One 1-hour repeating tape for pro shop
- 5 8 1/2 x 11 Posters
- 100 Safety pamphlets
- Instructor guidelines

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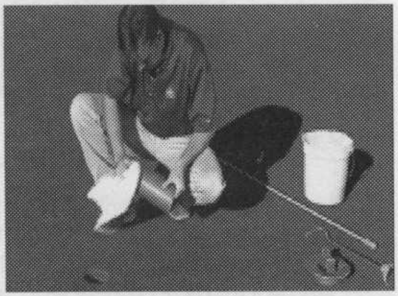

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Ross Kurcab, Denver Broncos, Denver, Colorado

About 10 years ago, we produced strain 1295-22 (also known as KRL-AG2) of *T. harzianum*, and this organism seemed to have a number of useful attributes. Not only did it have the ability to control disease when properly used, but it also was extremely efficient in colonizing roots. Once established on roots, it persisted for the lifetime of annual crops, and continued to colonize plant roots as they grew. Therefore, all parts of the root system were colonized. On perennial plants, such as turfgrass, the fungus survived on roots even over the cold winters of upstate New York. As a consequence, application of the fungus may substantially increase crop yield and increase root growth.

This fungus, and formulations based upon it, recently were registered with the US Environmental Protection Agency for plant disease control. It has received an exemption from tolerance for use on food crops, since toxicology testing has shown no observable toxic or pathogenic effects upon plants, mammals, or birds.

Products based on *Trichoderma harzianum* are manufactured by TGT Inc, Geneva, NY [Editor's note: no relation to *TurfGrass TRENDS* , which is frequently abbreviated "TGT"] and marketed for turf applications as Bio-Trek 22G by Wilbur-Ellis Co, Fresno, CA. Bio-Trek is the first EPA- registered biological disease control agent that is available commercially for turfgrass disease control in the United States.

The following is a description of tests and uses of Bio-Trek 22G, and an assessment of our expectations for future developments. It is also a story of the translation of basic biological findings at a university into commercial applications.

We first tested a granular formulation very similar to Bio-Trek 22G in 1990 and found that it reduced dollar spot incidence. Trials since that date in the Northeast, Midwest, and Far West have demonstrated continued efficacy. A critical aspect of this product's efficacy is the ability of *T. harzianum* to establish itself at effective levels on turfgrass roots. We expect that it can be established by one or two applications in the spring and that it will then persist over the following growing season. Data on establishment from our 1994 trials are given in Fig. 1. Two applications early in the year were sufficient to provide high levels of colonization of soil and creeping bentgrass roots that persisted at high levels throughout the year. We sampled this same area in August, 1995, and found *T. harzianum* at levels about 10 times higher than in adjacent turf areas. This indicates survival times of the

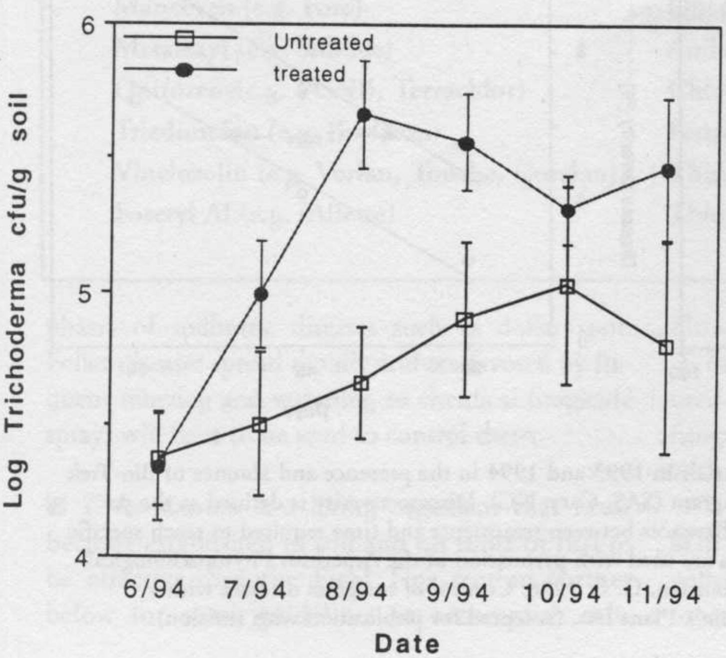

Fig. 1. Colonization of roots and soil of creeping bentgrass in a replicated trial on a creeping bentgrass golf green. Bio-Trek 22G was applied on the dates indicated, and root/soil samples were taken at monthly intervals. Note that *Trichoderma* persisted at a high level throughout the year. The y axis is a log scale, so each number given represents a 10-fold increase in *Trichoderma* levels. For example, log 5 represents 100,000 viable propagules of the fungus, and log 6 represents 1,000,000. The increase in *Trichoderma* levels in the nontreated plots over time probably is a consequence of spread of *T. harzianum* from adjacent treated plots. Data is from Lo, C-T, Nelson, E. B., and Harman, G. E. 1996. Improving the biocontrol efficacy of Trichoderma harzianum 1295-22 for controlling foliar phases of turf diseases by spray applications. Plant Dis. (in preparation)

biocontrol agent on turf roots for more than a year. However, in 1995, *T. harzianum* populations had dropped to levels necessitating another application. The cultivars used in these field trials were Pencross and Cobra.

This establishment of a biocontrol fungus resulted in reduced severity of several diseases. Dollar spot data are shown for 1993 and 1994 (Fig. 2), while control of brown patch and Pythium root rot are shown for 1994 (Fig. 3). In 1993, brown patch and Pythium were not evident.

Another benefit of Bio-Trek 22G was also evident in our trials. The product was applied in June and July, but in November the treated areas were easily recognizable: the plots that had received the granular formulation of *T. harzianum* were greener than adjacent plots. This turf had not been fertilized after mid-summer, so the enhanced color may have reflected the ability of a more vigorous root system to provide better uptake of nutrients. This improved color persisted into 1995, and was still evident in August of that year, even though no additional *T. harzianum* had been applied to those areas.

These data indicate that Bio-Trek 22G can be a useful product for turf disease management. Its advantages are:

- It provides a means of establishing *T. harzianum* in soil and on roots, thereby providing a means of restoring beneficial microbes in turf soils.

- It reduces the level of disease organisms in soil, and so initial disease levels will be lower once the biocontrol fungus is established.

- It is nontoxic and nonpolluting, but has good persistence, so its beneficial effects can persist over an extended time period.

Based on our experience with both turf and other crops, it can enhance root health and growth. However, there are some things that this biological agent cannot do, and these limitations must be recognized as well. These are:

- Bio-Trek 22G is applied to soil, and the beneficial fungus becomes established in roots and soil. Therefore, it cannot control foliar diseases, or foliar

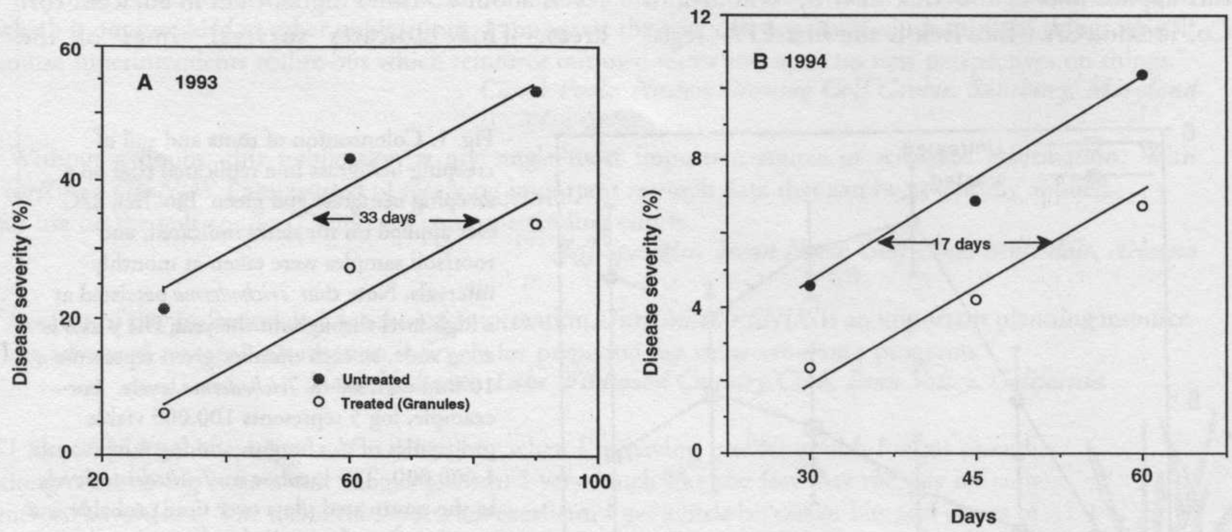

Fig. 2. Disease progress of dollar spot in replicated trials in 1993 and 1994 in the presence and absence of Bio-Trek 22G. Lines were fitted using the general models program (SAS, Cary, NC). Disease severity is defined as the percentage of total plot area with diseased turf. The differences between treatments and time required to reach specific disease levels were significantly different. These data are used with permission of the American Phytopathological Society, and are from Lo, C-T, Nelson, E. B., and Harman, G. E. 1996. Control of turfgrass diseases with a rhizosphere competent strain of *Trichoderma harzianum*. Plant Dis. (accepted for publication with revision).

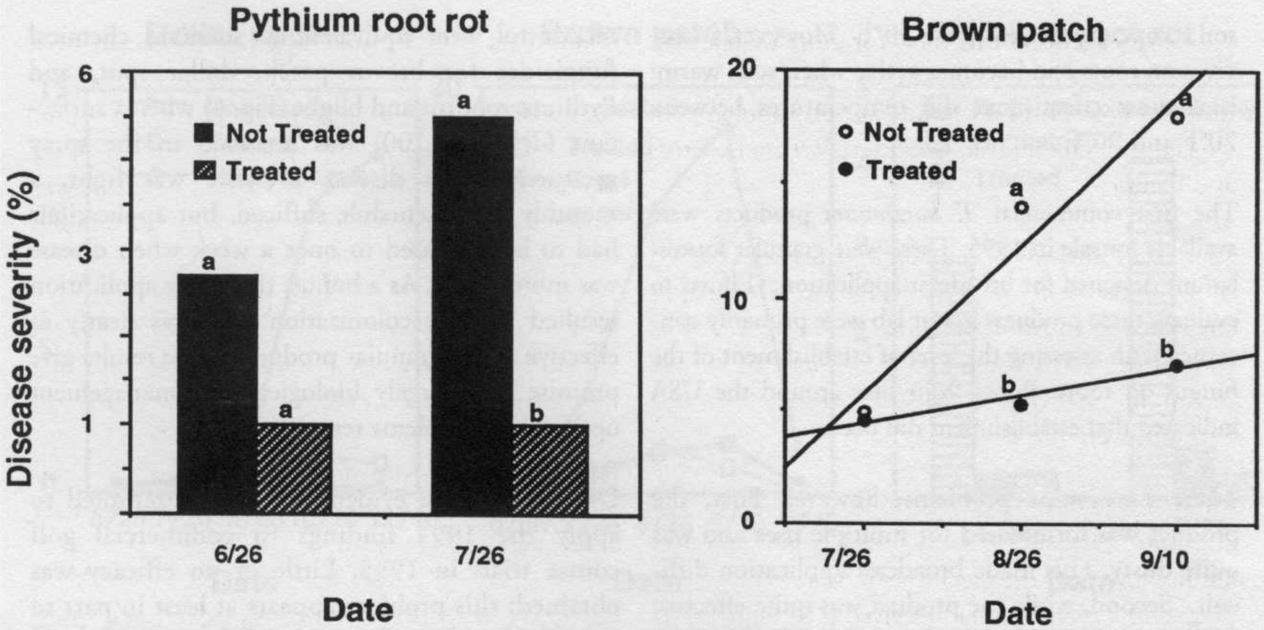

Fig. 3. Incidence of Pythium root rot and brown patch in replicated plots on a creeping bentgrass green after no treatment and treatment with Bio-Trek 22G. Disease severity is defined as the percentage of total plot area with diseased turf. Numbers followed by dissimilar letters are significantly different for the date shown. Data is from Lo, C-T, Nelson, E. B., and Harman, G. E. 1996. Improving the biocontrol efficacy of *Trichoderma harzianum* 1295-22 for controlling foliar phases of turf diseases by spray applications. Plant Dis. (in preparation).

Table 1. Fungicides compatible or incompatible with Bio-Trek 22G

Compatible fungicides	Incompatible fungicides
Chloroneb(e.g. Chloroneb, Terreneb)	Benomyl (e.g. Tersan 1991)
Etridiazole(e.g. Koban, Terrazole)	Propiconazole (Banner)
Iprodione (e.g. Chipco 26019)	
Mancozeb (e.g. Fore)	**Questionable, or no data**
Metalaxyl (e.g. Subdue)	Anilazene (e.g. Dryene)
Quitozene(e.g. PCNB, Terrachlor)	Chlorothalonil (e.g. Daconil 2787)
Triadimefon (e.g. Bayleton)	Fenarimol (e.g. Rubigan, Lesco Twosome)
Vinclozolin (e.g. Vorlan, Touche, Curalan)	Thiram (e.g. Spotrete)
Fosetyl Al (e.g. (Aliette)	Thiophanate methyl (e.g. Clearys 3336,Fungo)

phases of soilborne diseases such as dollar spot. Foliar diseases spread rapidly and are favored by frequent mowing and watering, so chemical fungicide sprays will have to be used to control them.

■ *T. harzianum* is a living organism that must become established in soil and on roots of turf to be effective. See the Field Tips section further below for some guidelines to accomplish this. However, some chemical fungicides are lethal to *T. harzianum*, and if possible they should not be used in conjunction with Bio-Trek 22G. A list of fungicides and their compatibility/incompatibility with *T. harzianum* is given in Table 1.

■ In addition, like all living organisms, *T. harzianum* will be more active under some conditions than others. In particular, it will not be effective when soil temperatures are below 50°F. However, it survives on roots and becomes active when soils warm. It is most effective at soil temperatures between 70°F and 90°F.

The first commercial *T. harzianum* products were available for sale in 1995. These were granular formulations designed for broadcast application. Efforts to evaluate these products in our lab were primarily concerned with assessing the level of establishment of the fungus on roots. Roots from sites around the USA indicated that establishment did occur.

There were some problems, however. First, the product was formulated for multiple uses and was quite dusty. This made broadcast application difficult. Second, while the product was quite effective for many applications, we found that transfer of the fungus from the granule to the roots was not as effective with broadcast application as it was when the granules were directly incorporated into soil. As a consequence, even though the fungus did become established, in some cases its population level remained at suboptimal levels.

Therefore, in 1996, TGT Inc. will formulate Bio-Trek 22G specifically for broadcast application to turf, and its properties will be different from the general use material. The turf product will have a larger particle size to facilitate broadcast application, the dust level will be substantially reduced, and its concentration of *T. harzianum* will be higher to enhance root and soil colonization. We expect that this product will be effective for its intended uses.

The development of future technologies

Bio-Trek 22G is highly useful: but, as noted above, it has limitations. Most notably, since the product is applied to the soil and the fungus is located in the root-soil zone, it cannot protect against foliar pathogens. With this factor in mind, we have begun testing a spray formulation that consists primarily of conidia (spores) of the fungus. The first trials, conducted in 1994, were successful. Levels of control were equivalent to standard chemical fungicides for brown patch, dollar spot, and Pythium root rot and blight (Fig. 4) when a surfactant (Triton X-100) was included in the spray mixture. When disease pressure was light, a monthly spray schedule sufficed, but applications had to be increased to once a week when disease was more severe. As a bonus, this spray application resulted in root colonization that was nearly as effective as the granular product. These results give promise of a largely biological turf management option, but problems remain.

Difficulties were evident when we attempted to apply the 1994 findings to commercial golf course trials in 1995. Little or no efficacy was obtained; this problem appears at least in part to be related to toxic fungicide residues in the spray tank. As the biocontrol agent was suspended in tanks that have been used repeatedly to apply fungicides, some factor, probably low levels of residual pesticides, prevented spores of the fungus from germinating.

Other problems also remain. Technologies for large-scale manufacture of sprayable biological formulations at a reasonable cost are not fully developed, and so only prototype preparations are available now. Further, *T. harzianum* is useful only as a preventative application and cannot cure existing disease. Of course, like all materials available to golf course managers, this fungus will not be effective against all diseases. These last two factors indicate a need for the development of integrated biological-chemical control systems that reduce the need for chemical fungicides.

Research efforts at Cornell University will focus on the development of spray formulations for commercial golf courses. We will determine which chemicals cannot be used in sprayers employed for *T. harzianum* application, and attempt to devise methods for removal of the most important toxic materials. We anticipate that only a few of the incompatible materials in Table 1 will cause most of the problems. At least, we should be able to make recommendations regarding fungicides to be avoided.

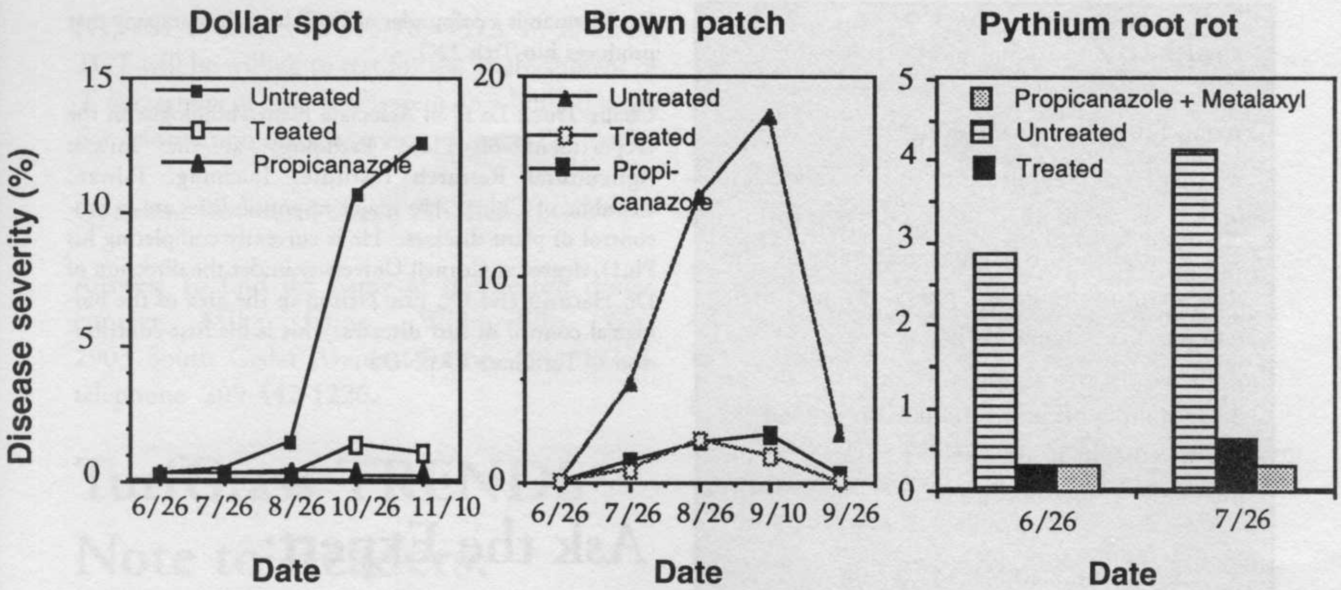

Fig. 4. Severity of dollar spot, brown patch, or Pythium root rot in replicated plots on a creeping bentgrass green after no treatment, treatment with a standard fungicide, or treatment with sprays containing spores of *T. harzianum* and Triton X-100. Disease severity is defined as the percentage of total plot area with diseased turf. *T. harzianum* treatments were applied monthly until July 26, and thereafter weekly. In all cases, the disease severity in nontreated plots was significantly different from treated plots, but fungicide and *T. harzianum* treatments were not significantly different. Data is from Lo, C-T, Nelson, E. B., and Harman, G. E. 1996. Improving the biocontrol efficacy of *Trichoderma harzianum* 1295-22 for controlling foliar phases of turf diseases by spray applications. Plant Dis. (in preparation).

We will also test prototype commercial products and develop full dosage information for them. And we will determine spray adjuvants, primarily spreader/sticker materials, that provide the best results with *T. harzianum.*

With this information, we will develop recommendations for using *T. harzianum* that will be tested on golf courses and other commercial sites. In addition, we will investigate development of integrated sprays that combine reduced rates of a compatible fungicide with the beneficial fungus. An integrated biological-chemical system may lessen fungicide use, provide some of the curative ability of fungicides, result in root colonization of *T. harzianum,* establish diverse microbial soil populations that promote plant health, and be competitively priced. We hope to begin research scale trials of both full biological and biological-chemical control systems this summer.

In summary

The first registered biological control product Bio-Trek 22G, for the control of turf diseases is now available. This product contains a strain of the beneficial soil fungus, *Trichoderma harzianum,* and is designed for broadcast application to turf. The fungus becomes established on the roots and in the soil of turf and persists for months after application. Once establishment occurs, it can become a component of a healthy soil microbial community and reduce soilborne disease. It cannot control foliar diseases, however, and therefore must be used in conjunction with compatible fungicides. We anticipate that Bio-Trek 22G will be the first of several biological products for turf disease control. Other biological and integrated biological-chemical control products will be manufactured by TGT that will extend the usefulness of Bio-Trek 22G.

Key words

Trichoderma - is a genus of beneficial fungus that is common in soils. There are a number of types and kinds. *Trichoderma harzianum* (*T. harzianum*) strain 1295-22 is a selection of this fungus that is particularly able to colonize plant roots. It is formulated as Bio-Trek 22G for disease suppression in golf course management.

Nontarget organisms - These are living components of the turf-soil ecosystem that, while not intended as targets for pesticides, can be adversely affected, sometimes even killed, by fungicide applications.

Field tips

1. For initial establishment of *T. harzianum,* we suggest two applications of Bio-Trek 22G, four to six weeks apart during the first spring. These applications should be made as the soils warm in the spring, preferably after their temperature reaches 50°F.

2. Another application should also be made as the soils begin to cool in the autumn, again preferably while they are warm (above 60°F).

3. Single applications in spring and fall should suffice thereafter.

4. As an alternative to broadcast applications of Bio-Trek 22G, we anticipate that it will be effective if incorporated into new golf greens at the time of planting.

5. If possible, only compatible fungicides from the list on Table 1 should be used with Bio-Trek 22G; and they should be applied only one to two weeks after the application of Bio-Trek 22G (so that the fungicide is not applied directly to Bio-Trek 22G).

6. Holding pH values below neutral (7.0) is best for Trichoderma.

Gary E. Harman is a Professor in the Departments of Horticultural Sciences and Plant Pathology at Cornell University's New York State Agricultural Experiment Station, Geneva, NY. He has a B.S. from Colorado State University and a Ph.D. from Oregon State University. Dr. Harman has devoted much of his career to the development of biological alternatives to chemical pesticides for a variety of applications, including perennial, row, and greenhouse crops, as well as turf. He has focused recently on identifying genes and gene products that may be useful in agriculture, and developing biocontrol systems based on beneficial fungi. This is his first contribution to TurfGrass TRENDS .

Dr. Harman is a cofounder of TGT Inc., the company that produces Bio-Trek 22G.

Chaur-Tsuen Lo is an Associate Plant Pathologist in the Department of Plant Pathology at the Taiwan Agricultural Research Institute, Taichung, Taiwan, Republic of China. His major responsibilities are in biocontrol of plant diseases. He is currently completing his Ph.D. degree at Cornell University under the direction of Dr. Harman and Dr. Eric Nelson in the area of the biological control of turf diseases. This is his first contribution to TurfGrass TRENDS .

Ask the Expert: Questions regarding Bio-Trek 22G *T. harzianum*

By G. E. Harman
Cornell University

Question: How does *T. harzianum* control disease?

Answer: This biocontrol fungus probably has several modes of action. Physically, it coils around fungi and digests their cell walls. In addition, pathogenic fungi attack plants when nutrients from the plants leak into soil, stimulating fungal growth. *T. harzianum* appear to limit this nutrient leakage, thereby reducing fungal infection. Other mechanisms also may be operating, including simply colonizing roots sufficiently that other fungi have difficulty becoming established on or in roots.

Question: If I have questions about Bio-Trek 22G, who can I ask? Also, if I wonder whether it has become established in my turf, how can I test this?

Answer: TGT Inc. is strongly interested in your experiences with Bio-Trek 22G in 1996. Questions on its use can be addressed to Dr. Christopher Hayes, Director of Research and Product Development, TGT Inc., Geneva, NY, 14456, telephone 315-789-7573. In addition, TGT will be willing to test for the establishment of *T. harzianum* in your turf system on a limited basis. For information on this service, contact Dr. Hayes.

Question: How can I obtain Bio-Trek 22G?

Answer: To find the name of the nearest dealer, contact Mike Cline, Wilbur-Ellis Co., 2903 South Cedar Avenue, Fresno, CA, 93726, telephone 209-442-1220.

TurfGrass TRENDS Note to Readers:

The research reported in this article was conducted at Cornell University in conjunction with Dr. Eric Nelson. Dr. Harman has been developing biological control systems at Cornell for use in commercial agriculture for the past two decades. A primary goal has been not only to discover strains, delivery systems, and other aspects of biocontrol, but also to ensure that the results translate into useful products and processes for use in commercial agriculture and horticulture. He has found that the most difficult aspect of development of biocontrol systems is not solving technical problems but rather developing methods or vehicles to implement and provide biocontrol products. This is an important goal; otherwise biocontrol will remain only in the lab, and will never become available to growers, managers, and the public.

Implementation of biocontrol research requires a for-profit company to register, develop, produce, and market the organisms and processes developed in University laboratories. Dr. Harman has investigated and tested various methods of accomplishing this, and has decided that the best method was to co-found a company to bring biocontrol products to the marketplace. Therefore, he and two colleagues, a scientist-lawyer and a businessman, formed TGT Inc. $2\frac{1}{2}$ years ago. TGT operates under license from Cornell University and has developed methods for large-scale manufacture of biocontrol products. It is beginning to sell substantial quantities of EPA-registered biological fungicides as alternatives to existing purely chemical pest-control methods for several different purposes. Dr. Harman remains a full-time professor at Cornell University, and continues to develop new biocontrol strategies in the University setting. He provides advice and guidance to his colleagues at TGT who use his findings to implement new biocontrol products and strategies.

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